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Graphic Engineering and Design

5<sup>th</sup> International Symposium on  
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Grid '10

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Proceedings

# Grid '10

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## NONPRINTING AREAS ON THE OFFSET PRINTING PLATES

### What we know – What we should know

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Faculty of Graphic Arts, University of Zagreb

**Abstract:** Majority of the offset printing plates are today built of aluminium sheets. To ensure surface characteristics needed in the printing process, aluminium surface is mechanically, chemically and electrochemically processed. All those processes are made to make a specific micro roughness of aluminium-oxide anodic layer. Micro roughness and aluminium-oxide layer have on all printing plates similar characteristic, but vary depending on the supplier and printing process in which printing plate will be exploited.

In the final stage of the printing plate production, aluminium-oxide surface is covered with a photoactive layer which enables image transfer on the plate in conventional or CtP plate making process. This layer must change its solubility in defined developing solution by electromagnetic irradiation.

After irradiation plates are processed in defined developing solution which dissolves parts of the photoactive layer to expose aluminium-oxide surface - nonprinting areas. Aluminium oxide is as well as aluminium amphoteric, which means that is soluble in both acid and alkaline solutions. On the other hand, majority of the photoactive layers present on the market today are soluble in highly alkaline solutions.

This fact makes developing process highly important. After dissolving photoactive layer, developing solution is in contact with aluminium-oxide layer and dissolves peaks of the micro roughened layer. This fact causes degradation of wetting properties and makes control of the wetting characteristics obligatory, knowing that wetting properties of the printing plate's nonprinting areas are one of most important variables in achieving high quality printing.

Definition of wetting properties of a solid surface is done by observing contact angle results, surface free energy determination, its polar and dispersive part.

**Key words:** Offset printing plate, developing process, contact angle, surface free energy, pH value, electrical conductivity

#### 1. What we know

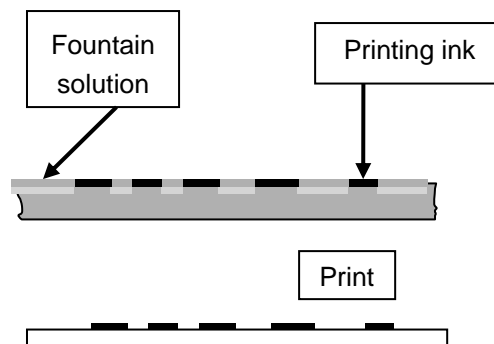
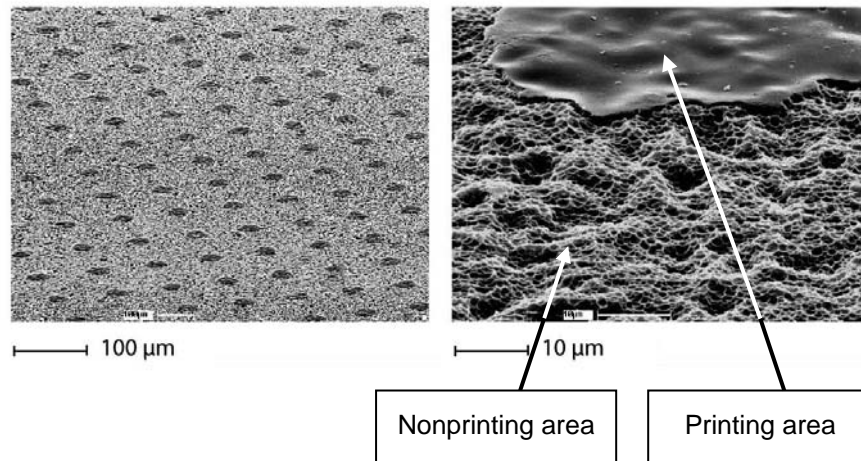
Lithography is based on the difference in some surface properties of printing and nonprinting areas. These areas are all in nearly same geometric level, difference of about 2 – 3 µm does not influence attraction or repulsion of printing ink in the printing process.

Selective wetting is the key which enables lithographic printing. A solid surface is hydrophobic if in the selective wetting condition a dispersive liquid is better damping that solid surface than water based liquids. Vice versa, hydrophilic surfaces are in selective wetting conditions better damped with a water based liquids than a dispersive ones. Hydrophobic surfaces are waxes, oils, pure metals, although pure metals have tendency to react with oxygen and cover its surface with oxide layer which gives these areas hydrophilic properties. Beside metal-oxides, hydrophilic are compounds which are polar built (for example organic compounds with a polar functional group, -OH, - SO<sub>3</sub>H, - NH<sub>2</sub>, etc.). In lithography, printing areas are hydrophobic and nonprinting areas are hydrophilic.

Monometal aluminium printing plates are today most commonly used as printing plates in lithography [1]. Aluminium foils must be mechanically, chemically and electrochemically processed. Those treatments are made to ensure specific surface properties of aluminium-oxide layer which would enable this layer to attract water based fountain solution.

After aluminium-oxide layer is enriched with wanted surface properties, printing plate is covered with thin photoactive layer which enables transfer of image on the printing plate. Beside its role in transfer of image, photoactive layer builds printing areas which means that in printing process must repel fountain solution and in the same time attract printing ink which is oil based (Fig. 1.).

The plate making process is generally made of two main sub processes, exposure and developing process. Exposure of the photoactive layer is irradiation of photoactive layer by electromagnetic energy of defined wave length. This energy causes photochemical reaction in the layer which results with change of its solubility in defined solvent (developing solution).



*Fig 1. Offset printing plate*

During developing process part of the photoactive layer which is soluble is dissolved in processing solution to remove it from nonprinting areas (aluminium-oxide).

Fountain solution is beside plate making process very important precondition in achieving prints of highest quality. As said before, printing plate consists of hydrophilic nonprinting areas which attract fountain solution and of printing areas which attract printing ink and repel fountain solution. These areas and their ability to attract or repel fountain solution or printing ink are defined during plate making process. The main role of fountain solution in the printing process is to prevent acceptance of printing ink on nonprinting areas.

At first, fountain solution was just water without any additives. As the demand for higher print quality and increase of printing speed rose, additives had to be put into water to increase properties which are essential in achieving needed demands. Fountain solution is today composed of water in which buffer, to control pH value, alcohol, to reduce surface tension, and some others additives are added in order to make this solution functional in printing process [2]. Fountain solution has many secondary effects on the printing process, it cools down printing plate, regenerates some surface properties, cleans printing plate's surface of particles. On the other hand, fountain solution could cause problem and result with lower printing quality. If fountain solution penetrates, more then needed, into printing ink, result would be decrease in coverage values on prints, unsharp edges of printing elements and cause problem in drying of prints. As problems caused by fountain solution are proportional to the amount of fountain solution on printing plate's surface, amount of needed fountain solution for functionality of printing process must be decreased.

Another problem in fountain solution is that it is changed by the printing process. Therefore, control of fountain solution's properties must be conducted during printing process. Only two parameters which could be controlled in such dynamic process, as printing process is, are pH value and electrical conductivity [2].

Measurement of these parameters must be done before application of fountain solution in printing process in order to determine how some additives influence pH value and electrical conductivity.

Electrical conductivity of a solution depends on the number of movable ions in the solution, but in the same time on the ion type which is capable to transfer the charge.

In Fig. 2 one can see the behaviour of fountain solution's electrical conductivity when type and amount of concentrate (Fig. 2. a.) or alcohol (Fig. 2. b.) is changed.

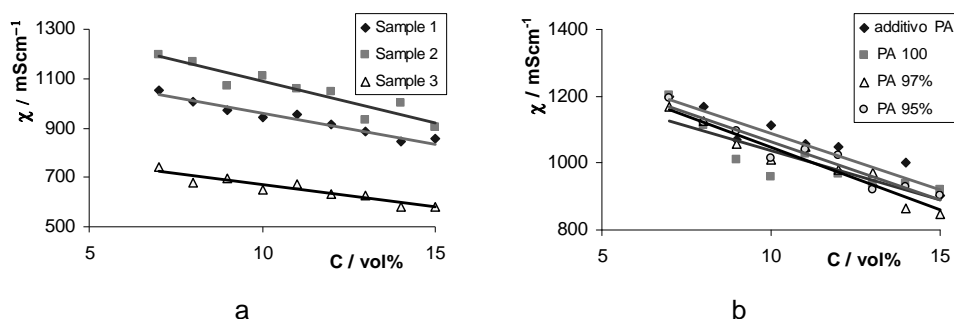


Fig 2. Dependence of electrical conductivity on: a. type of concentrate, b. type of alcohol

As one could see, electrical conductivity of investigated solutions decreases by increasing volume of concentrates or alcohol of any type. These results would be useful in printing process to add more water if electrical conductivity has dropped below optimal value or to add more concentrate or alcohol if electrical conductivity value is increased. Change of electrical conductivity could show if some additives have evaporated out of fountain solution or if some chemical substances have dissolved in fountain solution and could cause problems. The value of electrical conductivity of a fountain solution is highly influenced by the used concentrate and alcohol type [3,4].

Type of used concentrate can also influence pH value of a fountain solution. In Fig. 3 a. One can observe dependence of pH value on concentrate type and amount added. It can be seen that difference can be even more than 0,5 pH unit.

Influence of alcohol type and amount added on pH value of fountain solution is smaller, but is present and must be taken into account.

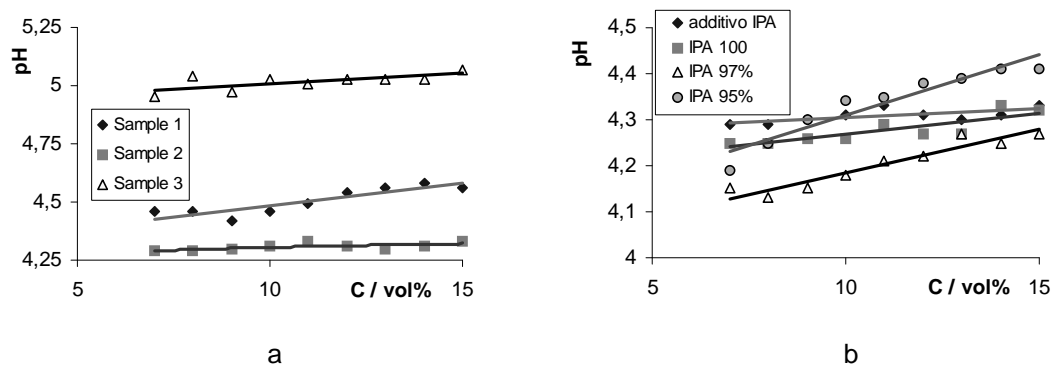


Fig 3. Dependence of pH value on: a. type of concentrate, b. type of alcohol

## 2. What we should know

To enable greater understanding of processes which are happening before and in the offset printing, one must gain more information about materials which are used in printing plate production. Majority of the printing plates used today in lithography are made of aluminium.

Aluminium has some valuable properties as low density, high thermal and electrical conductivity which gives it widespread application in many industries. Usually it is used as an alloy with 0,5 percent of added metals which give this alloy better mechanical properties than pure aluminium.

Aluminium foil must be mechanically, chemically and electrochemically processed to make it usable as a lithographic printing plate. At first, aluminium surface is more or less roughened in a



process which is called graining. Graining is mechanical and/or electrochemical process. This process makes real area of aluminium significantly larger than geometrical area which enables better adsorption of fountain solution during printing process but as well greater adhesion between aluminium surface and photoactive layer.

In the same time graining must be done in precise process parameters because as surface must be roughened, too much roughening could cause some negative consequences for example, it could cause too much fountain solution on the printing plate surface which leads to bad water ink balance, problems with paper dimensions etc. Besides fountain solution, too roughened surface causes deviations in edges of printing areas or even loss of the small printing elements (at low coverage values). This makes control of roughening important not only to control graining, but to monitor changes in the printing plate surface as a consequence of plate making process or printing process. Besides roughening, aluminium foil is electrochemically processed to make thin, porous film of aluminium-oxide (Fig. 4.) which gives high adsorption potential and hydrophilic properties [5, 6].

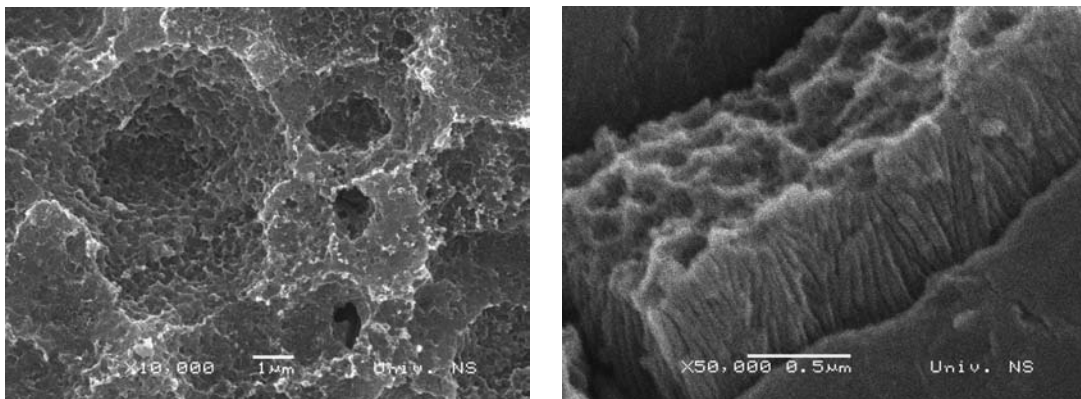


Fig 4. SEM Images of aluminium-oxide film at printing plate

Surface roughness is defined as deviation of a surface from ideal surface shape. It includes all micro geometric discontinuities, peaks and valleys, made during surface mechanical or chemical processing. Surface roughness is determined by observing one dimensional parameters based on two dimensional surface profile (Fig. 5.).

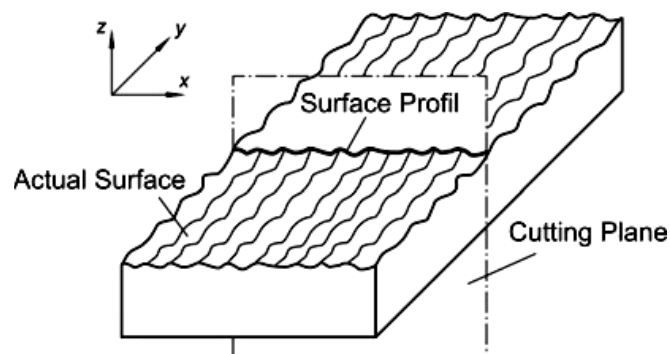


Fig. 5. Surface profile

International standards define choice of method for making profile and roughness parameters observed when investigation of a surface is made. Profile of a investigated surface could be joint of many various components of high and low frequencies. High frequencies are called rough and consequently domination of high frequencies is called roughness. On the other hand low frequencies are called waves and domination of low frequencies is called waviness. Roughness of the surface determines its interaction with other surfaces in contact, adsorption, sensitivity to wear, appearance etc.

Measurement of surface texture is made by determination of roughness parameters. There are many roughness parameters but which one will be used is defined by characteristics and functionality of surface which is meant to be described. [7,8]

Roughness parameters mostly used in investigation of printing plate's nonprinting surfaces are:

- Average arithmetic profile deviation,  $R_a$  – arithmetic mean of absolute values of function  $Z(x)$  in the referent length  $l_r$  (Fig. 6.).

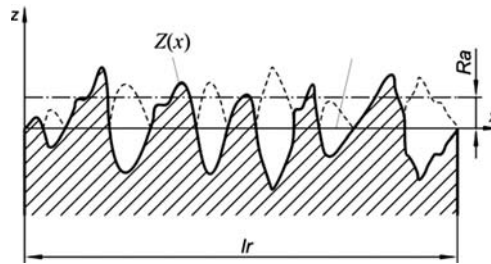


Fig 6. Average arithmetic profile deviation  $R_a$

- Maximal value of profile peak,  $R_p$  is highest height of profile function  $Z_p$  in the referent length  $l_r$  (Fig. 7.)
- Maximal depth of valley,  $R_v$  is deepest depth of profile  $Z_v$  in the referent length  $l_r$  (Fig. 7.).

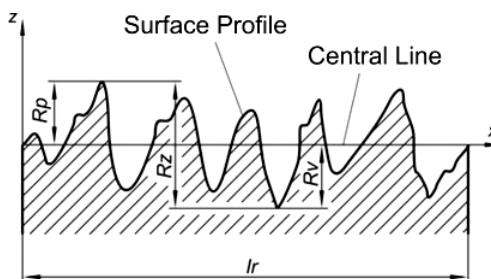
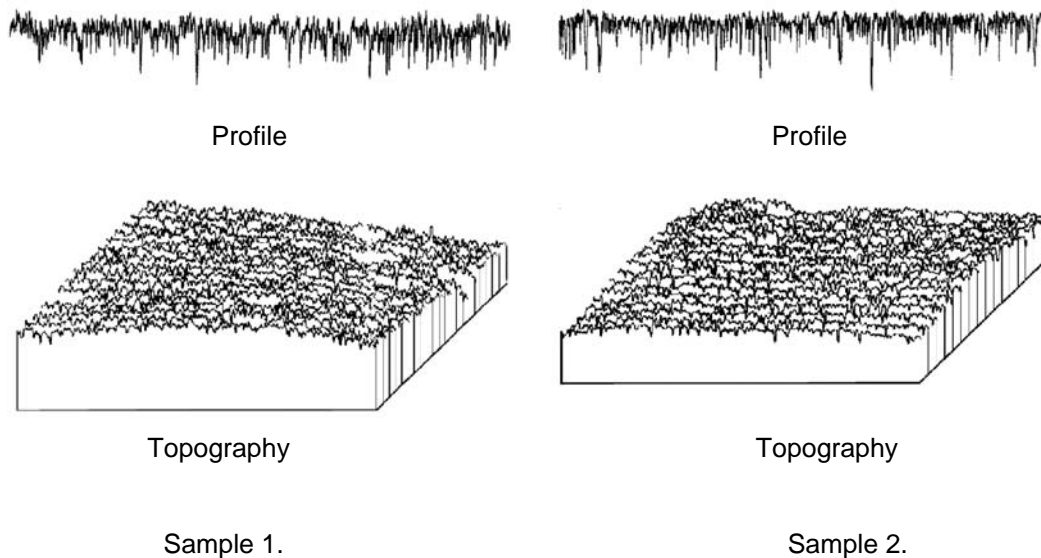


Fig. 7. The maximum height of the peak profiles  $R_p$  and maximum depth of the bottom profile  $R_v$

Beside graining surface roughness of printing plate is under many influences in the plate making process and in the printing process.

In Fig. 8. one could see topography and profile of two printing plate samples which are made in different process parameters. It is easy to see that processing has caused by Sample 2 (Fig. 8., right) more valleys in comparison to the Sample 1 (Fig. 8., left). During processing of the printing plate in the plate making process, surface of the plate comes in contact with aggressive chemicals which cause degradation of roughness, especially  $R_p$  i  $R_v$  parameters [5, 9, 20].



Sample 1.

Sample 2.

Fig. 8. Profile and surface topography of printing plate samples made in different processing parameters

As said before, lithography is based on surface phenomena, difference in surface properties of printing and nonprinting areas and their ability to attract or repel water based liquids.

Surface phenomena is phenomena that take place on the boundaries of neighbour phases, solid and vapour, solid and liquid, liquid and vapour, liquid and liquid and all three phases. Some of these phenomena are adsorption, surface tension, wetting, capillary penetration etc.

Surface phenomena are caused by difference in properties of the molecules, ion or atoms on the matter's surface in relation to the ones in the matter mass. Compounds in the matter's mass are surrounded with same chemical substances and therefore are under the influence of attractive forces of those substances. As all substances are equal, all forces that effect observed compound are compensated. On the other hand, compounds on the matter surface are not surrounded by equal particles and are effected by forces which are not compensated, there is resultant force present which is usually working towards inside of the matter (Fig. 9.).

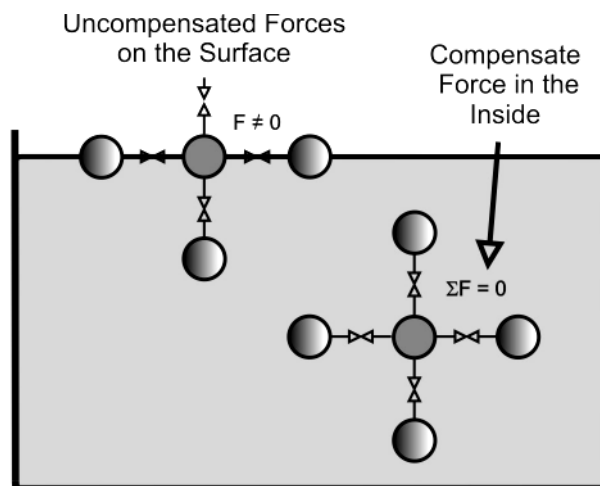


Fig 9. Forces effecting compound at the matter surface and inside the matter

Redundancy of the energy in the surface layer of the matter in relation to the energy in the matter's inside is called surface free energy (SFE). SFE is causing nearly all surface phenomena.

Adsorption and wetting are most used surface phenomena in the graphic arts industry. As said before, necessity of some areas to adsorb water and other to repel it is key feature on which lithography is based, but surface phenomena are also important in ink transfer from ink rollers to printing plate's printing areas and finally to printing substrates.

Adsorption is phenomenon of accumulation of a fluid or vapour particles on the solid or fluid surface caused by adsorption forces. The amount of adsorbed particles is under many influences, among others adsorption forces, size of real surface, chemical structure of surface, etc.

Amount of adsorbed particles is proportional to the specific area which means that micro roughened surface of porous aluminium-oxide film on the lithographic printing plate will adsorb significantly higher amount of fountain solution then a smooth surface would (Fig. 10.).



Fig 10. Adsorption on smooth and rough surface

Temperature of the solid surface is also very important because increase of a solids temperature causes decrease of the amount of adsorbed particles. This fact makes maintaining of printing plate's temperature constant during whole printing process essential in obtaining equal printing results in whole print run.

Second important phenomenon is wetting. Wetting is defined as a surface phenomenon conditioned by reduction of adsorption forces, i.e. reduction of surface tension in the liquid solid interaction.

Wetting of a solid with a fluid could be determined by observing shape of a fluid drop when dropped at the solid surface. Contact angle,  $\theta$ , (Fig. 11) is defined as angle between tangent on the solid surface ( $t_2$ ) and the tangent on the fluid drop ( $t_1$ ) drawn through point where all three phases (solid, fluid and vapour) are in contact [1, 5, 11, 12].

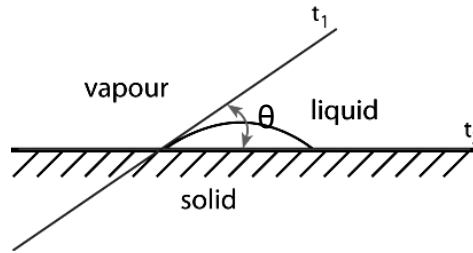


Fig. 11. Contact angle

In Fig. 12 one can see various degree's of wetting, from good (left) to bad (right).

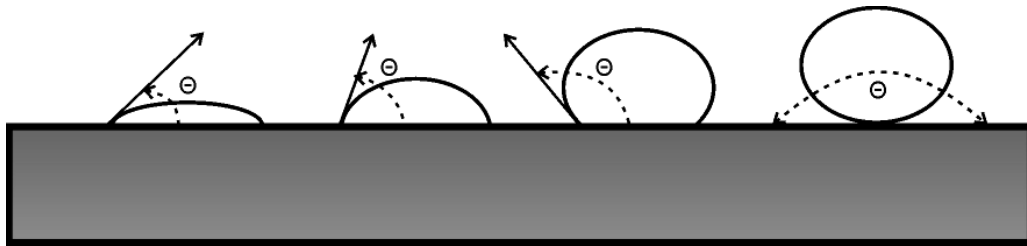


Fig. 12. Contact angles with varying degree of surface wettability

Knowing the phenomena that are essential in lithography, one could conclude that investigations of printing plate's surface, fountain solution properties and certainly interaction of the printing plate's nonprinting areas and fountain solution is key in achieving highest printing quality.

It was mentioned above, how investigation and measured parameters of a fountain solution must be done before, but also during printing process as fountain solution's properties are changed by printing process.

Before starting print process it is needed to investigate interaction of the fountain solution's interaction with printing plate. These measurements will give proper information what to expect in the print process, but in the same time help in finding precise composition of fountain solution. Optimal composure of fountain solution is important for functionality of the fountain solution, but as well in the economical aspect through reduction of expenses. Behaviour of the fountain solution in the printing process could be anticipated by observing contact angle of a fountain solution in contact with printing plate's nonprinting areas [13].

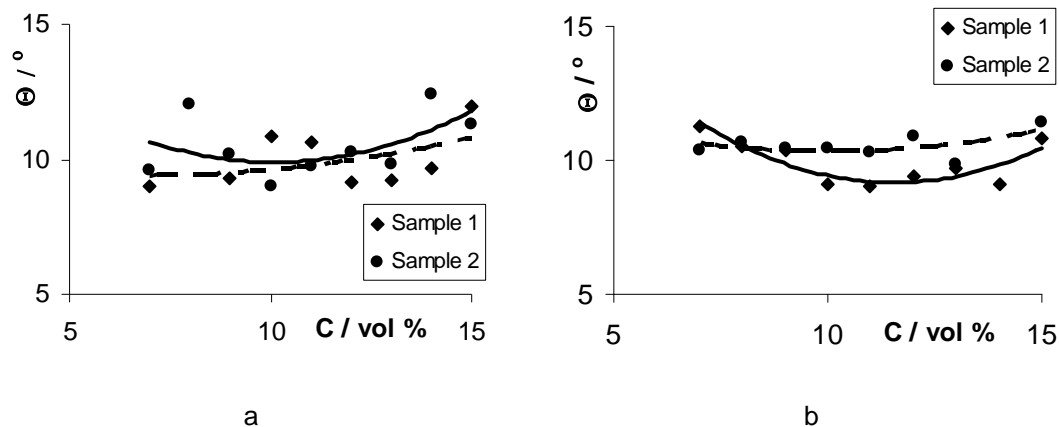


Fig. 13. Dependence of contact angle:  
a) on the type of wetting solution; b) on the type of alcohol

In Fig. 13. one could see results of contact angle measurement when applying various fountain solutions on the printing plate's nonprinting areas. Results show that higher concentrations of concentrate or used alcohol type will not lead always to better wetting.

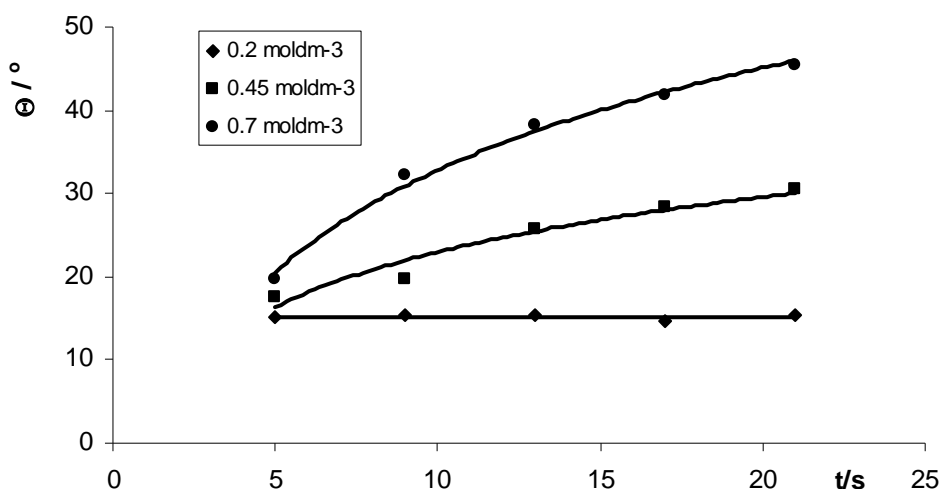


Fig. 14. Dependence of contact angle on developing time

In the same time, adsorption and wetting is beside liquid properties, significantly influenced by solid surface and any change of the surface would consequently lead to decrease of wetting properties. Nonprinting areas are most commonly built of aluminium-oxide prepared to have needed roughness and adsorption potential which enables good adsorption of fountain solution. But, as well as aluminium, aluminium-oxide is amphoteric, which means it could be dissolved in acid and base solutions. Majority of the photoactive layer used are developed in highly alkaline solution (pH 13 – 14) and it is impossible to avoid reaction of aluminium-oxide and developing solution during developing process. This leads to the dissolving of aluminium-oxide and change in nonprinting areas' surface properties, i.e. wetting of these surfaces with fountain solution.

Used developing solution has influence on the processing speed and could dissolve more or less aluminium oxide surface and cause different change in wetting properties (Fig. 14.). Results of contact angle measurement shown in Fig. 14. show that contact angle measurement must be taken into account when determining optimal conditions in which developing process will be conducted.

Calculation of the surface free energy is made to separate determination of the wetting properties of printing plate's surface from fountain solution. Calculation of surface free energy is made by measurement of standard liquids of known surface tension.

Decrease of the surface free energy consequently leads to the decrease of wetting properties.

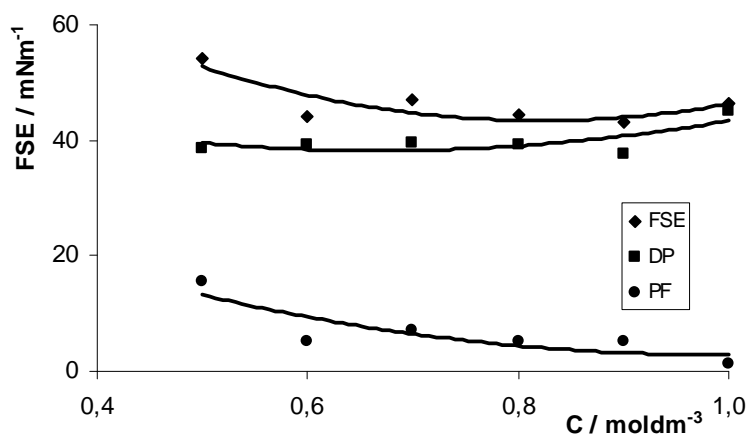


Fig. 15. Dependence of surface free energy on concentration of developer

Results of the printing plate samples developed in various developing solution is shown in Fig. 15. It can be seen that increase of concentration of developing solution cause decrease of surface free energy, especially its polar part.

Change of the surface free energy value could imply that roughness of investigated surface has changed or that change in chemical composition of the surface occurred.

### 3. Conclusion

As it can be seen by observing presented theory and results, lithography is a very complex process. In this process are many parameters which all have smaller or larger influence on the quality of end product.

This fact makes it essential to make investigations and try to optimize all sub processes in the production. Results of defining some properties of fountain solution show that they must be constantly monitored during printing process and make proper corrections in keeping them in defined limits.

On the other hand, optimisation and standardisation of plate making process is also one of key elements in production process. As it could have been seen, mentioned measurement could help us in detecting changes, but for complete understanding and defining of printing plates, processes that are running on printing plate surface one must make investigation with more measuring methods, like mentioned contact angle, surface free energy calculation and surface analysis of SEM images, fractal analysis, impedance spectroscopy [14, 15, 16].

Conducting those investigations would give ability to precisely determine plate making process and enable users to produce high quality product, position themselves on the market, and be more flexible and fearless in implementation of new technologies.

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# TRENDS AND NEW TECHNOLOGY DEVELOPMENTS IN PRINT AND MEDIA INDUSTRY

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**Abstract:** *The emergence of digital and Internet technologies in recent years have brought about new printing trends that will forever change the printing industry. These printing industry trends have changed the way companies do business from the design to the printing phase of operations. The world economic crises put an additional pressure on the printing and media industry during this period especially in the traditional media (newspapers and commercial printing) while opening up new media channels for content distribution. Printing as a mean of information transfer technology becomes a technology for producing commodity and specialty products, and opens up a new segment of material printing on almost all physical substrates. The emergence of new portable devices like mobile phones, iPads and other digital book readers further expands the cross media market, and digitalize the content transfer of literature works. The package printing as a steady growing and developing market segment continues with the application of new surface enhancement technologies as well as smart label technologies like the RFID technology. The industry is currently is going through changes induces by economy demands as well through the changes of the customer demands. This paper will summarize the most important emerging trends and changes in the print and media industry.*

**Key words:** *digital printing, software integration, automatization, trends*

## 1. Introduction

The industry is in an unprecedented period of change, exacerbated by the deep economic recession. The printing industry as a service to production industry has suffered due to lower demands and growing economic uncertainty. The economic pressure has caught the printing and media industry during its own transition in the emergence of digital and Internet technologies. The changes in the method of information transfer, job management and automatization and content management and presentation possibilities. Printers and media content providers must change and make possible sustainable business concepts which can be competitive in the future days of print media markets. The high rise of energy, raw material costs as well waste management regulations in many countries makes all the changes more challenging. The new business model demands versatile, very flexible, cost effective and environmentally acceptable printing solutions. The printed sheet became a very cheap commodity item and printers must provide much more added value to the plain ink on paper. The saturation of the paper based products and fierce competitions drive the printing to new materials and new 3D dimensions. A year between two DRUPA exhibitions had an IPEX show in Birmingham and FESPA Digital World show in Munich as a preview shows of the new emerging trends and developments in the print and media industry. The solutions to all these challenges lie in additional services and the synergy of digital, conventional and Internet technologies.

## 2. Overview of software and prepress solutions

Software solutions which accompany the machines in the graphic art have been before much more directly in the sole function of the machine and hardware operating. The advance in software technologies brought large improvements in the prepress area. The software which drive the machines, the RIPs, the workflows and web solutions have become a very competitive market, and innovations and improvements are done very frequently. Almost all of the big companies both from the digital and conventional printing sectors showed off the new and improved versions of their software. Escoartwork has introduced the new Studio 10 which comprises: Studio Designer, which provides 3D preview windows in Adobe Illustrator and now also Packedge and Artpro; the different Studio Toolkits supplying the 3D models; and Studio Visualizer, an on-screen mock-up including finishing effects. Studio allows designers to create 3D visuals that are representative for the real production artwork. The software is also deployed as a quality assurance tool. Studio Toolkit for shrink sleeves is said to automate the design and pre-press for shrink sleeves on round or irregular shapes, and even multi-packs. The toolkit



provides 3D visualization of shrink sleeve packaging and tools for artwork distortion. Users can preview the artwork on the screen as it is shrunk on the packaging. The pre-distortion tools can compensate for the complex combination of horizontal and vertical distortions that come with irregular shapes. The Internet part of the software modules is the Shapes software an online library of 3D packaging shapes.(printing talk). Other software's like OneVision's automated solution for intelligent image enhancement Amendo works on individual parts of the image separately – not simply the image as a whole. Brightness and contrasts, shadows and highlights are enhanced, together with improved sharpness. The software also analyzes colour values of numerous common elements such as vegetation, sky and skin and modifies the colours according to the human viewing patterns. Automatic resizing, colour management and red eye removal are further reducing the time-to-press. In addition to improved job ticket support, the latest version of Amendo has been refined to support various file formats.[1] This software with its intelligent digital image processing, shows a trend also introduced in new Adobe CS5 software package where adaptive and content aware algorithms take over in matter of seconds prepress tasks which were time consuming. Other product which gives an idea of future trend is Voyager which gives end users the ability to easily upload and submit their files 24/7 to publishers and printers. The integrated approval process allows each user to accept or reject the real-time proof online, thus minimizing administrative work for both publishing and printing companies and their customers. To further enhance automation, Voyager now offers the possibility to set up multiple hot folder configurations, which extend the use of Voyager for automatically submitting and retrieving processed files (round-tripping). This improvement and the other solutions of similar software companies drive the digital workflow from offline and intranet solutions to fully Internet based operations. This trend is also gaining momentum not just in the classic graphic arts fields like book printing or newspaper publishing, but in the secondary printing market like stationary printing, direct mail and forms. The US Internal Revenue Service plans to stop mailing paper income tax forms. The IRS cites continued growth in electronic filing and cost cutting for the change. According to the IRS nearly 100 Million people prepared and filed their taxes electronically in 2009. The Washington Post reports [2] the change will save the agency 10 million dollars a year in printing and postage costs. This data shows a shift in trend where the initial PDF form was printed and thus keeping the paper consumption high enough in the early days of its introduction, but now people are more adjusted to electronic communication channels and will be using electronic to electronic form exchange. In 2009 and 2010 there was a big boom in PDA and net book market and Tablet PC where Apple's iPad had made a tremendous market share, and in company with the Amazon Kindle eBook Reader device now opens up a struggle between electronic and paper based books. E-book sales have brought Amazon from \$135 million (per Credit Suisse) to \$194 million (from a Lazard Frères report last month). That number could grow above \$215 million by year-end and triple to \$775 million by 2015. [3] Growth in the e-book market is expected from consumers trying out e-reading on Apple's iPad, buying e-books through Google's upcoming Editions program, spending money on Barnes & Noble's (BKS) Nook (which, after a rocky start, appears to have found its footing), and sticking with the e-readers and smartphones they already use. Amazon.com CEO Jeff Bezos has stated [4] that for every 100 hardback books sold by Amazon.com over the past three months 143 Kindle eBooks have been sold, according to new figures released by the company. These figures go even to 180 in the newest reports. One new technology which can make these tablet's to overcome the problem of "paper feel" is the Senseg's company E-sense technology. Senseg technology applies an innovation in biophysics to bring a haptic effect to the traditionally passive touch user interface. When felt through one's fingertips, it provides a sophisticated sensory experience. Whether flat or curved, transparent or opaque, the Senseg solution can be easily applied to any touch interface surface. The Senseg E-Sense Software API parameters enable the texture of the grains to be programmed from smooth to rough, from sticky to slippery. Further, combining single grains to create a composition makes it easy to create a very wide range of effects. The basic set of default effects is included with the Senseg E-Sense package. This technology can enable the different paper grades and feels for the iPad and other ebook reader devices which can further increase their adaptation rate. In the light of the expanding market of portable devices a new very promising technology powered by Google and HP further extends the connections between Internet, portable devices and printing technology.

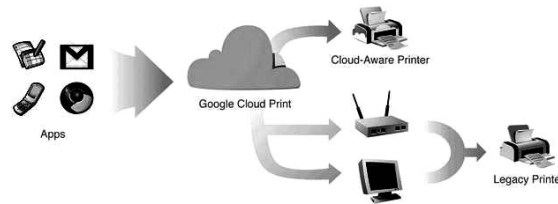


Figure 1: Google Cloud Print schema

To print out a document, a user has to have a driver installed for the intended printer on its local operating system. As this seems usual there is a complication when a content is coming from a mobile device, like an iPad, or from a laptop based on Google's Chrome OS, which relies entirely on web apps and services. This is why Google [5] is working on Google Cloud Print, a service that enables "any application (web, desktop, or mobile) on any device to print to any printer. Google Cloud Print is still in the early days of development, but Google made the code and documentation public as part of the Chromium and Chromium OS projects. The documentation reveals how Google plans to solve some of the issues it will inevitably face, such as making Cloud Print work with legacy printers. If print jobs are handled in the cloud there won't be need for drivers, and most of the problems users have with printing from devices like smartphones and tablets will be solved. HP can already begun the implementation of this concept through its own ePrintCenter solution. The HP ePrintCenter is an online hub for all HP customers to explore new services and customize their printing experience. For example, people can register their products and receive updates according to their preferences, configure their devices, track ePrint jobs, and browse and suggest new print apps. HP has announced a new service called Scheduled Delivery, which allows customers to choose content to be pushed to a printer at a designated time each day or week. For example, they might choose a customized news feed from msnbc.com to arrive at 7 a.m. for picking up on their way out of the door, or they might choose fun kids activities from Disney to be ready when the children get home from school.[6]

The market of CtP platemaking and proofing solutions had entered a stabilization and mature period after the introduction of violet procesless plates, which defined the market on thermal and violet solutions both championing procesless technology in order to reduce chemical consumption during the plate development process. One truly new promising technology which can make some disturbances in this area is the Miracle Plate. This technology according to the JP Imaging company can ensure a rewritable offset anodized aluminium offset plate. JPI have been able to switch the hydrophobic uncoated alumina surface back to a hydrophilic state using ultra fast laser pulsing to temporarily hydrophilise the aluminium surface. It does this by modifying the alumina, which creates highly hydrophilic species. The imaged area is visible as a darker area under normal viewing conditions and as a physically modified area under magnification; on the printing press the plate performs in a similar fashion to a normal printing plate. The imaged areas take fount and the non imaged areas take ink. The plate prints for several thousand copies, the maximum run length has not yet been determined. After printing the plate can be cleaned of ink with a standard plate cleaner and returned into the normal hydrophobic state in a variety of ways, for example, by allowing to 'stand' under normal atmospheric conditions for several days or by simply heating for a few minutes in an oven.[7]

### 3. Printing trends and technologies

Offset printing, also known as offset lithography, is still the most commonly used high volume commercial printing option. Digital printing in all forms is advancing and gaining momentum in all aspects which were previously held exclusively by offset and other conventional printing market. The 2010 Ipex trade show as the biggest event which can provide an insight into the market trends showed a decrease in floor space rented by offset producers an increase by digital vendors. The difference between the previous Ipex in 2006 is a 12% increase in digital technologies and decrease in 15% in analog press in terms of rented floor space. The previous Drupa indicated that offset technology is moving towards XXL formats and make ready automatization to keep up the pressure from the digital printing market. An important trend in the packaging sector is large-format offset printing, with a number of presses already on the market, including the Roland 900, the KBA 142, 162 and 205 machines and the Heidelberg Speedmaster SM XL 145 and XL 162. Three trends are important both in sheetfed and webfed printing: machines must be fast, productive, environmentally-friendly and economic. Web print systems have to compete with increasingly faster and wider sheetfed presses, and smaller

sheetfed machines are losing market share to digital printers. All industry segments strive to achieve fully-automated production. The trend towards added value solutions has also emerged as a way of differentiating printers from the competition. There were no big announcements and technology improvements in the hardware parts of the offset and other analog printing market but in production workflows and system management for the companies like KBA and Komori. The most important challenge for offset printing is to remain competitive, and the winners here will be the companies that exploit all the technical possibilities in the fight for new orders and prices, and produce fast, efficiently and economically. This may be achieved with a perfectly harmonised workflow or the use of automated features. The market of the offset presses which will be under pressure from digital technologies is the B2 market, where several digital presses were introduced for the end of this year and the beginning of 2011. One of these solutions is a dry toner based cut sheet press from Jadason Enterprise, which is marketed as the world's first B2 digital press made by Japanese and Chinese collaboration. The specification are not groundbreaking with 5 colour technology and 20 pages per minute what is with 1200 pages per hour far from the productivity of offset. Two other large companies also promoted at IpeX 2010 a B2 digital press for the first quarter of 2011: the single pass high productivity B2 ink jet press which can print on any offset commercial stock with the possibility of personalization, and an interesting digital press presented by Fuji the Jet Press 720.



Figure 2: Fuji Film Jet Press 720

Firstly, the Jet Press 720 makes use of SAMBATM print-head technology for single-pass inkjet printing developed by FUJIFILM Dimatix. This piezoelectric MEMS\*1 precision fabrication technology achieves resolutions of 1,200dpi x 1,200dpi with four levels of grey scale, a specification unobtainable from any other digital printing system.[8] As with any inkjet system, however, the performance of the ink through the print-head onto the printed sheet is critical to delivering benchmark quality. Fujifilm has therefore made use of the company's advanced chemical technology to develop water-based inks which enable bleed-free, high quality images to be produced. The quality is enhanced through Fujifilm's unique "anti-curling" and "rapid coagulation ink" technologies, which prevent paper curl and dot gain.

Finally, the repeatability from sheet –to-sheet is second to none. This is because the Jet Press 720 makes use of the superb registration accuracy of an offset press (the paper handling is identical to offset) and combines it with the inherent stability of an inkjet printing system. This is further enhanced through the use of a CCD sensor which scans every sheet and makes any necessary alterations in real time. Fujifilm estimates that the Jet Press 720 will be particularly competitive for print runs under 2,000 sheets. Productivity is further improved as the B2 printed sheet emerges from the press completely dry, thanks to the drying process that occurs once the paper is imaged. This means that 1,000 copies of a 32-page brochure can be printed and ready for finishing in half the time taken for the same job to be produced on a traditional offset press. The other part of the digital world is the stratification of different digital printing technologies between themselves. In previous years there was some predictions that ink jet technology will kill off other digital printing technologies (*"Inkjet Printers Get Set to Turn the Page," William Buckley, May 29, 2008*)[9], but the market shows there is space for both worlds. According to the Pira Market and Technology Forecast report The Future of Colour Electrophotographic Printing to 2015 - Market and Technology Forecasts [10] The global electrophotographic printing market was worth \$57.6 billion in 2009, and is to grow to almost \$90 billion by 2015, according to a new report by Pira International. This is equivalent to 761 billion and 904 billion A4 impressions, respectively. The increasing volume and much greater value are being driven by increasing use of colour and variable data printing. By value, the fastest expanding applications of electrophotographic print by 2015 are going to be labels, books, magazines, packaging and catalogues. The report reveals that the importance of electrophotography in the printing industry is growing quickly. According to Pira, electrophotography currently accounts for 9.4% of the value of the global print market (worth \$654 billion in 2010). This constitutes a sharp jump from the 2009's 8.7% and the 4.3% recorded in 2004. Similarly dynamic development is predicted for the coming years, as the report puts electrophotography's share in the global print market in 2014 at 13%, almost 50% more than in 2009. Digital print processes

(electrophotography and inkjet) are forecast to generally gain share from conventional print, with the exception of flexo, which is expected to expand its foothold during 2004-14.

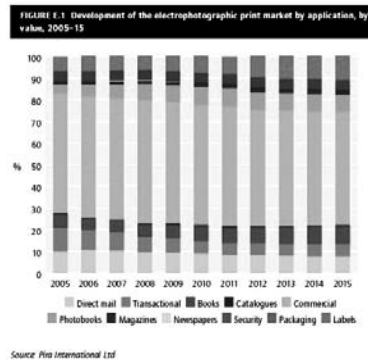


Figure 3: Forecast of the electrophotographic print market for the period 2005-2015 by PIRA

Pira estimates the volume growth of electrophotographic print output in 2010 at 1.7%. However, in value terms this output will grow much faster, by 7%, which reflects the big change that is happening in electrophotography. Increasing volume and much greater value are being generated through the growing popularity of colour and variable data printing, which make printed products more valuable to buyers and end consumers. According to the study, the value share of colour in the total electrophotographic market is to increase from 61% in 2005 to 72% in 2015. In volume terms the growth is going to be even more dramatic, from 16% to 41%. Commercial printing is currently by far the largest segment by value in the electrophotographic market, with a 56% share in 2009. However, according to Pira, its proportion is going to shrink in the coming years. The report predicts that during 2005-15 the fastest growing segments of the electrophotographic print market are going to be books, magazines, catalogues, packaging and, in particular, labels. On the other hand, newspapers printed with electrophotography are forecast to decline from their already small base - the underlying reason being more cost effective and appropriate inkjet technologies which are currently being commercialised. In volume terms, Pira predicts a different picture, with book share declining in 2010-2015 as mono text moves to inkjet, and packaging increasing its share very quickly. The report also forecasts declines in direct mail and transactional volume, due to replacement of large volumes of mono overprinting with full colour, particularly inkjet.

Inkjet printing technology is not just grasping market share from other conventional and digital print markets but expanding its own market especially in wide format printing. The two trade shows the Ipex in Birmingham and FESPA in Munich have showed some very exciting new ink jet possibilities. One of the indicators is that core electrophotography producer like Xerox announced their first ink jet printing press in the production market for 2011. The other very competitive and attractive field this year was the wide format print market. Technological advances in print head technology, print equipment and inks will help to drive the market forward and with the inventions of new types of inks it seems there is no boundary to which substrate can be enriched by printing. The expanded use of large-format inkjet printers is due to the fact that they can be used in the graphics, photography, fine art reproduction, sign and display markets, where the demand for shorter runs and quicker turnarounds continues to dominate. The worldwide wide-format aqueous inkjet market is a fairly large and mature market comprised of three primary market segments – technical, creative and production graphics. Aqueous inkjet is the most flexible wide-format print technology, especially in the technical and production graphics markets. According to InfoTrends, these three segments comprise a hardware, ink, and media market that is expected to grow to \$5.98 billion by 2012. The trend toward environmentally-friendly printing processes and the sustainability of print has also been gaining momentum, and there are no signs that it's likely to stop anytime soon. Canon, Epson and Hewlett-Packard have all launched new systems to increase speeds and improve resolution and image quality as well as use new ink formulations to expand the colour gamut and improve outdoor durability. We are now seeing an emergence of durable aqueous inkjet printing systems from leading manufacturers, which will create a whole new opportunity for aqueous inkjet printers as an eco-friendly alternative to solvent and UV-curable inkjet. It is expected that the worldwide market for large-format aqueous inkjet printers will continue to grow, driven by trends in the photographic, fine art, trade show, technical document, graphic design, prepress proofing and the general office/business environment. The technology of UV inkjet printing is rapidly developing and growing on the industrial side of inkjet printing. I.T. Strategies forecasted a three

per cent decline in total UV-based flatbed printer sales in 2009 compared to 2008, before sales started to grow again. Indeed, there is no doubt that UV-based printers are changing the world of industrial digital printing. Agfa, 3M, DuPont, Durst, Gerber, HP, Inca, Mimaki, Nur, Scitex, Vutek and Zund, among others, have jumped on the UV bandwagon with new machines designed to print on everything from wood to glass to vinyl. These new UV printers can range in price from about \$50,000 to \$500,000 and more. The third segment of the inkjet portfolio solvent printers had also I.T. Strategies forecasted a 23 per cent decline in total solvent based printer sales in 2009 compared to 2008, but it is expected that sales will start to gradually recover in 2010 in solvent type printers. On FESPA 2010 there was also noticeable some trends, often in an overseen markets like garment printing and other non paper based printed products. While inkjet is clearly on the rise in areas which were once dominated by screen printing, new silkscreen technologies are entering specialised applications, and developments in the garment industry are favouring all kinds of add-ons used in textile printing. These transformations are pointing into two main directions. At the level of enterprises catering for lower print runs, there is a rapidly increasing shift towards digital workflows and a gradual replacement of analog processes, including screen printing, by inkjet. At the level of high-volume and high-speed industrial applications, screen is still the favoured technology for years to come, even though it will be complemented by digital inkjet. In addition, screen is becoming the technology of choice for important niche applications such as electronics, solar panels, electroluminescence and bio-medical sensors, but also as a high-precision and low-cost process for specific label requirements and printing on objects.

In industrial applications such as high-volume textile printing, screen is still the more robust and at least ten times faster technology option, but inkjet is making big leaps in this segment. According to a Pira study commissioned by Fespa, the market for digital print on textiles is forecast to grow from EUR 115 million in 2009 to close to EUR 1 billion by 2014. The total installed base of digital printers for textiles is forecast to grow to 52,800 units globally by then, a CAGR of 23 per cent.

At the same time, the development of better, stronger and more versatile screen printing presses has not slowed down at all, and specialised manufacturers such as Thieme also have their customers benefit from the on-going progress in other printing processes, such as the breathtaking improvements made in inks, substrates, coatings and press engineering, over the past few years. Apart from some unique material properties, screen has the advantage of being the only printing technique capable of varying and controlling the thickness of the ink or paste to be applied. It still has certain cost advantages as well, such as the price of the inks, including fluorescent and metallic inks. [11]

One more specialty field of printing which is growing more and more interesting is the 3D prototyping industry. 3D printing is used to come up with three dimensional objects and is a form of additive manufacturing. It is now easier and more affordable to come up with a prototype using the 3D technology. One form of 3D printing technology is made up of inkjet printing systems. Fine powder layers made of resins, corn starch or plaster is bonded selectively on adhesives produced by the inkjet print heads. This kind of technology makes it possible to print a full color prototype and is considered to be one of the fastest methods. Another technology involves the use of machines that feed liquids like photopolymer using an inkjet print head to create every layer of the model. This kind of photopolymer machine uses an ultraviolet flood lamp that is placed on the print head so that each layer is cured once it is deposited. Fused deposition modeling is also used as a 3D technology and is mainly applied is traditional prototyping. This technology makes use of nozzles to place the molten polymer on a support structure. The molten polymer has to be deposited layer by layer. These technological advances can be very useful in the packaging industry where designer's can make a product prototype in 3D for proofing stage instead of 2D preview on the screen.

#### 4. Package printing and technologies

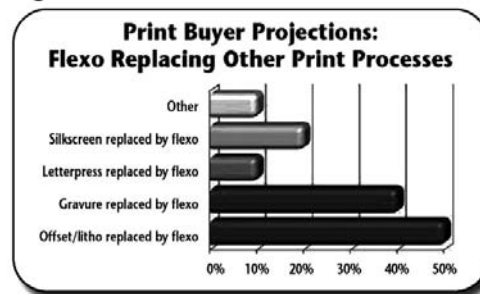
The packaging market is one of the few very lucrative businesses where all the printing technologies are fighting fierce for market share. While offset is trying with full automatization and long perfectors as well added value printing and large sheet printing, flexo is becoming more and more competitive concerning that flexographic printing and converting can often be performed entirely inline, on a wide range of materials and substrates, and the quality has improved substantially. These factors equate to a cost-effective process that produces minimal waste. And, in fact, many would be surprised to learn that flexo is the fastest growing global analog print method.

Since packaging is a key growth engine for the graphic communications industry, and flexography is a dominant process for many packaging applications, PRIMIR recently

commissioned LPC Inc. to conduct research on the topic. The resulting outcome is a new report, "Benchmarking and Worldwide Market Trends for Flexographic Printing" which was released in May 2010.[12] The study provides a comprehensive assessment of the global flexographic industry while answering how this analog print process fits into a world that is increasingly going digital and which world regions are likely to provide opportunities for future growth. The study investigates flexo in packaging as well as non-packaging applications. According to the new PRIMIR study, packaging comprises nearly 92% of the global flexographic volume; the remaining volume is in non-package printing applications such as security printing, pharmaceutical products and commercially printed electronics. In the next several years flexo will enjoy a 4-5% growth rate—largely coming from growth in the developing regions, more specifically the BRIC countries.

LPC reports in the study that flexography accounts for nearly 60%, or just more than \$260 billion, of the \$440 billion printed packaging market. In 2009, flexo's market share for packaging applications included: \$125 billion for corrugated, \$81 billion for flexible packaging, \$56 billion for labels and tags, and \$1.2 billion for folding carton. One of the more exciting growth areas for flexography is printed electronics. While reportedly only accounting for \$3 million in sales in 2008, the printed electronics market is forecast to grow to \$89 billion by 2020. Even sharing this growth with the other print processes, there are tremendous opportunities for flexo in this area.[13]

**Figure 1**



Source: PRIMIR "Benchmarking and Worldwide Market Trends for Flexographic Printing" by LPC, Inc. 2010

**Figure 4: PRIMIR projections for flexo market share advancement**

With RFID technology, cost of components, especially cost of individual tags, will play a major role in determining its ultimate success and ubiquity. From an economic perspective, the cost of tags is expected to continue to drop as the volume production goes up to meet demand. However, both alternative chipless tag designs and advances in fabrication and manufacturing of integrated circuits (IC) are expected to drive the cost of tags dramatically lower. The *5 cents tag*, as it has been called, has been widely viewed as the inflection point where wide adoption of RFID will quickly occur. To be clear, the supply and demand equation alone is unlikely to drive the price of IC-based tags down to the 5 cents mark. Today, tag prices barely dip below 25 cents, even in high volumes. Therefore, alternative tag designs and more efficient tag manufacturing are likely to be important factors in driving the cost of tags down by another factor of five. Many factors, including physical and environmental, affect the readable range and accuracy of tags. Some examples are detection near metal or liquid and extreme weather conditions such as low temperature or high humidity. Besides simply improving on existing technology to overcome these limitations, alternative physics are being employed that can sidestep or leapfrog these limitations. Chipless tags promise to improve upon the physical limitations of radio frequency detection while potentially offering reduced costs due to the absence of integrated circuitry. Chipless tags can be more easily applied near metal and liquid or embedded in items like paper, thereby offering greater flexibility and functionality with their use. One chipless tag technology showing promise in supply chain applications uses Surface Acoustic Wave (SAW) technology. SAW technology involves the propagation of radio frequency acoustic waves on the surface of polished crystals. Other promising chipless technologies that have the potential to revolutionize RFID applications use nanotechnology, genomics, or even chemistry to achieve chipless tagging and unique identification of objects such as paper currency and product labels. When it comes to major advancements in IC-based tag design, Smart Active Label (SAL) technology is gaining momentum in the market. SAL offers enhanced range and accuracy attributes while being less vulnerable to liquid or metal. A SAL tag is essentially a semi-active smart label with its power source in the form of a thin, flexible battery. Using SAL tags, tagging and detecting cans of soda and bottles containing liquid can become more practical and economical.[14]

## 5. Conclusion

Summarizing the aforementioned trends and developments we can see that with information distribution and presentation methods and channels the classic printing industry needs to change its business model from the hardware and machinery based to service based business models. It needs to be versatile, efficient with very good logistics and software networking for fast access information transfer. It needs to combine several short run type printing jobs combining digital and conventional technologies, while the specialized printers are mainly to stay in large volume package printing. The most affected print market share will be the book and publishing market where new ebook and tablet PC will decrease the printed stock volume. Ink jet technology promises very versatile applications and is still growing and expanding in the non paper based markets. With the advance in new ink technologies and 3D prototyping it opens up market for possibilities where beside classic poster and banner printing the printing house can produce tiles, garments and other home decorative elements.

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# SENSITIZATION OF PHOTOINITIATORS FOR UV POLYMERISATION

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**Abstract:** In this paper is investigated sensitization of 3 photoinitiators. Prepared hybrid photoinitiator HP1 – ( $\eta^5$ -2,4-cyclopentadien-1-yl){(1,2,3,4,5,6-  $\eta$ )-{[4-(2-hydroxy-2-methylpropanoyl)phenoxy]-ethoxy}-benzene}-Fe(II)-hexafluorophosphate) and two commercially available photoinitiators Irgacure 2959 – (1-[4-(2-hydroxyethoxy)-phenyl]-2-hydroxy-2-methylpropan-1-on) and Irgacure 261 – ( $\eta^5$ -2,4-cyclopentadien-1-yl)-[(1,2,3,4,5,6-  $\eta$ )-chlorobenzene]-Fe(II)-hexafluorophosphate. HP1 is hybrid photoinitiator with higher molecular weight containing chemical groups suitable for starting free radical and cationic polymerization simultaneously. Irgacure 261 is cationic photoinitiator and Irgacure 2959 is free radical photoinitiator.

Anthracene and isopropyl thioxanthone in two different concentrations (0.5 and 1 molar %) were used as sensitizers. Molar absorption coefficients of photoinitiators and sensitizers were determined by UV-VIS spectroscopy. The sensitization efficiency was examined in acrylate binder PETIA (pentaerythritol triacrylate) and epoxide binder Celloxide 2021P (3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexanecarboxylate) and was followed by FTIR spectroscopy. Results proved that hybrid photoinitiator HP1 and cationic photoinitiator Irgacure 261 can be efficiently sensitized in epoxide binder Celloxide 2021P curable by cationic polymerization. Photoinitiator sensitization in binder PETIA curable by free radical polymerization was efficient only in presence of oxygen whereas in absence of oxygen was ineffective.

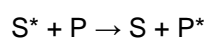
**Key words:** photoinitiator, sensitization, UV-VIS, FTIR, UV polymerization

## 1. Introduction

Photoinitiated polymerization of multifunctional monomers and oligomers is one of the most efficient methods to produce highly cross-linked polymer networks. It has found a large number of commercial applications (printing inks and varnishes, coatings, adhesives, etc.), because of its unique advantages (rapid curing time, enhanced material properties, elimination of volatile organic compounds, etc.).

Important compound of UV cured systems are photoinitiators that decompose into free radicals or ions when exposed to light and start polymerization reactions. There are many factors that influence the decomposition of photoinitiators and polymerization reactions. Amongst important factors belong UV source (emission spectrum and intensity of radiation), oxygen inhibition (in case of free radical polymerization), presence of pigments (pigments can absorb strongly in the UV spectrum, particularly in the short wave UV and adverse effect the curing process since very little remaining UV energy may be available to activate the photoinitiator), presence of additives (sensitizers, coinitiators), used monomers and oligomers, etc.

The efficiency of photoinitiator decomposition can be enhanced by sensitization. The sensitization is the process of energy transfer between a sensitizer and a photoinitiator. A sensitizer is simply a photoinitiator that has high triplet energy from the absorbed UV light. This energy can be transferred very efficiently to another photoinitiator in the ground state that has lower triplet energy. For example, the sensitizer S (such as isopropyl thioxanthone) absorbs UV at long wavelengths to produce a high energy triplet intermediate  $S^*$ , without a hydrogen donor. Energy is transferred to a photoinitiator P to produce an excited initiator  $P^*$ , leaving a ground state sensitizer to pick up more energy in a catalytic fashion. [1]





## 2. Experimental materials

In this work was investigated sensitization of three photoinitiators: prepared hybrid photoinitiator (HP1) [2, 3], commercially available free-radical photoinitiator Irgacure 2959 and cationic photoinitiator Irgacure 261 (both are supplied by Ciba Specialty Chemicals). As sensitizers were used anthracene and isopropyl thioxanthone (ITX). The polymerization reactions were studied in cationic binder Celloxide 2021P (3,4-epoxycyclohexylmethyl-3,4-epoxycyclohexane carboxy-ate) and in radical binder PETIA (pentaerythritol triacrylate). Both binders are supplied by UCB Chemicals. The detailed synthesis of HP1 was described in [2]. The investigated photoinitiators, sensitizers and binders are shown in Figure 1.

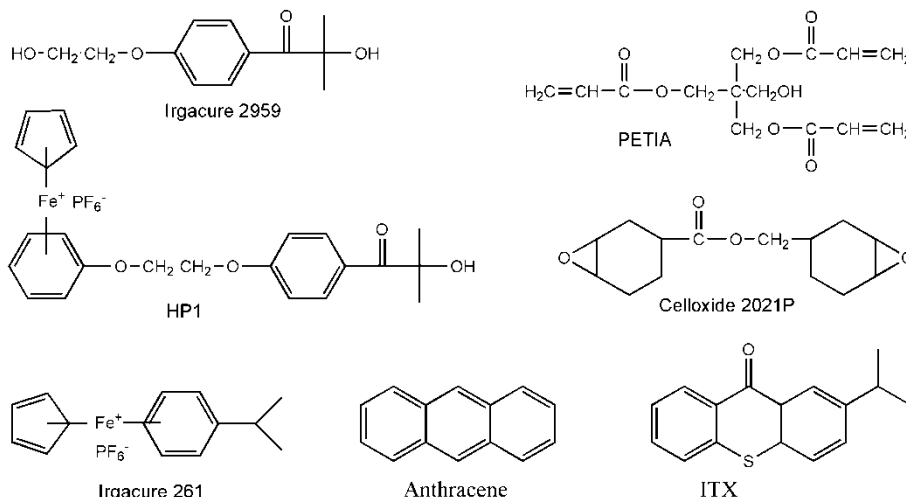


Figure 1: Tested photoinitiators, sensitizers and binders

## 3. Results and discussion

### 3.1 UV-VIS spectroscopy

UV-VIS absorption spectra of photoinitiators and sensitizers were monitored by UV-VIS spectrometer Specord 210 (Analytik Jena AG, Germany) in acetonitrile at room temperature. The molar extinction coefficients were calculated using the Lambert-Beer's law. In table 1 are summarized molar extinction coefficients of absorption bands maxima of tested photoinitiators and sensitizers.

Table 1: Molar extinction coefficients  $\epsilon_{\lambda}$  ( $l \cdot mol^{-1} \cdot cm^{-1}$ ) for maxima of absorption bands  $\lambda_{max}$  (nm)

Anthracene		ITX		Irgacure 2959		Irgacure 261		HP1	
$\lambda_{max}$	$\epsilon_{\lambda}$	$\lambda_{max}$	$\epsilon_{\lambda}$	$\lambda_{max}$	$\epsilon_{\lambda}$	$\lambda_{max}$	$\epsilon_{\lambda}$	$\lambda_{max}$	$\epsilon_{\lambda}$
222	7 825	221	13 297	194	17 549	199	37 443	200	46 985
253	115 136	258	37 416	221	10 603	244	14 424	245	18 258
311	862	290	3 642	275	15 782	389	75	270	16 258
325	1 942	302	3 100	—	—	455	60	392	195
341	3 691	384	4 866	—	—	—	—	456	121
358	5 113	—	—	—	—	—	—	—	—
377	5 395	—	—	—	—	—	—	—	—

Super pressure mercury lamp (CE Green Spot from UV Source Inc., USA) was used as a UV source for starting of polymerization reactions of prepared samples. In table 2 are summarized molar extinction coefficients at the most important emission wavelengths of the super pressure mercury lamp. From table 2 is obvious that sensitizers have higher molar extinction coefficients at main emission bands in long wave UV region (both sensitizers for 352 nm and ITX also for 390 nm) and in short wave UV region for emission band at 245 nm. Short wave UV around 250 nm has little penetrative power and is mainly used to provide surface cure. Long wave UV and near visible light at 350–450 nm penetrates much further and is more useful for depth cure.

Table 2: Molar extinction coefficients ( $\text{l.mol}^{-1}.\text{cm}^{-1}$ ) for main emission wavelengths of the super pressure mercury lamp

	emission bands (nm) of super pressure mercury lamp						
	245	295	305	324	352	390	419
Anthracene	62 692	316	529	1 912	2 996	62	18
ITX	21 492	2 833	2 398	290	3 505	1 893	4 281
Irgacure 2959	2 255	6 525	1 198	244	61	12	8
Irgacure 261	14 285	803	511	333	168	184	172
HP1	17 287	4 653	1 326	659	264	194	165

### 3.2 FTIR spectroscopy

Polymerization reactions were studied by FTIR spectroscopy. The infrared spectra were recorded with Avatar 320 FTIR spectrometer (Nicolet Instrument Corp., USA) at room temperature.

The reaction course was investigated for concentration 3 molar % of photoinitiators and with addition of sensitizers 0, 0.5 or 1 molar %. The samples were prepared by coating thin layer of curing mixture (liquid binder with initiating system) on aluminum foil. For observation cationic polymerization the samples were measured by FTIR before exposure and then, after 1 second exposure by super pressure mercury lamp, were samples measured in defined time lags up to 160 minutes. For observation free radical polymerization the samples were measured by FTIR before exposure and then, after exposures 0.05, 0.15, 0.3, 0.8, 1.5, 2, 3, 5, 7, 10, 20, 40, 60 and 80 seconds. Measurements of polymerization were done under  $\text{O}_2$  and  $\text{O}_2$ -free conditions. For observation under  $\text{O}_2$ -free condition were measured samples covered with thin high density polyethylene (HDPE) film (8  $\mu\text{m}$ ). The irradiation intensity was in both cases  $150 \text{ mW/cm}^2$  (measured by Compact Radiometer from UV Process Supply, USA).

The disappearance of the functional groups was monitored by selecting the IR wave number where these functional groups exhibit their absorption bands:  $809 \text{ cm}^{-1}$  for acrylate double bond (PETIA) and three overlapping bands of epoxy rings of Celloxide 2021P (788, 798,  $808 \text{ cm}^{-1}$ ). The degree of conversion (X) was calculated from the decrease in IR absorbance after a given exposure (free-radical polymerization) or defined time lag (cationic polymerization) by equation:  $X = 1 - (A_t/A_0)$ , where  $A_0$  is the quotient measured band and internal standard without UV exposure and  $A_t$  is the quotient measured band and internal standard after UV exposure and defined time lag for cationic polymerization and for free radical polymerization after determinate exposure time. Carbonyl group was chosen as internal standard ( $1738 \text{ cm}^{-1}$  for acrylate binder and  $1727 \text{ cm}^{-1}$  for epoxide binder).

Figure 2 shows conversion curves of epoxide binder with 3 molar % of hybrid photoinitiator HP1 (Figure 2a) or commercially available Irgacure 261 (Figure 2b) with various addition of sensitizers (0, 0.5 and 1 molar %). The conversions reached after 10, 20, 160 minutes and 24 hours are shown in Figure 3. Greater differences in reached conversion of epoxide binder can be seen in first stage of polymerization and particularly with addition of 1 molar % of sensitizers (Figure 3). The conversion reached after 10 or 20 minutes after UV exposure was higher about 10–20 % (depends on photoinitiator and sensitizer). The addition of sensitizers has only small influence on reached conversion after 160 minutes or 24 hours.

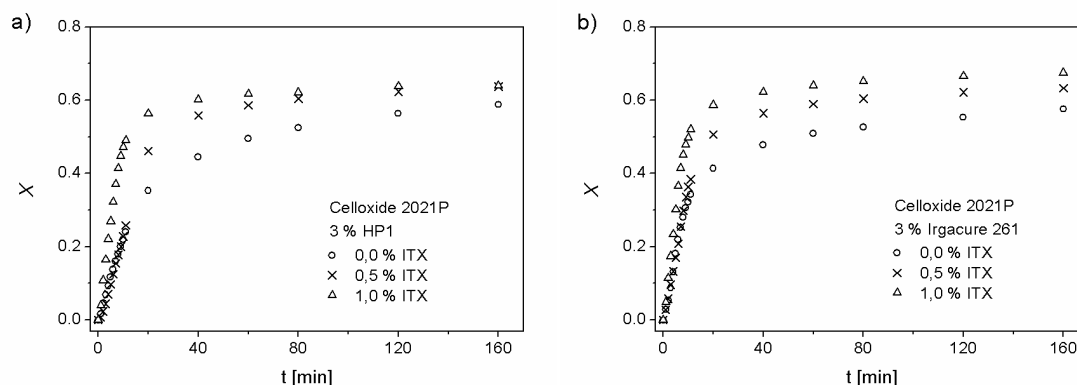


Figure 2: The conversion curves of epoxide binder Celloxide 2021P with photoinitiator HP1 (a) or Irgacure 261 (b) with addition of sensitizers

Figure 4 shows conversion curves of acrylate binder PETIA with 3 molar % of hybrid photoinitiator HP1 under  $O_2$  condition (Figure 4a) or  $O_2$ -free condition (Figure 4b) with various addition of sensitizers (0, 0.5 and 1 molar %). Figure 5 shows reached conversion of acrylate binder after UV exposure 3 or 80 seconds (intensity of irradiation  $150 \text{ mW/cm}^2$ ) with both type of photoinitiators (HP1 – Figure 5a, Irgacure 2959 – Figure 5b). From Figures 4 and 5 is apparent, that influence of sensitizers on reached conversion is not as obvious as it was at epoxide binder (cationic polymerization). Under  $O_2$ -free condition were reached higher conversions much faster than under  $O_2$  condition for both type of photoinitiators (hybrid HP1 and commercially available Irgacure 2959). Under  $O_2$  condition can be seen positive effect of sensitizer ITX on reached conversion of binder PETIA with hybrid photoinitiator HP1 (Figure 4a and 5a). Second sensitizer (anthracene) has not this positive effect. Neither sensitizer is suitable for sensitization of commercial photoinitiator Irgacure 2959 (Figure 5b).

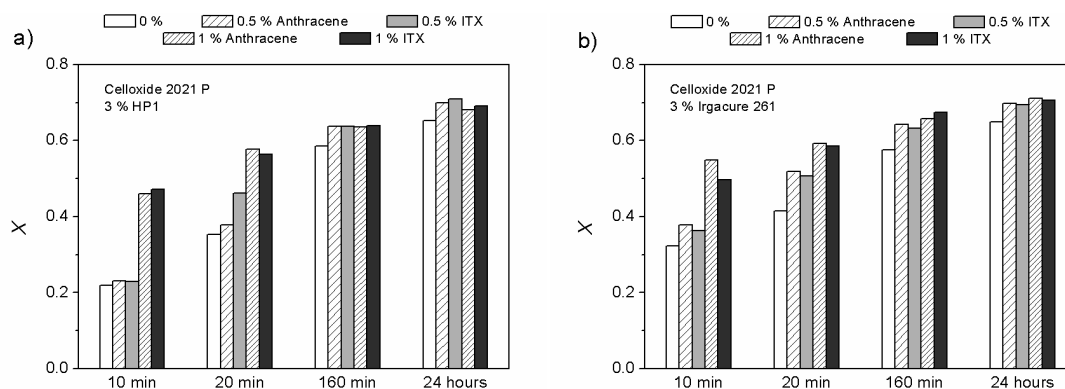


Figure 3: Conversions of epoxide binder reached after 10, 20 160 minutes and 24 hours after UV exposure with photoinitiator HP1 (a) and Irgacure 261 (b)

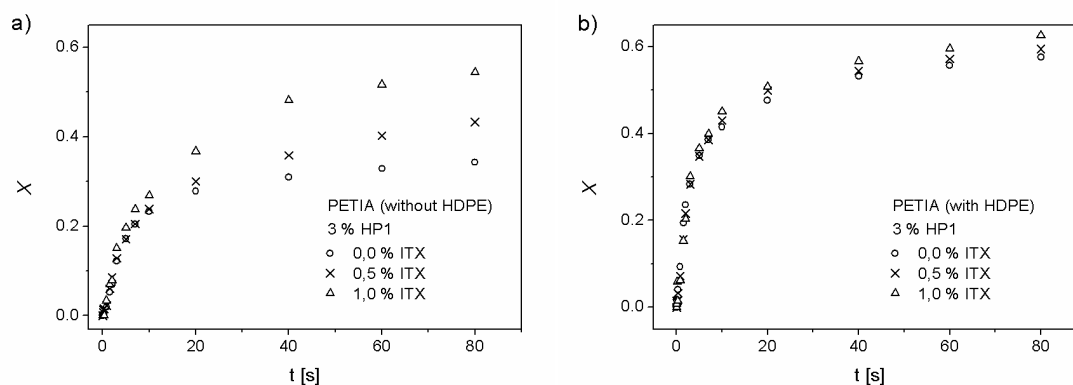


Figure 4: The conversion curves of acrylate binder PETIA with photoinitiator HP1 under  $O_2$  (a) and  $O_2$ -free (b) condition with addition of sensitizers

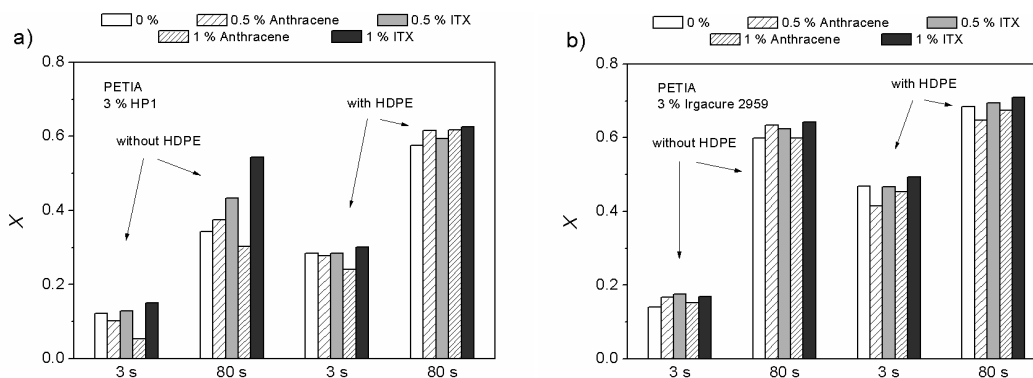


Figure 5: Conversions of acrylate binder reached after UV exposure 3 or 80 s with photoinitiator HP1 (a) and Irgacure 2959 (b) under  $O_2$  (without HDPE) and  $O_2$ -free (with HDPE) condition

#### 4. Conclusion

Tested sensitizers ITX and anthracene effectively sensitize cationic polymerization of epoxide binder Celloxide 2021P with both type of photoinitiators (hybrid HP1 and commercially available Irgacure 261). In case of free radical polymerization of acrylate binder PETIA, ITX effectively sensitize hybrid photoinitiator HP1 under O<sub>2</sub> condition. Under O<sub>2</sub>-free condition was not seen obvious effect of sensitizers on reached conversion of acrylate binder. Commercially available free radical initiator Irgacure 2959 was sensitizing neither ITX, not anthracene.

#### 5. Acknowledgement

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## STABILITY OF THERMOCHROMIC PRINTING INKS

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**Abstract:** Thermochromic (TC) printing inks change their colour regarding the change in temperature. One of the most frequently used TC material in printing inks are leuco dyes. This TC composite usually consists of a colour former (leuco dye), a colour developer and a solvent, protected in polymer capsules. The colour of TC prints is dynamic, but it is not just temperature dependent, but also depends on thermal history. The effect is described by colour hysteresis. Leuco dye-based TC inks are known for their short pot life, poor lightfastness and low resistivity to high temperatures and many chemicals. The effect of UV light, humidity and high temperatures on dynamic colour properties was tested. The effect was evaluated by total colour difference between unexposed and differently exposed samples in both states (fully coloured and totally discoloured), by the total colour contrast between fully coloured and totally discoloured states of the samples and by the sample discolouration ability.

**Key words:** thermochromic printing inks, stability, laboratory weathering, xenon arc, lightfastness, resistance to high temperatures, resistance to humidity, total colour contrast

### 1. Introduction

Most frequently applied thermochromic (TC) printing inks are based on organic composite which is protected in pigment capsules from unwanted reactions with their surroundings [Seeboth & Löttsch, 2008, Seeboth et al., 2007]. The capsule is hard, non-polar, thermally very stable and relatively impermeable [Small, 1996]. The TC composite usually consists of a colour former (leuco dye), a colour developer and a solvent. The reaction between dye and developer prevails at lower temperatures and gives rise to coloured complexes. At higher temperatures the solvent melts, making the solvent-developer interaction dominant, and colour complexes are destroyed [Seeboth & Löttsch, 2008, Seeboth et al., 2007, White & LeBlanc, 1999]. The colour of samples printed with such ink depends on temperature and on thermal history – the effect is described by colour hysteresis [Kulčar et al., 2009]. Dynamic colour may be described by the area of colour hysteresis in 3D colour space or, alternatively, by four characteristic temperatures of the hysteresis loop [Kulčar et al., 2010].

Leuco dye-based TC inks have short pot life, poor lightfastness, low resistivity to high temperatures and many chemicals. Polymer envelopes are much more stable than the polymer binder in TC ink [Kulčar et al., 2010]. However, lightfastness and chemical stability of TC capsules in the applied vehicle were considered to be the origin of poor stability of TC inks [Small, 1996]. Lightfastness can be improved by applying a protective layer.

### 2. Experimental part

We tested three different commercially available red TC inks (Table 1). They were screen printed using a flatprint SD 05 machine (RokuPrint, Germany) over OBA-free gloss coated paper (150 g/m<sup>2</sup>) employing SEFAR PET 1500 monofilament polyester mesh 120/34Y. UV based samples were cured with energy of ~ 400 mJ/cm<sup>2</sup>.

*Table 1: Selected data of applied inks: drying method, activation temperature ( $T_A$ ), the size of the largest pigment particles (grindometer value) and specular gloss evaluated at 60° (gloss units, GU).*

sample	drying method	$T_A$ (°C)	grindometer value (µm)	gloss (GU)
TCX	UV curing	31	11	35
SIC	UV curing	33	1,5	63
STR	air drying	15	1	5

Spectral reflectance was measured using Lambda 950 UV-VIS-NIR spectrophotometer (Perkin-Elmer) using 150 mm integrating sphere with (8°:di) measuring geometry. The fully coloured state was measured at 5 °C and completely discoloured at 50 °C. The temperature of

the sample was regulated by circulation of thermostatically controlled water through copper base of water block (EK Water Blocks, EKWB d.o.o. Slovenia). The CIELAB values were calculated using 2° standard observer and D50 illuminant. The total colour differences were calculated according to the CIEDE2000 colour difference equation [CIE Publication, 2004].

The following laboratory tests were carried out:

- stability to UV light (Suntest XLS+, Atlas),
- stability to elevated temperatures and humidity (Climacell 222 Comfort, MMM),
- stability to high temperatures (oven SP-55 EASY, Kambič).

For the light fastness testing part of the samples was printed with a protective lacquer. Spectral transmittance of this lacquer was measured in collimated beam over UV and visible spectral region. The samples were applied over fused silica wafer (Corning 7980).

## 2.1 Stability to UV light

We tested and compared results for unprotected samples and samples protected with a UV absorbing lacquer WPT325 (Siltech Ltd, England), which is a water based lacquer for flexographic and gravure printing, designated for UV protection. The lacquer blocks almost all radiation below 400 nm. Prepared samples were exposed to xenon lamp in a SunTest XLS+ instrument for different periods of time. Dose dependency on exposure time is shown in Table 2.

*Table 2: Dose dependency on exposure time.*

time [h]	1,5	6	24
dose [kJ/m <sup>2</sup> ]	2700	10800	43200

## 2.2 Stability to elevated temperatures and moisture

Samples were placed in a conditioned chamber ClimaCell 222 Comfort with a constant temperature of 80 °C and 50 % relative humidity for three days.

## 2.3 Stability to high temperatures

Since samples were going to be exposed to high temperatures, we printed them on white aluminium plate. Samples were heated to two different temperatures and for six different time periods. Used temperatures and exposure times are shown in Table 3.

*Table 3: Used temperatures and exposure times.*

T (°C)	150, 200
t (min)	15, 30, 60, 120, 240, 600

# 3. Results & discussion

We compared unexposed samples with exposed ones. CIELAB colour values were calculated and represented in ( $a^*$ ,  $b^*$ ) plane. Total colour difference CIEDE2000 between unexposed and differently exposed samples in coloured and discoloured state was also calculated for each sample. Since a TC sample is considered to work properly if the difference between the fully coloured and totally discoloured state is clearly recognizable, we defined this characteristic as the total colour contrast (TCC).

## 3.1 Stability to UV light

Paths on the ( $a^*$ ,  $b^*$ ) plane made by the samples during exposure to UV light are shown on Figure 1. They are shorter for the protected samples in both states. Compared to the used paper, STR sample has the best discolouration properties with and without the protective layer.

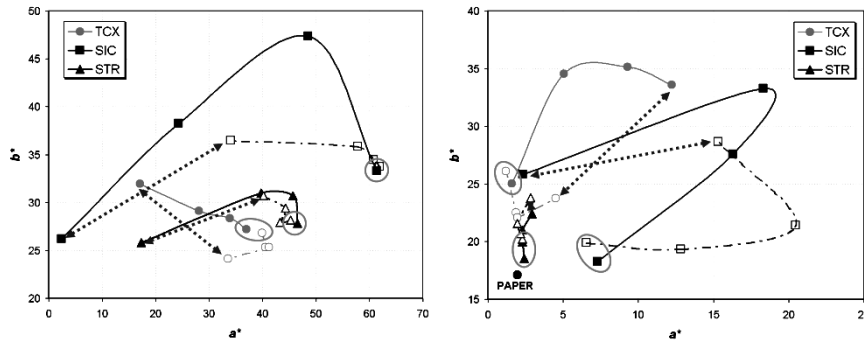


Figure 1: TC samples in  $(a^*, b^*)$  plane before and after exposure to UV light in totally coloured (left) and totally discoloured state (right). Unprotected samples are represented in solid line and solid signs, samples protected with the lacquer in dash-dot line and open signs. Initial values (before exposure) are denoted with gray circles and continue for different exposure times till the final exposure (24 h). Difference between final values of unprotected and protected sample is shown with gray arrows.

The exposure to UV radiation influences the colour of all samples. The colour difference between the unexposed and exposed samples in fully coloured and totally discoloured state increases with exposure time, more rapidly for unprotected samples (Figure 2). Effect is the largest for SIC sample and similar for TCX and STR samples. The results show that the application of a protective layer has a large influence.

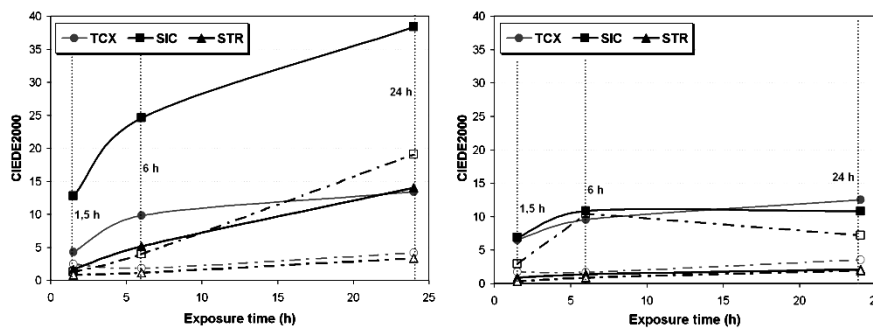


Figure 2: The total colour difference between unexposed and exposed samples in dependence on exposure time for fully coloured (left) and totally discoloured state (right). Unprotected samples are represented in solid line and solid signs, samples protected with the lacquer in dash-dot line and open signs.

The total colour contrast for the unexposed and exposed samples is shown in Figure 3. After 24 hours of exposure unprotected SIC sample has no dynamic colour. TCC value drops below 5 CIELAB units for unprotected TCX sample but remains above 15 CIELAB units for unprotected STR sample. Protective layers give great benefit to the operating ability of the TCX and STR samples; for TCX sample TCC remains 81 % of the initial value and for the STR sample 85 %. For SIC sample the remaining value is only 34 %. STR sample obtains the best dynamic colour properties when exposed to UV light.

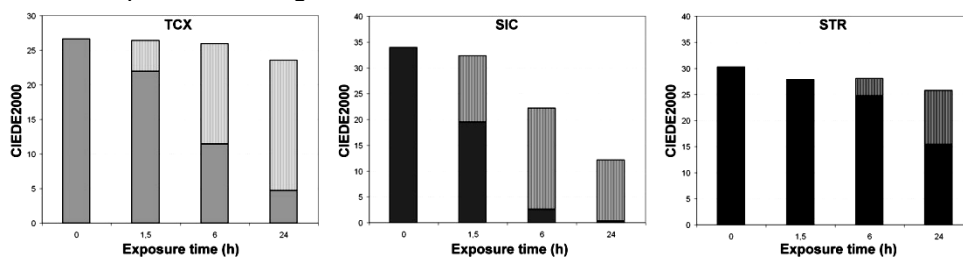


Figure 3: The total colour contrast between fully coloured and totally discoloured states of unprotected samples (solid colour) and protected with the lacquer (lines) in dependence on exposure time.



### 3.2 Stability to moderate temperatures and humidity

After three hour exposure to 80 °C and 50 % relative humidity all samples show small colour changes. CIELAB values of samples in coloured and discoloured state on ( $a^*$ , $b^*$ ) plane are represented in Figure 4. Colour difference between exposed and unexposed sample is below 3 CIELAB units in coloured state and below 2 CIELAB units in discoloured state for all the samples.

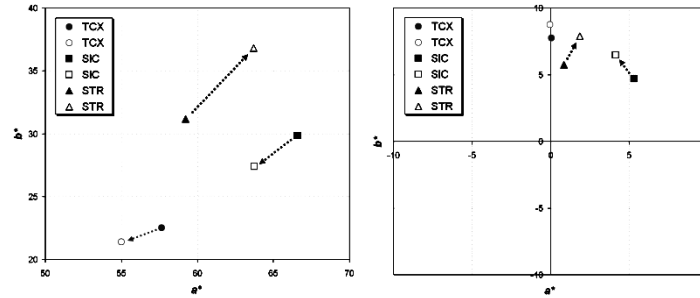


Figure 4: TC samples in ( $a^*$ , $b^*$ ) plane before (solid signs) and after exposure (open signs) to moderate temperatures and humidity in coloured (left) and discoloured state (left).

After exposure TCC reduces for TCX and SIC sample: 4 % for TCX and 3 % for SIC sample. For the STR sample TCC actually increases for 4 %. Results can be seen in Figure 5.

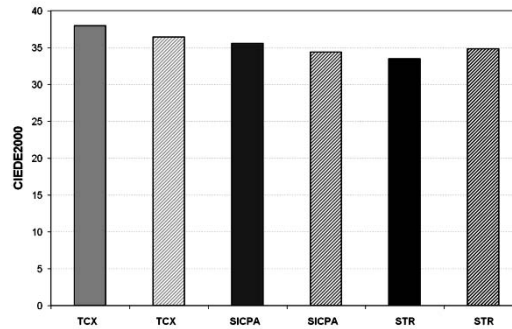


Figure 5: The total colour contrast (TCC) for unexposed samples (solid colour) and samples exposed to 80 °C and 50 % relative humidity for three days (diagonal lines).

### 3.3 Stability to high temperatures

Paths on the ( $a^*$ , $b^*$ ) plane made by the samples during exposure to high temperatures are much longer for the samples exposed to higher temperature (200 °C) in both states. These samples change more than those exposed to 150 °C (Figure 6). In discoloured state, samples exposed to 150 °C change mostly in  $a^*$  direction but when exposed to 200 °C they also considerably change in  $b^*$  direction (yellowing of the binder). Compared to the used substrate (white aluminium plate) STR samples has the best discolouration properties, followed by TCX sample and SIC sample.

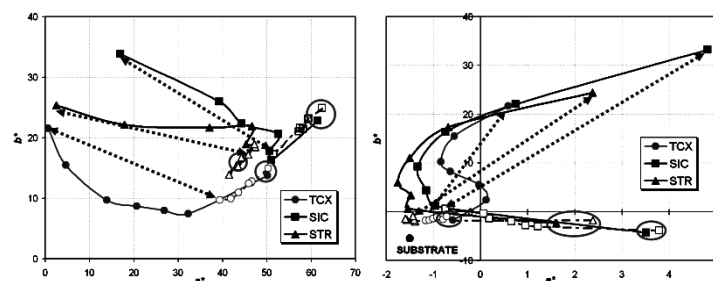


Figure 6: TC samples in ( $a^*$ , $b^*$ ) plane before and after exposure to high temperatures in totally coloured (left) and totally discoloured state (right). Samples exposed to 200 °C are represented in solid line and solid signs, samples exposed to 150 °C in dash-dot line and open signs. Initial values (before exposure) are denoted with gray circles and continue for different exposure times till the final exposure (10 h). Differences between final values of samples exposed to different temperatures are shown with gray arrows.

Colour difference between unexposed and exposed samples is increasing with exposure time in both states, coloured and discoloured (Figure 7). In coloured state the biggest colour difference is obtained for the TCX sample, regardless the temperature. STR sample functions a bit better than SIC sample. In the colourless state the biggest colour difference is obtained for the SIC sample, especially at 200 °C, TCX sample changes the least.

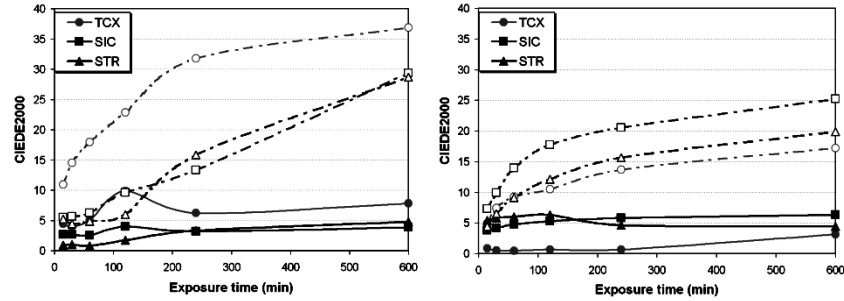


Figure 7: Total colour difference between unexposed samples and samples exposed for different time periods in fully coloured state (left) and totally discoloured state (right). Solid lines and solid signs denote exposure to 150 °C, dash-dot lines and open signs exposure to 200 °C.

Total colour contrast (TCC) of samples is decreasing with temperature increase: exposure to 150 °C gives wider colour contrast than that to 200 °C for the same exposure time (Figure 8). After 10 hour exposure at 150 °C, the TCC reduces for 14 % for TCX, for 7 % for SIC and for 3 % for STR, according to the initial values. After 10 hour exposure at 200 °C, the TCC reduces for 98 % for TCX, for 74 % for SIC and for 95 % for STR, according to the remaining values. SIC sample obtains the best colour contrast when exposed to high temperatures.

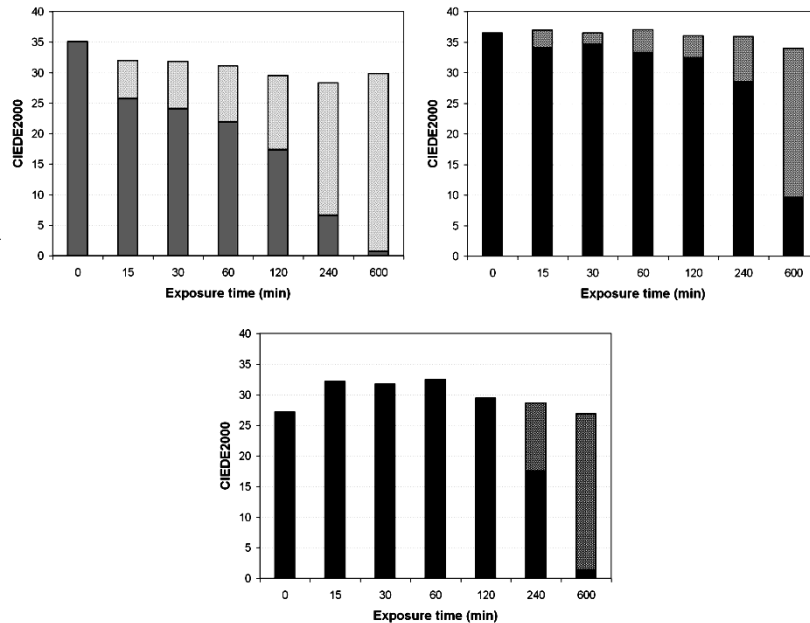


Figure 8: Total colour contrast (TCC) for unexposed samples and samples exposed for different time periods. Samples exposed to 150 °C are represented in dots and to 200 °C in full colour.

#### 4. Conclusion

Stability of thermochromic printing ink depends on the stability of the following components:

- binder,
- polymeric envelopes of microcapsules,
- thermochromic composite,

thus it is actually a combined effect of all three components listed above.

When testing stability to UV light all three components are included. In the coloured state the effect of the composite stability is mostly visible, as the samples get less saturated or have no colour at all. In discoloured state the effect of the binder and polymeric envelopes of the microcapsules prevails. It is a well known fact that polymers start yellowing with longer exposures to UV light. Using a protective layer can help preserve dynamic colour properties of TC samples.

When having samples in a conditioned chamber, we tested the samples stability to moderate temperatures (80 °C) and humidity (50 %). Humidity can influence only the binder, since it can not penetrate through the layer into the microcapsules and the composite inside. Temperature on the other hand impacts all the components, but it is not high enough to noticeably impact the TC samples. Used parameters did not affect the dynamic colour change of the samples.

After testing stability to high temperatures, we discovered that 150 °C is not fatal for TC prints. Even after 10-hour exposure, there were no major colour changes. In the coloured state the colour change is less than 5 CIELAB units for SIC and STR samples, and around 8 for the TCX one. In discolour state the change is even smaller, it is less or around 5 CIELAB values. Exposing samples to 200 °C has a big impact even by shorter exposure times. After 15 minutes of exposure colour change is above 5 CIELAB units for all the samples in coloured and discoloured state.

After preformed tests, we can say that TC prints are mostly affected by UV light and really high temperatures. Humidity and moderate temperatures don't impact their dynamic properties. Also different TC inks react differently to various exposures.

## 5. Literature

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# INVESTIGATION OF THERMAL AGEING AND INFLUENCE OF CONSERVATION TREATMENT ON COLOUR CHARACTERISTICS AND PHYSICAL AND MECHANICAL PROPERTIES OF OFFSET IMPRINTS ON GLOSSY COATED PAPER

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**Abstract:** *The conservation and restoration of printing materials is meant to conserve or restore them as to their initial status as much as possible. At present the offset method is the most world-accepted printing method. Therefore, it is important to investigate the ageing of offset imprints (in this case thermal ageing), since very soon we will find ourselves in a situation of facing huge quantities of offset printing products, filling the libraries and we should be able to react adequately and to keep and conserve them as long as possible. Glossy coated paper has been used in the experiment. In standardized conditions, it has been printed control strips, which contain 999 colour patches with different combinations of Cyan, Magenta, Yellow and Black. The study has investigated the impact of conservation water treatment with surface-active substances and bleaching with  $H_2O_2$  on the thermal paper ageing process and the inks colours changing. The control patches have been measured with spectrophotometer in CIE Lab colour system before and after thermal ageing and before and after water treatment and bleaching. In this paper it has been ascertained the influence of thermal ageing process and chemical treatment to inks colours, shifting of colour gamut and physical and mechanical properties of glossy coated paper.*

**Key words:** *Ageing, Offset Print, Thermal Ageing, Colour Gamut, Physical and Mechanical properties, Colour difference*

## 1. Introduction

Examination of paper and ink ageing processes provides important information about preventive care and conservation treatment, which should be undertaken for the purpose of preservation of printed materials kept in museums, libraries and archives and increase of their durability [1].

Paper ageing is manifested by discoloration and change of its physical and mechanical characteristics. Colour characteristics of inks used on such paper also change in time. The processes leading to paper ageing include acid hydrolysis and oxidation [2], which are interrelated.

Various conservation and restoration procedures may result either in delay or facilitation of ageing depending on conditions. Some commonly implemented procedures include water treatment and bleaching with chemical reagents.

The purpose of this study is to examine the effect of conservation water treatment (with surfactants) and bleaching (with  $H_2O_2$ ) on paper ageing processes and the change of colours and colour gamut (all colours resulting from C, M, Y, and K for a specific combination of paper - ink - printing press) of offset imprints on glossy coated paper subjected to artificial thermal ageing.

## 2. Experimental

In experiments, in real production conditions (in one of the biggest offset printing houses in Bulgaria with modern technique), with specialized software, was generated offset test form and printed on glossy coated paper. The paper selected for the experiment is the one of the most commonly used for printing of high quality colour reproductions, covers of luxury publications, magazines, etc. Imprints were obtained by the offset printing method, which is the most widely implemented method worldwide. Paper samples were characterized in terms of mass, fiber content, pH of water extract, tensile index, number of double folds and tear index. These physico mechanical paper parameters were measured before and after artificial thermal ageing at temperature 105°C for 48 hours. The effects of water treatment and bleaching with  $H_2O_2$  were studied.

#### *Water treatment of printed paper samples*

For water treatment, Lutensol AP6 was used, which is a non-ion surfactant base on nonylphenol: RO (CH<sub>2</sub>CH<sub>2</sub>O)<sub>x</sub>H, where x is the degree of etoxylation and x=6, 7, 8, 9, 10, 14, 20. Samples of the two paper types were subjected to treatment with 1% water solution of Lutensol AP6, under the following conditions: temperature – 20°C, duration – 30 minutes, hydromodule 1:50 and pH=6.5. The treatment was carried out by the submersion method.

#### *Bleaching of printed paper samples*

Paper samples were subjected to breaching with 3% water solution of H<sub>2</sub>O<sub>2</sub> [3]. Ammonium was added to achieve pH 9.5 ÷ 10. Bleaching conditions: temperature – 20°C, duration – 30 minutes [4].

The treatment was carried out by the submersion method. After the specified time had elapsed, the samples were washed with running water to remove any residues of the breaching reagent, then dried on filter paper and left to dry at room temperature.

#### *Printing conditions, density and color measurements of imprints*

Printing was done in real production conditions with state-of-the-art-equipment. Implemented print forms were negative acting and were exposed by Computer to Plate System for direct exposure. Sheet offset printing machines with alcohol dampening KBA RAPIDA 105 was emoloyed. Ink sequence – Black (K), Cyan (C), Magenta (M), Yellow (Y). Temperature in the printing department was 22°C, relative air humidity – 57%. Optimal inking (expressed by optical density of solid colours Dv) for the specific technological conditions was predefined by the maximal print contrast method. For glossy coated paper Dv is – C – 1.60, M – 1.65, Y – 1.45, K – 1.80. After printing of all test copies, imprints were selected meeting the optimal inking requirements and corresponding to all examinations [5, 6]. Measurements were performed with densitometer Gretag Macbeth D19C. Paper samples with printed control scales (TC 6.02) containing 999 colour fields of dimensions 5x5 mm were treated and subjected to thermal ageing. The fields have single, double, triple and quadruple overprinting of inks. Resulting colours are the most common one, in respect where of human eye is particularly sensitive. Control scales may be used to examine changes in colour characteristics of a printed image on the respective paper during the ageing process.

Colour measurements wer performed with spectrophotometer GretagMacbeth Spectrolino installed on a scanning table GretagMacbeth X-Y SpectroScan. Measurement conditions – standard light source D50, measuring geometry 45°/0° or 0°/45°, 2° standard observer.

### 3. Results and discussion

Results of glossy coated paper analysis, subject to examination, are shown in Table 1.

*Table 1: Paper parameters*

Paper type	Mass, g/m <sup>2</sup>	Fiber content	pH of water extract
Glossy coated paper	198.0	Sulphate pulp from Hardwood - 80% Sulphate pulp from Softwood – 20%	8.2

It can be seen, that Sulphate pulp from Hardwood is the prevailing content of glossy coated paper. It has high pH values of water extract. Table 2 shows values of physical and mechanical paper parameters before and after thermal ageing for 48 hours. The biggest changes were observed with double folds number, which, for glossy coated paper, decreases about 80% on average.

Table 2: Physical mechanical paper properties

Paper type	Physical mechanical paper properties	Before ageing		After ageing	
		Machine direction of fibers	Cross direction of fibers	Machine direction of fibers	Cross direction of fibers
Glossy coated paper	Tensile index (N.m.g <sup>-1</sup> )	47.15	26.50	46.36	26.38
	Double folds (number)	44	6	5	2
	Tear index, (mN.m <sup>2</sup> .g <sup>-1</sup> )	5.7	4.9	4.3	4.8
	pH of water extract	8.2		8.0	

Thermal treatment has substantial effect on fiber elasticity and flexibility, making paper more brittle and fragile. At the same time, pH of water extract changes only slightly, which shows that no major changes have occurred in the chemical compositions of fiber material components.

The main purpose of colour measurements is to study the change of colour gamut after various conservation treatments (water treatment and bleaching) and different ageing periods and to compare these with untreated paper samples. In addition to colour gamut changes, it is essential to study colour changes expressed by the colour difference ( $\Delta E$ ) resulting from chemical treatment and thermal ageing as compared to untreated sample. For objectivity reasons, colour difference was assessed using two indices:

$\Delta E_{\text{AVERAGE}}$  – mean arithmetic colour difference of 999 measured fields between the specific sample and the original untreated sample, before and after a certain process (depending on treatment and thermal ageing period) calculated by formula 1;

$$\Delta E_{\text{AVERAGE}} = \frac{\Delta E_{\text{Sample / Original}}^{\text{Field 1}} + \Delta E_{\text{Sample / Original}}^{\text{Field 2}} + \dots + \Delta E_{\text{Sample / Original}}^{\text{Field 999}}}{999}, \quad (1)$$

where,  $\Delta E_{\text{Sample / Original}}^{\text{Field}}$  – colour difference between a specific sample colour field and the same field of the original untreated sample.

$\Delta E_{\text{MAX}}$  – maximal resulting colour difference of 999 measured fields, before and after a certain process (treatment and thermal ageing period).

For completeness and objectivity reasons, assessment of colour parameter changes of offset imprints is presented on figure 1, figure 2 and in table 3 with the two values  $\Delta E_{\text{AVERAGE}}$  and  $\Delta E_{\text{MAX}}$  depending on ageing time.

Table 3 shows that sample treatment (water and H<sub>2</sub>O<sub>2</sub>) generally has small influence on image colours -  $\Delta E_{\text{AVERAGE}}$  is between 0.75 and 0.69 units (hardly noticeable colour difference). Only in isolated cases H<sub>2</sub>O<sub>2</sub> treatment results in big colour differences as compared to the untreated sample –  $\Delta E_{\text{MAX}} = 8.00$ .

Figure 1 shows that, after ageing for 48 hours,  $\Delta E_{\text{AVERAGE}}$  for untreated, bleached and water treated samples reaches 2.72 – 3.12, i.e. visually, there is relatively small difference between colours. With such values of  $\Delta E_{\text{AVERAGE}}$ , the human eye will perceive the difference in the image before and after ageing but such difference will not be big. In rare cases high values of  $\Delta E_{\text{MAX}}$  are obtained, especially for H<sub>2</sub>O<sub>2</sub> treatment where colour difference reaches 13.95 units.

Table 3: Values of  $\Delta E_{AVERAGE}$  and  $\Delta E_{MAX}$  depending on thermal ageing period

Paper type	Treatment method		Before treatment	After treatment	After ageing (h)		
					12	36	48
Glossy coated paper	Without treatment	$\Delta E_{AVERAGE}$	0	0	1.60	2.75	3.12
		$\Delta E_{MAX}$	0	0	6.98	10.78	11.79
	Treated with $H_2O_2$	$\Delta E_{AVERAGE}$	0	0.69	1.26	2.16	2.41
		$\Delta E_{MAX}$	0	8.00	8.52	9.51	13.95
	Water treated	$\Delta E_{AVERAGE}$	0	0.75	1.47	2.35	2.72
		$\Delta E_{MAX}$	0	2.13	4.80	7.23	8.31

This means that only certain specific colours have undergone substantial changes as a result of thermal ageing or conservation treatment. Generally, the conclusion may be drawn that ageing process duration sets a trend for colour difference increase, both  $\Delta E_{AVERAGE}$  for all samples and  $\Delta E_{MAX}$ .

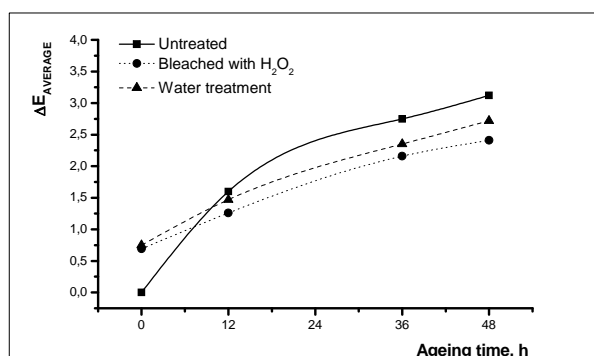


Figure 1: Change of  $\Delta E_{AVERAGE}$  depending on thermal ageing time for glossy coated paper imprints\*

\*Note: The graph for  $\Delta E_{AVERAGE}$  of bleached samples and of water treated samples does not start at zero, because  $\Delta E_{AVERAGE}$  values measured after treatment are different from zero.

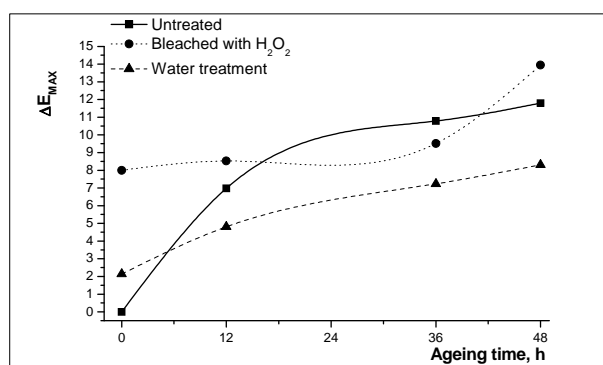


Figure 2: Change of  $\Delta E_{MAX}$  depending on thermal ageing time for glossy coated paper imprints\*

\*Note: The graph for  $\Delta E_{MAX}$  of bleached samples and of water treated samples does not start at zero, because  $\Delta E_{MAX}$  values measured after treatment are different from zero.

For a more comprehensive characterization of printed image colour changes resulting from thermal ageing after different conservation treatments, a cross-section of the 3D colour body of the colour gamut is presented at  $L=50$  (middle tone shades) and  $L=86$  (light tone shades), where  $L$  is the coordinate corresponding to colour lightness. These cross-sections of 3D colour body of the colour gamut are chosen because, the human eye is more sensitive in these light and middle tone shades.

Figures 3 and 4 shows graphs of colour gamut for untreated glossy coated paper, and figures 5 and 6 – for bleached paper. For  $L=50$  both printed sample types (untreated and bleached) show colour displacement from blue and red areas after ageing. This means that such colours either „disappear“ or are being replaced by the same ones but with less saturation

and with a different hue. For  $L=86$ , greater displacement can be seen and even disappearance of light blue and light red hues. Displacement is towards the yellow area, which to a certain extent may be explained with paper yellowing itself. In reality, this means that, for a colour reproduction, the hue and colour saturation will change substantially in the middle shades (colour gamut contraction), and in the light shades there will be even loss of details. These phenomena, caused by thermal ageing, occur both in printed images on untreated paper and in printed images on paper subjected to conservation – restoration bleaching and water treatment.

Bleaching and water procedures did not expect additional negative effect on ink stability, printed image respectively.

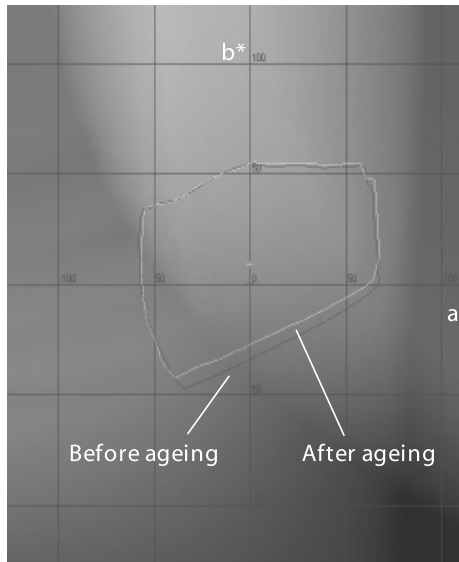


Figure 3: Cross-section at  $L = 50$  of the 3D body of the colour gamut in CIE Lab colour space for offset printed glossy coated paper (untreated)

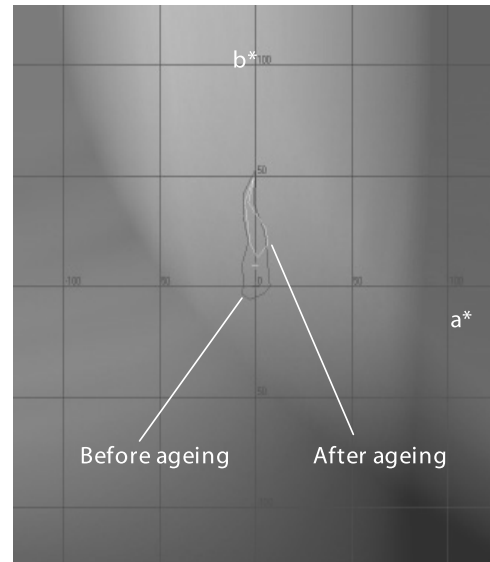


Figure 4: Cross-section at  $L = 86$  of the 3D body of the colour gamut in CIE Lab colour space for offset glossy coated paper (untreated)

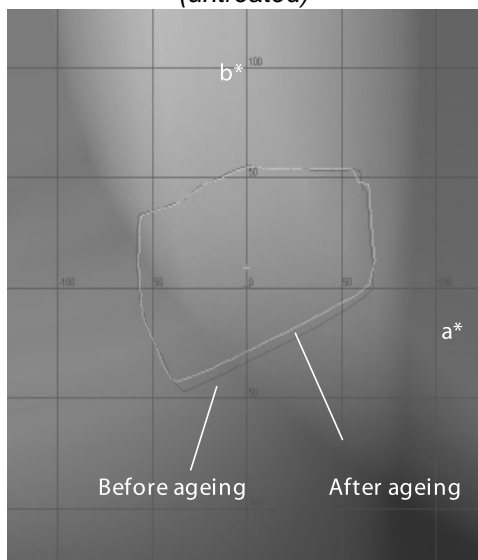


Figure 5: Cross-section at  $L = 50$  of the 3D body of the colour gamut in CIE Lab colour space for offset printed glossy coated paper (treated with  $H_2O_2$ )

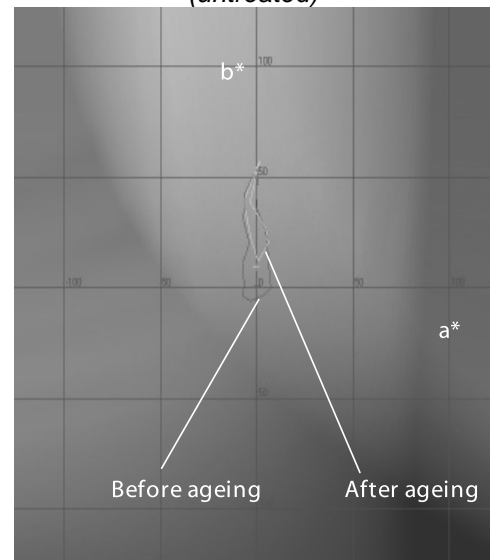


Figure 6: Cross-section at  $L = 86$  of the 3D body of the colour gamut in CIE Lab colour space for offset glossy coated paper (treated with  $H_2O_2$ )



## 4. Conclusions

For the first time a methodology is suggested and implemented for examination of paper and ink ageing processes by studying colour gamut changes of imprints and colour changes in single, double, triple, and quadruple overprinting of inks.

For offset imprints on glossy coated paper subjected to conservation treatment (after treatment and peroxide bleaching), colours change most between the 12<sup>th</sup> and the 36<sup>th</sup> hour of thermal ageing.

The peroxide-bleached glossy coated paper imprint has a high average colour difference as a result of the chemical treatment ( $\Delta E_{\text{AVERAGE}} = 0.69$ ) as compared to water-treated glossy coated paper imprint ( $\Delta E_{\text{AVERAGE}} = 0.75$ ).

The smallest colour changes of glossy coated paper imprints are observed with bleached ( $\Delta E_{\text{AVERAGE}} = 2.41$ ), then with water-treated ( $\Delta E_{\text{AVERAGE}} = 2.72$ ) and finally, with untreated glossy coated paper imprint ( $\Delta E_{\text{AVERAGE}} = 3.12$ ).

The peroxide-bleached glossy coated paper imprint has higher maximal colour difference resulting from thermal ageing ( $\Delta E_{\text{MAX}} = 8.00$ ) as compared to water-treated glossy coated paper imprint ( $\Delta E_{\text{MAX}} = 2.13$ ).

Conservation – restoration procedures (water treatment and bleaching) have relatively small influence on changes in colour characteristics and colour gamut during thermal ageing. This means that offset imprint processing is possible with slightly noticeable effect on ink colour characteristics ( $\Delta E_{\text{AVERAGE}} = 2.72 - 3.12$ ) during ageing of printed materials.

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## **SURFACE ROUGHNESS FACTORS OF FLEXO PRINTED SOLID AREAS ON ALUMINIUM FOIL AND CHARACTERISATION OF UCA (UNCOVERED PRINT AREAS)**

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**Abstract:** *The surface of the substrate is one of the important factors which widely influence the printing process, especially in impact printing processes such as flexo printing. The flexographic printability and subsequent print quality is certainly influenced by topographical characteristic of a used substrate. Structural properties of the printing substrate significantly influence the ink distribution during printing and limit the subsequently attainable print quality. In that terms, the definition of the substrate topography via roughness factors is rather significant. In this paper the surface roughness of flexo printed aluminium foil as a printing substrate has been investigated. Through four most distinguish ISO surface roughness factors ( $R_a$ ,  $R_q$ ,  $R_z$  and  $R_p$ ) the characterization of surface of aluminium foil before printing and after printing with opaque white ink, as well as with black UV ink correlated with printing speed has been given. In addition, the inspection of uncovered print areas of solid tone areas, through images gained with SEM and microscope with the camera, has been presented.*

**Key words:** *surface roughness, aluminium foil, flexo printing, uncovered areas (UCA)*

### **1. Introduction**

Successful printing requires ink to be transferred to the substrate in a controlled and uniform way. In flexo printing, the ink transfer is directly influenced by substrate and printing plate properties related to pressure and printing speed [1, 2].

Thus the substrate topography, or roughness is one of the most significant factors which greatly influence print quality since it has a significant influence on print properties such as gloss, mottle and uncovered printing areas. In order to maintain the uniformity of printing, the definition of the surface substrate properties is of the most importance [2].

For the definition of surface roughness, different imaging methods such as SEM-scanning electron microscopy or AFM-atomic force microscopy, as well as profilometric methods, like MSP-mechanical stylus profilometry or non – contact laser profilometry can be used [3].

Profilometric analysis is a technique used in material science to quantify the morphology of material surfaces. Standard techniques for assessing surface roughness measure directly the peaks and the valleys on the surface [4].

Surface roughness, when flexo printing is in question, is correlated with the occurrence of uncovered areas. This problem widely occurs when water and solvent based printing is preformed. The problem can be described as the occurrence of the local unprinted areas on a solid tone field. This phenomenon is generally associated with poor wettability and depressions in the printing surface [5].

In this paper the characterization of surface roughness of flexo printed aluminium foil in with printing speed through ISO surface roughness factors has been presented. The characterization of uncovered printing areas on solid tone fields was also performed.

### **2. Materials and methods**

For this study, as printing substrate, aluminum foil 35  $\mu\text{m}$  thick was used. The printing process was performed on Omet Variflex 530 printing machine using white opaque ink and UV black ink. Used printing plate was CTP flexo printing plate Asahi DSH, 1.14 mm tick. Two different kinds of imprints were made: first with directly printed UV black ink on aluminium foil and second where before printing with black ink, printing of opaque white ink was preformed. The printing in both cases was performed with speeds of 10, 30, 60, 100 and 130 m/min.

Measurements of roughness parameters were carried out on unprinted foil, foil printed with black ink foil printed with white base primer and after overprinting with black ink. Three solid tone patches were measured on three different imprints, three times in both x and y direction, in the direction of printing and perpendicular to the direction of printing. Results presented in the paper are the mean values of obtained measurements.

The profilometric parameters were measured with the hand held Portable Surface Roughness Tester TR200 with a diamond tip of 2  $\mu\text{m}$  stylus tip radius. This instrument can be

used for measuring following roughness parameters [6]:  $R_a$ ,  $R_z$ ,  $R_y$ ,  $R_q$ ,  $R_t$ ,  $R_p$ ,  $R_{max}$ ,  $R_m$ ,  $R_{3z}$ ,  $S$ ,  $S_m$ ,  $S_k$  and  $t_p$ . It is compatible with ISO 4287, DIN 4768, ANSI B 46.1 and JIS B601 standards and it provides four different filtering methods: RC, PC – RC, Gauss and D – P and four measuring ranges: automatic,  $\pm 20 \mu m$ ,  $\pm 40 \mu m$ ,  $\pm 80 \mu m$  with the resolution of  $0.01 \mu m \sim 0.04 \mu m$ ,  $0.01 \mu m$ ,  $0.02 \mu m$  and  $0.04 \mu m$ , respectively [6].

In this study, measurement's parameters were: sampling length  $0.25 \text{ mm}$ , corresponding traversing speed  $V_t = 0.135 \text{ mm/s}$ , Gauss filtering method, measuring range  $\pm 20 \mu m$  and corresponding resolution  $0.01 \mu m$ , compatibility with ISO 4287 standard.

For the characterization of investigated surfaces, the four ISO roughness parameters were studied:  $R_a$ ,  $R_q$ ,  $R_{zDIN}$  and  $R_p$ .

$R_a$  or average surface roughness represents the arithmetic mean of the absolute values of profile deviation of mean within sampling length [6-8]:

$$R_a = \frac{1}{l} \int_0^l |y(x)| dx \quad (1)$$

$R_q$  (Rms) or root-mean-square deviation is the average of the square value of the data of the profile inside an evaluation length. It represents the square root of the arithmetic mean of the squares of profile deviation from mean within sampling length [6-8]:

$$R_q = \sqrt{\frac{1}{l} \int_0^l y^2(x) dx} \quad (2)$$

$R_{zDIN}$  is mean value of the single roughness depths  $Z_i$  or, in other words, average maximum height of the profile (average of all vertical distances between the highest and the lowest point for a sampling length).  $R_{zDIN}$ , used for contact measurements, according to DIN 4768 is defined as [6-8]:

$$R_{zDIN} = \frac{1}{n} (Z_1 + Z_2 + \dots + Z_n) \quad (3)$$

$R_p$  or leveling depth is the distance between the highest point and the median line. In another words, the height from the highest profile peak line to mean line within the sampling length [6-8].

For the detection and characterization of uncovered areas on solid tone patches, two different kind of images were taken; one with the digital microscope Sibress PIT (Print Inspection Tool), the magnification of  $140\times$ , and other with scanning electron microscope made by JEOL JSM 6460 LV. The samples were gold coated by ion sputtering ( $15.0 \text{ nm}$  thick, density  $19.32 \text{ g/cm}^3$ ). The images were taken at working distance of  $15 \text{ mm}$  at voltage  $20 \text{ kV}$  with magnification  $500\times$ .

### 3. Results and discussion

#### 3.1 Measurement of the roughness parameters

In Fig. 1 are graphically presented obtained results for amplitude profilometric parameters  $R_a$ ,  $R_q$ ,  $R_{zDIN}$  and  $R_p$  measured on unprinted aluminium foil (plain aluminium foil) and aluminium foil printed with white base primer. As it was expected, values of parameters  $R_a$ ,  $R_q$  and  $R_z$  are lower in case of printed aluminium foil. Factor  $R_p$  has almost the same value in both cases. This result showed that surface roughness was lowered with printed layer of opaque white ink.

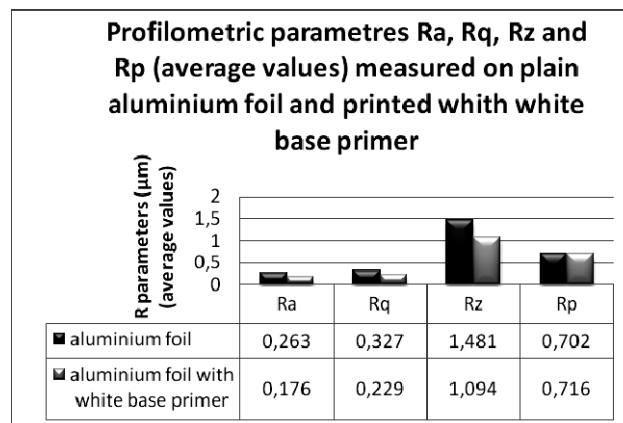


Figure 1: Profilometric parameters  $R_a$ ,  $R_q$ ,  $R_z$  and  $R_p$  (average values) measured on unprinted (plain) aluminium foil and aluminium foil printed with white base primer

On Fig. 2 are presented values for  $R_a$  parameter measured on solid tone patches printed directly on aluminium foil (plain aluminium foil) and aluminium foil previously printed with white base primer. Since  $R_a$  parameter gives the information about average absolute deviation of the roughness irregularities from the mean line over assessment length [8] it provides information about the height variations. It is obvious that in both cases,  $R_a$  factor has lower values in comparison with  $R_a$  factor measured on aluminium foil before any printing. When considering given values for the patches of solid tones measured in case of direct printing on aluminium foil and over white base primer, lower values are detected in first case, for the printing speeds of 10, 30 and 60 m/min, but higher for printing speed of 100 and 130 m/min. It is also important to notice that in both cases,  $R_a$  factor values increase with the printing speed. In case of printing over white base primer, the correlation between  $R_a$  values and printing speed is linear ( $R^2=0,95$ ).

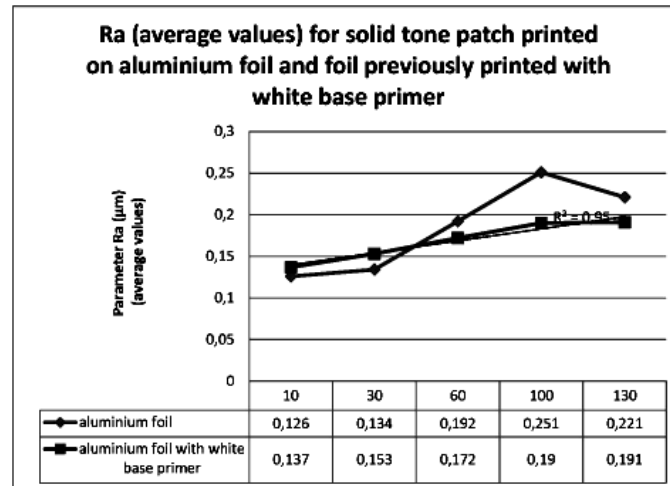


Figure 2: Profilometric parameter  $R_a$  (average values) for solid tone patch printed on unprinted (plain) aluminium foil and aluminium foil with white base primer

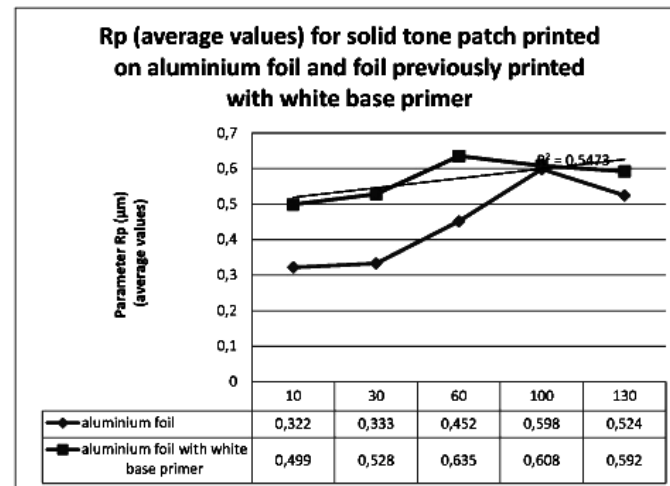


Figure 3: Profilometric parameter  $R_p$  (average values) for solid tone patch printed on unprinted (plain) aluminium foil and aluminium foil with white base primer

On Fig. 3 are presented values for  $R_p$  parameter measured on solid tone patches printed directly on aluminium foil and aluminium foil previously printed with white base primer. Being the parameter which gives the information about the maximum height of the profile above the mean line within one sampling length [8], it is obvious that in both cases and regardless of printing speed, maximum heights of the profile are lower in comparison with unprinted aluminium foil. Higher values are recorded in case of printing on a foil with white base primer.  $R_p$  factor values increase with the printing speed in both cases.

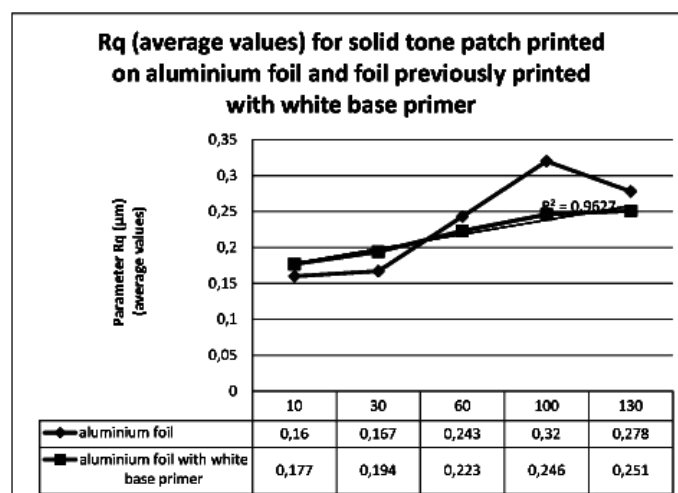


Figure 4: Profilometric parameter  $R_q$  (average values) for solid tone patch printed on unprinted (plain) aluminium foil and aluminium foil with white base primer

On Fig. 4 are graphically presented values for  $R_q$  parameter measured on solid tone patches printed directly on aluminium foil and aluminium foil previously printed with white base primer. It is shown that higher printing speed has direct influence on increase values of  $R_q$  factor. Linear correlation between  $R_q$  values and printing speed is noticed for the printing on foil with the layer of white base primer. As in the case of  $R_a$  and  $R_p$  factor, printing of UV black ink resulted in lowering  $R_q$  values.

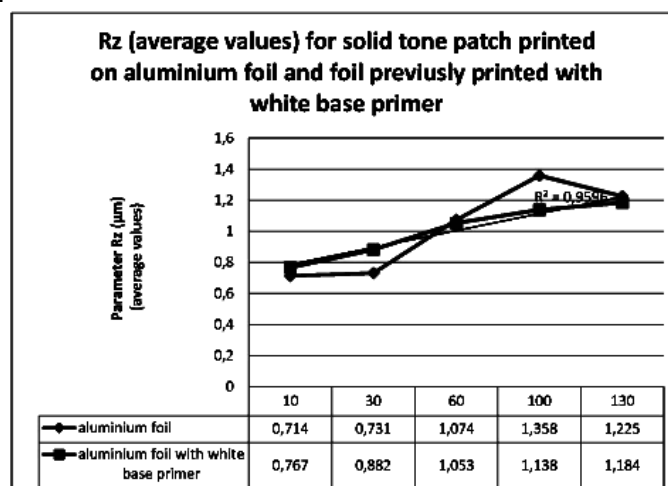
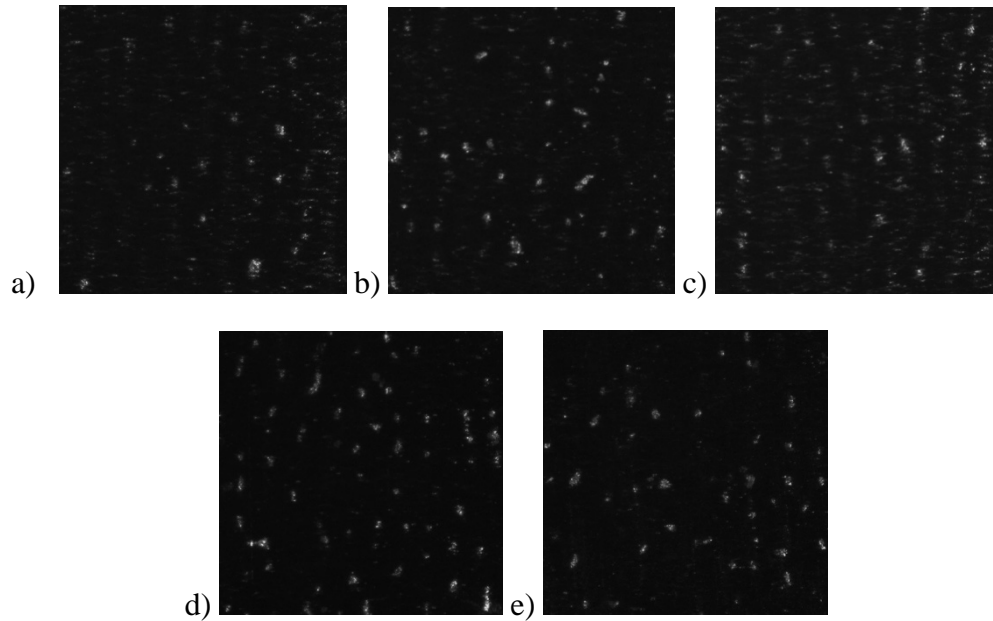


Figure 5: Profilometric parameter  $R_{zDIN}$  (average values) for solid tone patch printed on unprinted (plain) aluminium foil and aluminium foil with white base primer

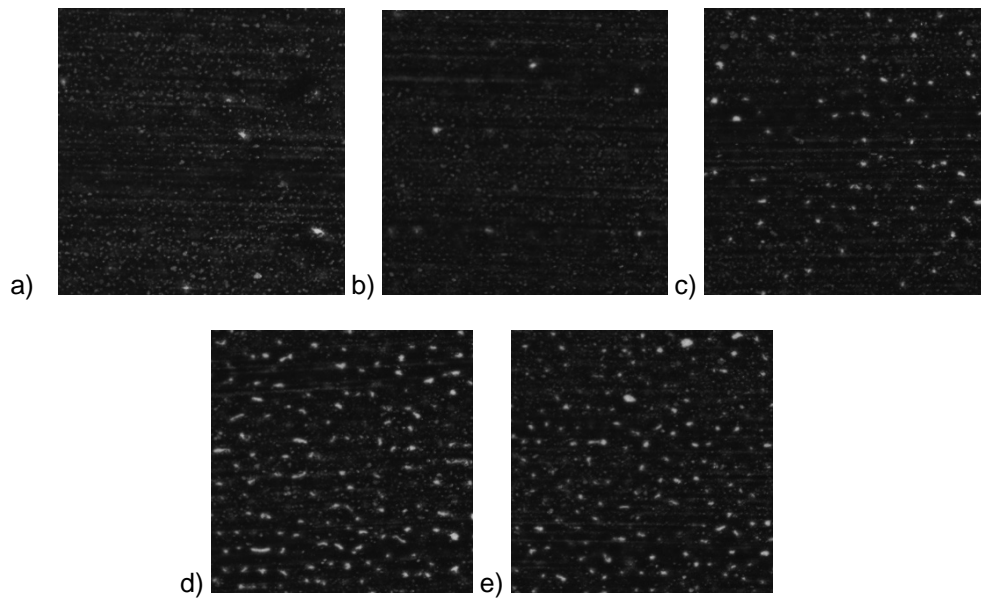
Fig. 5 graphically presents values for  $R_{zDIN}$  parameter measured on solid tone patches printed directly on aluminium foil and aluminium foil previously printed with white base primer. It can be seen from the graph that with the higher printing speed, values of  $R_{zDIN}$  factor also increase. Linear correlation between  $R_{zDIN}$  values and printing speed is noticed for the printing on foil previously printed with opaque white ink.

### 3.2 Analysis of microscopic pictures of solid tone areas

As it was previously mentioned, this study included inspection of solid tone areas over microscopic pictures gained with digital microscope (magnification 140x) and SEM (magnification 500x). On Fig. 6 and Fig. 7 are presented microscopic pictures of printed solid patches on aluminium foil and aluminum foil previously printed with white base primer captured with digital microscope.

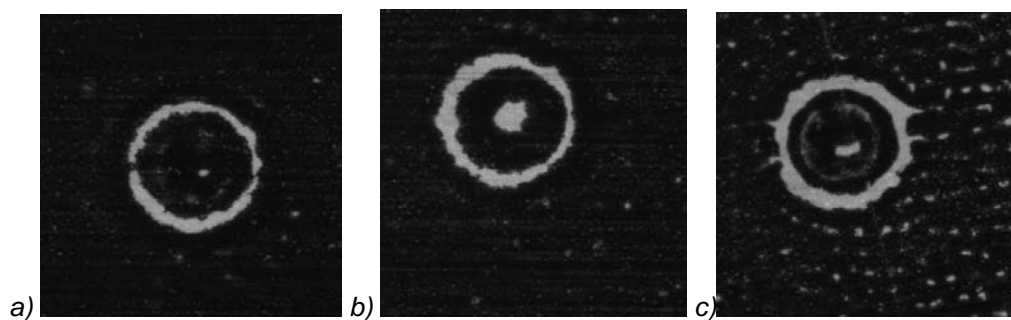


*Figure 6: Microscopic pictures of solid tone patches printed directly on aluminium foil (pictures taken with digital microscope, magnification 140x); printing speed a) 10 m/min, b) 30 m/min, c) 60 m/min, d) 100 m/min, e) 130 m/min*



*Figure 7: Microscopic pictures of solid tone patches printed on aluminium foil previously printed with opaque white ink (pictures taken with digital microscope, magnification 140x); printing speed a) 10 m/min, b) 30 m/min, c) 60 m/min, d) 100 m/min, e) 130 m/min*

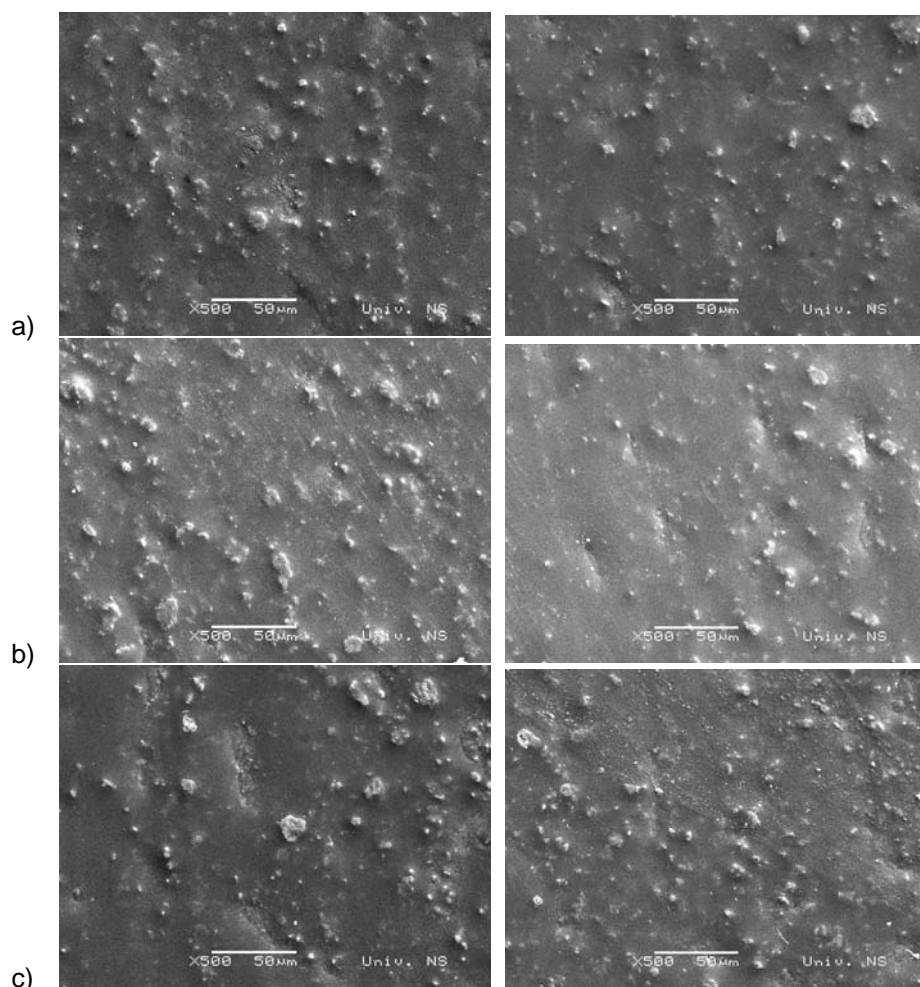
On Fig. 8 are presented examples of uncovered areas classified as ring with white spot in the middle [5]. Those examples were taken on printed areas on aluminum foil previously printed with white base primer. Although the serious of microscopic shots were made, types of uncovered areas, such as rings without white spot in the middle and spots without ring [5], was not detected.



*Figure 8: Examples of uncovered areas taken with digital microscope on printed areas on aluminum foil previously printed with white base primer (magnification 140x, ); printing speed a) 60 m/min, b) 100 m/min, c) 130 m/min*

According to microscopic pictures presented on figure 6 and 7, the number of small white dots, which represents micro fields that were not covered with ink during printing, is greater when printing on aluminium foil with layer of opaque white ink. It can be assumed that they are caused by the impurities on printing form since they appearance on great number of sheets printed in sequence. It can be assumed that those dots can also be a consequence of previously printed white base primer.

On Fig. 9 are presented microscopic pictures of printed solid patches on aluminium foil previously printed with white base primer captured with SEM. The micrographs showed uneven distribution of pigment particles of opaque white ink which might be the reason of white dots spotted on Fig. 7.



*Figure 9: Microscopic pictures of solid tone patches printed on aluminium foil previously printed with opaque white ink (pictures taken with SEM, magnification 500x)); printing speed a) 60 m/min, b) 100 m/min, c) 130 m/min*

## 5. Conclusions

In this paper the surface roughness of flexo printed aluminium foil has been investigated. The characterization of surface of aluminium foil before printing and after printing with opaque white ink, as well as with black UV ink correlated with printing speed has been given. In addition, the determination of uncovered print areas on solid tone patches, through images obtained with SEM and digital microscope, has been presented.

The presented results for amplitude profilometric parameters  $R_a$ ,  $R_q$ ,  $R_{zDIN}$  and  $R_p$  measured on unprinted aluminium foil and aluminium foil printed with white base primer showed that surface roughness was lowered with printing of a layer of opaque white ink. Also, as it was expected, the surface roughness increases with printing speed, which can be explained with lower ink transfer from printing plate onto the substrate with higher speed. The taken microscopic pictures revealed the uncovered areas on imprints classified as ring with white spot in the middle. These areas were detected in small amount on imprints previously printed with white base primer. It can be explained with the fact that UV ink was used and in comparison with water or solvent based inks [5] this type of ink has better coverage ability and also wettability and drying. Micrographs taken with SEM indicates that greater amount of white dots detected on imprints on foil previously printed with white base primer (in comparison with the same fields directly printed on aluminium foil) can be consequence of uneven pigment particles detected in opaque white ink.



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## INKJET PRINTOUTS LONG-TERM AGEING

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**Abstract:** The stability of inkjet print is influenced by a lot of factors. The surrounding environment, types of receiving layers or ink composition belong to the main ones which affect the stability of prints.

In this work, the long-term ageing of inkjet prints was studied. Samples were prepared using dye-based inks. The study of resistance of inkjet prints was realized on three types of media with different receiving layers. The attention was especially focused on the influence of light and air born pollutants. The study was compared with accelerated ageing results. Light conditions were precisely monitored during the long-term ageing. Colour fading was measured and evaluated in colorimetric quantities. The dependence of colour gamut volumes on UV and VIS exposure dose was evaluated.

**Key words:** inkjet, long-term ageing, accelerated ageing, gamut volume

### 1. Introduction

Inkjet printing technique has become over the last few years highly requested reproduction technology. Consumers demand stability improvement of prints exposed to environmental conditions. There are several ways to determine the light-fastness of prints. The simplest way is the exposure of the print to real conditions. This method is time consuming and brings various problems. On the other hand, it gives information about the long-term ageing in real conditions. The prints lose their original quality and degrade. This is the result of complex impact of the factors affecting the stability.

Every day the photography is supposed to be exposed to 5.4 klx h. Long-term display conditions should be 450 lx for 12 hrs. Results of long-term ageing must be recalculated to the corresponding daily exposure period.

### 2. Methods

The test targets were printed by printer Epson Stylus Photo R220 on Ilford Classic Gloss media, Ilford Smooth Gloss and Foma 1224 with inks supplied by MIS Associates, Inc. The prints were let to fully dry. Their reflective spectra were measured by spectrophotometer Gretag MacBeth Spectrolino and they were adjusted to picture frames with and without glass. The prints in the glass-free frame were exposed to both light and pollutants. The samples placed in the frame with glass and photosensitive (TSL235, TAOS) sensor were exposed only to light. The sensor was connected to digital multimeter UT70B. The frames were situated in a bright sunny corridor. Frequency values collected to a PC from the photosensitive sensor are linearly proportional to the intensity of incident radiation in the range of 5 orders of magnitude, which is sufficient for normal environmental light intensity variations.

### 3. Results and Discussion

During the long-term test the reflective spectra were measured by the spectrophotometer Gretag MacBeth Spectrolino on a 990 patch test target. The ICC profiles were calculated from the reflective spectra (with program Gretag Macbeth™ ProfileMaker 5.0.5) and volumes of colour gamut were calculated by program Imatest LLC Gamutvision™.

Incident radiation intensities were measured by radiometers (X11 optometer with probe XD-9502 and X97 irradiance meter with probe X9-7). Measured values were then used to calibrate the light sensitive sensor. Measurements took place regularly every week and the results were to certain level dependent on weather. For the real condition characterisation, intensities were measured every month in any atmospheric state.

Monthly average intensities for each frame were calculated from the measured intensities. Monthly average intensities were recalculated to give the total dose of irradiation or light exposure.

Particular values of radiation intensities in the UV and VIS spectrum were plotted against months of the years in which the test took place (see fig. 1). The highest values of intensities were obtained in the summer months. Annual average of irradiance in VIS spectrum was  $22.4 \pm 0.65 \text{ W m}^{-2}$ , annual average of irradiance in UV-A spectrum was  $1.28 \times 10^{-2} \pm 0.24 \times 10^{-2} \text{ W m}^{-2}$  and annual average of illuminance was  $4.61 \pm 0.98 \text{ klx}$ .

In table 1, there are particular values of dose of irradiation in UV-A ( $H_e^{\text{UV}}$ ) and VIS ( $H_e^{\text{VIS}}$ ) spectrum and the dose of light exposure ( $H$ ).

It is important to evaluate ratio of UV radiation in incident radiation. This is usually expressed as the ratio of exposure intensity to light intensity. This ratio was during long-term experiment low and didn't achieve the threshold  $50 \mu\text{W lm}^{-1}$ . Above this value a significant deterioration of all documents, including photographs can occur. The content of the UV component is significantly changing depending on the seasons (see fig. 2). The higher content of UV component was present in summer months.

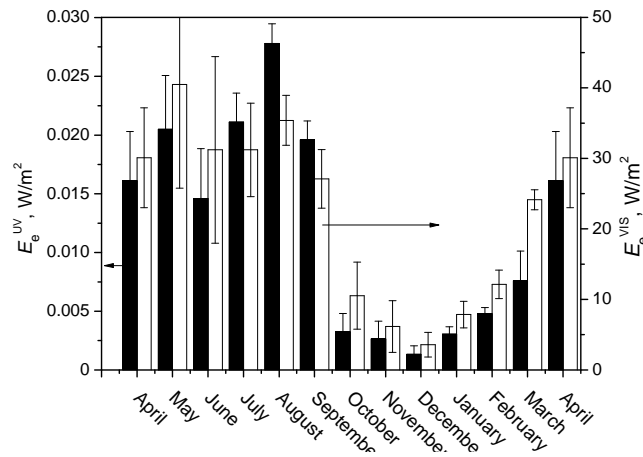


Figure 1: Irradiance in UV and VIS spectrum vs. tested months.

Tab. 1: Values of total doses of irradiance and light exposure.

Test target	$H_e^{\text{UV}}$ [ $\text{kJ m}^{-2}$ ]		$H_e^{\text{VIS}}$ [ $\text{MJ m}^{-2}$ ]		$H$ [ $\text{klx h}$ ]	
	with glass	Without glass	with glass	without glass	with glass	without glass
Ilford Classic Gloss						
Foma 1224	120.42	133.31	$2.6 \cdot 10^2$	$2.58 \cdot 10^2$	$1.24 \cdot 10^4$	$1.27 \cdot 10^4$
Ilford Smooth Gloss						

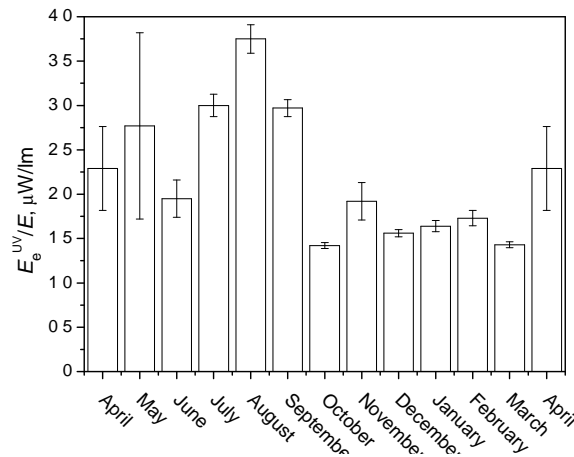


Figure 2: Ratio change of irradiance in the UV spectrum to the intensity of light depending on the month.

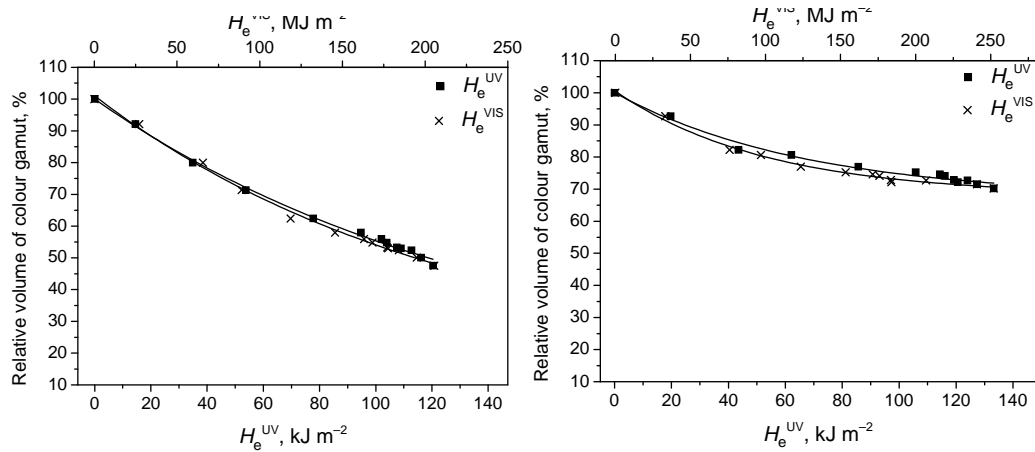


Figure 3: Decrease of relative volume of colour gamut on Ilford Classic Gloss paper, depending on the dose of irradiance in UV and VIS spectrum. Left sample was located in a frame with glass, right it was located in a glass-free frame.

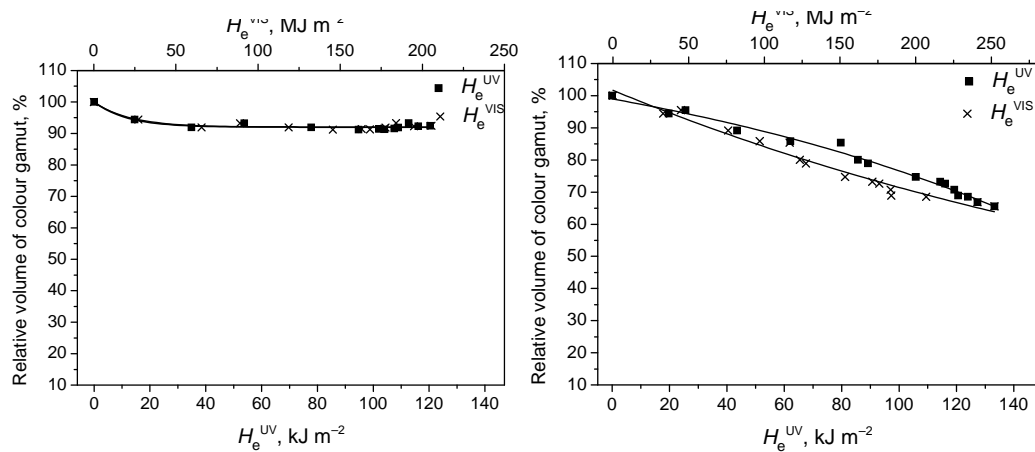


Figure 4: Decrease of relative volume of colour gamut on Ilford Smooth Gloss paper, depending on the dose of irradiance in UV and VIS spectrum. Left sample was located in a frame with glass, right it was located in a glass-free frame.

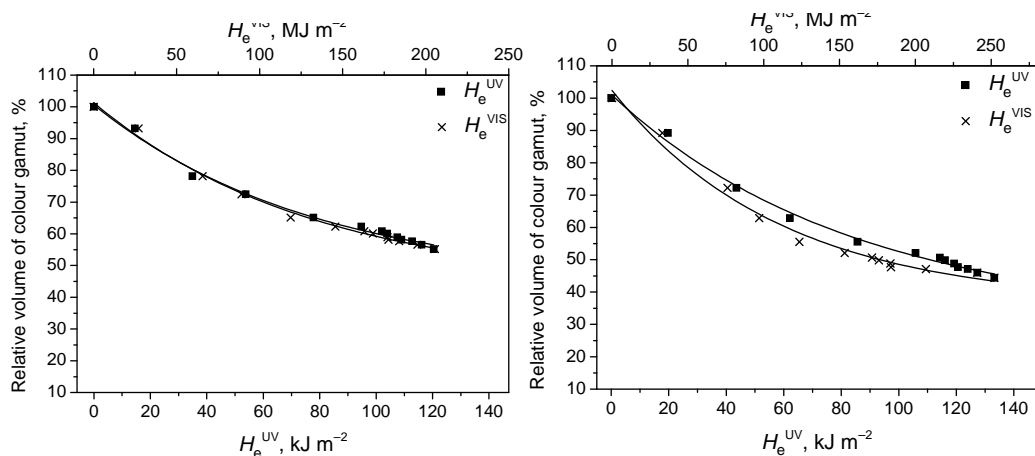


Figure 5: Decrease of relative volume of colour gamut on Foma 1224 paper, depending on the dose of irradiance in UV and VIS spectrum. Left sample was located in a frame with glass, right it was located in a glass-free frame.

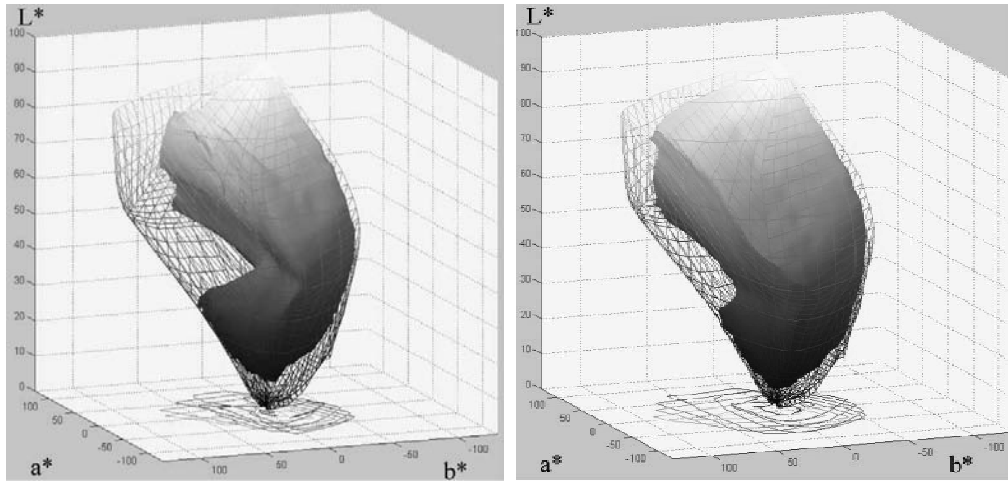


Figure 6: The colour gamut volume change of target on Ilford Classic Gloss paper. Left is sample located in a frame with glass, right in a glass-free frame. Before exposure (grid); after exposure (full volume).

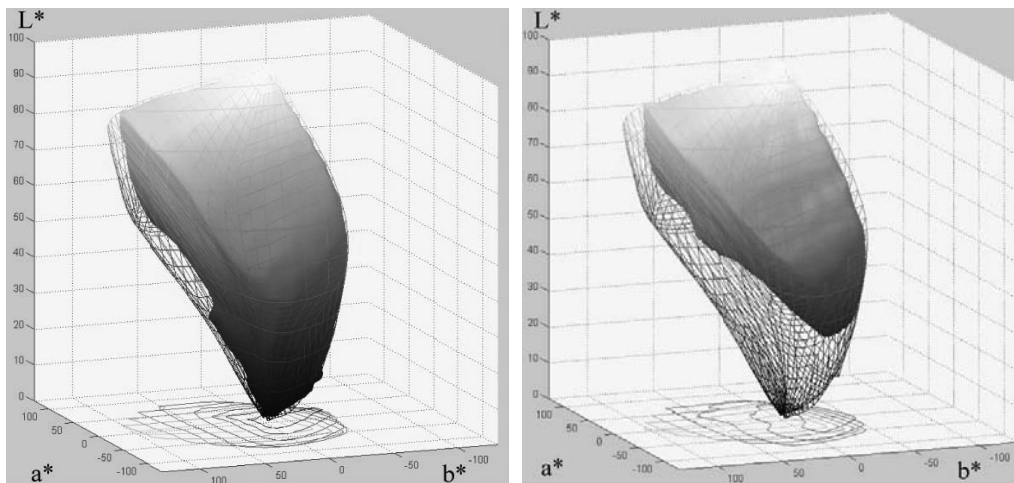


Figure 7: The colour gamut volume change of target on Ilford Smooth Gloss paper. Left is sample located in a frame with glass, right in a glass-free frame. Before exposure (grid); after exposure (full volume).

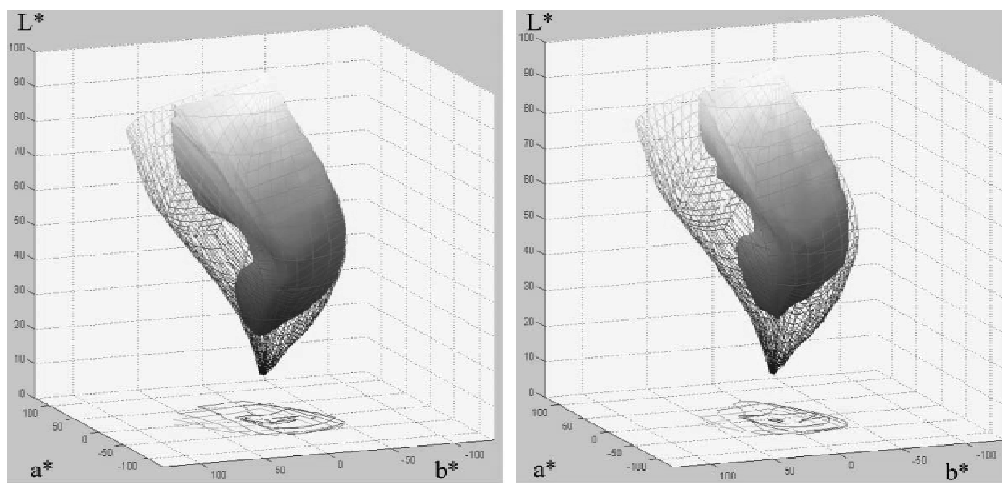


Figure 8: The colour gamut volume change of target on Foma 1224 paper. Left is sample located in a frame with glass, right in a glass-free frame. Before exposure (grid); after exposure (full volume).

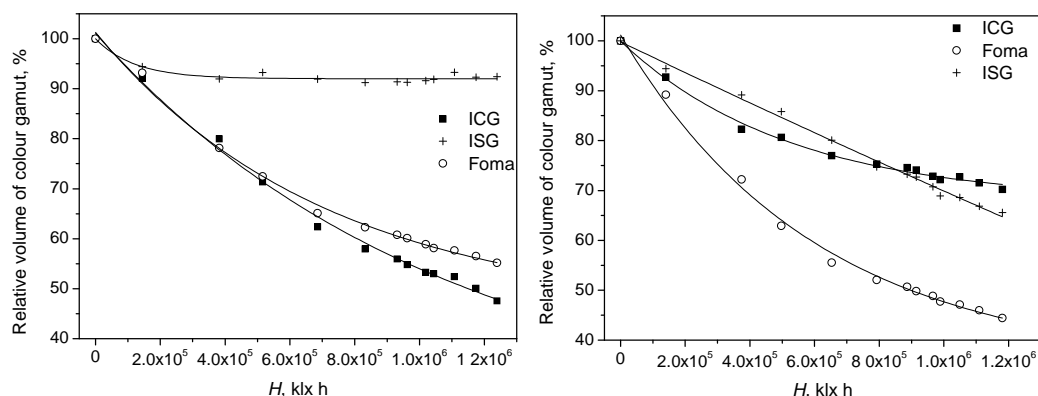


Figure 9: Relative volume colour gamut decrease of Ilford Classic Gloss (ICG), Ilford Smooth Gloss (ISG) and Foma 1224 papers, plotted against light exposure dose. Left sample was placed in a frame with glass; right one was placed in a glass-free frame.

See fig. 3 for the decrease of relative volume of colour gamut depending on the dose of irradiation in UV and VIS spectrum of the swellable receiving layer Ilford Classic Gloss. By the end of the experiment, volume decrease of colour gamut caused by light was 55 % (left). Light and pollutants impact caused a volume decrease of colour gamut by 30 % (right).

Ilford Smooth Gloss was chosen as the representative of porous receiving layer media. For the volume decrease of sample colour gamut, which was placed in a frame with glass, see fig. 4. Volume decrease of colour gamut after 331 days of exposure was only 10 %, although degradation was caused by light. On the other hand, test target printed on the same paper type, which was placed in a frame without glass, had gamut volume loss 35 %.

Fig. 5 depicts the relative volume decrease of colour gamut on conventional receiving layer paper Foma 1224. The volume of colour gamut decreased due to light by 45 % (left). If there was the simultaneous impact of light and pollutants, the volume decrease of colour gamut was 55 % (right).

The changes of colour gamut volumes before and after exposure on different type of receiving layer and the effect of various factors are shown in fig. 6, 7 and 8. Mostly long-term ageing influenced by light led to the degradation of yellow and magenta dye. This results in a significant reduction of colour gamut volumes. On the other hand, long-term light and pollutants ageing led to a greater degradation, and thus to a greater reduction of colour gamut volumes. Porous receiving medium Ilford Smooth Gloss gave the opposite results. This material consists of porous absorbents capable of absorbing pollutants molecules, especially of ozone. They cause competitive oxidation reaction of dyes. Only in this case cyan dye faded. Cyan dye degradation compared to the yellow and magenta dye degradation on the other media was negligible.

Decrease of relative volume of colour gamut on swellable receiving layer Ilford Classic Gloss (ICG), porous receiving layer Ilford Smooth Gloss (ISG) and conventional receiving layer Foma 1224 depending on the exposure is shown at fig. 9. Left samples degraded by light and they were placed in a frame with glass. Of these samples, the most stable was Ilford Smooth Gloss. Right samples faded influenced by light and pollutants and they were adjusted in glass-free frames. From these the most stable print was sample on the Ilford Classic Gloss paper.

## 5. Conclusions

Light condition analysis showed that the maximum value of UV radiation was very low  $4.41 \pm 0.79 \mu\text{W lm}^{-1}$ . In the experimental conditions VIS radiation has the greatest impact on the dye degradation. The most stable print, when faded by light, was Ilford Smooth Gloss paper. Ilford Classic Gloss paper and Foma 1224 samples showed very similar behaviour. The most stable print, when faded by light and pollutants, was sample on Ilford Classic Gloss paper.

Test target printed on porous material Ilford Smooth Gloss indicated different behaviour under influence of many factors, than prints on swellable or conventional media. In the case of porous media, pollutants caused the biggest changes on cyan dye.

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## DETERMINATION OF THE COLLOIDAL STRUCTURE OF PULP FIBRES

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**Abstract:** The technological processes of the pulp and paper making cause the change of the surface of the cellulose fibres with a different order of magnitude. The determination of the colloidal structure and surface character of pulp fibres is important not only in the papermaking technology and environmental protection, but the technologies of the sizing, the filling, and the coloration are all influenced by the specific surface of the pulp fibres.

In the experimental part of scientific work it was studied how the sizes of molecular, colloidal and coarse surface areas are dependent on the beating degree of cellulose fibres from different types of and differently cured pulps. For this purpose the adsorbed quantities of particles with different size were measured using molecular size methylene-blue, colloidal size iron-hydroxide ( $\text{Fe}(\text{OH})_3$ ) and micronized titanium-hydroxide ( $\text{TiO}_2$ ) which formed saturated monolayers. The specific surface areas of pulp fibres were found to be increased with increasing beating degree, on a typical manner of the different pulp. From the measured surface parameters mentioned above three new different surface types were calculated and nominated as primary-, secondary and tertiary surfaces.

The use of the new concept system provides an opportunity to optimise the processes which modify the fibre surface and to optimise the properties of different paper products. The research work also includes the study of the connection between the variation of the surface character of the fibres and the mechanical properties of the papers made from the different fibrous materials.

**Key words:** paper products, cellulose fibre, fibre surface, specific surface, molecular size methylene-blue, colloidal size iron-hydroxide ( $\text{Fe}(\text{OH})_3$ ), micronized titanium-hydroxide ( $\text{TiO}_2$ ), primary-, secondary and tertiary surfaces, mechanical properties of the papers,

### 1. Introduction

In order to produce high quality paper products, it is very important to alter the construct of the fibre surface because the properties of the products of the paper industry depend on the raw- and auxiliary materials' surface quality. The paper's mechanical parameters, flexibility, and permeability are influenced by the content and the method by which the pulp is produced.

During pulp production, the type of cooking, chemical penetration, the type of chemical reaction, as well as the technological method used to separate lignin from plant fibres alters the surface characteristics of the pulp (Figure 1). At the same time, the success of these technologies depends on the properties of the fibre surface. During paper production, the water-based heterogenous contents significantly influence the qualitative properties of the paper.

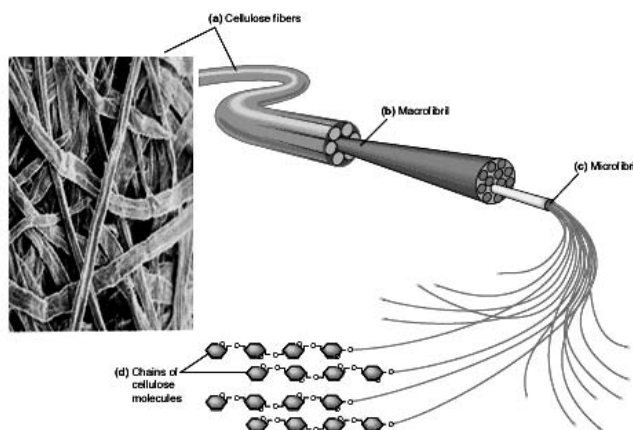


Figure 1: The structure of the cellulose fibre



For those producing paper, it is very important to know how the mechanism of the interaction between the fibre and the filling material, such as absorption and adhesion, works in an electrolytical water-based environment. To optimize and improve knowledge about processes like beating and suspending, it is necessary to determine the exact physical and chemical mechanism of the previously described processes.

The determination of the colloidal structure and specific surface of the pulp fibres has been studied by international as well as Hungarian researchers for a long time.

It is advantageous to conduct the experiments in liquid medium because the surface characteristic of the fibres alters irreversibly in dry condition. Scientific articles about surface properties of pulp fibres and the specific surface of the pulp have been published worldwide since the 1940s and 1950s.

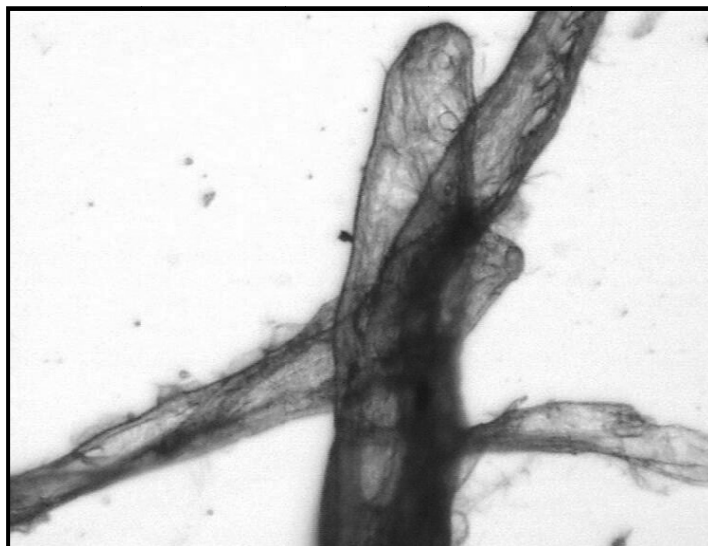
In the Obuda University, after a long period of scientific research, the so-called Three-Way Method. The essence of this method is the adsorption of the positively charged particle onto the negatively charged surface of the fibre. In order for this method to be useful, a monomolecular layer needs to be formed on the fibre surface. With respect to the monomolecular adsorption, the parameters of the electrolyte concentration, the pH level, the initial and equilibrium concentration, adsorption time, and the temperature have to be optimized. It is also very important that the adsorptives should stay in discrete forms.

The main objectives of the scientific work were to optimize the Three-Way Method, to develop it further, and to determine the industrial usefulness of the new result. An additional aim of the research was to determine how the surface characteristics and different specific surface values of the fibres changed during the beating process. Furthermore, it was a question whether there is a significant relationship between the specific surface of the fibres and the mechanical properties of the paper made up from these fibres.

## 2. Methods

Cotton, wheat, and pine fibres, cooked using different methods and beaten to different degrees, were examined by methylene blue, iron-hydroxide, and titanium-dioxide adsorption.

These different fibre materials from the sample collection were beaten to 30, 50, and 70 beating degrees (SR) using Valley beating instruments according to the standards (Figure 2).



*Figure 2: Tracheida fiber before the beating*

After the beating process the structure of the fibre-materials were studied with a WAT-250 D(W96P) - type video microscope (Figure 3).

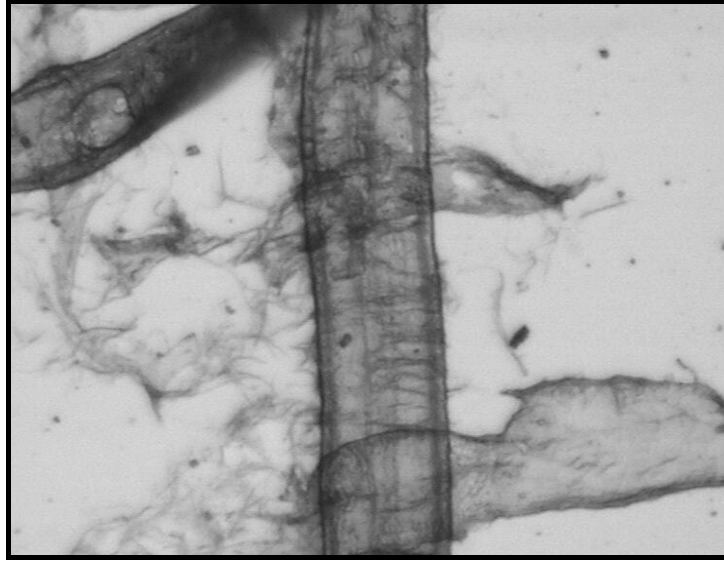


Figure 3: Tracheida fiber after the beating

After beating a part of the wet fibre sample were taken an Ernst-Hage type laboratory sheet-forming device, and 15 pieces of paper of about 80 g/m<sup>2</sup> were made. The rest of the sample was taken to the same laboratory sheet-forming device to filter it. Afterwards, the still-wet sample of filtered fibres was taken in a hermetically sealed polyethylene bag and stored at temperature between 274-276 K, until its use for the experiment. The pH level of the cellulose fibre samples was around 6.5 to 7 (that of tapwater), which was acceptable for laboratory paper forming, however the pH level had to be changed for the surface study.

Consequently, the pH level of the cellulose fibres were adjusted to be 3.8-4.0 with 0.01 mol/l HCl solution or 0.01 mol/l NaOH solution.

After having climatic preparation, the tearing, ripping and cracking parameters were determined.

The differently cured, various types of cellulose fibers were also studied according to valid cellulose chemistry laboratory standards.

In order to form monomolecular layer, the parameters of the surface adsorption were optimized. Because the mass of the layers is influenced by the repulsion of the particles, the aim was to minimize this effect.

As part of the preparation for the experiment, the electrolyte concentration, the pH level, the initial and equilibrium concentration, as well as the adsorption time were optimized with Langmuir type isotherm. Using the highest value of the adsorptive isotherm, the molecular-, the colloidal- and the micronised specific surface values were calculated.

The different types of specific surface of the cellulose fibres were measured using methylene-blue particles measuring 0.77 nm in diameter (C.I.52015 type); iron-hydroxide particles measuring 5.0 nm in diameter; and titanium dioxide particles measuring 524.0 nm (type RFD-1). The iron hydroxide was hydrolysed from iron chloride with ammonium carbonate. So the most important parameters of the measurement were the diameters of the particles. Using 1 mg methylene blue we can measure about 1 m<sup>2</sup> surface, 10 mg iron-hydroxide can measure 1.2 m<sup>2</sup> surface and 1000 mg titanium-dioxide, can measure 1.12 m<sup>2</sup> surface. Considering the molecular weight of the adsorptiums, we can calculate the surface of the cellulose (Eq.1-2).

$$m^{\sigma} = \frac{V \cdot (C_k - C_e)}{m}$$

(Eq. 1.)

Where:

*V*: volume of the suspension [dm<sup>3</sup>]

*C<sub>k</sub>*: concentration of the solution before the adsorption [mol/dm<sup>3</sup>]

*C<sub>e</sub>*: concentration of the solution after the adsorption, [mol/dm<sup>3</sup>]

*m*: weight of the cellulose [g]

*m<sup>σ</sup>*: weight of the adsorptiums [mol/g]

$$S = m^{\sigma} \cdot N \cdot S_0 \quad (\text{Eq. 2.})$$

Where:

$m^{\sigma}$ : weight of the adsorpted particles [mol/g]  
 $N$ : Avogadro- Loschmidt number [ $6 \cdot 10^{23}$  particle/mol]  
 $S_0$ : surface of one adsorpted particle [ $\text{m}^2/1$  particle ]  
 $S$ : specific surface [ $\text{m}^2/\text{g}$  ]

To characterise the fibre surface, the previous research carried out in this field was further developed and perfected. To use the adsorptive diameter data, the surface measured by methylene-blue, by iron-hydroxide and by titanium-dioxide was designated 'molecular surface', 'colloidal surface' and 'rough surface', respectively.

From the previously measured surface parameters, three new different surface types were calculated and defined as primary, secondary and tertiary surfaces. The primary surface value is equal to the rough surface value, the secondary surface is the difference between the colloid and the rough surface values, and the tertiary surface is the difference between the molecular and the colloid surface values.

This new concept system is useful for optimizing the processes which modify the fibre surface and for optimizing the paper-making processes such as sizing, filling, and coloration, as well as the properties of different paper products.

The research also includes the study of connection between the variation of the surface character of the fibres and the mechanical properties of the papers made from the different fibrous materials. For this purpose, correlation between changes of the mechanical values and the surface values were calculated.

### 3. Results

By the method which measures the specific surface using methylene-blue, it was determined that for  $1,0 \pm 0,5$  g absolutely dry mass of fibres, at 3,8-4,1 pH, at 297 K, and a 3,0 mmol/l volume of 20,0  $\text{cm}^3$  liquid, the total monomolecular layer forms within 5 hours (Figure 4).

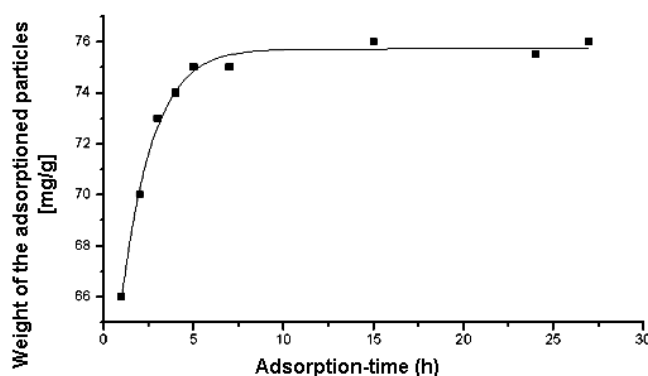


Figure 4: The adsorption-time of the methylene-blue monomolecular layer

Between the specific surface determined by the Three Way Method and the cellulose fibre type it was determined that the result of bleaching is significant in the fibres with a low beating degree by the titanium dioxide and iron hydroxide surface methods. Around 75 SR, the results of bleaching do not influence the specific surface values significantly.

As a result of the relationship between the values of the three new surface types and the beating degree, it was determined that the primary surface increased significantly by the beating degree. The values of the primary surface were changed between 0.3-4  $\text{m}^2/\text{g}$ . The secondary surface value increased significantly by the beating degree. Values changed between 2.1-35  $\text{m}^2/\text{g}$ . The tertiary surface value decreased with the beating degree in most of the fibers. Values changed between 17-8  $\text{m}^2/\text{g}$ . This indicates that the molecular order of magnitude of the fibre surface opened in the colloidal order of magnitude of the fibre surface during the beating process (Figure 5 and Figure 6).

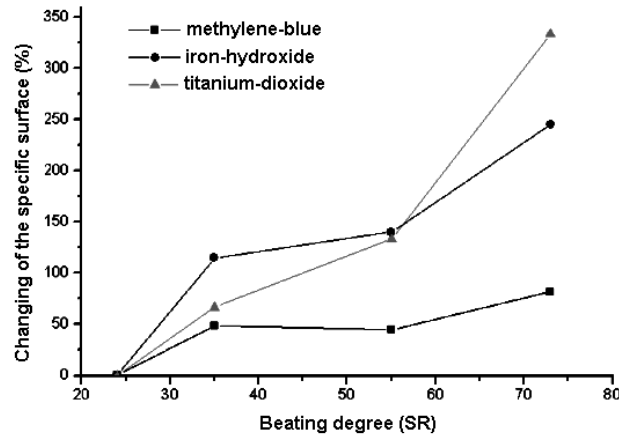


Figure 5: Relationship between the values of the three adsorptives surface types and the beating degree

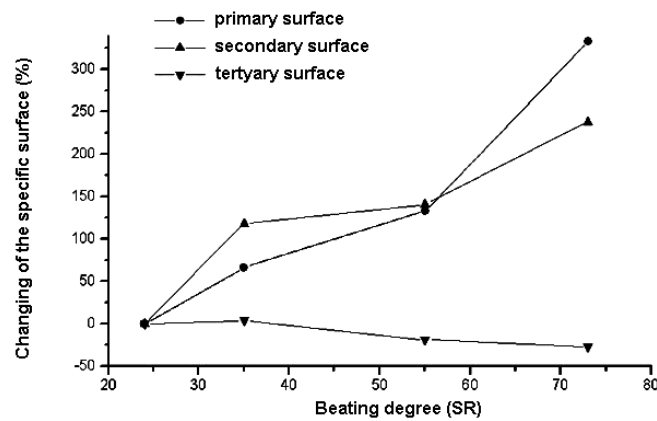


Figure 6: Relationship between the values of the three surface types and the beating degree

#### 4. Conclusions

As a result of sample fibre measurements, a strong correlation between the beating degree and beating time was determined. So it was possible to interpolate an empirical and exponential Boltzman graph or a linear graph to represent the beating process.

Strong positive correlation was experienced between the result of the specific surface values of the Three Way Method and the beating degree. By increasing the beating degree, the specific surface measurements also increased in a typical way which characterized the different pulps

The previous fibre surface definitions were perfected and three new designations were introduced: the primary, the secondary, and the tertiary surfaces. The primary surface value is equal to the rough surface value, the secondary surface value characterizes the difference between the colloid and the rough surface values, and the tertiary surface is the difference between the molecular and the colloid surface values.

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## EVALUATIONS OF CHEMICAL, OPTICAL, COLORIMETRIC AND PRINTING STABILITY OF DIGITAL PRINTS AND PROTECTIONS

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**Abstract:** The paper used, as a printing substrate in electro photographic techniques should achieve an appropriate structure, surface and optical properties as well as thermal stability. Printing products are often exposed to negative influence of external climate conditions. Surface treatment with varnishing and lamination is a common solution for protecting the final products against light, higher temperatures and elevated relative humidity.

In the frame of the applied research we studied permanence and durability of paper, image of prints and final printed product with two types of surface treatment. The evaluation of durability of paper and prints after accelerated artificial ageing indicates unsuitable optical and colorimetric properties, which consequently cause low optical and colorimetric stability. Colour prints with surface protection of polymer varnish or foil protection are very unstable, causing deterioration of colour, contrast and colour balance. The results of research work are very useful for the evaluation of durable printing paper used for various digital printing systems.

**Key words:** paper properties, electro photography printing system, printing varnishes, surface and optical and colorimetric properties, accelerated artificial ageing, permanence and durability.

### 1 Introduction

Due to a growing demand for quality and fast reproduction, the importance and use of digital printing, in comparison with conventional printing techniques, has been increasing rapidly. The important parameters for producing a quality print are the properties of inks/toners, printers and paper [1-3]. Electro photography differs from conventional printing techniques such as offset printing in the fact that a new printing form is applicable for each individual print. The image is created by neutralizing an electrical charge of a latent image and by applying electro statically charged toner particles that are fixed on paper by means of temperature and pressure. The characterization of the transfer function of a printing device is complex procedure involving not only the device itself but also the paper and its properties. Printing products are often exposed to negative influence of external climate conditions. Surface treatment with varnishing and lamination is a common solution for protecting the final products against light, higher temperatures and elevated relative humidity. Various varnishes (oil based-, water based dispersions, solvent based varnishes, UV varnishes) and polymers foils (PE, PP) are used depending on the requirements for the coating, and the transfer technology used [3-5].

In the frame of the applied research done in cooperation with the printing industry we studied permanence and durability of paper, image of prints and final printed product. We also analysed the influence of accelerated artificial ageing of paper and colour print in electro photographic printing technique (Xeikon) with the two types of surface treatment [6].

### 2 Experimental

The aim of the study was to determine the effect of accelerated ageing according to EN ISO 5630/3 (elevated temperature and relative humidity but without the presence of light) on chemical, surface, optical and colour degradation of paper and surface treated colour prints.

#### 2.1 Materials and methods

A sample of a one-side coated paper, 170 g/m<sup>2</sup> (sample 1) was analysed in accordance with EN ISO 9706 international standard requirements for permanent paper and after accelerated artificial ageing EN ISO 5630-3 [7, 8]. The results of comparative analysis are shown in Table 1.

Paper (sample 1) was printed with the print target IRIS on the XEIKON digital printing machine. Xeikon DCP/32 is a multicolour printing system that is used to print web material with powder toners. LED system with a resolution 600 dpi is used for imaging, and toner is transferred directly onto paper web.

One half of colour prints (sample 2) were protected with special heat-set oil varnished colour print-offset (sample 3) that was transferred onto the paper with offset inking units and can be compared to colourless offset printing inks. They are used to increase printing ink gloss, to

achieve specific matte effects and improve abrasion resistance. The other half of colour prints was laminated with polymer foil on heat-laminated system (sample 4). One half of all paper and print samples marked from 1 to 4 were subject to artificial accelerated ageing according to EN ISO 5630/3 standard at 80 °C and 65 % of relative humidity without exposure to light for a period of 24 days in a climatic chamber [12]. Several structural, chemical, surface, mechanical, optical and colour properties were tested on both aged and unaged samples under standard climate conditions (ISO 187) on the basis of ISO and TAPPI standard methods:

- Fiber furnishes structure of paper: microscopic qualitative and quantitative fiber composition analyses (ISO 9184/2),
- Basic physical – chemical properties of paper: grammage (ISO 536), thickness, density, specific volume (ISO 534), ash content (ISO 2144), pH of cold extract (ISO 6588),
- Mechanical properties of paper: tearing resistance (ISO1974), folding endurance MIT (ISO 5626),
- Surface properties of paper and prints: smoothness Bekk (ISO 5627), porosity Gurley (ISO 5636-5), contact angle FibroDat (TAPPI 558), FTIR spectrometry in reflectance light,
- Optical properties of paper and prints: gloss Lehmann (TAPPI 480), ISO brightness (ISO 2470), opacity (ISO 2471), light scattering and light absorption (ISO 9416),
- Colorimetric properties of prints: colour difference CIE L\*a\*b\*, colour degradation and colour balance (ISO 13656).

The results of tested properties of paper and prints are shown in Table 1 and Fig. 1-4.

*Table 1: The influence of ageing on permanence and durability of paper (sample 1)*

PROPERTIES	ATTAINED VALUE before ageing	ATTAINED VALUE after ageing ISO 5630/3 24 days	ISO 9706 (∞) requirement for permanence and from praxis
Fibre composition	- 50 % Sa bleached hardwood - 50 % Sa and Si bleached softwood		100 % bleached cellulose pulp
Grammage, g/m <sup>2</sup> Specific volume, cm <sup>3</sup> /g	168.1 1.02	168.9 1.02	
Ash content, % - 500 °C - 900 °C	31.0 20.5	31.4 20.2	min. 2 % CaCO <sub>3</sub>
pH of cold extract, -	9.7	9.9	7 -10
Kappa number	3.8	4.0	max. 5.0
Tearing resistance, M/C**, mN	1156 / 1379	1141 / 1432	min. 950
Folding endurance, MIT-1kg, M/C**,No.	704 / 116	666 / 38	min. 150
Smoothness, Bekk, A/B*, s	92 / 72	70 / 54	min. 50-70
Porosity, Gurley, s	2640	1731	
Surface pH, A, -	7.9	7.5	7 - 10
Water absorption, Cobb 60, A/B*, g/m <sup>2</sup>	23 / 22	17 / 18	min. 20-25
Contact angle FibroDat, A/B, 60s, °	73 / 75	110 / 130	min. 70 - 90
Gloss, Lehmann, A/B*, %	18.4	18.1	
ISO Brightness, A/B*, % - UV / + UV - fluorescence	86.3 / 95.3 9.0	72.3 / 76.8 4.3	min. 85 % max. 1.0
Opacity, A/B*, %	98.3	99.0	min. 90

\*A, top side, \*B, bottom side

\*\*M, machine direction, C, cross direction

### 3 Results and discussions

#### 3.1 Paper permanence and durability

A sample of unprinted one-side coated paper, 170 g/m<sup>2</sup> (sample 1), used as a carrier for determination of digitally printed product durability, is made of quality bleached pulp, neutrally sized and contains a high percentage of calcium carbonate functioning as a filler and a coating pigment. In addition, it attains good mechanical resistance and contains a considerable amount of optical bleaching agents. Thus paper quality does not meet the requirements for durability as specified in the EN ISO 9706 (∞) standard.

The results of measurements of individual properties provided by a comparative analysis of paper during accelerated artificial ageing (Table 1) show only slight changes in the basic physical-chemical properties (specific volume, pH extract, pH surface, and lignin content), which is an indication of small chemical changes in paper structure. During accelerated ageing absorptivity of water by Cobb-60 values decreased whereas the contact angle increased causing a decrease in surface wettability. For durability against external factors such as elevated temperature and humidity the hydrophobic paper surface is desired. Accelerated ageing caused only slight changes of gloss, whereas ISO brightness decreased significantly, mainly due to a presence of optical brightener agents in paper that decomposed and thus resulted in impaired durability of paper and printed products.

#### 3.2 Chemical stability of colour prints

FTIR reflectance spectra were obtained by Perkin Elmer 1000 IR spectrometric system, with DTGS detector [9, 10]. Only the coated side of paper and prints was tested. For the printed-paper samples surface spectra were recorded only from the unprinted area (Figure 1).

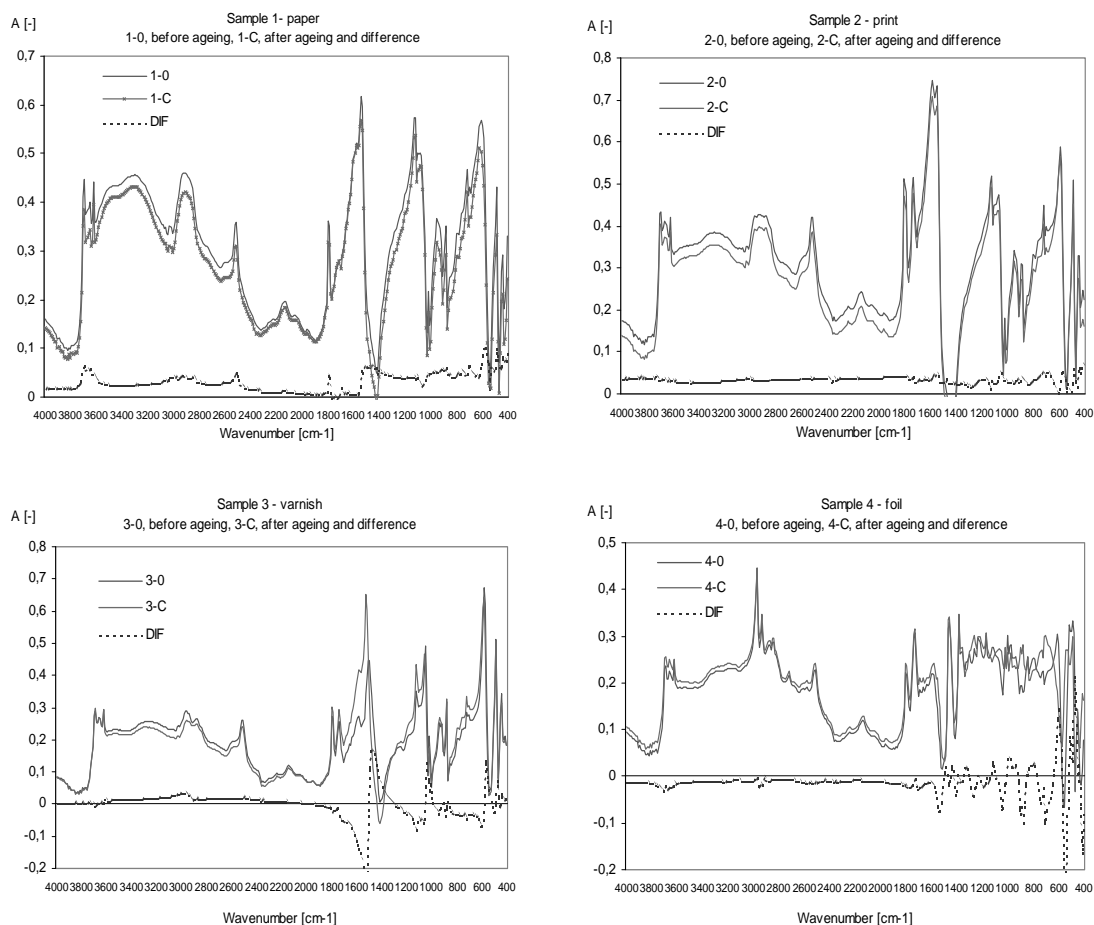


Figure 1: FTIR reflectance spectra before and after ageing for paper (sample 1), colour print (sample 2), print varnishes (sample 3) and print foil (sample 4).



All paper samples were coated with calcium carbonate. Sample 3 was additionally varnished with oil-based varnish and sample 4 was covered with polypropylene foil. Sample 1 remained unchanged after ageing which is clearly evident from FTIR spectra of the corresponding samples before and after ageing. Sample 2 behaves in a similar way, indicating that the applied wetting agent does not influence the ageing process. In contrast to the first two samples, sample 3 was affected considerably. Due to the complex composition of the applied varnish it is impossible to define its individual components. The greatest difference in surface structure was observed with sample 4, which indicates that the foil is much more liable to ageing than the coated paper surface.

### 3.3 Optical stability of colour prints

Comparative monitoring of the effect of artificial ageing on the change in gloss, brightness and opacity of prints coated with an offset varnish or with a polymeric protective foil was made by studying light spectra with and without UV light.

The results of *gloss* measurements of prints (Fig.2) indicate an increase in gloss values, especially in case of offset varnish- and polymeric foil protected prints (samples 3 and 4). The influence of ageing slightly decreases with varnish-protected sample 3. The influence of artificial ageing on the reduction of *brightness* quality is visible in all samples in the light spectrum with and without UV contribution. They achieved favorable brightness stability values, max. 15 % reduction, whereas the surface varnished sample (3) and the sample plastified by a polymeric foil (4) showed considerably lower values. The results indicate that ageing reduces the effect of optical bleaching agents. Samples 3 and 4 achieved the worst values of brightness stability and lightness, meaning that neither the selected agents nor the method of surface protection of prints were the most appropriate for quality protection of paper and the print as a durable graphic product [11]. *Opacity* does not change considerably with any of the printed or unprinted paper samples during accelerated ageing.

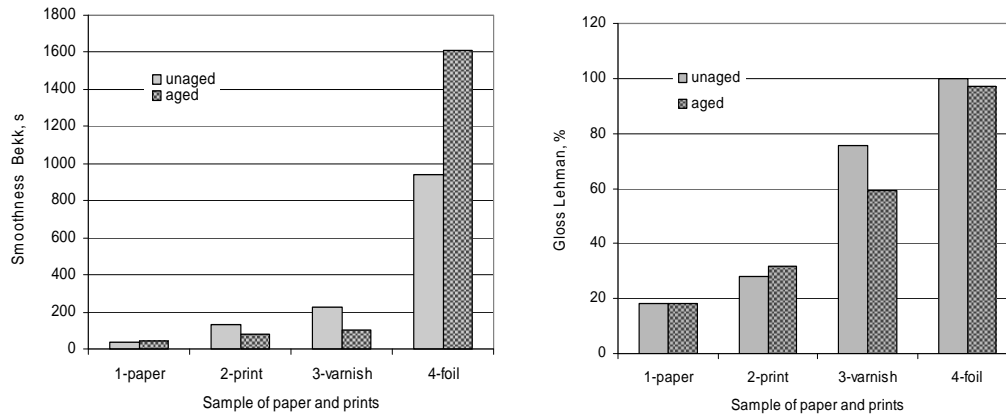


Figure 2: Surface and optical stability of prints: the influence of accelerated ageing on smoothness and gloss.

### 3.4 Colorimetric stability of colour prints

We conducted a comparative analysis of the effect of artificial ageing on the change of colorimetric differences, and print degradation of printed samples (sample 2) protected either by an offset coating varnish (sample 3) or a polymeric protective foil (sample 4).

Despite the CIE-L\*a\*b\* colour space being the most applicable in printing industry, it is not ideal because the calculated colour differences and visible perception do not match completely [12]. Colour differences between any two samples in a CIE-L\*a\*b\* space can be calculated from coordinate differences in all three directions of colour space on the following equations:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \quad (1)$$

where  $\Delta L^* = L^*(a) - L^*(0)$ ;  $\Delta a^* = a^*(a) - a^*(0)$ ;  $\Delta b^* = b^*(a) - b^*(0)$  are the differences calculated for the colour print after ageing (a) and before ageing (0).

Acceptable colour differences for offset print are 6.0 units or less [12-13]. A comparison of unaged and aged prints reveals that colour shades changed considerably with all samples during accelerated ageing. According to the classification of allowed colour differences, the differences with all colors and all tested samples were too high, with  $dE > 6.0$  for the offset prints to be used for production. Surface protection with a printing offset varnish or plastification did not give satisfactory results, i.e., it did not increase the stability of a print. Surface protection may be effective for a very short period, especially if paper is directly affected by external conditions such as physical and mechanical damage [14-16]. The applied agents and methods for surface protection do not protect a printed product from increased humidity or temperature. In addition, they are chemically unstable and thus exert the pronounced changes of optical and colour characteristics of paper and prints.

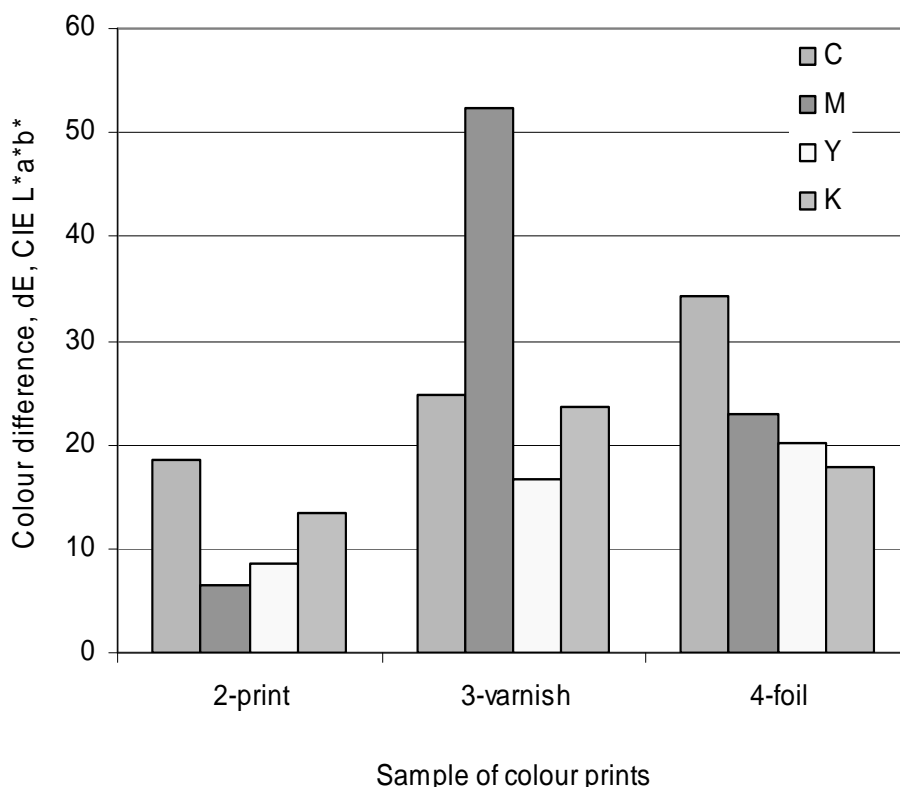


Figure 3: Colorimetric stability of prints - the influence of accelerated ageing on the colour differences.

### 3.5 Printing gradation and colour balance (CMYK)

Printing gradation is the transfer of raster tone values (RTV) from light to dark or the gradation of small to medium to large screen dots. Printing gradation is shown by a typical transfer-printing curve and can also be used for the determination of print colouration. During the formation of the »IRIS« test form, fields for measuring the primary and secondary printing colours were determined as well. The measuring fields were computer defined in a range of 0% to 100% of raster tone value (RTV) in step of 10% (Af). By means of densitometric measurements (Gretag D185) of these fields on a print we had obtained numeric values, which were then applied to individual primary printing colours (CMYK). Thus, we obtained four typical transfer curves that indicate the homogeneity of a print and the level of its colour (grey) balance (Figure 4).

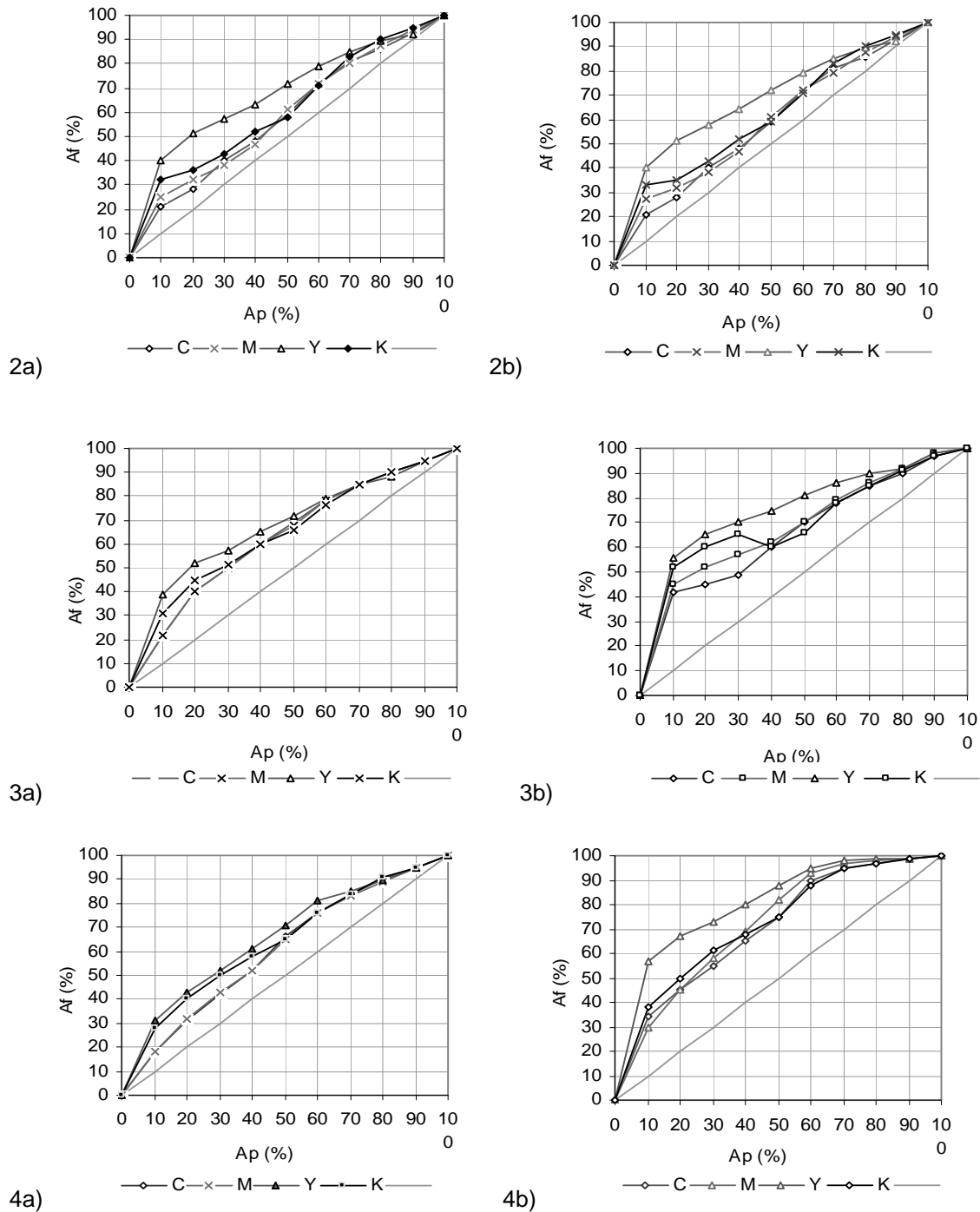


Figure 4: Colorimetric stability of prints - the influence of accelerated ageing on the printing gradation and color balance (CMYK) for samples 2 (print), 3 (varnish) and 4 (foil) before (a) and after ageing (b).

Printing gradations (Ap) are deformed or increased in all aged samples especially in the initial part, namely in light tones up to 50% RTV, which indicates colour instability of prints. Thus, colour balance is destroyed. The prints become shaded by the primary colour that changes the most, namely yellow Y, which was confirmed by printing gradation diagrams as well. In conclusion prints cannot be protected from ageing by surface treatment because of great changes in its characteristics. Colors fade, contrast decreases and the colour (gray) balance is destroyed.

## 4 Conclusions

On the basis of fibre analysis, basic chemical and physical, mechanical, surface and optical properties measurements results, and the EN ISO 9706 ( $\infty$ ), it can be concluded that paper corresponds to the standard requirements for chemical and mechanical properties. However it contains a very high level of unstable optical brightener agents and therefore does not meet the EN ISO 9706 ( $\infty$ ) standard requirements for permanent paper. The evaluation of durability of paper and prints after accelerated artificial ageing according to the EN ISO 5630-3 standard indicates unsuitable optical and colorimetric properties, which consequently cause low optical and colorimetric stability. Colour prints with surface protection of polymer varnish or foil protection are very unstable, causing deterioration of colour, contrast and colour balance [6, 16].

The results of durability of digital prints on paper confirm that it is important for papermakers, printing colour manufacturers, paper auxiliary agents and lacquers and varnishes manufacturers to cooperate in order to assure maximum printing runnability and printability as well as final printed product quality. The results of research work are very useful for the evaluation of durable printing paper by means of various new digital printing systems, and for the evaluation of printing material with durable quality.

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## GAMUT VOLUME AS A TOOL FOR PRINT LIFETIME ESTIMATION

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**Abstract:** Photography as a part of the cultural heritage is an ever-lasting subject of various stability experiments and analyses. In this work, samples produced by chromogenic and special photographic processes were used in a long-term lightfastness test. The test took place on bright indirectly sunlit corridor, where the samples were placed in glass covered frames. Light conditions were monitored by a photo-sensitive sensor, which was calibrated by radiometers. Test samples were measured by spectrophotometer. Measured spectral data were converted into Lab values and corresponding ICC profiles were calculated. Further, gamut volumes were calculated. Relative gamut volume changes plotted as a function of exposure dose were used to determine formal rate constants, which express the degradation rate of each sample. Samples were compared on the basis of calculation of time needed for 30 % gamut loss.

**Key words:** colour photography, gamut volume, lightfastness

### 1. Introduction

At the present, there are several standard practices and ISO standards, which deal with the light-fastness testing of colour photography and prints. Those papers include information about test conditions, methodology and endpoint criteria. With the determination of exact endpoint criteria many complications arise. Psycho-physical studies show, that suggested endpoint criteria aren't often compatible with the criteria set by independent observers.

### 2. Methods

Standard calibration target RGB 9.18 (see figure 1) was printed by different processes on various photo-papers. Glass covered frames placed at an indirectly sunlit corridor were used for sample mounting. Samples were regularly measured by the spectrophotometer Gretag Macbeth Spectrolino. Also, a digital photosensitive sensor, which recorded the light conditions during the test period, was placed into one of the frames.

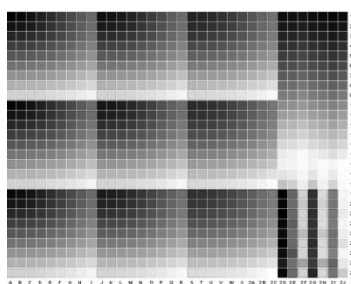


Figure 1: Test target

Reflectance spectra as measured data were used to calculate corresponding ICC profiles. Those profiles were then visualized in the Gamutvision software and gamut volume was calculated for each measurement. These values were plotted against the exposure dose. Equivalent sample age  $A$  was calculated according to equation (1) as the total exposure dose  $H$  to average daily dose ratio. Average daily dose is assumed to be 540 lx for 12 hrs, as recommended by company standards.

$$A = \frac{H}{450 \cdot 12} \quad (1)$$

Formal rate constants were then calculated as well as the  $S$  parameter according to fig. 2, 3, 4. The  $S$  parameter is a measure of the quality of the linear model fitting to the experimental data.

$$y = 100 - ax \quad (2)$$

$$a = \frac{100 \sum_{i=1}^N x_i - \sum_{i=1}^N x_i y_i}{\sum_{i=1}^N x_i^2} \quad (3)$$

$$S = \sqrt{\frac{1}{N} \sum_{i=1}^N \frac{(100 - ax_i - y_i)^2}{y_i^2}} \quad (4)$$

Table 1: Tested materials

Sample	Machine	Reproduction process	Material
1	Canon iPF5000	Inkjet, pigment set Lucia	Canon Glosy 190
2	Noritsu DryLab	Inkjet, pigment set	Noritsu Epson Ecography
3	OCE Lightjet	RA-4	Kodak Endura Lesk
4	OCE Lightjet	P-3	Ilfochrome Classic

### 3. Results and discussion

Calculated gamut volumes were plotted as a function of the exposure dose. In the graphs, there are also included equations containing formal rate constants determining the speed of image deterioration and the S parameter which shows the accuracy of line fitting. Zero value of the S parameter indicates that all points belong to the fitted line. When S is near one, points are scattered randomly and do not resemble a linear trend at all.

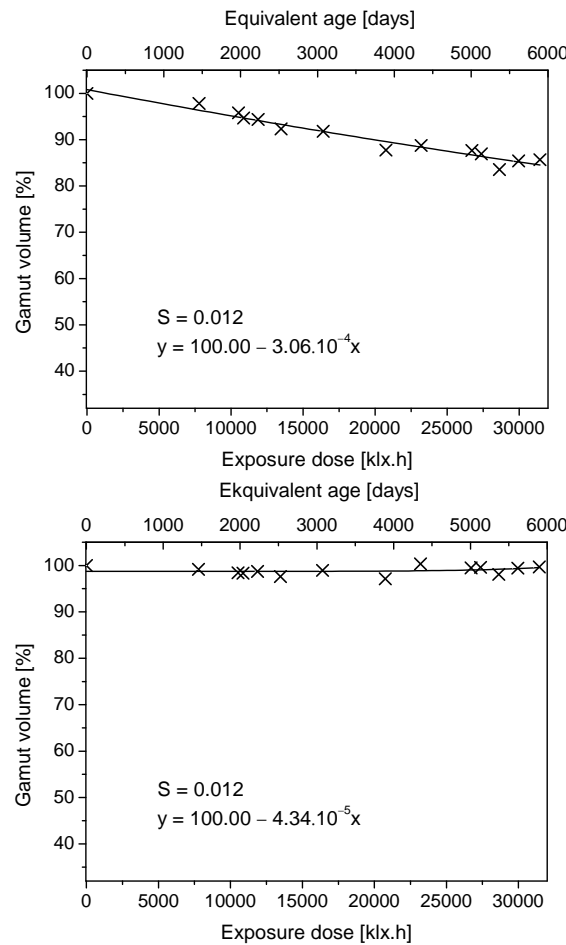


Figure 2: Graphs of first (left) and second (right) sample change in gamut volume as a function of exposure dose

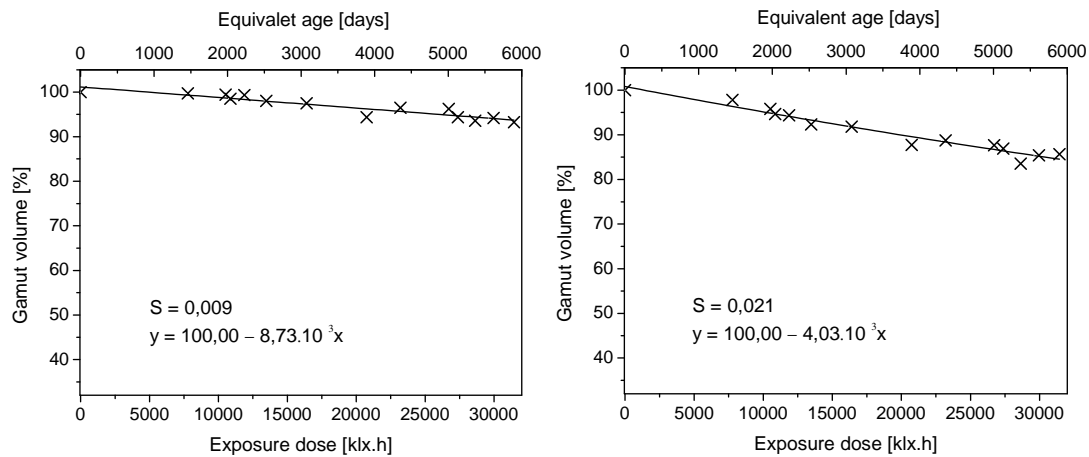


Figure 3: Graphs of third (left) and fourth (right) sample change in gamut volume as a function of exposure dose

From the figures it is obvious that sample volumes generally shrink linearly in the studied range of exposure doses. Minor fluctuation of values appeared in all cases, but only in one case the final volume ended up larger than original one. Authors think it might be caused by regrouping of pigment particles during print ageing and corresponding changes in gloss.

Table 1: Results

Sample	Long-term ageing		
	k [day <sup>-1</sup> ]	S	Gamut volume change
1	$3,06 \cdot 10^{-4}$	0,012	-2%
2	$3,55 \cdot 10^{-4}$	0,007	+2%
3	$8,73 \cdot 10^{-3}$	0,009	-7%
4	$4,03 \cdot 10^{-3}$	0,021	-14%

## 5. Conclusions

After exposure dose equivalent to 6000 days of standard sample display, the results show that the most stable samples are nr. 1 and 2, both inkjet pigment prints. The least stable is, on the other hand and quite surprisingly, sample nr. 4 processed by P-3 technique. Although there is no proven linkage between optical density loss and gamut volume contraction, this particular change can specify the image deterioration rate and its stability. Visualization of changed gamut can also provide valuable information about particular hues and gamut parts are most likely to be lost first and which one later during the print display.



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## PROFILOMETRIC ANALYSIS OF FOIL LAMINATED PAPERS

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**Abstract:** Foil lamination is a surface treatment operation for achieving some special effects, improving the resistance of the base paper to various physical and chemical influences and mechanical stresses. Surface micro-topography has influence on light scattering therefore on the colour gamut too, but also on operation steps and the quality of the post printing process. Besides the adhesive materials, surface adhesion of the foil in the laminating process depends on the roughness of the paper and foil surfaces which are bonded together. This paper presents the correlations of changes in surface roughness of various laminating foils depending on the roughness of base papers.

**Key words:** laminating foil, paper, surface roughness

### 1. Introduction

The surface roughness of paper and paperboard defines the quality and visual appearance of final product. It is an important aesthetic feature and also a functionally important characteristic because it affects the paper's printability and runability in many post printing processes [1, 2]. One of the post printing processes is the foil lamination, which provides paper and paperboard with some special effects, improving their resistance to various physical and chemical influences and mechanical stresses. If after the laminating process another surface treatment has to be applied, like foil stamping or spot varnishing, the surface roughness of the laminated structure becomes more interesting [3]. The standardized paper surface roughness measurement methods in paper and printing industries use air flow techniques. The measured roughness is given in micrometers in Parker Print Surf method or milliliters per second in Bendtsen methods [4, 5]. These methods are fast and relatively simply, but a single parameter is not sufficient for complex surface analysis, therefore surface topography methods are needed, like contact or non-contact profilometry (mechanical stylus and laser profilometry) or imaging methods (scanning electron microscopy (SEM), atomic force microscopy (AFM)) can be used [6, 7].

The main objective of this research was to compare the surface profiles of typical printing paper before and after foil laminating on with foils of different thickness. In order to characterize the vertical deviation of the measured surface, the mechanical stylus profilometer has been used. Stylus profilometry involves moving a stylus with constant speed across a surface while measuring its vertical deflection by converting the vertical movement to an electric signal. This signal is amplified, digitalized, post-processed (filtered) and converted to parameter values. The calculated roughness parameters are often referred to as two-dimensional parameters, since they are computed on the basis of single profiles containing information in two dimensions (horizontal and vertical) [7-9].

### 2. Materials and methods

Three types of commercial paper have been chosen for this study: uncoated, with basic weight of 140 g/m<sup>2</sup>, gloss- and matte-coated papers with basic weights of 150 g/m<sup>2</sup>. The selected papers have been laminated one and both sides too, on Aspira 76 hot foil laminating machine (temperature 115 °C, speed 8m/min, pressing force 22kN) with three standard gloss laminating foils: 24 µm thick BOPP roll laminating foil, 75 µm and 125 µm thick OPP laminating foils. Each sample was measured three times in machine and cross direction on five randomly marked patches (altogether 30 measurements for each sample) to ensure the accuracy of the measurements.

The surface roughness of the prepared samples was measured using the Portable Surface Roughness Tester TR 200 with a diamond stylus tip of 2 µm radius. The used surface tester is compatible with ISO 4287, DIN 4768, ANSI B 46.1 and JIS B601 standards and it can be used for measuring 13 different roughness parameters with four filtering methods, four sampling lengths, five different evaluation lengths and four measuring ranges with the corresponding resolution [10].

The measuring range of 20  $\mu\text{m}$  with corresponding resolution of 0.01  $\mu\text{m}$ , evaluation or assessment length of 5 sampling lengths and the Gauss filtering method have been used for measuring all samples. The sampling lengths with the corresponding traversing speed have been chosen according to the range of  $R_a$  parameter values (average surface roughness) for different samples. These values are presented in Table 1 [10-12].

Table 1. Selected sampling length with the corresponding traversing speed

Type of samples	Sampling length [mm]	Traversing speed [mm/s]	$R_a$ [ $\mu\text{m}$ ]	Evaluation length [mm]
Uncoated paper without foil	2.5	1	2 ~ 10	12.5
Matt coated paper without foil Gloss coated paper without foil Uncoated paper with 24 $\mu\text{m}$ foil Matt coated paper with 24 $\mu\text{m}$ foil Gloss coated paper with 24 $\mu\text{m}$ foil	0.8	0.5	0.1 ~ 2	4
24 $\mu\text{m}$ foil 75 $\mu\text{m}$ foil 125 $\mu\text{m}$ foil Uncoated paper with 75 $\mu\text{m}$ foil Uncoated paper with 125 $\mu\text{m}$ foil Matt coated paper with 75 $\mu\text{m}$ foil Matt coated paper with 125 $\mu\text{m}$ foil Gloss coated paper with 75 $\mu\text{m}$ foil Gloss coated paper with 125 $\mu\text{m}$ foil	0.25	0.135	0.02 ~ 0.1	1.25

The followings surface parameters served as a basis for the surface analysis [10-12]:

- $R_a$  - average surface roughness is defined as the average absolute deviation of the roughness irregularities from the mean line over one sampling length. Mathematically it can be defined as:

$$R_a = \frac{1}{L} \int_0^L |y(x)| dx \quad (1)$$

where  $y$  is the height from the mean line.

- $R_q$  or  $R_{ms}$  - root mean square roughness represents the standard deviation of the distribution of surface heights. It can be calculated as the square root of the arithmetic mean of the squares of profile deviation from the mean line within the sampling length:

$$R_q = \sqrt{\frac{1}{L} \int_0^L \{y(x)\}^2 dx} \quad (2)$$

- $R_{zDIN}$  – is the ten-point height parameter for the non-contact measurements or mean value of roughness depths for contact measurements. For the contact measurements it is defined as the average of the summation of the five highest peaks and five lowest valleys along the assessment length of the profile. The mathematical definitions is as follows:

$$R_{z(DIN)} = \frac{1}{2n} \left( \sum_{i=1}^n p_i + \sum_{i=1}^n v_i \right) \quad (3)$$

where  $n$  is the number of samples along the evaluation length ( $n=5$ ),  $p_i$  is the high of the peak,  $v_i$  is the depth of the valley.

- $R_p$  - leveling depth is defined as the maximum height of the profile above the mean line within the evaluation length.

### 3. Results and discussion

The mean values of the measured roughness parameters ( $R_a$ ,  $R_q$ ,  $R_{zDIN}$  and  $R_p$ ) for each laminated sample and for the base materials (papers and foils) are shown in Table 2. The mean values have been calculated from 30 individual measurements for each sample, measured in machine and cross direction of the paper (directions were the same on the laminate samples, too). In general, with this approach the influence of the direction of paper formation on the measured values could be avoided.

Table 2. The mean values of measured roughness parameters

Type of samples	$R_a$ [ $\mu\text{m}$ ]	$R_q$ [ $\mu\text{m}$ ]	$R_z$ [ $\mu\text{m}$ ]	$R_p$ [ $\mu\text{m}$ ]
24 $\mu\text{m}$ foil	0.072	0.088	0.355	0.187
75 $\mu\text{m}$ foil	0.031	0.047	0.259	0.189
125 $\mu\text{m}$ foil	0.022	0.033	0.187	0.140
Uncoated paper without foil	3.084	3.844	20.694	8.109
Uncoated paper with 24 $\mu\text{m}$ foil	0.704	0.835	2.856	1.440
Uncoated paper with 75 $\mu\text{m}$ foil	0.033	0.049	0.287	0.202
Uncoated paper with 125 $\mu\text{m}$ foil	0.027	0.041	0.247	0.176
Matt coated paper without foil	0.657	0.836	4.250	1.828
Matt coated paper with 24 $\mu\text{m}$ foil	0.267	0.325	1.195	0.618
Matt coated paper with 75 $\mu\text{m}$ foil	0.026	0.039	0.222	0.167
Matt coated paper with 125 $\mu\text{m}$ foil	0.021	0.032	0.215	0.146
Gloss coated paper without foil	0.396	0.514	2.635	1.047
Gloss coated paper with 24 $\mu\text{m}$ foil	0.212	0.256	0.929	0.483
Gloss coated paper with 75 $\mu\text{m}$ foil	0.031	0.047	0.266	0.199
Gloss coated paper with 125 $\mu\text{m}$ foil	0.021	0.033	0.195	0.145

In general, all surface roughness parameters have similar tendency of decreasing as the thickness of laminating foil increase, which can be clearly seen on the charts for single parameters  $R_a$ ,  $R_q$ ,  $R_z$  and  $R_p$  based on mean values from Table 2 and presented on Figure 1a-b and Figure 2a-b, respectively. From the presented charts on Figure 1 and 2 it can be observed that the uncoated paper (without foil lamination) has the highest values for all roughness parameters, corresponding to stochastic nature of paper surface without any surface processing techniques.

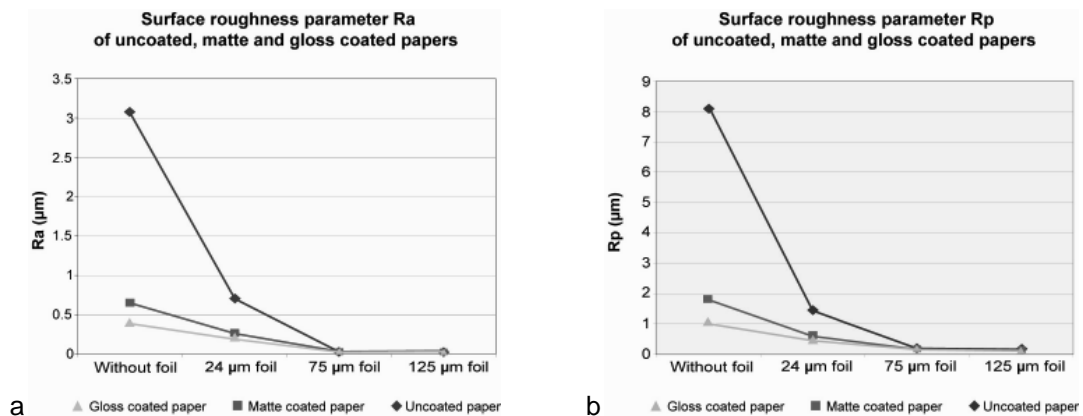


Figure 1: Tendency of changes in mean values of roughness parameter  $R_a$  (a) and  $R_q$  (b)

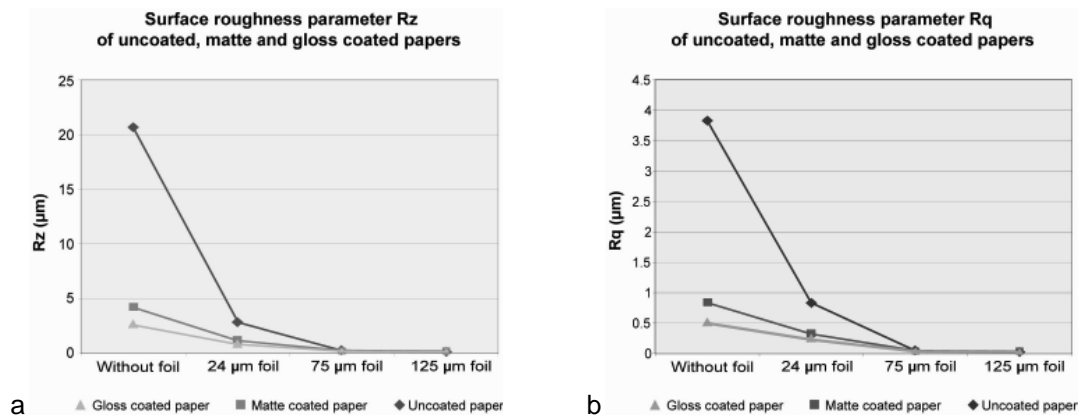


Figure 2: The tendency of changes of surface roughness parameter  $R_z$  (a) and  $R_p$  (b)

Coated papers, as can be seen on Figure 1 and 2, have significantly lower values for all observed parameters in comparison to uncoated paper's parameters. The difference between the mean values of roughness parameters for matte and gloss coated papers without foil lamination is according to the theoretical expectation, since the gloss of paper is determined among others by the surface roughness of the paper.

During laminating process the uncoated paper's surface structures endured the most significant changes (as it was expected). The most rapid decay of values for all roughness parameters was registered for the uncoated paper + 24  $\mu\text{m}$  foil laminate structure, which means that most of the high peaks and deep valleys on the base paper's surface have been straightened by foil lamination (heat-treatment and pressure). With thicker foils this straightening is more intensive, since there is more material (foil and adhesives) to fill the valleys and leveling the peaks.

Analyzing the changes in surface roughness of the foils before and after lamination processes, it can be noticed that foils with different thickness behave different. The  $R_a$  parameter of the 24  $\mu\text{m}$  thick, raw foil has been increased in the laminating process: instead of 0.077  $\mu\text{m}$ , it becomes 0.704, 0.267 and 0.212  $\mu\text{m}$  for the uncoated, matte and gloss coated paper, respectively (see in Table 2). In comparison with obtained results of 75 and 125  $\mu\text{m}$  thick foils and laminated structures, it can be observed that there are no significant changes in surface roughness of raw foils and all combinations of laminated structures, since the measured values of  $R_a$  and  $R_q$  for all paper-foil combinations are close to each other (see Table 1, Figure 1 and Figure 2).

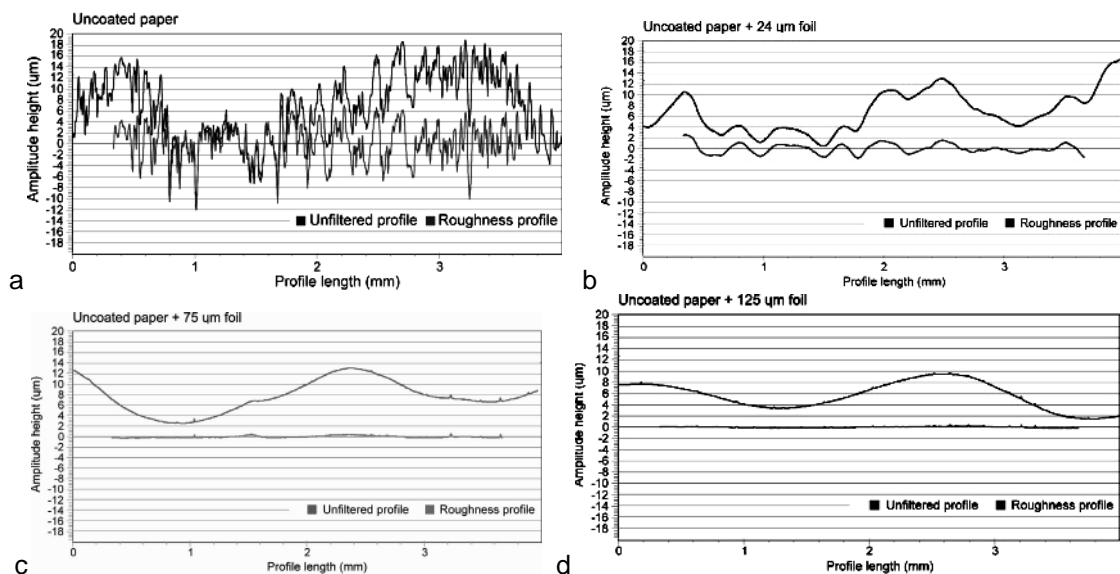


Figure 3: Typical surface profiles of uncoated paper without foil lamination (a), laminated with foil of 24  $\mu\text{m}$  (b), 75  $\mu\text{m}$  (c) and 125  $\mu\text{m}$  (d)

By inspection of raw data (unfiltered profile) recorded by the surface roughness tester, it can be observed that the surfaces of different papers become less rough after lamination, but the initial waviness of paper surfaces is reflected on the surface characteristics of laminated materials. To enable the direct comparison of the obtained surface profiles, each of them is shown with the sampling length of 0.8 mm. The typical surface profiles of the uncoated, matte and gloss coated papers without foil, with foil of 24  $\mu\text{m}$ , 75  $\mu\text{m}$  and 125  $\mu\text{m}$  are shown in Figure 3, 4 and 5, respectively.

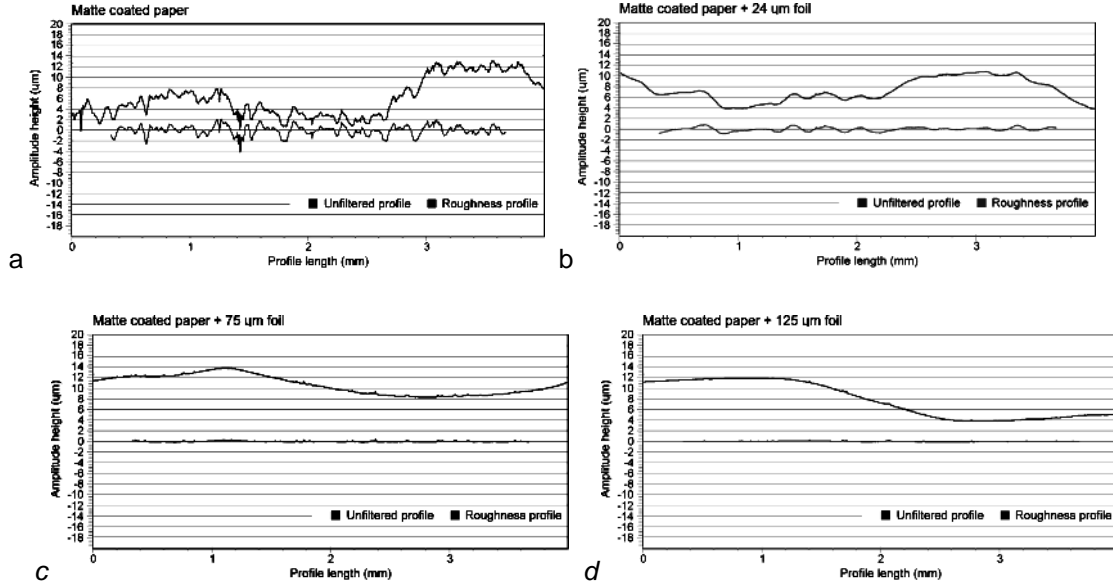


Figure 4: Typical surface profiles of matte coated paper without foil laminating (a), laminated with foil of 24  $\mu\text{m}$  (b), 75  $\mu\text{m}$  (c) and 125  $\mu\text{m}$  (d)

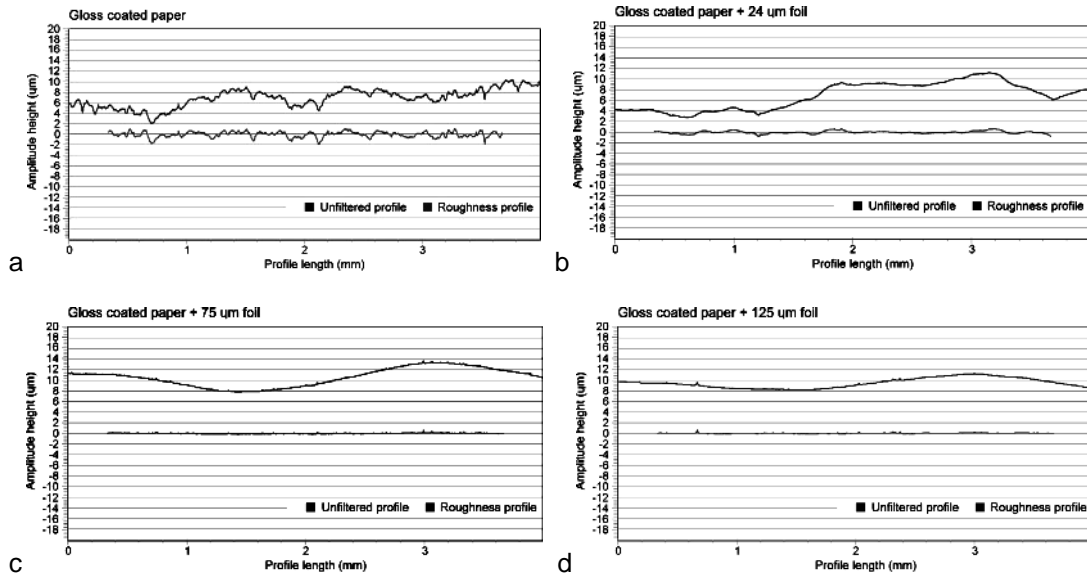


Figure 5: Typical surface profiles of gloss coated paper without foil laminating (a), laminated with foil of 24  $\mu\text{m}$  (b), 75  $\mu\text{m}$  (c) and 125  $\mu\text{m}$  (d)

The unfiltered profiles for all paper-foil combinations show that the waviness of the base paper is an important parameter for the surface characteristics of laminated structure. It could be observed that the amplitude of waviness profile has changed by applying different foils, but still affected visual appearance of the surface. The uncoated paper's waviness reflected the most significantly on the laminated structure.

## 4. Conclusions

In order to better understand the visual effects of laminating process, mechanical profilometry method has been used to quantify the surface changes of different types of paper and those same papers laminated with three different foils. The obtained results of surface roughness show that all observed surface roughness parameters have similar tendency of decreasing as the thickness of laminating foil increased. The results clearly reflect the essence of the lamination process: every type of paper can be laminated to get a smoother surface, but depending on the foil thickness the waviness of the base papers is reflected in some extent to the laminated structure. The materials and laminating conditions described in this paper cover just a small segment of industrial applications. For detailed analysis, in further work a broader range of foils (different polymer materials like PE, PS with different thicknesses) and laminating conditions (temperature, pressure) have to be observed. Since the quantitative assessment of surface texture can lead to wrong conclusions, the visual examination of surface topography (by optical or electron scanning microscope) could be used in connection with the profilometric method for adequate interpretation of the obtained results.

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## COMPARISON OF OPTIMAL INKING OBTAINED BY USING THE METHOD OF MAXIMUM PRINT CONTRAST AND INKING OBTAINED BY ACHIEVING THE COLOUR VALUES IN CIE LAB

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**Abstract:** Defining of optimal inking in the offset printing process is one of the most important conditions for achieving of high quality and predictable results. Besides defining the exact values of optimal inking, expressed by  $D_v$ , applying the method of maximum print contrast for the different combinations of printing substrate-offset printing press-ink, it is also necessary to check whether these values can result in correct colour characteristics, expressed by CIE Lab of the main ink types – C, M, Y and K. In order to achieve the goals of the experiment, a number of measurements have been performed (from underinking to overinking) for defining the optimal inking by the method of maximum print contrast. Also, the colour coordinates CIE Lab have been defined and the respective corresponding density of the fields, at which the smallest colour difference is achieved between the measured fields and the colour values in CIE Lab included in the ISO Standards for colour characteristics of inks for offset printing. A comparison has been made between the optimal inking results obtained by the two methods. The experiment has been made on heatset offset printing press on newsprint paper. The analysis of the  $D_v$  results achieved by the two methods also compares the values of the print contrast, the tone value increasing (dot gain), etc. It also gives some recommendations of practical importance.

**Key words:** Print Quality, Offset Print, Optimization of printing processes, Optimal Inking Values, Print Contrast

### 1. Introduction

One of the most important factors, influencing the offset image quality is the ink quantity onto the printed sheet. This ink quantity depends on the specific combination printing substrate-printing machine-ink.

The major methods exist on determination and control of inking:

1. Method for determination of optimal inking density –  $D_v$ , based on maximal print contrast [1]. Its main purpose is to produce as deep as possible colours with the highest ink quantity, while keeping the dot gain in the admissible limits and it is characterized by good quality of the prints' dark tones.

2. Method based on colourimetry, aiming at gaining of color levels for C, M, Y and Black as defined in the ISO standards [2,3,4]. These standards provide the following interpretation. Density values can be very valuable for process control during a print run, where the instrument, the ink and the print substrate remain the same (see ISO 13656 [3]). However, in a general situation, density values do not define a colour to the required degree. Therefore, for the purpose of ISO 12647-2, reflection density values are only recommended for the determination of tone values. Following ISO 13656, the production press operator first achieves the correct colour of the solids on the press, then reads the densities with the instrument from the OK print. The densities are then used as target values for process control during the production run. According to the ISO 12647-2 [2], the leading method for inking determination is the colourimetry, while the densitometric measurements appear to be informative only.

### 2. Experimental

The major goal of this experiment was to determine and compare the inking for CMYK, for two various treatments - the maximal print contrast method expressed as  $D_v$ , and the colourimetric method defined as per the ISO standards [2,3,4] for newsprint paper, printed on Heatset printing press.



### 3. Results and Discussion

The test form that have been used contains different control strips and elements: solid patches for C, M, Y, K, two color overprint patches, 40% and 80% dot gain patches [5,6], slur/doubling control elements and etc. All measuring components are with screen value 133 lines per inch. During the experiments were used printing plates FUJI LH-PCe Brilia 1005x680mm, obtained via calibrated and linearised CtPlate device Kodak Trendsetter Quantum II have been used. The paper that has been used is Kondopoga, 42 g/m<sup>2</sup>, Inks - Maxink Phantom HP. The printing machine, which has been used is web offset heatset press KOMORY SYSTEM 40.

The printing process was performed at standardized conditions.

A densitometer D19C and spectrophotometer of type SpectroEye of GretagMacbeth have been used for measuring of optical density, print contrast, dot gain and the colour characteristics in the CIE Lab color system. All measurements are in accordance with ISO 12647-1[7]: D50 illuminant, 2° observer, 0/45 or 45/0 geometry, black backing and in accordance with [8,9,10].

Colour characteristics of used paper (print substrate color) are in accordance with ISO 12647-2 [2] tolerances ( $L \pm 3$ ,  $a \pm 2$ ,  $b \pm 2$ ).

In the above-mentioned conditions, were printed series of samples characterized by gradual smooth changes in ink quantity - from underinking to overinking.

In order to achieve the goals of the experiment, series of measurements of  $D_v$  and Print Contrast have been performed (from underinking to overinking) for defining the optimal inking by the method of maximum print contrast for Cyan, Magenta, Yellow and Black. A statistical analysis of the results was performed.

The experimental data, representing the changes in the print contrast –  $C$  (the ordinate axis on the left side on figures), depending on the  $D_v$  for the process colors, are given in Figures 1, 2, 3 and 4.

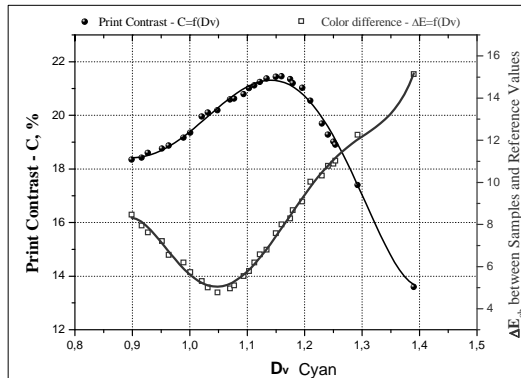


Fig. 1  $C=f(D_v)$ ,  $\Delta E=f(D_v)$  for Cyan

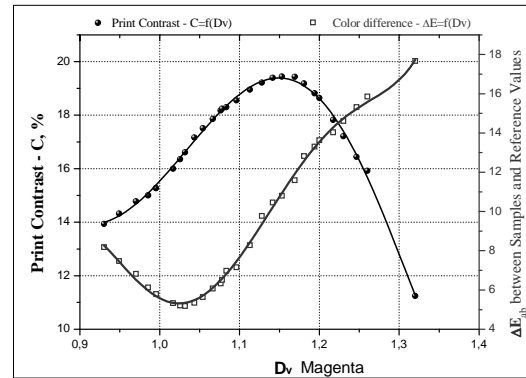


Fig. 2  $C=f(D_v)$ ,  $\Delta E=f(D_v)$  for Magenta

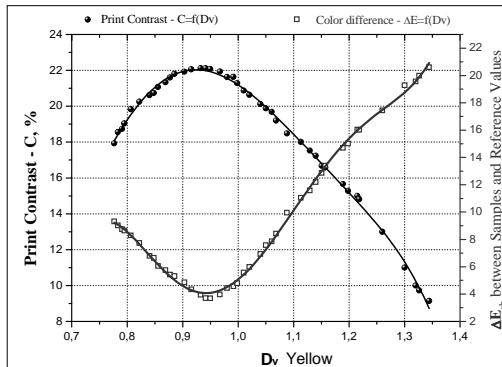


Fig. 3  $C=f(D_v)$ ,  $\Delta E=f(D_v)$  for Yellow

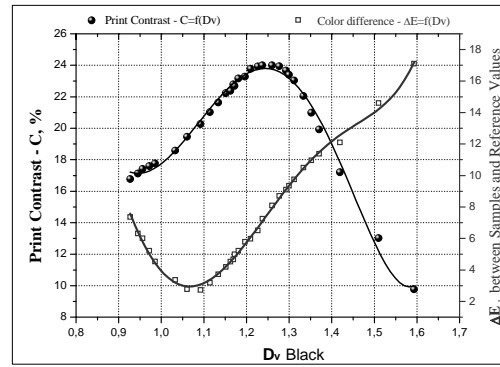


Fig. 4  $C=f(D_v)$ ,  $\Delta E=f(D_v)$  for Black

The graphs show clearly visible peaks, visualizing the maximal value of the print contrast and its corresponding  $D_v$ . The optimal inking has been defined through the optical density of 100% solid patch -  $D_v$ . Experimentally defined values for optimal quantity of printing ink for the newsprint paper are shown in Table 1.

*Table 1: Experimentally defined values for optimal quantity of printing ink by the Print Contrast Method*

Type of paper	D <sub>v</sub> (Optimal density defined by maximal print contrast method)			
	Cyan	Magenta	Yellow	Black
Newspaper	1.15	1.15	0.95	1.25

In order to determine the inking via the second methods, series of colourimetric measurements were performed on printing sheets with different ink quantity (from underinking to overinking). The major goal was to determine the ink quantity, which provides the smallest colour difference ( $\Delta E$ ) according to the reference values defined in ISO [2,4].

Figures 1, 2, 3 and 4 represent graphically the dependence of  $\Delta E$  (colour difference between measured values in CIE Lab for solid patches for C, M, Y, K with varying ink quantity and the reference colour values from ISO) to  $D_v$ . To achieve better visualization of the experimental data, at the figures 1, 2, 3 and 4, the colour differences -  $\Delta E$  are presented on second ordinate (the ordinate axis on the right side on figures).

The curve that connects the values of the measurements shows the changes in  $\Delta E$  from reference values, depending on the printing ink quantity. All graphics show that the curve lies at a determined distance close to the reference value. This distance represents the smallest  $\Delta E$  between the experimental data and the standard values as per ISO. According to [2,4], the printing process must be performed with ink quantity, which corresponds to the colour in the CIELab system characterized with this smallest  $\Delta E$ .

Table 2 presents the relevant (corresponding) optical densities –  $D_v$  to the smallest values of  $\Delta E$ , obtained from the experiment.

*Table 2: Experimentally defined values for smallest colour differences -  $\Delta E_{min}$  and relevant ink quantity defined by  $D_v$*

Paper	Cyan		Magenta		Yellow		Black	
Newspaper	$\Delta E_{min}$	Corresponding $D_v$	$\Delta E_{min}$	Corresponding $D_v$	$\Delta E_{min}$	Corresponding $D_v$	$\Delta E_{min}$	Corresponding $D_v$
	4.70	1.05	5.10	1.03	3.6	0.95	2.7	1.10

Analyses of the achieved results shows:

It is clearly visible from the graphs that for some of the colours exist relatively big differences between the values of  $D_v$ , where K has highest levels, and  $D_v$  where  $\Delta E$  has lowest levels.

The experimental results and the comparison of the data in Tables 1 and Table 2 shows that the optimal inking, determined by the two methods differ substantially for Cyan, Magenta and Black. A relatively big difference in  $D_v$  is observed – about 0.15 units for Black, 0.12 for Magenta and 0.10 units for Cyan. For Yellow it has no difference for obtained ink quantity defined by  $D_v$ .

#### 4. Conclusions

The results achieved are important from practical point of view. They lead to the conclusion that it is necessarily not only to achieve the maximal accuracy of reference colours from ISO standards, but also taking into strict consideration the concrete printing conditions - as dot gain, print contrast, screen frequency, type of printing press, ink properties (viscosity, adhesion to substrate) etc.

It is clearly visible from the experimental results and graphs that exist relatively big differences between the values of  $D_v$ , where print contrast has highest levels, and  $D_v$  where  $\Delta E$  has lowest levels. This means that the implemented two different methods for inking determination result in different levels for  $D_v$ .

According to the recommendations of the ISO standards, the leading issue is to achieve of the reference colour values for C, M, Y, K, while the concrete technological printing process

conditions are not taken into consideration, for example - dot gain, type of printing plates, ink types, printing paper specificity, printing press, screen frequency etc.

The inking process, as determined by the maximal contrast method takes into account all above mentioned technological conditions, except for the ink color characteristics.

Both methods for inking determination have their advantages and disadvantages. The advantages of one of the methods appear to be disadvantages of the another one.

In order to reach the level of maximal accurate colour reproduction, the condition to achieve colour characteristics C, M, Y, K is not sufficient, without taking into consideration the concrete technological conditions. Taking into account the concrete printing conditions for determination of the inking, but without considering ink colour characteristics would not lead us to predictable results too.

From the point of view of the human perception, it is very important to achieve maximal accurate reproduction of key tones that could be fulfilled only if the Print Contrast method is implemented.

The experimental results lead to the idea that it is necessarily to take into consideration both methods for inking determination, while the best performance from the viewpoint of accuracy of colour reproduction is the generation of ICC colour profiles. The experience has shown that during the ICC profile application, both concrete technological conditions and ink color characteristics are taken into consideration.

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## IMPROVING RELIABILITY-BASED MAINTENANCE CULTURE IN PRINTING PLANTS

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**Abstract:** *In several aspects, maintenance organization relies on the results of organization sciences, and therefore the results, correlations surfacing during the analysis and examination of organizational cultures may as well be applicable to this field of studies. Cultural elements can be clearly linked to the maintenance strategic model elaborated by the authors, thus demonstrating that the improvement of maintenance efficiency and changes in certain elements of the organizational culture can be assigned to each other. The authors have worked out correlations and methods, conducted studies to see how in contrast with the reactive (troubleshooting) maintenance approach the foresighted reliability culture can be made a part of the corporate culture at printing businesses, what steps, procedures are needed for a successful change.*

**Key words:** *corporate culture, reliability, maintenance of printing plants.*

### 1. Scope of the research

With a focus on the development of maintenance organization, as part of a larger work we assessed the situation of maintenance in printing industry maintenance, at Hungarian printing enterprises in 2003 and 2004. A series of questionnaire-based surveys conducted with the involvement of professionals working in the examined field formed the basis of the assessment. With respect to the production value created, the survey could be performed at 26 of the 30 largest printing companies. At that time, these printing enterprises represented approximately 60% of the registered production volume of the sector. All the competent maintenance managers – altogether 67 people – responded to our questions. From the “private soldiers” of maintenance, we sought for and received answers from almost 20% of the representatives of the profession.

This questionnaire-based survey of the existing conditions tried to reveal the situation of maintenance in printing industry at that time, the professional preparedness and organization of these activities, technical facilities, expectations and the foreseeable tendencies of development [2].

Some of the questions in the survey also concerned problems relating to corporate culture, and the responses implied that in printing industry – including maintenance – traditions, the printer attitude and insistence on well-established ways of behaviour. It was apparent that major internal changes took place at the company, accompanied by a change in the culture. These factors have motivated us to examine whether the available means of organizational culture can contribute to the efficient adoption of the reliability-centered orientation in maintenance. Hereunder, our associated researches are presented.

### 2. Methodology of the research

When we were framing our integrated maintenance model, we considered all those means and abilities that were needed for the betterment of maintenance, expected to allow the implementation of efficient foresighted maintenance management in printing industry, and at the same time comprised the elements of the structuring of our maintenance model.

Some of these elements belong to *hard means* or *hard skills* as they are called in Anglo-Saxon technical literature. They cover all those knowledge, professional contents, abilities that are needed for the performance of foresighted maintenance. They include tangible means such as professional and time planning, the performance of operating and stewardship tasks, condition monitoring, failure analysis, servicing know-how and so on.

*Key abilities* or in English terminology “soft skills” are not associated with the given profession, but rather successful work. On the other hand, there are so-called “intangible” characteristics, behavioural patterns and practices; long-term plans, short-term goals, personal management, communication and cooperation, problem solving and the assumption of responsibilities, learning skills and capabilities, team work, performance and evaluation skills.

Figure 1 shows how the pyramid of “hard” skills is built upon the foundation formed by the “soft” key abilities. Nevertheless, the deep foundation of both these types of skills is in fact the organizational culture. In the light of this attitude, the structuring of the corporate culture should unavoidably be associated with the development of a maintenance model.

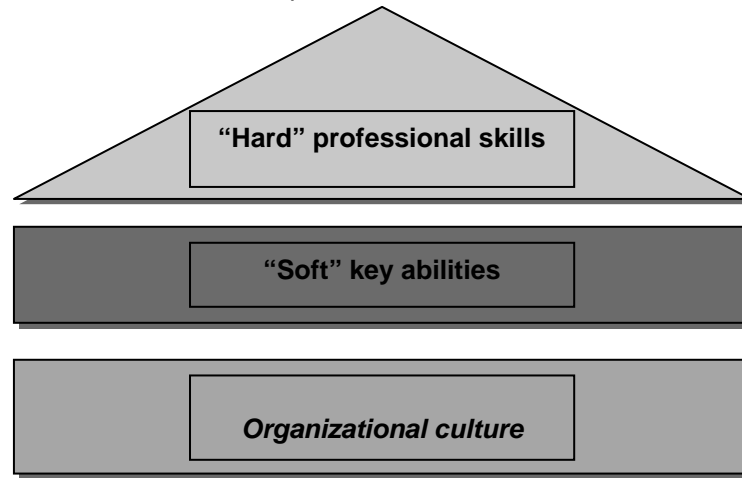


Figure 1: The pyramid of means and abilities stands on a foundation formed by organizational culture [3]

It has been examined how the reliability-centered culture can be incorporated into the work processes of the improvement of maintenance organization, how it is based on this maintenance model.

The interpretation of the reliability-centered attitude is demonstrated via ways of behaviour matched up and described in Figure 2 and 3.

Engineer Culture Change	
Mechanic	Technician
Lone ranger	Works in a team
Lubrication (if there is sufficient time)	Technically demanding
Inspection (if there is sufficient time)	Diagnostic and forecast
Troubleshooting panic	Works along time plans
Repeat breakdowns	Specialist of the given field
Permanent stress, but not a challenge	Challenging, but not stress

Figure 2: Repair-oriented and reliability-centered culture of engineers [1]

Today, the execution of maintenance tasks calls for a technician of independent and synthesized thinking rather than a repair-oriented workfellow who tends to lean back and regard himself to be a hero after any successful troubleshooting.

Management Culture Change	
Repair servicing administrator	Engineering manager
Get it fixed	Why did it break?
Work acceptability	What caused the work?
How much does it cost?	What caused the costs?
Inflexible in the face of budget constraints	To review the investment and planning
When will something break again?	Can do we prevent it?
Survived another week	How do we improve?

Figure 3: Repair-oriented and reliability-centered culture of maintenance management [1]

Similarly, completely different mentality and requirements are valid for a manager who plans maintenance with respect to reliability in comparison with a leader always waiting for the following day to come.

In the processes of maintenance organization, proper attention should be paid to supporting the forms of behaviour described in the right columns.

### 3. Structuring of a reliability-centered culture

Changes are always induced by economic factors, it is never the culture that itself “demands” change. In our case, the necessity to change the maintenance strategy is the main drive behind the change of the culture.

The control of the efficiency of the steps of change calls for the selection of such a cultural model where the concept of measurability can also be interpreted properly.

The cultural model suggested by Thomas (Thomas, 2005) assumes the existence of correlations among the eight concepts used in change management: the elements of change and the four fundamental elements of organizational culture as provided in *Figure 4*.

A scoring system can be worked out for the evaluation of the 8 elements of changes in the organizational culture model. The properties of the 32 correlations shown in *Figure 4* can be measured with tests. From the positive statements describing these correlations a test can be compiled. The responses can be evaluated via the grades of agreement pertaining to the elements of culture and focusing on the positive statements in view of the elements of changes, in a scale of 5 grades. The given responses can be summed up and evaluated towards the direction of the elements of changes. As a consequence, the tests to be compiled should minimally consist of 32 questions or the multiple of 32 questions.

Eight Elements of Change	Four Elements of Culture			
	Values	Role Models	Rites & Rituals	Cultural Infrastructure
Leadership	M	M	M	m
Work Process	M	M	M	m
Structure	M	m	M	m
Group Learning	M	M	m	m
Technology	M	M	M	m
Communication	M	M	M	M
Interrelationships	M	M	m	M
Reward	M	M	m	m
M – Major Interaction				m – minor interaction

*Figure 4: Correlations of the organizational culture and the elements of changes [3]*

With respect to the foregoing, such a questionnaire of 32 questions has been worked out that is suitable for testing our status and progress in the structuring of a reliability-centered maintenance culture. The test is based on the 8 pillars of the change of culture, in view of the four elements of culture. The responses and thus the extent of satisfaction reflect positive trends. In this case, the evaluation can be interpreted in a scale of 20 points in relation to each element of change.

The questionnaires can be processed, and the changes can be evaluated with the use of ordinary web or column charts. The direction of changes indicates our further orientation that we should take in our work of culture building.

As an example, below the statements from the questionnaire concerning structural issues are provided.

31. It is clear for everyone that reliability and maintenance affect the entire operation of the company.

32. The necessary structural changes always influence maintenance management.

33. The structure of the company (hierarchical order) corresponds to the regular activities determined by the work processes of maintenance.

34. The company’s management system minimizes the effects caused by whispering and corridor information exchange.

Figure 5 presents a situation assessment made in relation to a real maintenance workshop and shows the average changes of the reliability culture based the answers of 3 managers and 9 workers.

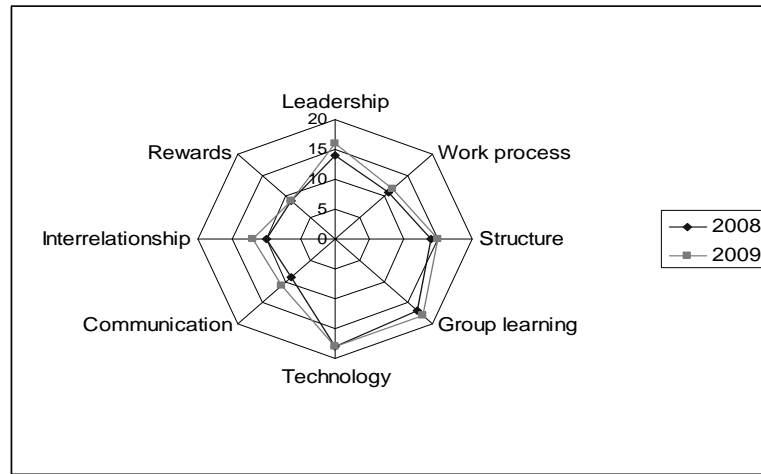


Figure 5: Evaluation of the changes of organizational culture in a web chart

#### 4. Conclusion

An important and brand new element of the maintenance organization model is the maintenance reliability culture structuring module (Figure 6) that relies on the results of the questionnaire-based assessment (culture test), and thus provides for a framework of continuous development and the secure sustainment of the achievements made. It calls for a novel approach, and is incorporated into all the organizational processes represented by information and managerial chains, relations. We have tested this method in 10 printing companies. The used it with success to test and improve their reliability culture.

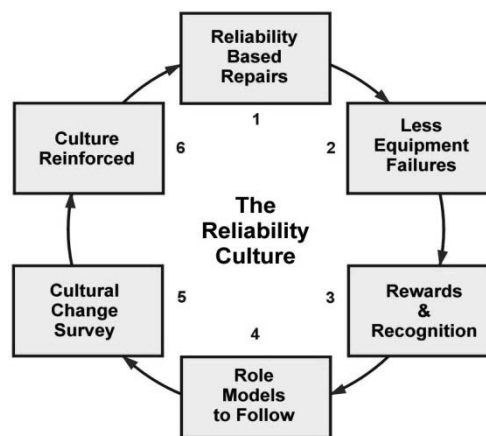


Figure 6: Model for the improvement of the maintenance culture at the printing businesses

#### 5. Literature

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## EVALUATION OF DIGITAL PRINT QUALITY ON RECYCLED PAPER

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**Abstract:** Recycled paper is produced from secondary, already used old paper fibres. The use of recycled fibres is increasing because of environmental awareness, especially because of forest cutting and accumulation of waste material. Recycling process involves collecting and sorting of old paper, fibre separation, removal of printing ink and other uncleanliness.

The main reason of our research is to find out print differences between recycled and classic papers. Special-test elements for negative phenomena evaluation were prepared and printed on our papers with digital printers. After printing the negative parameters as wicking, bleeding and mottling were determined by image analysis. Furthermore the prints were evaluated with spectrophotometric measurements. The differences in print quality between recycled and classic papers are discussed.

**Key words:** recycled paper, digital printing, image analyse, spectrophotometric measurements

### 1. Introduction

Due to increasing demand of paper, two main problems are coming in sight. More forests are being cut and more waste paper is accumulating in the dumps. One of the solution is reusing of waste paper, which is known as recycled paper (Novak, 2004). Recycling process involves repulping the old paper to reduce it to fibre slurry, separating ink from the fibre and removal of ink particles from the stock. The fibre slurry is then turned into paper using conventional papermaking machines (Thompson, 2004). Use of recycled fibres varies from country to country. It is defined differently due to quantity of natural pulpwood resources and environmental law requests in last decade. (Göttsching, Pakarinen, 2000, Stawicki, Read, 2010).

Unlike the preparation of pulp from virgin fibres, those obtained from printed waste must have the ink removed. Large particles of ink that are left in the pulp will produce papers that are blemished with visible specks of ink. If the particles of the ink are small, the eye cannot resolve them, therefore they add a greyiness or loss of whiteness to the paper. This reduces the dynamic range of the print (Thompson, 2004).

Main reason of this research was to evaluate the print quality on recycled papers. Moreover, the differences between electrophotography and ink jet prints on different type of papers were analysed. The print quality was evaluated with image analysis and spectrophotometric measurements. Phenomenon which presents inappropriate print quality can be evaluated with suitable software based on image analysis. Wicking phenomenon describes jagged strict edges at monochrome printing. Bleeding describes colour mixing interaction at multicolour printing. Meanwhile, mottling defines print nonuniformity (Hladnik, Muck, 2001).

### 2. Materials and methods

In the research four different **papers** were analysed: classic uncoated paper (CUP), classic matt coated paper (CCP), recycled uncoated paper (RUP) and recycled matt coated paper (RCP). Papers CUP and CCP are woodfree papers, meanwhile papers RUP and RCP are 100 % recycled papers. All papers have grammage of 100 g/m<sup>2</sup>.

The **surface and optical properties** of papers can be connected with print quality. Therefore the roughness with Bendtsen method (ISO 5636-3) and ISO brightness (ISO 2470) were determined. All measurements were done on front side of papers.

**Test chart** was prepared with program Adobe Illustrator. It is composed of special-test elements for negative phenomena evaluation. Letters of various sizes, lines of various thicknesses, lines which bisect each other in different angels and circular lines with different diameters were prepared to evaluate wicking and bleeding phenomena. Positive and negative monochrome test elements, separately for cyan, magenta, yellow and black were prepared for wicking evaluation (Figure 1). Meanwhile, the same test elements consist of two colours were prepared for bleeding evaluation (Figure 2).



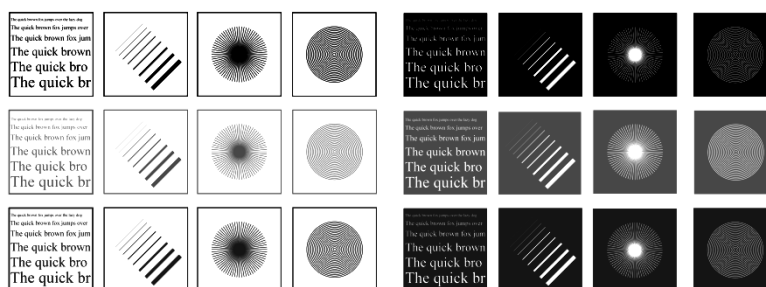


Figure 1: Test elements for wicking evaluation

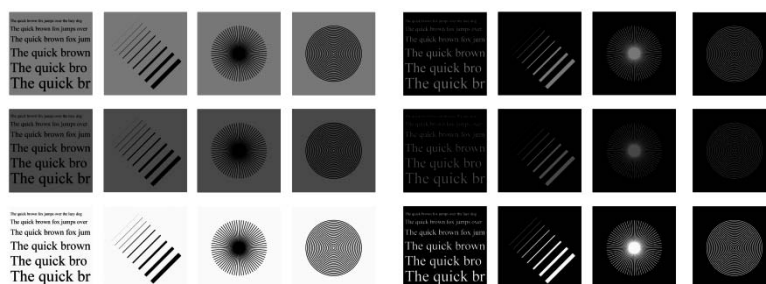


Figure 2: Test elements for bleeding evaluation

Fields of primary and secondary colours with size of 2 cm × 2 cm were prepared for mottling and colour gamut evaluation (Figure 3). Each colour has fields with covered area from 100 % to 10 %.



Figure 3: Test elements for mottling and colour gamut evaluation

Test chart was printed on two **digital printers** on the front side of papers. Canon imagePRESS C1+ is an electrophotographic printer. Auto gradation, shading correction and calibration were done before printing test chart on this printer. Prints were printed with CMYK inks, with resolution of 600 dpi × 600 dpi. The second, Canon imagePROGRAF W8400 is an ink jet printer. Individual channel ink reduction, total ink limit and linearization were determined. Prints were printed with CMYK, light cyan and light magenta inks, with resolution of 1200 dpi × 1200 dpi.

Prints were observed with **optical microscope** Leica EZ4 D with integrated digital camera. Photos were taken at 25 times magnification for wicking and bleeding evaluation and 16 times magnification for mottling evaluation.

The **spectrophotometer** Eye-One Pro was used to measure  $L^*a^*b^*$  values of primary and secondary colours with 100 % coverage area. The results were used to represent colour gamuts in CIELAB  $a^*b^*$  colour diagrams.

To calculate wicking, bleeding and mottling **program for image analysis** ImageJ was used. Wicking and bleeding were determined with values of area and perimeter of letters “x” and “o”. The print results were compared to the original (digital test elements) results which were also evaluated in the program. Mottling was determined on the surface of 1000 × 1000 pixels. Program calculated the value of print nonuniformity. The level of print nonuniformity is in connection with an intensity width span of picture dots. The larger is the value, the bigger is

mottling. Mottling index or so called nonuniformity number (NU) is calculated from average of dots intensity above median ( $U_x$ ) and those under median ( $L_x$ ) by the help of following equation (Hladnik, Muck, 2001):

$$NU = U_x - L_x. \quad (1)$$

### 3. Results and discussion

The roughness and ISO brightness of papers are quoted in Table 1.

Table 1: Roughness and ISO brightness

Paper	Roughness [ml/min]	ISO brightness [%]
CUP	159	99,24
CCP	42	98,15
RUP	213	84,00
RCP	80	86,16

#### 3.1 Wicking and bleeding

**Wicking effect** can be seen in Figure 4. Diagrams show perimeter and area values of letter “x” size of 8 points, which was printed on all papers with electrophotographic and ink jet printer, separately in black and cyan colour. The larger perimeter and area at the same time means the larger wicking or bleeding. Also, the small area and large perimeter means the larger wicking or bleeding.

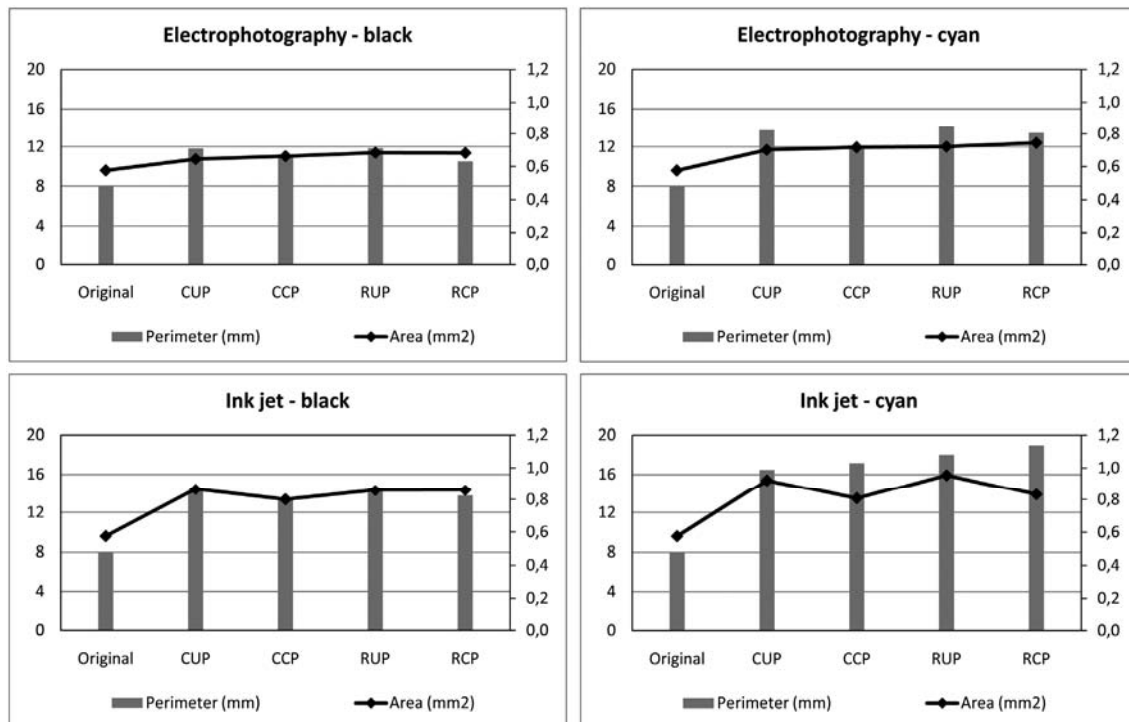


Figure 4: Perimeter and area of black and cyan letter “x” printed with electrophotographic and ink jet printer

The results for electrophotography are similar to all papers, especially for black colour. Small differences can be seen when the perimeter of uncoated papers is compared to coated papers. The perimeter for cyan colour of classic uncoated paper (CUP) is 13 % larger compared to classic coated paper (CCP) (this example is shown in Figure 5). While, the perimeter for cyan colour on recycled uncoated paper (RUP) is 5 % larger compared to recycled coated paper (RCP). Meanwhile, there is no significant difference between classic and recycled papers. Perimeters and areas on ink jet printer have larger wicking effect than those of electrophotography. Therefore the ink jet has a higher wicking. For the black colour the

differences are similarly small as in electrophotography. Diagram for cyan colour shows some differences between classic and recycled papers. The perimeter of classic uncoated papers is 9 % smaller compared to recycled uncoated paper. Meanwhile, the perimeter for classic coated paper is 10 % smaller compared to recycle coated paper. In both cases the area of classic and recycled paper is the same. Wicking is smaller for classic papers. Diagram for cyan also shows big differences between uncoated and coated papers, but this time uncoated papers have smaller, less visible wicking. This is because the researched coated papers are not suitable for ink jet print technology.

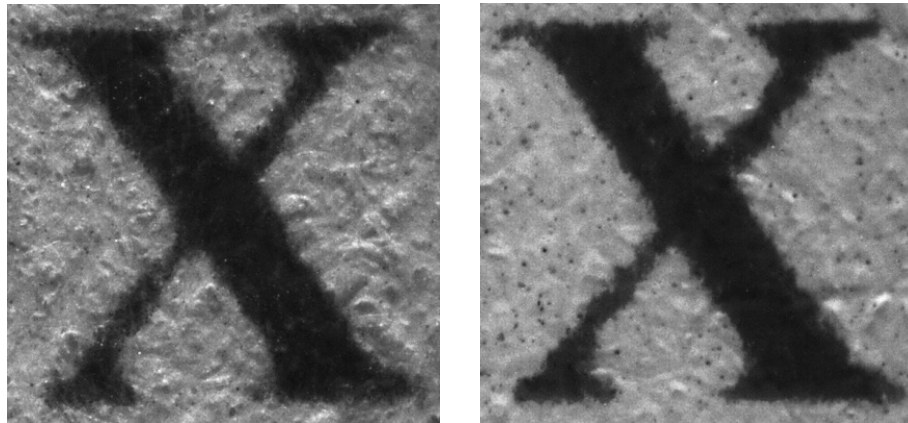


Figure 5: Letter “x” on classic uncoated paper (left) and classic coated paper (right) printed with electrophotographic printer

**Bleeding effect** can be seen in Figure 6. Diagrams show perimeters and areas of printed letter “o” size of 8 points. A black letter on cyan background and a cyan letter on black background were analysed.

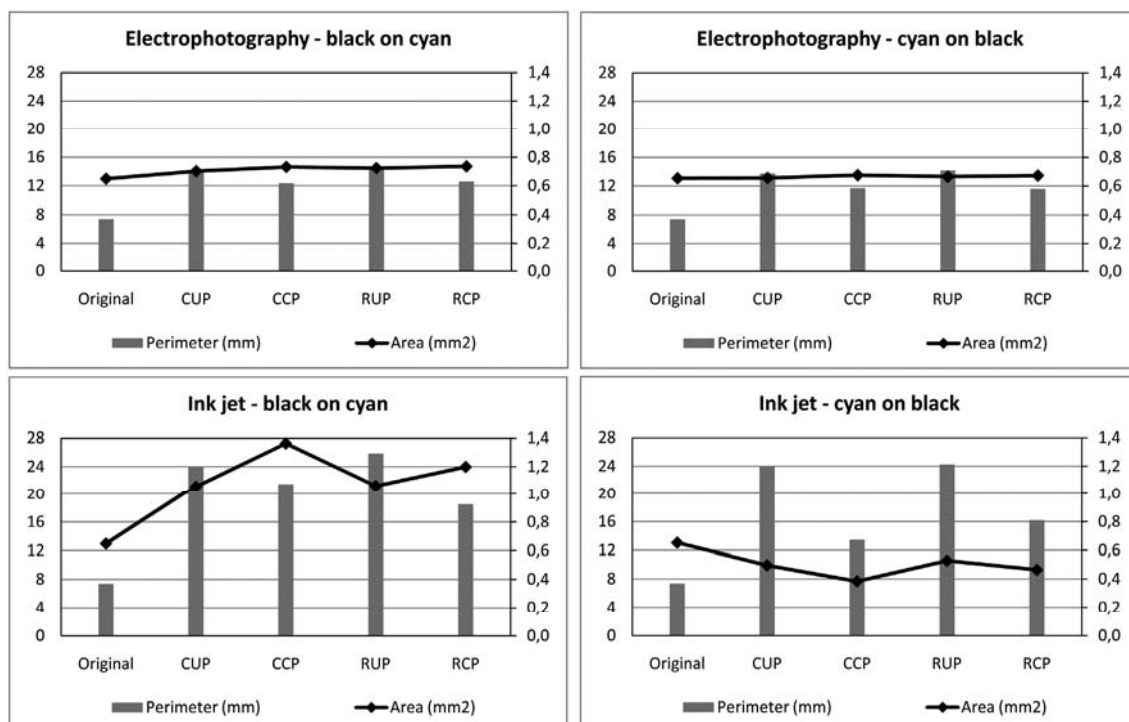
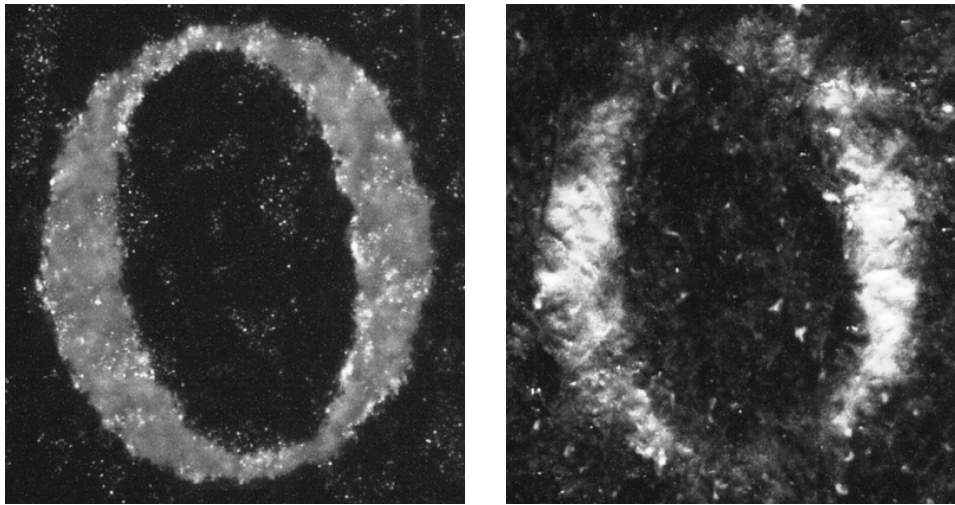


Figure 6: Perimeter and area of black letter “o” on cyan and cyan letter “o” on black printed with electrophotographic and ink jet printer

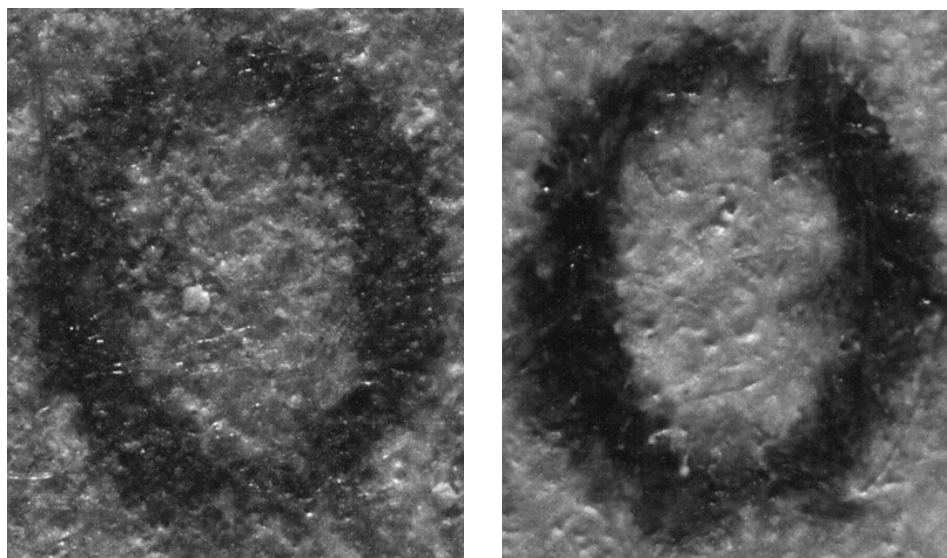
On both diagrams for electrophotography a similar values can be noticed. Perimeter values of coated papers are closer to the original than values of uncoated papers, meanwhile values of areas are similar. Therefore, bleeding effect for uncoated papers is larger. There is no

difference between classic and recycled papers. Perimeters of letters printed with ink jet are larger, so the ink jet technology has larger bleeding effect (example is shown in Figure 7). Furthermore, the differences between original and printed letter are very large, which shows on large bleeding.



*Figure 7: Letter “o” on recycled coated paper printed with electrophotographic printer (left) and ink jet printer (right)*

The results for ink jet show the similar values for both uncoated papers. Black letter on cyan background printed on uncoated recycled paper has a little larger perimeter than on uncoated classic paper. While the perimeter and area of cyan letter on black background on both papers are the same. Coated papers printed with ink jet printer have the largest bleeding effect. Unfortunately this effect is not visible very well on diagrams on Figure 6. Both diagrams for ink jet show smaller perimeters of coated papers compared to uncoated papers, despite bigger bleeding effect on coated papers (example is shown in Figure 8). In this case area values show more comparable results to actual picture than perimeter values. Black letter on cyan background printed on classic coated paper has extremely high value of area. Classic coated paper has 14 % larger area than recycled coated paper. For cyan letter on black background the effect is inverse. Classic coated paper has 17 % smaller area than recycled coated paper. The areas of both letters are smaller than original which mean that recycled coated paper has smaller bleeding effect compared to classic coated paper.



*Figure 8: Letter “o” on recycled uncoated paper (left) and recycled coated paper (right) printed with ink jet printer*

### 3.2 Mottling

Figure 9 shows nonuniformity number of 100 % covered cyan area. Electrophotography has smaller values of nonuniformity number compared to ink jet. Electrophotographic print on classic uncoated paper has 26 % smaller, on classic coated paper 39 % smaller, on recycled uncoated paper 21 % smaller and on recycled coated paper 31 % smaller nonuniformity number compared to ink jet print. Therefore, the mottling effect is smaller for electrophotography. Comparing classic and recycled papers, it can be seen that uncoated papers have similar nonuniformity number for electrophotography and separately for ink jet technology. Meanwhile, classic coated paper has smaller nonuniformity number than recycled coated paper for both print technologies. Nonuniformity number for classic coated paper is 39 % smaller for electrophotography and 32 % smaller for ink jet technology compared to recycled coated paper. The mottling effect is the smallest on classic coated paper. There can be also seen some influence of roughness (Table 1) on mottling effect, especially for electrophotography. The higher is roughness, the higher is mottling effect. The only deviation is at ink jet technology on recycled coated paper where despite of relatively small value of roughness, the nonuniformity number is large. In this case roughness has no big influence on mottling.

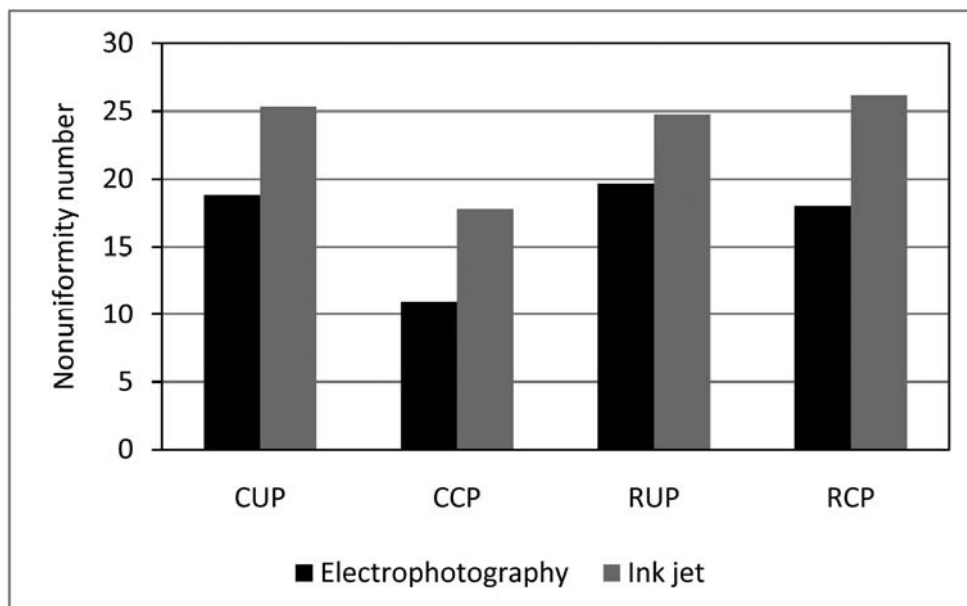


Figure 9: Nonuniformity number of 100 % covered cyan area printed with electrophotographic and ink jet printer

### 3.3 Colour gamut

Colour gamuts can be seen in Figure 10. Classic uncoated paper printed with electrophotographic printer has a little larger colour gamut compared to recycled uncoated paper. Differences are larger in blue area and smaller in yellow area, which is consequence of a yellow cast of recycled paper. Classic coated paper printed with electrophotographic printer has also larger colour gamut compared to recycled coated paper. In this case differences are more equal for all colours. Classic uncoated paper printed with ink jet printer has larger colour gamut compared to recycled one for all colours except for yellow for which both papers have almost the same chroma. Classic coated paper printed with ink jet printer has also larger colour gamut than recycled coated paper. Differences can be seen at yellow and blue area, meanwhile other colours have similar gamut. If colour gamut and brightness of paper (Table 1) are compared, the conclusion can be made that recycled papers have smaller colour gamuts because of smaller percentage of brightness. Furthermore, Figure 10 shows bigger colour gamuts for electrophotographic prints compared to ink jet. Coated papers printed on electrophotography have larger gamuts than uncoated. In contrast, coated papers printed with ink jet have oblong colour gamuts instead of round. The problem is in mixed colours (RGB) because these coated papers do not stand high ink coverage, this is why mixed colours do not reach enough vividness. Researched coated papers are not suitable for ink jet printing technology.

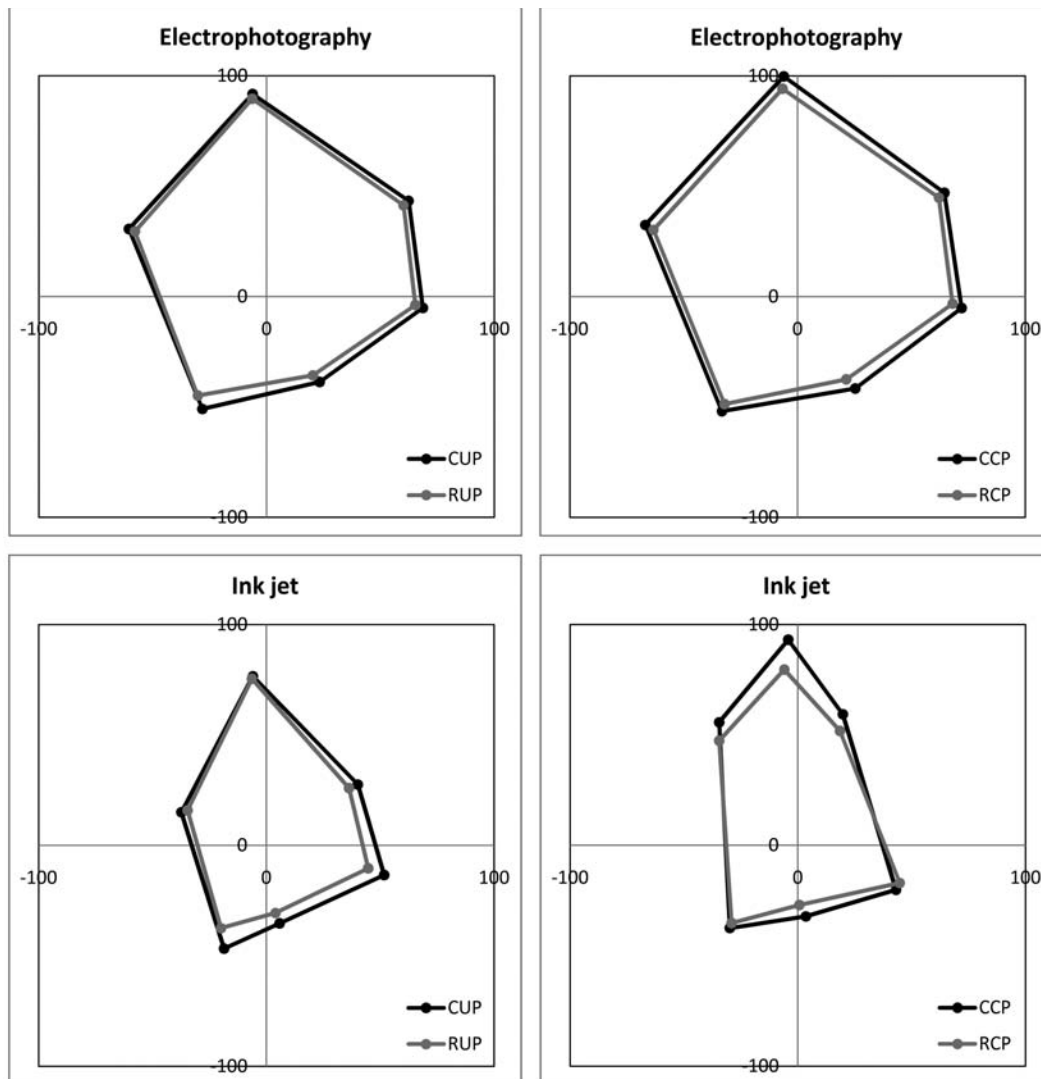


Figure 10: Colours gamuts for all papers on electrophotographic and ink jet printer

#### 4. Conclusions

The article presents digital print quality of classic and recycled papers. One of the main findings is that there are no significant differences in wicking, bleeding and mottling evaluation between classic and recycled papers. Meanwhile, the differences can be notice at spectrophotometric measurements. Recycled papers have smaller colour gamuts compared to classic papers, which is consequence of smaller percentage of brightness or yellow cast of recycled papers. The bigger differences can be seen between uncoated and coated papers. Coated papers achieve better print quality than uncoated papers with electrophotographic printer. Meanwhile, researched coated papers are not suitable for ink jet printer. A coat on both coated papers is inappropriate for this digital technology. Research also shows differences between electrophotographic and ink jet printer. The electrophotography achieves better print quality in all researched valuations compared to the ink jet.

#### 5. Acknowledgements

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## INK OPTIMIZATION FOR ACHIEVING THE SAME QUALITY USING HP LATEX PRINTING TECHNOLOGY

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**Abstract:** Print houses are facing a constant increase in the pressure of costs and deadlines. Consequently, stabilization of the printing process and cost savings are important issues to remain competitive in the marketplace. Ink optimization reduces the total ink application, while the visual color impression is retained at the same time. Ink reduction boosts productivity by improved printing properties, faster makeready, shorter drying time, faster finishing, less waste and up to 20% savings on ink depending on the printing process and the substrate.

In separation, the relationship of black to the other three colours cyan, magenta and yellow, plays a deciding role. Because cyan, magenta and yellow in certain proportions combine as neutral colour tones, they can be replaced in mixed colours to an extent with black. By replacing the cyan, magenta and yellow, total ink application is reduced.

The goal of this research was to find the best combination of cyan, magenta and yellow which are replaced with black, so that the ink consumption is reduced, while the print quality remains the same.

Samples were printed by HP Designjet L65500 with HP Latex Inks. The printed samples were measured with directional 45°/0° spectrophotometer. Spectrophotometric measurements were carried out to determine CIELab values of printed samples and to compare  $\Delta E$  values of these samples.

**Key words:** Ink optimization, HP Latex Printing Technology

### 1. Introduction

It is clear that the awareness and importance of color quality and consistency is dramatically increasing for the large format service provider. In everyday production it is important to produce quality prints and to optimize some costs. This could be done with ink optimization.

Combining the three primary colors, CMY, it is possible to reproduce all the colors, but those colors are not dark and sharp enough. To improve dark areas and to make images sharper it is necessary to use one more color – black. Theoretically, the maximum amount of ink in a 4-color process is 400%, but in practice that is never the best choice.

It is possible to create the same colour using a lot of cyan, magenta and yellow and little black, or by using less cyan, magenta, yellow and more black. Black is not strictly needed, but its use gives a certain amount of redundancy (Sharma, 2004).

Certain software solutions allow printing companies to reduce the consumption of chromatic inks per job, in that these inks are replaced by black without negatively impacting the image quality. There are certain settings that determine the replacement of inks by black such as GCR (Gray Component Replacement) and UCR (Under Color Removal) separation method and TAC (Total Area Coverage) or Max Ink.

The result is a lower level of ink application, reduced ink consumption, and less of a burden on the environment. As a result of using these software, an ink-saving potential of between 10 and 15% became apparent after just a short time (GMG, 2008).

The optimized color composition also has other decisive advantages. The image definition in the shadows is preserved far better. Not only is the contrast and definition of images improved, but the higher proportion of black is also particularly noticeable when controlling the gray balance, since it behaves far more stably over the entire print run and reacts less to colour fluctuations. This has a direct influence on quality, since it is precisely in the case of gray that the human eye reacts most sensitively to color casts. Optimized data also permits faster production of repeat jobs in the same quality.

At the same time, if ink-optimized data is used, the primary or secondary colours can more easily be adjusted to the required colour result or the proof on the press. As a result of achromatic composition, the gray balance and the tertiary colours, such as brown or olive, remain more stable if the end densities are adjusted.



Reducing the total ink application not only saves ink, but also has advantages in terms of production engineering: since less ink is applied, it can be absorbed more rapidly, and the drying time is shorter. There are fewer problems with strike-through and soiling so printing of the back or finishing can be started sooner. Moreover, make-ready time is shorter, there is less paper waste, more printed jobs per day and production is increased with lower amount of ink.

In this paper, during the profiling, total ink limit was set up at 185%; this unit has been a constant. We wanted to see if it is possible to reduce consumption of primary inks (CMY) when max ink value is varied within these 185% ink limit.

The max ink value (in %) is the amount of ink (C+M+Y+K) you want to use for the darkest composite black. It is recommended to set a value around 350% (Caldera, 2008). We wanted to see if the quality remains the same when the max ink is set up at lower value. Lower value of max ink reduces amount of cyan, magenta and yellow, while amount of black is increased. When this unit is set up at lower value it is possible to reduce ink consumption, not as much as changing the total ink, but it is still possible to reduce it when printing darker images.

We investigated this way of reducing inks consumption with latest printing technology which was introduced two years ago to reduce the impact of printing on the environment – HP Latex Printing Technology. This technology can produce a broad range of outdoor and indoor applications, from point-of-purchase displays, transit signage, wall murals and exhibition graphics to billboards, vehicle wraps and exterior event signage (Brun, 2008). HP Designjet L65500 with HP Latex inks is large format inkjet printer and it is the first printer to feature HP Latex Printing Technology.

Water-based HP Latex Inks provide many of the advantages over eco-solvent/low-solvent inks in commercial and industrial printing without imposing the typical environmental, health and safety considerations. HP Latex Inks consist of a liquid ink vehicle that carries latex polymer and pigment particles to the surface of the print media. Prints produced with HP Latex Inks are odorless and emit extremely low levels of volatile organic compounds (VOCs) and are completely cured inside the printer, requiring no external heaters, dryers or drying racks, which means less power usage.

## 2. Materials and Methods

For the investigations of ink optimization we used three different substrates, one matte paper – *City Light 150 g/m<sup>2</sup>* and two self-adhesive plastic foils – *Nechen PVC ADH 80GP* and *Nechen PVC ADH 80GP no lite*. The chosen printer, HP Designjet L65500, is based on inkjet printing process and it utilizes HP Latex inks. Printer was calibrated and profiled for each substrate. As a result profiles with different max ink were obtained.

Profiles were created in EasyMedia (component of the Caldera Graphics software - RIP). EasyMedia is Caldera's integrated colour management, colour calibration and profile making solution. Caldera Graphics is a software company specialized in color management, imaging and driving of large format printing machines.

Profile creation process involves several steps. Before all it is important to set up 4 curves, one per process ink, that the print driver will use to transform input densities into output densities – this step is called linearization. Then, it is important to set up the total ink limit. This step is followed by the last and decisive step – profiling. The goal of the profiling is to establish a mapping between all the colors that exist in nature and the colors that are available in printer, more exactly, in current print process, which includes the substrate and the print configuration.

Building of profile starts with printing and measuring the target. The used target is presented in Figure 1.

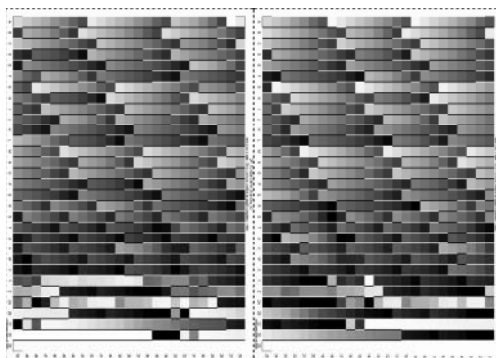


Figure 1: Target for building the profile

Target with 1550 patches was printed by HP Designjet L65500 (resolution: 300dpi, mode: CMYK, screening: stochastic, quality: 8-pass). After printing, target was measured with Eye-One (i1) Pro spectrophotometer combined with Eye-One (i1) iO Automated Scanning Table. The 45°/0° measurement geometry was used with D50 illuminant and observer angle 2°.

After measuring we set up a few options to build the profile: profile size - medium, perceptual rendering – paper gray axis and gamut mapping – LOGO colourful. The second (and last) set of options (the separation options) for profiling concerns the Black Generation options. This set of options is presented in Figure 2. The settings were as follows: GCR3 method was selected as separation method, black start - 30%, max black – 100% and max ink was varied (310, 330 and 350%). When all settings are set up EasyMedia then begins to compute the profile.

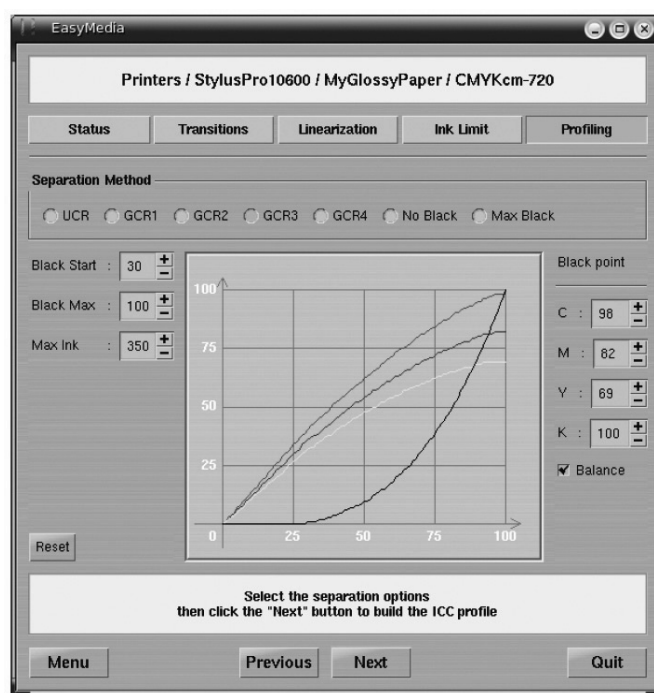


Figure 2: The separation options

As a result of profiling several different profiles were obtained, three profiles for each substrate, due to three different values of max ink. Profiles were not re-created, they were only modified. We have created a profile in which we changed only max ink value. The profiles were compared in two stages. First, profiles were inserted into the program Patch Tool to see the difference between them and to compute gamut volume of each profile. Results are presented in the next chapter.

Second, printed samples with different profiles assigned were visually estimated. For this comparison we chose a test image presented in Figure 3. Profiles have been assigned to the test image sequentially (depending on the substrate and value of max ink). After assigning images were printed on relevant substrate and were observed under appropriate illuminant. The visual assessments were carried out by 17 observers, including nine men and eight women. All observers are from Department of Graphic engineering and design. The visual assessments were conducted using an Agile Radiant™ Controlled Light 5 lightbox under the D50 illuminant.

### 3. Results and Discussion

To calculate gamut volume we used the program Patch Tool, option Gamut Tool. Profiles were inserted one by one and gamut volume was computed for two rendering intents: Perceptual intent (Black Point Compensation was turn on) and Absolute Colorimetric. The results are presented in Tables 1 and 2.

According to these tables we can see that higher value of max ink does not necessarily mean larger gamut volume. Profile CL\_310.icc with smallest max ink has the largest gamut volume, but this is not the case with profiles for foils. This applies in both cases of rendering intents. Only in the case of absolute rendering intent, profiles generally have smaller gamut volume.

Table 1: Gamut volume of profiles (rendering intent: Perceptual)

Substrate	City Light		PVC ADH 80GP		PVC ADH 80GP no lite	
	Profile	Gamut volume	Profile	Gamut volume	Profile	Gamut volume
	CL_310.icc	371143	PVC_310.icc	579359	PVCnl_310.icc	536852
	CL_330.icc	368889	PVC_330.icc	583643	PVCnl_330.icc	541270
	CL_350.icc	364047	PVC_350.icc	579713	PVCnl_350.icc	536870

Table 2: Gamut volume of profiles (rendering intent: Absolute Colorimetric)

Substrate	City Light		PVC ADH 80GP		PVC ADH 80GP no lite	
	Profile	Gamut volume	Profile	Gamut volume	Profile	Gamut volume
	CL_310.icc	285476	PVC_310.icc	475321	PVCnl_310.icc	424222
	CL_330.icc	283991	PVC_330.icc	476803	PVCnl_330.icc	425281
	CL_350.icc	281008	PVC_350.icc	474871	PVCnl_350.icc	423222

The data presented in next tables (Table 3, Table 4 and Table 5) are  $\Delta E$  values of profiles. Profiles were compared in Patch Tool and average  $\Delta E$  value was computed. We used  $\Delta E_{94}$  formula to calculate the colour difference.

Table 3: Colour difference values of profiles for paper City Light

City Light - profiles	CL_310 – CL_330	CL_310 – CL_350	CL_330 – CL_350
Average $\Delta E$	1.76	1.87	1.87
Best 90%	1.00	1.02	1.02
Worst 10%	8.62	9.53	9.51

Table 4: Colour difference values of profiles for plastic foil – Nechen PVC ADH 80GP

PVC ADH 80GP - profiles	PVC_310 - PVC_330	PVC_310 - PVC_350	PVC_330 - PVC_350
Average $\Delta E$	1.29	1.30	1.30
Best 90%	0.90	0.91	0.91
Worst 10%	4.83	4.83	4.80

Table 5: Colour difference values of profiles for plastic foil – Nechen PVC ADH 80GP no lite

PVC ADH 80GP no lite - profiles	PVCnl_310- PVCnl_330	PVCnl_310 – PVCnl_350	PVCnl_330 – PVCnl_350
Average $\Delta E$	1.26	1.27	1.27
Best 90%	0.87	0.87	0.88
Worst 10%	4.75	4.84	4.85

Tables 3, 4 and 5 summarize the  $\Delta E$  values of profiles. The average  $\Delta E$  values are less than 2 and according to these values we are able to conclude that the difference between two profiles is insignificant and that it can only be observed by professional. The smallest difference is between profiles with 310% and 330% max ink for all substrates. This program has the option

of viewing all patches, from patch with largest to patch with smallest  $\Delta E$  value. According to this patch view it can be seen that darkest patches have the largest colour difference, whereas the smallest  $\Delta E$  values result from the lightest patches.

After these measurements, profiles were analyzed visually. All the measurements made are represented by numbers, while human perception does not see numbers. Human perception sees colours. Profiles were assigned to the test image (Figure 3), which was printed and observed in lightbox.

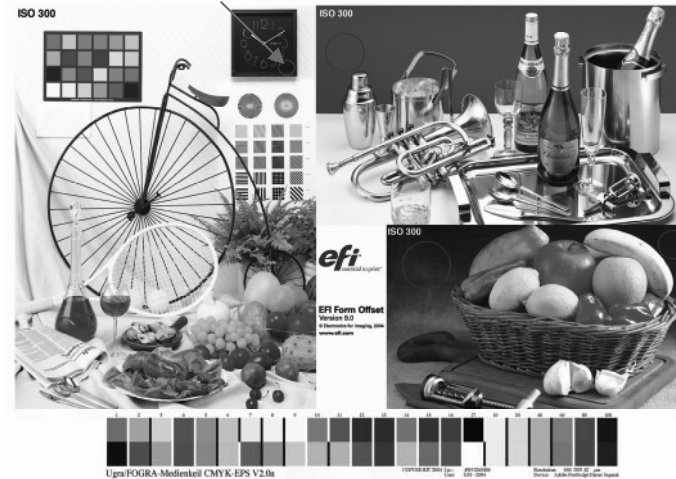


Figure 3: Test image

Printed samples were estimated by 17 observers, under illuminant D50. Observer's task was to compare samples and grade it from 1 to 4 (1-there is no difference, 2-very little difference, 3-mean difference, 4-large difference). In addition, if they noticed any differences they were supposed to mark in which tones (1-highlights, 2-midtones, 3-shadows). The results of visual assessment are shown in Tables 6, 7 and 8. About 50% observers have noticed very little difference mostly in the shadows. In Figure 3, blue circles indicate parts which observers marked as little different.

Table 6: The results of visual assessment – profiles for paper City Light

Profiles	Difference				Tones		
	1	2	3	4	1	2	3
CL_310 – CL_330	30%	65%	5%	-	8%	17%	75%
CL_330 – CL_350	47%	53%	-	-	11%	-	88%
CL_310 – CL_350	35%	53%	12%	-	-	-	100%

Table 7: The results of visual assessment – profiles for plastic foil – Nechen PVC ADH 80GP

Profiles	Difference				Tones		
	1	2	3	4	1	2	3
PVC_310 – PVC_330	59%	41%	-	-	14%	-	86%
PVC_330 – PVC_350	47%	53%	-	-	-	-	100%
PVC_310 – PVC_350	29%	59%	12%	-	-	-	100%

Table 8: The results of visual assessment – profiles for plastic foil – Nechen PVC ADH 80GP no lite

Profiles	Difference				Tones		
	1	2	3	4	1	2	3
PVCnl_310 – PVCnl_330	53%	47%	-	-	-	-	100%
PVCnl_330 – PVCnl_350	59%	41%	-	-	-	-	100%
PVCnl_310 – PVCnl_350	35%	65%	-	-	-	-	100%

In the end we chose one point in the image (red circle in Figure 3) and measured it with spectrophotometer in order to see if there is any difference. We chose that dark point because the early results pointed to the difference in dark tones. The  $\Delta E$  values are presented in Table 9.

Table 9: Colour difference values of selected point in the image

Substrate	City Light		PVC ADH 80GP		PVC ADH 80GP no lite	
	Profile	$\Delta E$	Profile	$\Delta E$	Profile	$\Delta E$
	CL_310.icc	1.32	PVC_310.icc	0.85	PVCnl_310.icc	0.39
	CL_330.icc	1.62	PVC_330.icc	1.17	PVCnl_330.icc	0.64
	CL_350.icc	1.81	PVC_350.icc	1.21	PVCnl_350.icc	1.34

On the basis of the results in Table 9, we can conclude that the largest difference is when profiles whit 310% and 350% max ink are compared, but that difference is less than 2 which means that is insignificant and it can only be observed by professional.

## 5. Conclusion

According to all the results we are able to conclude that there is no significant difference between the profiles with different value of max ink. Gamut volume is almost the same for all profiles and higher value of max ink does not necessarily mean larger gamut volume. Average  $\Delta E$  values of profiles are less than 2. This value is insignificant and it was also obtained when we measured the difference between the selected point.

The visual difference is barely noticeable between images assigned whit different profiles only in shadows. About 50% observers haven't noticed difference at all.

In conclusion, we saw instrumentally and visually that the difference between profiles is not very large when we set up max ink vale at 310%, 330% or 350%, so it is possible to print with lower value of max ink and save inks. But, a certain time is necessary to pass in order to detect reduced consumption of inks.

## 6. Acknowledgement

We would like to express our gratitude to Igor Karlović for the support, suggestions, and encouragement. We would also like to show our appreciation to printing house "NS plakat" for profiling and printing the samples.

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# INFLUENCE OF DIFFERENT PIGMENTATION ELECTROINK ON FORMATION CYAN, MAGENTA AND YELLOW SCREEN ELEMENTS

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**Abstract:** Change the pigmentation process printing inks will result in changes within all half tone area. This paper will focus on research electroink elektrophotographic inks, as well as different concentrations of pigments affect the smallest screen elements (print dots). paper will analyzed 5 different concentrations (density of liquid inks varied from  $d=1.20$  to  $d=2.00$ , the step of  $\delta d = 0.20$ ). the analysis included colorimetric changes in prints on fine art paper (cie lab  $\delta e_{2000}$ ), as well as microscopic and densitometric analysis reproduced the print dots ( $\delta d$ ,  $\delta r$ ). the colour difference, deviation in diameter and reflectance of print dots are given only for light tone values (20%), in which the print elements look perfectly. this research will get answer what are the optimal concentration of pigment particles, and how each the pigment composition affects of the final reproduction. it will also be considered as excessive concentration of pigment affects the image, and if they affect on additional problems during printing production.

**Key words:** electrophotographic printing, electroink, pigmentation variation, deformations of screen elements

## 1. Introduction

The main function of graphic ink is to transfer printed information (pictures, text) which can be visually distinctive. For multicolour printing it is necessary to carry out screening process (the conversion of continuous multitone of photographic original into one tone raster elements on printing plate) allowing observation of different halftones. Reproduced raster elements must be very small (below the threshold of separation capabilities of the human eye) so that a standard observer cannot detect them (only with the use of an optical tool). Thereat different sizes and concentrations of screen elements give the impression of lighter or darker tone.[1]

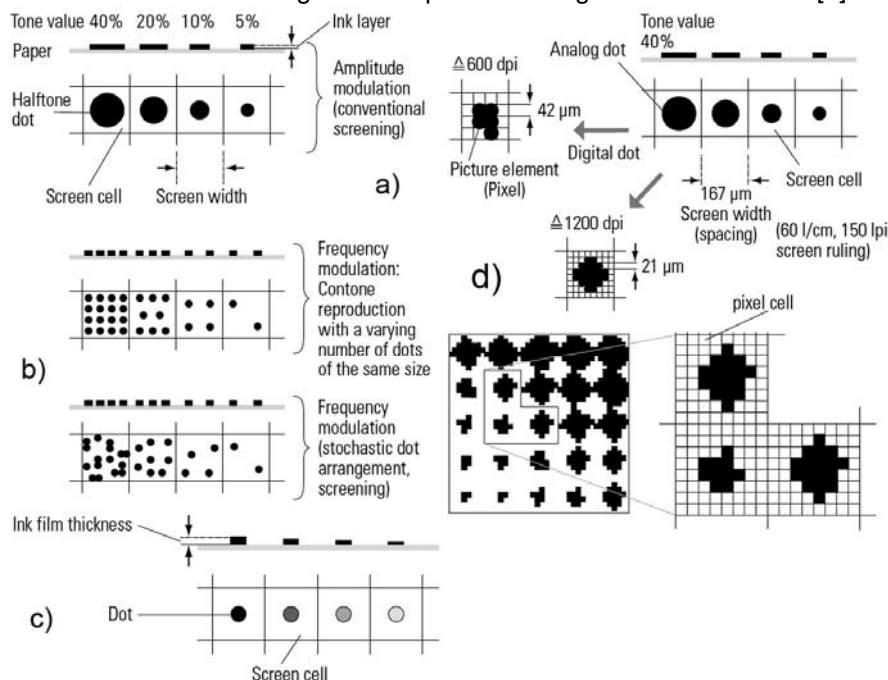


Figure 1. Screening methods in a modern printing: a) amplitude modulated screening b) two types of frequency modulated screening c) screening with modulation of color density d) the transition from analog to digital screening

The printing industry generally apply three methods of screening: a) amplitude modulated screening (AM), b) frequency modulated screening (FM) and c) screening with modulation of color density ODM (Optical Density modulation) (Figure 1). Amplitude modulated screening (autotypical screening, periodic screening) is process in which the individual dots are spaced the same distance apart, but have different diameters (or different areas, depending on the dot shape). In frequency modulated screening the individual dots have the same diameter but are different distances apart (non-periodic screening). When using the frequency modulation screening process to convert continuous tones of the original into a quantity of dots in a so-called screen cell, the dot spacing must be specified for a known dot size. This can be done according to various algorithms. Usually the distances for a certain tone value differ from individual dot to individual dot (which would lead to susceptibility to moiré patterns), but are distributed randomly. For this reason, frequency-modulated screening is also referred to as random or stochastic screening. Hybrid screening represents hybrid techniques for screening continuous-tone originals: both AM and FM screening are used, depending on the image. A possible algorithm is based on the approach of using FM screening for very light and very dark tones and AM screening for the remaining tone value range. [3]

Digitizing the printing system amplitude modulated screening has significantly changed, becoming a digital screening (Figure 1d). Raster elements mostly retained its size but not their circular shape. Raster point is defined with pixels formed within a matrix, also called super pixel. Resolution of the final image directly depends on the number of pixels, and its activation influence on achieving variation of greyness within superpixel. Also, with higher resolution, screen dots become more shaped and do not have a dominant stepped gradation. Thus formed screen elements can be easily modified what directly influence on dot gain and the final reproduction.[4]

Electrophotographic printing systems apply digital screening, which allows easy correction of LUT curves (Look Up Table) and the reproduction curves. Important role in digital printing has RIP (Raster Image Processor) that converts .pdf format in a 4 separate screened area in CMYK process colors. Electrophotographic ElektroInk is a mixture of different components. In the basic condition, the ink is the emulsion that consists of a thermal polymer, which is dispersed in a non-polar, volatile oil. The ratio of thermal pigment and volatile oil varies depending on the type of pigment. Ink contains additives for increasing conductivity (negative charge - about 1%). OPigment particles are an integrated part of thermal polymers. Their share varies, depending on the chemical composition. Cyan pigment is based on copper (C.I. 74160, Pigment Blue 15), and it is also known as copper ftalocyan blue. Molecular formula of that pigment is  $C_{32}H_{16}CuN_8$ . Pigment ink in the magenta (C.I. 73915, Pigment Red 122) has a crystal structure, with molecular formula  $C_{22}H_{16}N_2O_2$ . Yellow pigment, based on azo compounds is the Dalar yellow (C.I. .11741, Pigment Yellow 74) with molecular formula  $C_{18}H_{18}N_4O_6$ . Structural formulas of mentioned pigments are visible in Figure 2. [4]

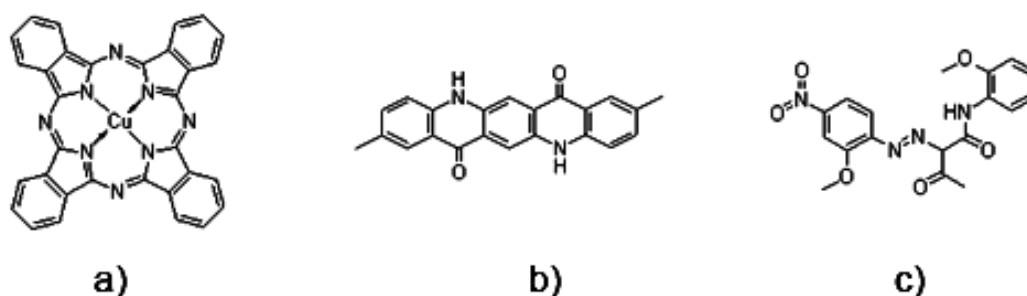


Figure 2. Chemical structure of cyan, magenta and yellow pigments embedded in ElektroInk dyes: a) C.I. Pigment Blue 15; b) C.I. Pigment Red 122; c) C.I. Pigment Yellow 74

Particles of thermal toner have a distinctive star shape, and particle size varies from 0.1 to 5  $\mu m$ . This shape is primarily used for better focusing of ink, and for easy acceptance of additives for increasing conductivity. Additives are explicitly polar molecules and catch star pigments with their positively charged part of the molecule. Caught pigment particles are then ready to move towards a more positive electrostatic field (the field with less negative charge). [6]

During printing, ElektroInk will change rapidly. In the initial phase, the ink is liquid and has low coefficient of dynamic viscosity, and in the final phase ink will condense so the coefficient of

dynamic viscosity will increase. Variation of viscosity is possible due to nonpolar isoparaffinic hydrocarbons (volatile oil) whose vaporization temperature is 40 °C. Due to the temperature of 125°C, which is achieved during the printing, ElektroInk lose liquid carrier (volatile oil) and turns into a sticky paste pigment. By heating the pigment polymer chemical process of powder coating begins. This process gives pigmented polymer star distinctive shape that is optimal for the acceptance on the printing surface. The final reproduction has a thin layer of ink (about 1 µm) which is, by its chromaticity and saturation, similar to conventional offset print. [7]

## 2. General and specific objectives

Liquid Electrophotographic ink, due to its small particles, non-uniform inflicts on the printing surface. Because of not using a standard fusing process, paper surface does not have be heated to allow the acceptance of toner. Thereat the properties of paper (the amount of moisture in the paper) do not change, which leads to higher quality of reproduction (dimensional stability of paper does not change). [8]

The aim of this paper is to determine the deformations that occur on color prints that contain lots of cyan, magenta and yellow screen elements. Therefore will be analyzed how different liquid toner pigmentation affects on the formation of color images. Changing the 5 different concentrations of pigmentation of liquid toner will result in print with a different contrast. Doing so will determine the optimal concentration of pigment particles and their impact on the final reproduction. In other words, possible pigmentation overdose will be considered, i.e. whether, in addition to price increases, any other problems will occur while printing digital raster elements.

## 3. Materials and methods

For creating this experimental study a digitized file that contains a variety of solid and screened chromatic tones was used. It was printed on Electrophotographic machine HP Indigo S 1000 on which the pigmentation of cyan, magenta and yellow inks was changed.[1] Monitoring the color density (pigmentation) was performed with built-in serial Indigo densitometers, which is designed to measure pigmentation of ElectroInk dyes. Specifically, there were printed samples with 5 pigmentations whose color density ranged from D=1.20 to D=2.00 with  $\Delta D = 0.20$ . As the printing substrate the glossy coated paper for art printing was used.

*Table 1. The relation of visual perception and color differences*

$\Delta E$	Visual Perception
Between 0 and 1	The average human eye can not see the difference
Between 1 and 2	Very small difference
Between 2 and 3,5	Moderate difference
Between 3,5 and 5	Difference
Above 5	Big difference

The obtained prints were analyzed with 3 different devices: spectrophotometer X-Rite CA20, a device for image analysis QUE Personal IAS, and a microscope Leica DM 2500 M. Spectrophotometer X-Rite CA20 as the final results gives  $L^*a^*b^*$  values. Based on the  $L^*a^*b^*$  values difference in color ( $\Delta E$ ) of two samples can be determined, where the obtained values can be visually compared. For visual evaluation of the obtained  $\Delta E$  results is used Table 1. [8]

Calculation of the color differences of two samples is done using the following formula. The basic formula of  $\Delta E$  is defined as:

$$\Delta E_{ab}^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

where:

$$\Delta L^{*2} = L_r^* - L_{or}^* \quad \Delta a^{*2} = a_r^* - a_{or}^* \quad \Delta b^{*2} = b_r^* - b_{or}^* \quad (2)$$



This formula is very important for graphic reproduction because it directly compares the two tones, or the quality of prints (according to ISO 12647-5). In order to accurately determine the color difference (especially the chromaticity  $\Delta C$ ) basic formula has undergone various modifications. The latest version of the formula was published in year 2000., which further corrects deviations in the blue area. [9]

The formula is:

$$\Delta E_{2000}^* = \sqrt{\left(\frac{\Delta L^*}{S_L k_L}\right)^2 + \left(\frac{\Delta C^*}{S_C k_C}\right)^2 + \left(\frac{\Delta H^*}{S_H k_H}\right)^2 + R_T \left(\frac{\Delta C^*}{S_C k_C}\right) \left(\frac{\Delta H^*}{S_H k_H}\right)} \quad (3)$$

where  $\Delta L^*$ ,  $\Delta C^*$  and  $\Delta H^*$  are differences of brightness, saturation and tone between the two samples (prints). Other parameters listed  $\Delta E_{2000}$  formula are defined in the following way:

$$S_L = 1 + \frac{0,015(\overline{L'} - 50)^2}{\sqrt{20 + (\overline{L'} - 50)^2}} \quad S_C = 1 + 0,045\overline{C'} \quad S_H = 1 + 0,015\overline{C'}T \quad (4)$$

$$T = 1 - 0,17 \cos(h' - 30^\circ) + 0,24 \cos(2h') + 0,32 \cos(3h' + 6^\circ) - 0,20 \cos(4h' - 63^\circ) \quad (5)$$

$$R_C = 2\sqrt{\frac{\overline{C'}^7}{\overline{C'}^7 + 25^7}} \quad R_T = -\sin(2\Delta\Theta)R_C \quad \Delta\Theta = 30 \exp\left\{-\left[\frac{(h' - 275^\circ)}{25}\right]^2\right\} \quad (6)$$

Color difference ( $\Delta E$ ) shows the quality of reproduction and deviations of the reproduction from the original. In an indirect way, this value represents the loss and deviation of three stimulus values that correspond to color perception in the human eye.

Schematic presentation of performed research is shown in Figure 3.

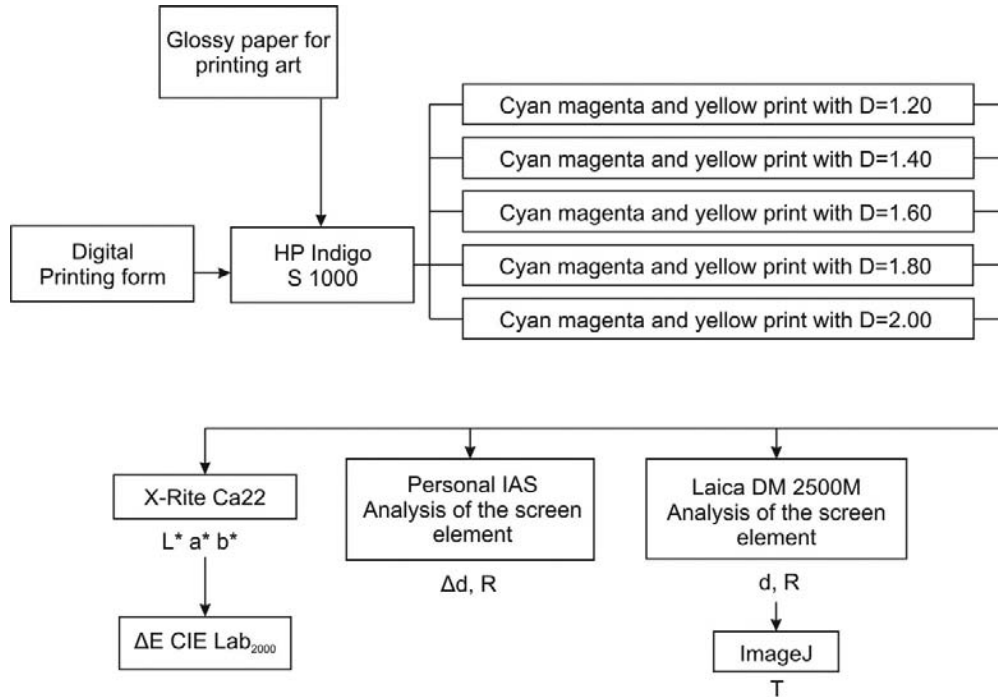


Figure 3. Schematic presentation of research

#### 4. Results and discussion

Impact of changing color pigmentation on the formation of cyan, magenta and yellow screen elements is shown in Figure 3. It presents a chart showing the 3D  $L^*a^*b^*$  values which are result of changing pigmentation for all three inks. The  $L^*a^*b^*$  values present the average values that occurred on 10 measurements of the same field.

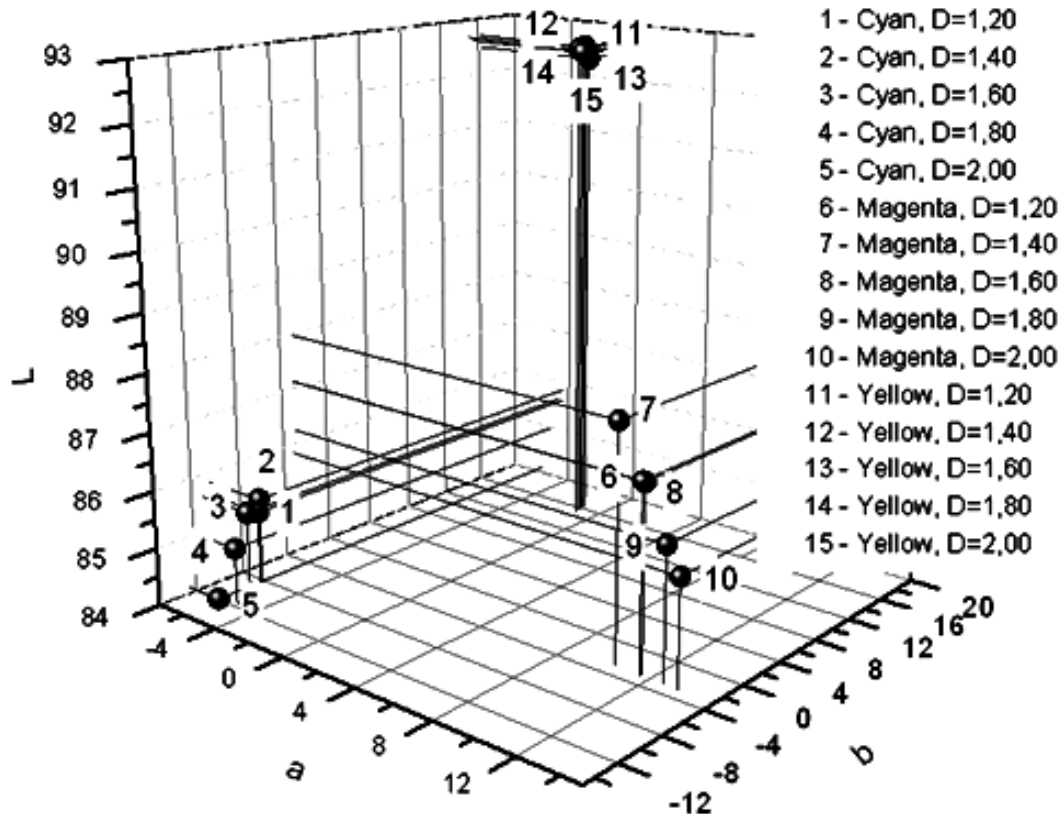


Figure 4.  $L^*a^*b^*$  values for 20% of screen tone value of cyan, magenta and yellow prints

With variation of ink pigmentation, from the initial 1.20 to final 2.00, ( $\Delta D=0.80$ ) were obtained cyan prints which, in relation to the density of =1.20 differ in color:  $\Delta E_{1.20-1.40}=0,1715$ ,  $\Delta E_{1.20-1.60}=0,4227$ ,  $\Delta E_{1.20-1.80}=1,0623$  i  $\Delta E_{1.20-2.00}=1,9205$ . Changing the ink (magenta) had the following color differences:  $\Delta E_{1.20-1.40}=1,2134$ ,  $\Delta E_{1.20-1.60}=0,1490$ ,  $\Delta E_{1.20-1.80}=1,0355$  i  $\Delta E_{1.20-2.00}=1,6497$ . The prints with yellow ink produced deviations of:  $\Delta E_{1.20-1.40}=0,1146$ ,  $\Delta E_{1.20-1.60}=0,7521$ ,  $\Delta E_{1.20-1.80}=0,4827$  i  $\Delta E_{1.20-2.00}=0,1697$ .

Variation of ink pigmentation chromaticity does not change significantly. Larger deviations occur for luminance ( $L^*$ ) forming a linear regularity, which is most obvious in the magenta prints. The color difference properly increases with the pigmentation increment of the cyan ink prints, while the magenta and yellow prints do not show linear growth.

Color changes achieved with variation of ink pigmentation, on the yellow prints are not noticeable to the human eye. On the cyan and magenta prints, change of the pigmentation of  $\Delta D=0.60$  achieved the first difference visible to the human eye ( $\Delta E > 1$ ). It is nevertheless important for the formation of larger tonal values, where the dot gain will be higher, and thus impress a lot darker.

Pigmentation changes inevitably affect the size of the reproduced screen elements. The deviations of the screen elements were analyzed in the range of 20% of screen tone value, which is very light tone area (the screen elements do not touch, do not overlap, and are suitable for analysis). Detailed analysis of reproduced characteristic element is shown in Figures 5, 6 and 7. Unevenly infliction of ink with variations in pigmentation can be displayed with 3D topography of the screen element.

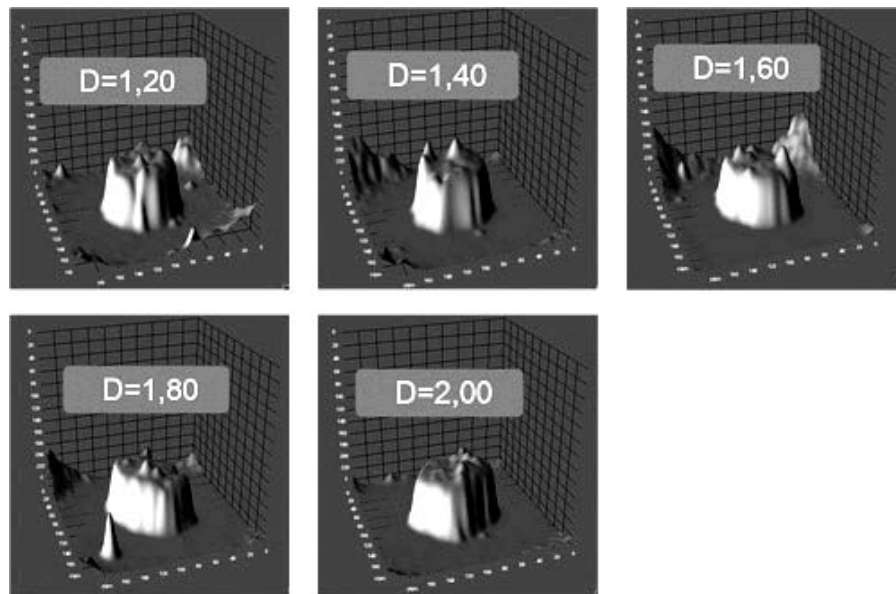


Figure 5. Topographic presentation of characteristic cyan screen element.

By analyzing a series of screen elements, due to variations in cyan ink pigmentation the following elements diameters were obtained:  $d_{1,20}=90,92\mu\text{m}$  (187 analyzed elements),  $d_{1,40}=89,32\mu\text{m}$  (197 analyzed elements),  $d_{1,60}=91,83\mu\text{m}$  (196 of the analyzed elements),  $d_{1,80}=96,34\mu\text{m}$  (186 analyzed elements) and  $d_{2,00}=98,91\mu\text{m}$  (184 analyzes the elements). The almost linear increase in diameter of the proper screen element with the increase in ink pigmentation is noticeable, except for the color density of  $D=1,40$ , which, contrary to expectation, produced a slight reduction in screen element diameter.

Acceptance of the ink on printing substrate is visible in the topographic presentation of the characteristic element. Visual assessment reflects more properly formatted element in ink pigmentation  $D=2,00$  (4 characteristic peaks). At lower pigmentation ink elements have more characteristic peaks, so the  $D=1,80$  shows six peaks, at ink pigmentation  $D=1,60$  and  $D=1,40$  elements have 7, and at  $D=1,20$  there is 9 characteristic peaks. For screening digital dot is better to apply as possible high ink pigmentation.

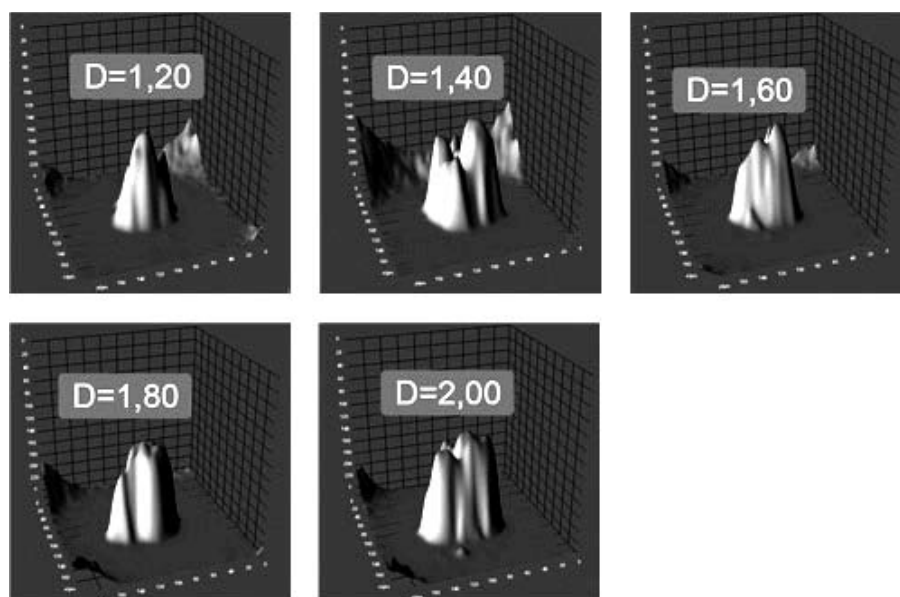


Figure 6. Topographic presentation of characteristic magenta screen element.

By analyzing a series of magenta screen elements, due to variations in magenta ink pigmentation, were obtained the following diameters:  $d_{1,20}=74,27\mu\text{m}$  (201 analyzes the element),  $d_{1,40}=66,85\mu\text{m}$  (199 analyzed elements),  $d_{1,60}=76,46\mu\text{m}$  (197 of the analyzed elements),  $d_{1,80}=80,17\mu\text{m}$  (180 analyzed elements) and  $d_{2,00}=84,15\mu\text{m}$  (196 analyzed

elements). As the cyan screen elements, magenta dots show a nearly linear increase in diameter of the proper screen element with the increase of ink pigmentation, with the exception of the change  $\Delta D=0.20$ , where occurs the reduction of the screen element.

The ink acceptance on print substrate is visible in the topographic presentation of the characteristic screen element. Visual assessment reflects properly formatted element in ink pigmentation  $D=2.00$  (4 characteristic peaks). At lower pigmentation ink elements have more characteristic peaks, but the difference in height between the peaks is also higher, so at the  $D=1.80$  element has 4 peaks, the ink pigmentation of  $D=1.60$ ,  $D=1.40$  and  $D=1.20$  shows 5 characteristic peaks.

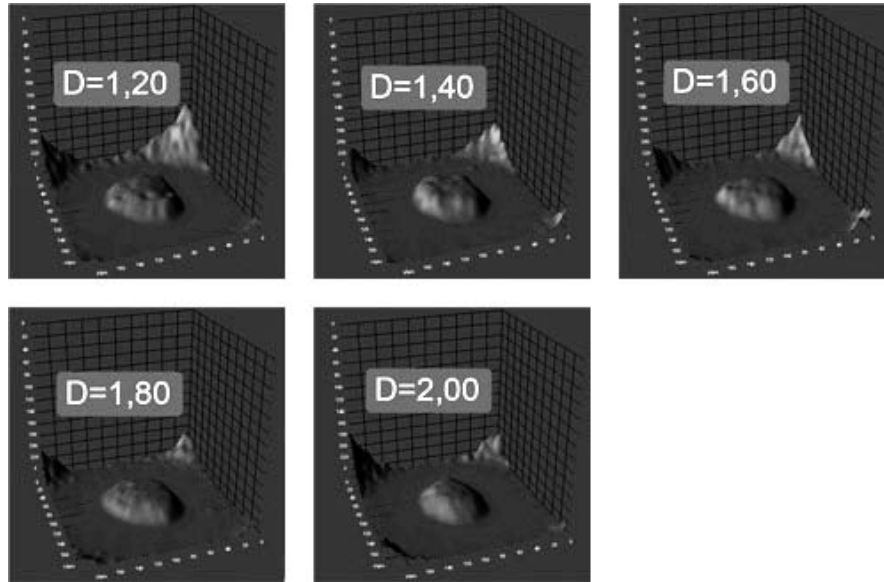


Figure 7. Topographic presentation of the characteristic yellow screen element.

Change of the yellow ink pigmentation resulted in a change of the diameter of the screen elements. The average diameters of the analyzed elements are:  $d_{1,20}=91,89\mu\text{m}$  (256 analyzed elements),  $d_{1,40}=90,68\mu\text{m}$  (256 analyzed elements),  $d_{1,60}=89,98\mu\text{m}$  (243 analyzed the elements),  $d_{1,80}=90,98\mu\text{m}$  (256 analyzed elements) and  $d_{2,00}=92,35\mu\text{m}$  (256 analyzed elements). The screen element diameter increase is not very regular, the pigmentation increase of  $\Delta D=0,20$  and  $\Delta D=0,40$  do not lead to an increase in diameter, but to its reduction.

Visual valuation reveals that the yellow screen elements are lower, with no characteristic peaks expressed in relation to the cyan and magenta screen elements. It may be observed that the most properly formatted element is in ink pigmentation  $D=2.00$  (3 characteristic peak). At lower ink pigmentation elements have more characteristic peaks, but peaks are not very visible, so at  $D=1.80$  is recognized 3 peaks, the ink pigmentation of  $D=1.60$ ,  $D=1.40$  and  $D=1.20$  show 5 peaks.

## 5. Conclusions

Due to different pigment structure in cyan, magenta and yellow ink, reproduced screen elements are visually considerably differ. Brightness of screen elements decreases proportionally to increase of ink pigmentation. The maximum color difference was for the cyan  $\Delta E_{\text{max}} = 1.7490$ , and minimum  $\Delta E_{\text{min}}=0.2512$ , for magenta  $\Delta E_{\text{max}}=1,5007$  and  $\Delta E_{\text{min}}=0,4363$ , while for yellow  $\Delta E_{\text{max}}=0.6375$  and  $\Delta E_{\text{min}}=0.0551$ .

Screen elements printed with cyan ink have the largest diameter, and screen elements printed with magenta have the smallest average diameter. The biggest difference between cyan screen elements diameter was  $\Delta d_{1,40-2,00}=9,59\mu\text{m}$  and the smallest difference ( $\Delta d_{1,20-1,40}=1,60\mu\text{m}$ ) was created at the first change of ink pigmentation. At the screen elements printed with magenta ink biggest diameter difference was  $\Delta d_{1,40-2,00}=17,30\mu\text{m}$ , and the lowest  $\Delta d_{1,20-1,60}=2,19\mu\text{m}$ . Yellow screen elements had a maximum deviation of diameter  $\Delta d_{1,60-2,00}=2,37\mu\text{m}$ , and the lowest  $\Delta d_{1,40-1,80}=0,30\mu\text{m}$ .

Topographic analysis of a typical screen element showed the most properly formation of the screen element at the highest pigmentation of cyan, magenta and yellow inks. The most improperly shaped elements were those with the lowest ink pigmentation. Yellow screen

elements had the lowest number of characteristic peaks, which means they are weakly accepted at the substrate (paper). For digital printing of screen elements is better to apply as possible high ink pigmentation because it will lead to better acceptance of ink to the substrate.

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## THE EFFECT OF UV INKJET INK DROPLETS SPREADING ON CURING PROCESS

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**Abstract:** Spreading of inkjet inks over a substrate surface depend on inter-facial tensions at the boundary-line of liquid and solid contact. Physical properties (viscosity, surface tension) of two commercial CMYK sets of UV curable inkjet inks and surface properties of various polymer foils were measured. Printing tests and curing energy measurements were done with laboratory printing machine equipped with Xaar XJ500/40 print head and mid-pressure Fe doped Hg lamp. The spreading of print droplets in short time scale was examined by varying the time interval between printing and curing. Specific spreading behaviour of ink droplets on substrates with different surface properties was observed. Excessive spreading led to large dots with low optical density which were difficult to cure. The bad curability of such thin dot layer could be related to oxygen inhibition of polymerization. The UV curing process is affected by substrate and ink interaction.

### 1. Introduction

UV curable inkjet inks are deposited by printhead on the substrate surface in form of discrete droplets. These droplets of liquid ink spread on the substrate surface until UV exposure occurs. Fotoinduced polymerization transforms ink droplets into the solid polymeric print dots which shape is result of spreading period. The shape of print dots affects print quality as optical density and image sharpness. The print dot radius/size and optical density of prints is given by rate of ink spreading and time delay between print and UV exposure. The print dot shape is affected by surface roughness and by texture of printing substrate. The ink spreading rate is generally influenced by surface free energy of the substrate, ink surface tension, viscosity and specific gravity. In this study, the print dot shapes of commercial UV curable inkjet inks on various polymeric substrates were analysed by image analysis.

### 2. Methods

Two CMYK sets of commercially available inks Crystal – SunJet (Midsomer Norton, England), Svang – Grapo (Olomouc, Czech Republic) were used in this study. The viscosity, surface tension and specific gravity were measured as ink properties. Ink viscosity was estimated from flow curves measured by rotary viscosimeter (Haake RotVisco 1) with double-gap sensor (DG 43-Ti). Surface tension was estimated by Owens-Wendt model from contact angles of “sessile” drops measured on defined substrates. [1] Specific gravity was determined pycnometrically.

Substrates used in this study were: PP (Radici Film – Radil C, 30  $\mu\text{m}$ ), PE (SlovPack – PackCEN white, 60  $\mu\text{m}$ ), PET (Mitsubishi Polyester film – Hostaphan RNK C, 12  $\mu\text{m}$ ), LDPE (50  $\mu\text{m}$ ) foils, synthetic paper Synapse (Agfa – polyester based, coated with ink receiving layer), coated paper CoreGloss (Ospap – glossy coated paper – 135  $\text{g/m}^2$ ). The measured substrate properties were roughness and surface free energy. Substrate roughness were measured by Parker Print Surf machine (PPS) as mean value of 5 measurements with standard deviation below 0,06  $\mu\text{m}$ . Surface free energy was estimated by Owens-Wendt model from measured contact angles of “sessile” drops of defined liquids (water, diiodomethane, formamide, ethylene glycol).

The test pattern containing i.a. discrete print dots was printed by laboratory printing machine equipped with Xaar XJ500/40 printhead with 40 pl drop volume and 1 kW mid-pressure Fe doped UV lamp. Images of print dots were taken by optical microscope equipped with CMOS camera and analysed using ImageJ software. The area covered by print dot and its perimeter were identified by thresholding the camera image and quantified by pixel counting. The area of one image pixel was determined by calibration with standard gauge. The dot radius was determined as radius of circle with equivalent area. The dot perimeter was determined as sum of edge pixels dimensions. The dot circularity was calculated according equation 1. The dot circularity takes the value of 1 in case of ideal circular shape with smooth edge and decrease with increasing dot elongation in one dimension or with increasing edge roughness. For cyan

and magenta inks the print dot spreading in short time scale was observed by varying time delay between printing and curing.

$$\text{circularity} = 4\pi \frac{\text{area}}{\text{perimeter}^2} \quad (1)$$

### 3. Results and Discussion

Values of the measured ink and substrate properties are presented in Table 1 and 2.

*Table 1: Roughness and surface free energy of printing substrates*

	PPS roughness [ $\mu\text{m}$ ]	Surface free energy [ $\text{mJ.m}^{-2}$ ]		
		total	disperse part	polar part
PP30	1.48	38.63	31.30	7.33
PET	1.68	44.99	35.87	9.12
LDPE	0.91	50.71	27.65	23.06
PE	0.90	45.91	37.92	7.99
Synaps	1.44	44.71	38.06	6.63
CoreGloss	1.07	50.09	33.53	16.56

Two inks sets from two manufacturers differ above all in surface tension (Table 2). The Crystal inks have slightly higher surface tension, lower it's polar part and higher it's disperse part than the Svang inks. The Crystal inks spreaded into larger print dots than the Svang ink, and their spreading is more affected by the substrate (Figure 1). In spite of lower surface tension the Svang inks spreaded into smaller print dots. The surface tension of the ink is modified by surface agents which are block copolymers with certain diffusion speed. The result of limited surfactant diffusion is time dependent surface tension (so-called dynamic surface tension) of newly created surfaces of the print droplets. The dot spreading in short time scale (the tenths of second) is affected by the dynamic surface tension. The static method of surface tension measuring used in this study is probably not able to distinguish these rapid changes at all. Therefore it is possible that different spreading of Crystal and Svang inks is caused by different behaviour of used surfactants in short time scale.

*Table 2: Measured ink properties*

		Specific gravity [ $\text{kg.m}^{-3}$ ]	Viscosity (40 °C) [ $\text{mPa.s}$ ]	Surface tension [ $\text{mN.m}^{-1}$ ]		
				total	disperse part	polar part
SVANG	C	1057.4	9.00	22.77	18.87	3.90
	M	1065.8	14.25	20.30	15.87	4.43
	Y	1090.7	8.90	22.95	20.68	2.27
	K	1073.0	9.20	21.91	17.74	4.18
CRYSTAL	C	1083.6	10.65	26.78	24.90	1.88
	M	1046.8	9.20	24.62	21.93	2.69
	Y	1062.0	11.25	28.50	27.16	1.34
	K	1072.0	10.40	26.49	24.66	1.83

*Within CMYK set the viscosity and surface tension of the inks are similar to obtain similar jetting behaviour in printing machine. Specific gravities of the inks are similar due to similar acrylic raw materials (Table 2). Spreading of Crystal cyan and magenta inks on different substrates is very similar. The same is for Svang inks except of Synapse.*

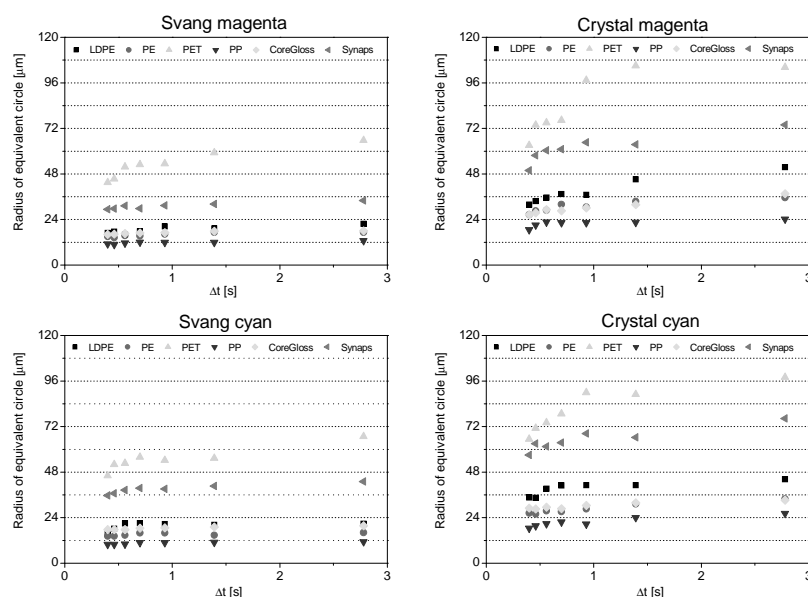


Figure 1: Influence of time delay between print and UV exposure on print dot radius of equivalent circle

Table 2: Circularity of print dots for selected printing substrate

	Svang		Crystal	
	C	M	C	M
PP30	0.880	0.877	0.863	0.876
PET	0.569	0.791	0.825	0.748
LDPE	0.863	0.854	0.810	0.817
PE	0.868	0.845	0.874	0.780
Synaps	0.571	0.686	0.661	0.561
CoreGloss	0.868	0.853	0.846	0.879

Comparing dots radius on PE and LDPE with the same roughness, slightly larger dots on LDPE can be seen. This substrate also exhibit higher free surface energy. Comparing dots radius on PE and PET with the same free surface energy, it is evident that larger dots on PET were caused by higher roughness of this substrate. It was not possible to fully cure any of the ink on the PET substrate. It was probably caused by extensive oxygen inhibition in very thin layer of the ink. The smallest dots radius were observed on PP with the lowest surface free energy. Comparing substrates Synaps and CoreGloss which are defined by higher porosity of surface with foils with closed surface is problematic. Ink penetrates in to the porous substrate by capillary forces. The print dots on substrate Synaps has rough edges (Figure 2) as ink penetrates through unhomogeneous substrate surface. This is reflected by low value of circularity of the print dots. On the other hand Ink spreading on CoreGloss with relatively high surface free energy might be inhibited by ink swallowing of the surface coating.

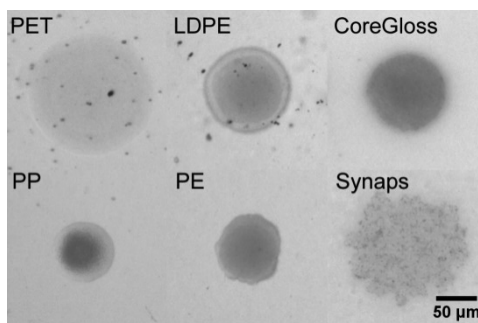


Figure 2: The shape of print dots for selected substrate and Svang cyan ink



## 4. Conclusions

The wettability of the ink on the substrate can be estimated by difference of inks surface tension value and substrate surface free energy value. This affects print droplet spreading rate, resulting in shape of the print dot and print quality. The smaller the value of ink surface tension than the value of substrate surface free energy is, the better the wettability is, which results into the larger print dots. During short time delay between printing and curing the ink surface tension is dynamically changing as surfactant molecules migrate onto the droplet surface. Therefore the surface tension values measured by used static method are not appropriate description. For dynamic surface tension measurements in this short time scale the “maximum bubble pressure” method is more appropriate. Beside substrate surface free energy, the ink droplets spreading is also affected by the structure of the surface described by PPS roughness measurement. Surface irregularities enlarge real surface area which amplify the wetting or non-wetting performance. Measured data implies that differences in substrates roughness affected ink spreading markedly than differences in substrates surface free energy. In case of substrate Synaps with relatively low surface free energy the porous surface of ink receiving layer accelerated the ink spreading by capillary forces. In case of CorreGloss with relatively high surface free energy the porous coating surface swallows the ink easily and thus blocks ink spreading into larger print dots.

The study of print droplets spreading on the substrate in short time scale is possible by changing the time delay between printing and curing. The shape of spreading ink droplet is freezed by curing in subsequent stages of spreading and thus can be easily captured by common camera and analyzed. Our inkjet laboratory machine allows to set the shortest time delay between printing and curing about 0,4 s which is in comparison with production printing machines not short enough. According to a carriage construction and velocity the time delay between printing and curing varies between 0,1 to 1,0 s in production printing machines. So our inkjet laboratory machine needs to be modified by mounting the lamp closer to print head to obtain shorter time delay between printing and curing.

Despite of universal usability of UV inkjet, it was found that not all synthetic materials are successfully printable due to unsuitable interaction with substrate. Excessive ink spreading leads to low optical density dots. There is a curing problem on PET substrate. High surface porosity negatively influences the print quality of UV inkjet printing.

## 5. Literature

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# DETERMINATION OF THE DEVIATIONS TOLERANCES OF THE PROCESS-COLOUR SOLIDS FROM THE OK PRINT BY EXAMINING THE RELATIONSHIP BETWEEN OPTICAL DENSITY AND COLOUR DIFFERENCE IN OFFSET PRINTING METHOD FOR DIFFERENT TYPES OF PAPER

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**Abstract:** *The goal of the present study is to define the correlation between the optical density and colour difference of the main ink colours cyan, magenta, yellow and black in printing on different types of paper, printed on four-colour sheet-feed offset printing machines. A test form has been used that contains different control strips for densitometric and colorimetric measurings.*

*By the methods of Regression analysis it has been ascertained that the correlation between the optical density deviations -  $\Delta D$  from the optimal values and color difference -  $\Delta E_{ab}$ , can be presented by the following regression model (equation):  $\Delta E_{ab} = a \cdot \Delta D^2 + b \cdot \Delta D + c$  ( $y = ax^2 + bx + c$ ). The coefficients received are not equal for the different paper-ink combinations, which suppose different limits for  $\Delta D$ . By using of the allowed limits for colour difference  $\Delta E_{ab}$  (defined in ISO standards), it is graphically defined which  $\Delta D$  limit values correspond to every colour and every paper-ink combination.*

*The results achieved are important from scientific and practical point of view. For the first time in an experimental way a well-grounded proof has been achieved with regard to the limits of the optical density deviation from the optimal values for various ink-paper combinations, by provision of colour differences in compliance with the international standards.*

**Key words:** *Print Quality, Offset Print, Optical Density, Colour Difference*

## 1. Introduction

The offset printing method has a leader position in graphic arts technology. The quality of printing production is the most important factor, which determines the market position of the printing houses. Quality parameters are accounted in the European standards. In printing processes we operate with parameters like ink quantity, registration of colours, dampening process, pressure in printing zone and so on. Quality of printing image is function of supporting of printing process parameters in precise boundaries. The valuation of quality of printing image can be finished by the human eye and by colourimetric methods.

In the practice we use two methods to measure the quantity of printing ink [1,2,3,4,5]:

Densitometric methods – used for control and management of printing processes. The measurement of the optical density refers to solid and raster images, which are printed by the basic colours – cyan, magenta, yellow and black. The measurement results cannot be used to estimate the visual perception of colour. When we measure the optical density we ensure control of reproduction and printing processes with two ways:

measuring of quantity of printing inks in way of generant of form cylinder in narrow borders for each of main colours;

measuring of dot area, based on optical density of solid field.

Colourimetric methods – based on colour difference  $\Delta E_{ab}$ , needed to estimate the first approved printing sheet of paper related to the printing proof, to compare real printing process to first approved printing sheet of paper, for digital printing.

All the two methods have advantages and disadvantages.

## 2. Experimental

The main goals of this research is to define the correlation between optical density and colour difference of basic ink colours – cyan, magenta, yellow and black in printing on two types of paper – mat coated paper and uncoated paper, on four colour sheet feed offset printing machine.

### 3. Results and Discussion

A test form that have been used contains control and measuring components: registration marks, solid patches for cyan, magenta, yellow and black – for control of optical density and colour difference, patches for estimating of dot gain and grey balance, strip which contains raster lines in different slope for doubling and slur control. All measuring components are with screen value 150 lines per inch.

All four printing plates are positive working and exposed on CtPlate system UV Setter 710, BasysPrint. The offset printing machine, which has been used, is four colour sheet feed "KBA RAPIDA 105". The paper, which has been used, is 90 g/m<sup>2</sup> mat coated paper, and 90 g/m<sup>2</sup> uncoated paper. The printing inks, which have been used, are manufactured by "Huber gruppe", Reflecta EcolIntensive series. The optimal quantity of printing ink has been determined by method of maximum printing contrast [1] for each combination of paper-ink.

A spectrophotometer/densitometer of type SpectroEye of GretagMacbeth has been used for measuring of optical density and the colour characteristics in the CIE Lab colour system. All measurements are in accordance with ISO 12647-1[5]: D50 illuminant, 2° observer, 0/45 or 45/0 geometry, black backing and in accordance with [6,7,8]

Colour characteristics of used papers (print substrate colour) are in accordance with ISO 12647-2 [2] tolerances ( $L\pm3$ ,  $a\pm2$ ,  $b\pm2$ ).

When the test samples are printed, we use the optimal quantity of printing ink that has been determined by method of maximum printing contrast. We used for operating conditions the limits [9,10], which have considerable difference and it have no evidence for their determination. In table 1 are shown experimental defined values for optimal quantity of printing ink (presented by Dv) for the two types of paper.

*Table 1: Experimental defined values for optimal quantity of printing ink for the two types of paper.*

Type of paper	Dv (optical density of 100% solids)			
	Cyan	Magenta	Yellow	Black
Mat coated	1,55	1,55	1,40	1,75
Uncoated white paper	1,10	1,10	0,95	1,30

From the already printed paper fortuitously are taken printed sheets, which have not a slur defect. For the each type of paper are measured the four process colours in solid fields, which are parallel to the generant, the deviation of optical density from optimal value and the difference in colour co-ordinates related to the reference. The reference colour is a field, which have an optimal density (table 1). The numbers of measurements are different for four colours and it is determined from the variety of colour differences – from minimum up to in excess of determinate limits [2].

The main goal of this research is formulated on the base of the advantages and disadvantages of the densitometry and colourimetry, as follows: to determine the dependence between the optical densities and the colour differences of the basic ink colours.

The previous version of the ISO 12647-2:1996 standard has defined the following admissible deviations from the reference colours:  $\Delta E$  cyan - 2,5;  $\Delta E$  magenta - 4;  $\Delta E$  yellow - 3;  $\Delta E$  black - 2. The last version of ISO 12647-2 [2] defines admissible deviation tolerances as follows:  $\Delta E$  cyan - 4;  $\Delta E$  magenta - 4;  $\Delta E$  yellow - 5;  $\Delta E$  black - 4. From the data available it is obvious that the deviation tolerance for magenta has remained unchanged, but the values for C, Y and K have increased. During previous researches [11], the relation between  $\Delta D$  and  $\Delta E_{ab}$  was investigated in accordance with reference values, as set by the previous ISO standard version.

In order to express the analytical dependence between  $\Delta D$  and  $\Delta E_{ab}$ , it is needed to apply mathematical modeling. It is recommendable to use regression analyses for data processing and to determine the deviation tolerances Dv for the process colours, taking into consideration the optical perception for various paper types.

That's why in this study was made a Mathematical modeling of the data, describing the correlation between  $\Delta E$  and  $\Delta D$  and determination of deviation tolerances from optimal inking for C, M, Y, K, considering the human perception specificity.

It was determined, that the experimental curve is a square function – parabola, described with the formula:  $y=ax^2+bx+c$  (in this concrete case -  $\Delta E= a.\Delta D^2+b.\Delta D+c$ ). After experimental data analyzes, for some of the cases the coefficient b was omitted. Therefore the function type was transformed to:  $y=ax^2+c$  (in this concrete case -  $\Delta E= a.\Delta D^2+c$ ).

Results of measurements are shown in following graphics. On “x” axis is projected deviations  $\Delta D$  from the optimal ink quantity and on “y” axis – colour difference  $\Delta E_{ab}$  from the reference value.

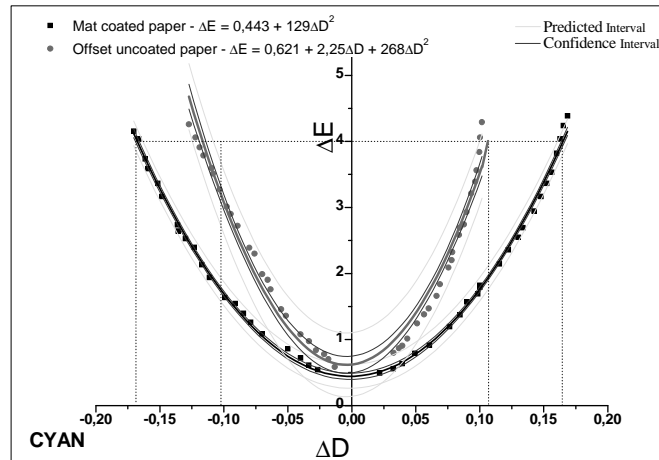


Fig. 1  $\Delta D - \Delta E$  function for Cyan

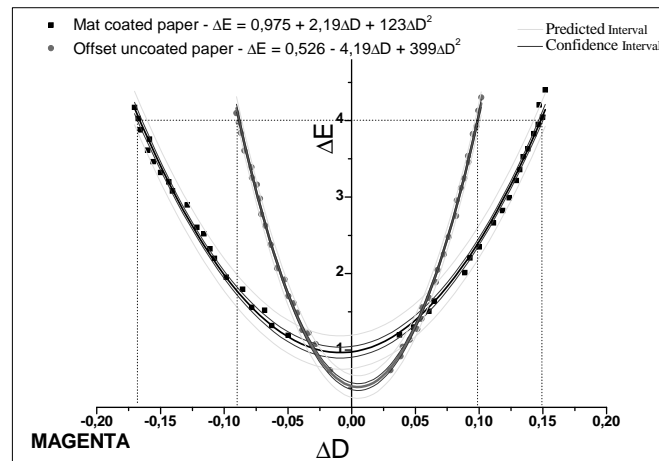


Fig. 2  $\Delta D - \Delta E$  function for Magenta

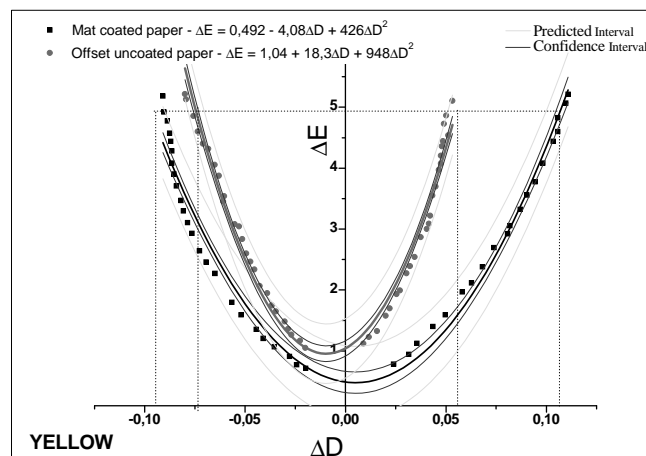


Fig. 3  $\Delta D - \Delta E$  function for Yellow

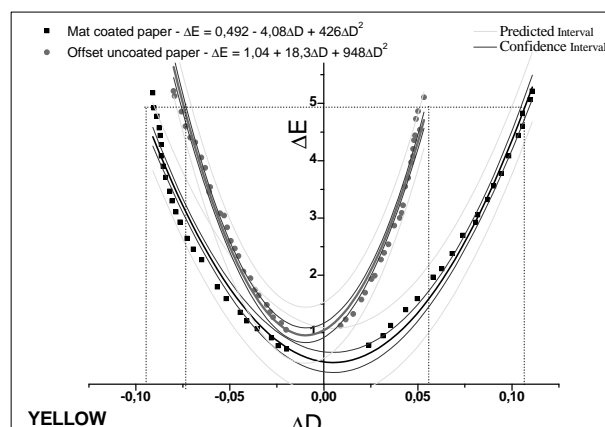


Fig. 4  $\Delta D - \Delta E$  function for Black

One of the most important conditions, that guarantee formulation of realistic and practically applicable model -  $\Delta E = f(\Delta D)$ , is the statistical analyses of the regression model. This analyzes consists of several steps: 1. Dispersion analyzes; 2. Examination of the hypothesis for coefficient significance; 3. Examination of the significance of determination coefficient -  $R^2$ ; 4. Examination of the adequacy hypothesis of regression model through repetitive trials. The regression models obtained by experimental data are presented in table 2.

Table 2: Regression models  $\Delta E = f(\Delta D)$  obtained by experimental data for C, M, Y, K and two types of paper

Paper Type	$\Delta E = a \cdot \Delta D^2 + b \cdot \Delta D + c$ ( $y = ax^2 + bx + c$ )			
	Cyan	Magenta	Yellow	Black
Mat coated	$\Delta E = 0,443 + 129 \Delta D^2$	$\Delta E = 0,975 + 2,19 \Delta D + 123 \Delta D^2$	$\Delta E = 0,492 - 4,08 \Delta D + 426 \Delta D^2$	$\Delta E = 0,129 - 3,17 \Delta D + 196 \Delta D^2$
Offset uncoated	$\Delta E = 0,621 + 2,25 \Delta D + 268 \Delta D^2$	$\Delta E = 0,526 - 4,19 \Delta D + 399 \Delta D^2$	$\Delta E = 1,04 + 18,3 \Delta D + 948 \Delta D^2$	$\Delta E = 0,381 + 442 \Delta D^2$

Figures 1-4 represent the experimental data and the graphics of the regression models  $\Delta E = f(\Delta D)$ . In addition to the models obtained (in this case - parabola), the confidence and the predicted intervals are visualized also.

When  $\Delta E_{ab}$  is restricted with accepted limits, graphical and analytical can be determined for which values of  $\Delta D$  limitations are executed for each colour and for each combination paper-ink. The results are in Table 3.

Table 3: Density difference limitations (deviation tolerances) for plus (+) and minus (-) direction for two types of paper

Paper	$\Delta D$			
	Cyan	Magenta	Yellow	Black
Mat coated	+ 0.166 - 0.166	+ 0.148 - 0.166	+ 0.108 - 0.098	+ 0.149 - 0.132
Uncoated white paper	+ 0.108 - 0.117	+ 0.099 - 0.088	+ 0.055 - 0.075	+ 0.090 - 0.090

Analyses of the achieved results shows:

For mat coated and for uncoated papers, the coefficients for main ink colours are different, "a" have a biggest value for yellow, and lowest value for magenta (fig.1-4). Therefore for yellow we have smaller limits, and for magenta and cyan more wide limits. Coefficient "b" shift the parabola for 3 of equations -  $\Delta E = f(\Delta D)$  in right hand direction, and for 5 cases in left hand direction. Therefore for some cases the limits in plus (+) will be higher, and for other cases in

negative (-). The examination of the hypothesis for the coefficient significance for two regression models, shows that in this two cases (mat coated paper, cyan and uncoated paper black) coefficient “b” is not significant and the deviation tolerances in + and – are equal.

The parabola in not a one case does not cross zero point. Coefficient “c” is smaller than 1, which show us that are possible little colour differences in the references, but they can not be seen by human eyes.

When we compare the main colours in the different type of papers we determine that the coefficient “a” is from 2 to 3 times bigger for the uncoated paper. Therefore for uncoated paper we have lowest limits. The reason is in optimal ink quantity for uncoated papers.

#### 4. Conclusions

For first time via experimental research in real production conditions, the deviation tolerances for optimal inking were determined, taking into consideration the human optical perception and the specific production conditions – print substrate – ink – printing machine. It is unallowable to use equal limits for deviations of optical density from optimal inking value for different types of paper. The obtained results can be used in practice for preparing for print for sheet feed offset machines and for quality control of printing process, if we in advance are determined the optimal ink quantity by maximum print contrast method. The limits for different types of paper, does not depend of used equipment. If the print house have only a densitometer, by the black and white drawings can be approximately determined the colour differences, which are result of measured deviations of optical density.

The obtained from the regression models, deviation tolerances for optimal inking relevant to different paper types, differ between each other.

The obtained from the regression models, deviation tolerances for optimal inking for different colors relevant to specific paper type, differ between each other.

For most of the paper types and colors, deviations in different directions – positive or negative, were observed. From the total of 8 developed models, 6 of them are characterized by different tolerances in positive or negative direction. The deviation tolerances’ values for 2 models are similar.

The results achieved are important from scientific and practical point of view. For the first time in an experimental way a well-grounded proof has been achieved with regard to the limits of the optical density deviation from the optimal values for various ink-paper combinations, by provision of colour differences in compliance with the international standards.

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## THE INFLUENCE OF RECYCLING TONERS ON PRINTING QUALITY

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**Abstract:** Digital printing is very fast evolving type of printing technology. Electrophotography is widely used in both commercial and SOHO printing. The using of recycling toners is very often from price reasons, but it is not recommended by printer producers due to lower quality of prints. Purpose of this paper is compare how sort of toner influence print quality and print properties. Low-end desk laser printer (Samsung CLP-300N) was used and toners from three suppliers (Samsung, Xerox and PrintWell) were subsequently tested. Test charts were printed in three quality setting on several range of papers and final properties ( $L^*$ ,  $a^*$ ,  $b^*$  values, optical density, tone value increase, resolution, sharpness of edges, abrasion resistance and lightfastness) of prints were observed.

**Key words:** Electrophotography, Recycling Toner, Printing Quality

### 1. Introduction

In present day the major part of information circulate in digital form. When we need have this information on paper, we usually use some desk printer. Although the amount of prints from concrete printer per month is generally low, huge quantity of these printers cause that SOHO and home market create significant part of printed production. Continuous development in computer techniques causes, that prices of desk printers continually slope down so most of users have possibility to buy a colour printer. If purchase price is low, the most costs are for operating i.e. prices of inks and toners. Many of users therefore apply refills. Printer manufacturers often warn against using of refills and protect theirs product e.g. by chips. Is using of refills in low-end laser printers hazard? Some parameters of prints by original and non-original toners are comparing in this paper. [1, 2]

### 2. Materials and methods

Colour laser printer Samsung CLP-300N and three sorts of toners (original Samsung and non-original refills Xerox and PrintWell) were used for print of tests. Test pattern contained (for each process colour): strips of solid and 50% areas in vertical and horizontal direction, tone scale 100 % with step 10 %, Siemens stars, line charts (20–600 lpi), positive and negative texts (1–11 pt) and solid areas 6x6 cm for abrasion test. Whole test (3 pages A4) was printed ten times for each toner/paper/print quality combination. Printer has three steps of print quality setting – concept, normal, best, and three types of papers (white, wood-free office paper, 80 g/m<sup>2</sup>, A4) was used – Océ Yellow Label (cheapest), Master (better) and Top Colour (best). Next parameters were evaluated on prints:

- Colour homogeneity in horizontal and vertical direction – test strips was separate into 10 zones in which optical density  $D$  and colour coordinates  $L^*a^*b^*$  was measured by spectrophotometer X-Rite 530 ( $D_{50}$ , 2°observer, black backing, status E).
- Tone value increasing – tone scale was measured by spectrophotometer X-Rite 530.
- Abrasion resistance – samples were rub by Ink Rub Tester (weight 1.81 kg, speed 85 min<sup>-1</sup>, 20 cycles), rate of abrasion was determined as  $\Delta E$  between  $L^*a^*b^*$  coordinates of clean abrasive paper before and after test.
- Lightfastness – printed samples came through UV tunnel Minitherm 220 (medium pressure mercury lamp) and  $\Delta E$  between  $L^*a^*b^*$  coordinates of solid areas of process colour was measured after dose 6 750 mJcm<sup>-2</sup> (UV Integrator from uv-technik).
- Maximal resolution – it was determined visually from line charts and from Siemens star by equation 1, where  $p$  is number of star segments and  $d$  is diameter of circle where segments are fused.

$$R = p / (\pi \cdot d) \quad (1)$$

- Dusting – it was visually evaluate from image magnified by digitally microscope Bresser Erudit DLX 5102000.

For all toners the melting point was measured by apparatus Boetius.



### 3. Results and discussion

The reasons for using of refills are their lower prices. In Table 1 are data shown differences in price of toners.

Table 1: Comparison of prices of toner cartridges [3]

Price of toner cartridge [€]			
	Samsung	Xerox	PrintWell
black	59.0	39.6	28.5
cyan	43.7	33.1	25.7
magenta	44.8	33.1	25.7
yellow	44.6	33.1	25.7

#### 3.1 Melting point

In Table 2 are summarised results of melting point measurement. It is evident, that original toners have narrower range of melting, but differences are not too big.

Table 2: Comparison of melting points of toners

Melting points [°C]			
	Samsung	Xerox	PrintWell
black	114–123	104–123	104–122
cyan	111–119	110–128	110–126
magenta	112–120	110–127	110–124
yellow	112–120	110–128	105–119

#### 3.2 Colour match and homogeneity

Measurement of optical density and colour coordinates  $L^*a^*b^*$  showed, that colour are not homogenous neither for lengthwise or for transverse direction. In Tables 3 and 4 are recapitulated colour differences for average values measured on edge and centre of strips for all combination of toners, papers and print quality.

Table 3: Comparison of colour unhomogeneity for horizontal strips

$\Delta E$ for edge and centre of strips (horizontal strip)										
	print quality	Samsung			Xerox			PrintWell		
		Océ	Master	Top	Océ	Master	Top	Océ	Master	Top
black	concept	2	1	1	2	0	1	5	1	2
	normal	1	2	1	1	1	1	3	1	2
	best	2	1	1	0	1	0	1	2	1
cyan	concept	10	3	3	4	6	6	8	5	6
	normal	7	4	3	4	7	7	8	7	8
	best	7	4	3	6	6	6	8	8	7
magenta	concept	6	4	3	5	6	8	6	4	4
	normal	5	5	4	6	4	8	6	4	5
	best	2	3	4	8	3	9	7	5	4
yellow	concept	7	3	1	2	6	1	3	3	3
	normal	4	5	2	3	3	2	3	4	1
	best	4	3	2	2	2	2	2	2	2

Table 4: Comparison of colour unhomogeneity for vertical strips

<b>ΔE for edge and centre of strips (vertical strip)</b>										
	print quality	Samsung			Xerox			PrintWell		
		Océ	Master	Top	Océ	Master	Top	Océ	Master	Top
black	concept	4	5	4	3	1	1	3	4	4
	normal	4	3	4	2	0	1	3	4	4
	best	3	5	6	3	1	0	5	6	6
cyan	concept	5	6	7	3	1	2	5	6	4
	normal	9	9	8	4	2	1	7	6	8
	best	6	8	8	4	1	2	6	4	5
magenta	concept	3	5	5	2	1	2	1	4	3
	normal	8	3	7	4	2	2	4	4	7
	best	7	6	5	4	1	0	5	3	4
yellow	concept	10	6	11	7	1	1	9	10	8
	normal	13	13	12	7	2	2	10	9	13
	best	9	11	12	8	2	2	7	8	8

For comparison of colour differences for various toners are in Table 5 values, which were measured on centre of transverse strips (approximately on centre of page), on paper Top Colour, for best print quality.

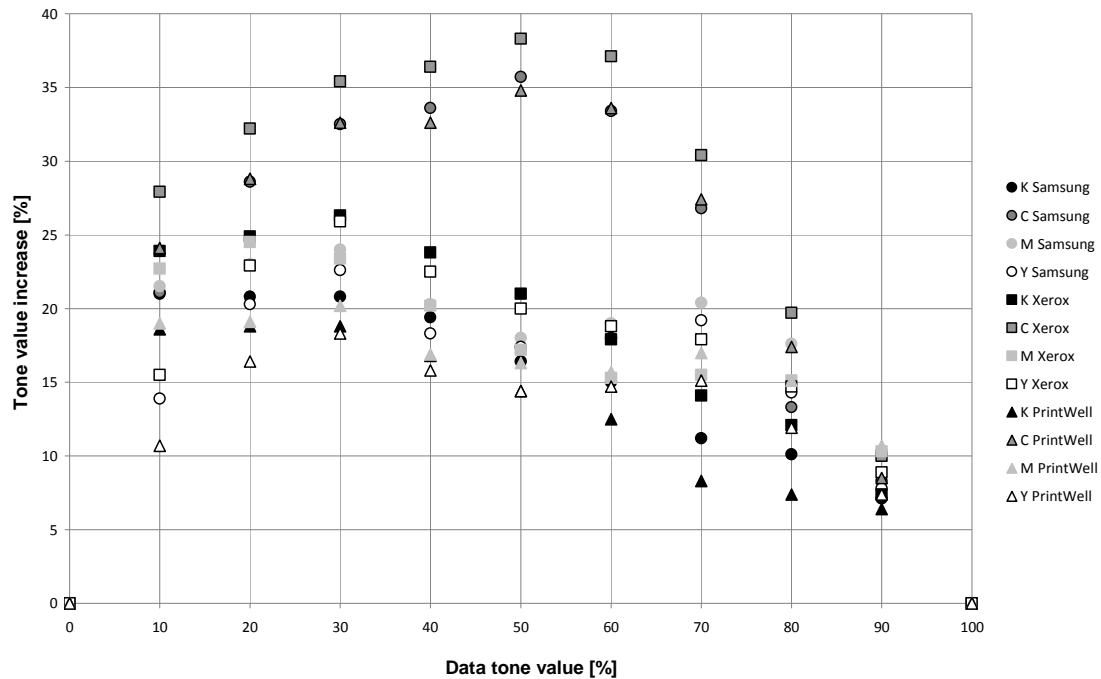
Table 5: Comparison of toner colours

<b>Optical density and colour coordinates (Top Colour, best quality, centre of strip)</b>														
	Samsung				Xerox					PrintWell				
	D	L*	a*	b*	D	L*	a*	b*	ΔE	D	L*	a*	b*	ΔE
black	1.26	25	4	-2	1.20	27	3	-3	<b>2.4</b>	1,22	27	3	-3	<b>2.4</b>
cyan	1.00	52	-17	-50	1.10	48	-12	-53	<b>7.1</b>	0,93	55	-17	-48	<b>3.6</b>
magenta	0.83	56	58	1	0.85	58	58	2	<b>2.2</b>	0,77	59	55	-2	<b>5.2</b>
yellow	1.13	88	-11	84	1.17	89	-9	84	<b>2.2</b>	1,07	89	-11	80	<b>4.1</b>

It is evident that colours differences between toners are lower that differences in the one strip caused by unhomogeneity.

### 3.3 Tone value increase

Tone value increase was measured for all combinations toner/paper/quality. Naturally, it was influenced by unhomogeneity too, but some tendencies are evident. The most increase is for cyan, other colours have similar lower increasing. Differences for various papers or print quality settings are insignificant, in the case of various toners higher increase was found for original toner Samsung and the lowest for toner PrintWell. Graph 1 tone value increase for paper Top Colour and best print setting.



Graph 1: Tone value increase (paper Top Colour, best quality)

### 3.4 Abrasion resistance

In Table 6 are summarized results of abrasion resistance. There were found significant differences between toners. Prints with refill Xerox have unambiguously worst abrasion resistance. The best results had prints with toners Samsung and PrintWell on paper Top Colour. Paper Océ Yellow Label is not suitable for print with toner Samsung. Paper Master is not suitable for print with toner PrintWell for concept or normal quality setting. With best quality setting is toner PrintWell suitable for all papers.

Table 6: Comparison of abrasion resistance of toners

<b>ΔE for abrasive paper before and after test</b>										
	print quality	Samsung			Xerox			PrintWell		
		Océ	Master	Top	Océ	Master	Top	Océ	Master	Top
black	concept	6	1	0	4	4	3	0	3	1
	normal	2	2	0	4	5	2	0	4	0
	best	4	3	0	4	5	2	0	1	0
cyan	concept	8	2	1	6	10	6	1	10	1
	normal	6	2	1	12	11	8	3	10	1
	best	3	4	0	12	7	7	0	2	1
magenta	concept	9	3	1	8	8	5	3	8	2
	normal	4	2	1	9	9	7	3	10	2
	best	5	6	2	11	8	7	2	2	1
yellow	concept	7	5	1	11	10	5	1	15	2
	normal	3	2	1	9	9	7	3	12	1
	best	3	2	1	12	9	4	1	2	1

### 3.5 Lightfastness

There were not found big differences in colour changes after irradiation. The biggest changes were found out for yellow colour independent on used toner. The lowest changes are for cyan (toners Samsung and PrintWell) and for magenta (toner Xerox). Results are summarised in Table 7.

Table 7: Comparison of lightfastness of toners

<b>ΔE for measured solid areas before and after lightfastness test</b>										
	dose [Jcm <sup>-2</sup> ]	Samsung			Xerox			Printwell		
		Océ	Master	Top	Océ	Master	Top	Océ	Master	Top
black	6.75	1	2	3	3	5	6	2	2	4
	13.5	1	2	4	2	5	6	3	2	5
	27	2	2	3	3	5	7	3	3	5
cyan	6.75	2	1	1	2	3	3	1	2	1
	13.5	1	2	2	3	3	3	1	1	2
	27	2	2	2	2	4	3	2	2	3
magenta	6.75	2	2	2	2	1	2	2	2	2
	13.5	4	2	2	3	1	2	3	3	3
	27	3	3	3	3	2	3	3	3	4
yellow	6.75	4	3	2	4	5	4	3	3	3
	13.5	6	4	3	5	6	5	5	5	4
	27	7	5	5	6	6	6	6	6	5

### 3.6 Resolution

Results are summarised in Table 8. The results shows that prints with original toner Samsung have better resolution than prints with refills.

Table 8: Comparison of maximal resolution

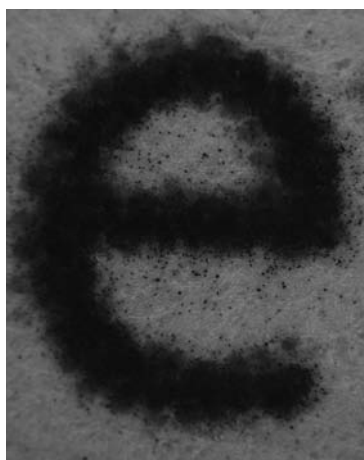
<b>Resolution [l/cm]</b>										
	print quality	Samsung			Xerox			PrintWell		
		Océ	Master	Top	Océ	Master	Top	Océ	Master	Top
black	concept	48	51	48	38	38	42	47	38	47
	normal	47	38	47	38	36	38	38	39	36
	best	54	47	38	38	38	38	40	38	45
cyan	concept	50	42	47	39	38	36	44	42	39
	normal	47	42	47	36	38	38	45	42	38
	best	47	54	47	42	42	47	48	47	39
magenta	concept	47	38	47	31	31	34	38	31	33
	normal	47	38	38	31	29	31	38	34	34
	best	42	34	36	31	31	34	38	36	38
yellow	concept	48	47	47	42	38	47	47	28	47
	normal	46	42	42	38	38	34	38	47	38
	best	47	46	39	42	47	38	38	47	38

### 3.7 Dusting

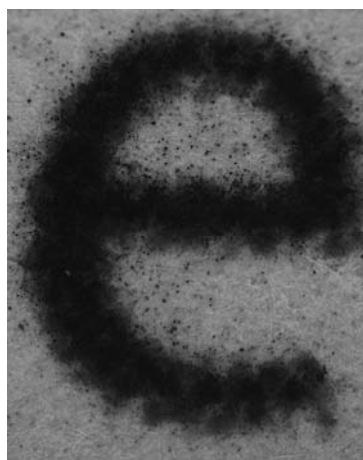
The magnified images of prints with various toners did not show noticeable differences between toners. In figures 1–3 are captured images of prints on paper Top Colour with best quality settings.



*Fig. 1: Samsung*



*Fig. 2: Xerox*



*Fig. 3: PrintWell*

## 4. Conclusions

It was found out, that quality of prints performed by refill toners is in most cases comparable with quality of prints performed by original toner. From tested parameters, only resolution and lightfastness were slightly better with original toner than with refills. Abrasion resistance depends on combination of used toner and paper. The comparison of colour was distorted by unhomogeneity caused by used printer. From results is evident, that refill toner PrintWell has most of the tested parameters comparable as original toner Samsung, but it is much cheaper. From this point of view toner PrintWell is the best choice for used printer. Possible influence of refills on printer lifetime was not tested.

## 5. Acknowledgement

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic, project No. MSM 0021627501.

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## GRAPHICS IN TELEVISION BROADCAST PRESENTED IN ASPECT RATIO 16 : 9

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**Abstract:** The entertainment programme of the Slovenian national television has been producing the television broadcast NLP for the last 10 years. During this period, several changes have taken place in the use of graphic design and typography. The latter are strongly connected to the broadcast NLP scene. According to our preliminary research, an inverse combination of graphics proved to be the most suitable for TV broadcasts. The newest graphic design has been changed from a positive combination into an inverse corporate identity. In the research, we wanted to find out how viewers ( $n = 55$ ) react to the changes in graphic design, comparing the previous and new graphics in the positive and inverse combination. Furthermore, we experimented with different typefaces in the newest graphic design which were presented in the aspect ratio 16 : 9. The students who participated in the research evaluated various graphic solutions representing good visibility and legibility of graphics for a television screen. Originally, the typeface Arial is in use, which was by our research participants unfortunately not accepted as well as it was expected it would be. On the other hand, the typeface Tahoma as another option was found as more visible and legible. The research results gave clear data how viewers accept various typefaces in the same and different environment (i.e. colour combinations).

**Key words:** graphics, legibility, typeface, TV broadcast, visibility.

### 1. Introduction

The legibility of fonts that are in use for television broadcasts is strongly connected to visibility. Various studies have shown that the shape of letters is very important when being observed. The specifics of each typeface have advantages as well as disadvantages which are important when measuring the legibility of fonts (Carter, 1997; Gaultney, 2001; Tracy, 2003). It has been more than 10 years since the broadcast NLP (*Beautiful Sunday Afternoon*, Slo. *Nedeljsko lepo popoldne*) was presented on the Slovenian national television for the first time. During this period, changes have taken place mainly to put broadcast onto a higher level, despite the broadcast already having the highest rating among all broadcasts on the national television. The structure of the broadcast remaining the same, changes have been made in graphic design, which is strongly connected to the broadcast scene. When the producers decide to change a scene, graphic designers change the corporate identity. At the beginning, a positive colour combination of the graphic design was in use. During the transitions, designers were mainly changing the typeface and colour, while the overall colour combination remained the same, i.e. positive. Previous researches show that a positive combination is not the best solution for television screens. The visibility of graphic elements is poor and has a strong effect on legibility. Good visibility and legibility are of essence for television signs. Therefore, designers have decided in the last two years to change the corporate identity into an inverse combination. In the last year, the changes in the television standard have been taking place, the TV picture being converted from the aspect ratio 4 : 3 to 16 : 9 (Strehovec, 2008). In consequence, the changes in the television picture dimensions and in the preparation of television graphics are taking place. The new dimensions represent a different appearance of graphic elements, which were observed in this research.

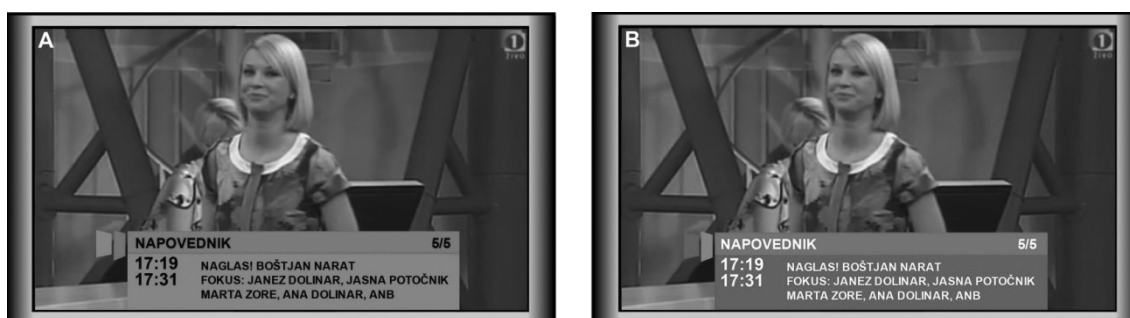
### 2. Experimental

The research was performed according to the method known as 'readers' preferences' (Možina, 2001; Reynolds, 1979). The viewers (i.e. students of graphic arts technology,  $n = 55$ ) were measuring visibility and legibility of typefaces that are in use for the television broadcast NLP. They were grading the previous graphics with the typeface which was in use in the television broadcast a few years ago and variations of it, and the new original appearance and its variations, all in the aspect ratio 16 : 9. The comparison was mainly conducted between the positive and inverse combinations with different typefaces.

### 3. Results and discussion

30.9% of research participants were male and 69.1% female. 94.5% of students fit into the age group from 19–21, which means that the programme contents of NLP correspond to their interests, the latter being confirmed by 78.2% of participants being familiar with the broadcast. The percentage of participants who know the broadcast NLP is according to the study relatively high, as well as of those who believe that television signage in a broadcast is important, i.e. 81.8% of participants. The latter believed that signage is important in the aspect of television graphics and information added to the television broadcast.

The first comparison (cf. Figure 1) was made between the recent corporate identities, i.e. positive (A) and inverse (B) combination (which is currently in use) with the Arial typeface.



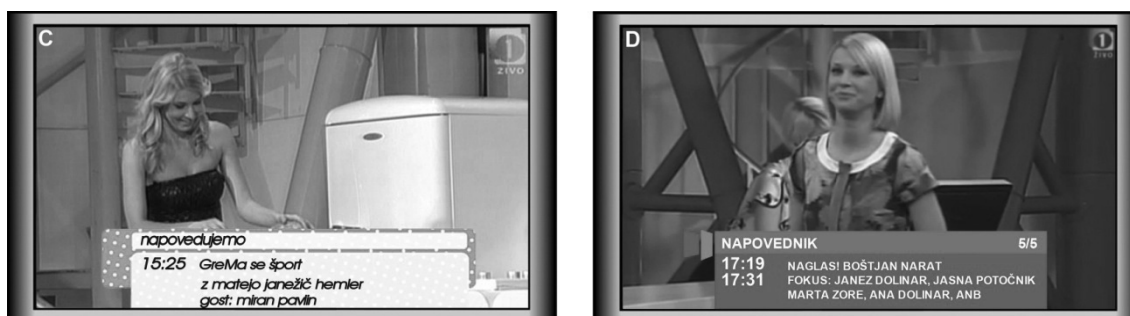
*Figure 1: A – positive combination with Arial typeface;  
B – inverse combination with Arial typeface*

The results show (cf. Table 1) that the inverse combination is more visible and also more legible. As predicted, a lighter colour for the typeface and a darker colour for the background make the signs more visible and consequently more legible.

*Table 1: Visibility and legibility of Arial typeface*

A – Arial, positive	B – Arial, inverse
47.3%	52.7%

The second comparison (cf. Figure 2) was between the previous and the new graphic design. An old example with the Avantgarde Book BT typeface was in the positive combination (C), and the opposite is the inverse combination with the Arial typeface (D).



*Figure 2: C – positive combination with Avantgarde Book BT typeface;  
D – inverse combination with Arial typeface*

The results show (cf. Table 2) that the inverse combination was again more favourably accepted, which might be explained with the use of the typeface and colour combination. In the previous graphic design, very wide italic lower case letters were in use.

*Table 2: Visibility and legibility of positive combination with Avantgarde Book BT typeface and inverse combination with Arial typeface*

C – Avantgarde Book BT, positive	D – Arial, inverse
29.1%	70.9%

In the third part of the study, a comparison was made between the previous and the new combination. In both cases, the positive combination is in use (cf. Figure 3); however, with different typefaces, i.e. Avantgarde Book BT (E) and Arial (F).

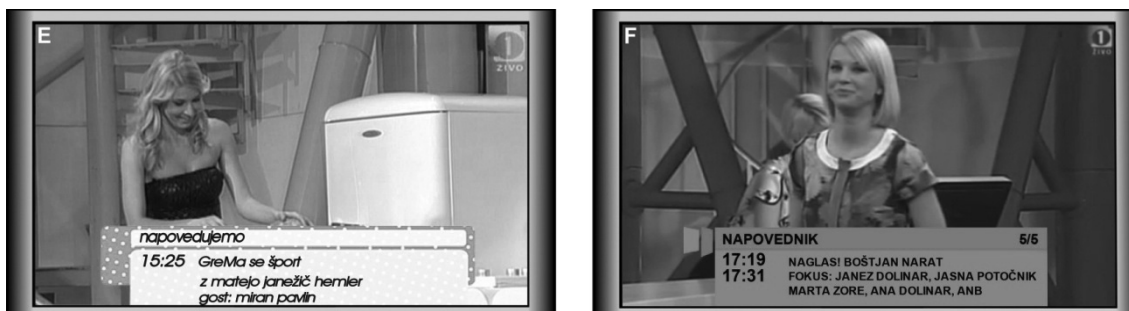


Figure 3: E – positive combination with Avantgarde Book BT typeface;  
F – positive combination with Arial typeface

The interest of the study was to establish whether the respondents' opinion would change if one of the examples from the previous part was altered. While the previous graphic design with the Avantgarde Book BT typeface (E) remained the same, the change was made in the new example, where the Arial typeface (F) was in use. The inverse combination was turned into the positive one. Table 3 shows the results which demonstrate that the respondents' opinion remained the same despite the change in the colour combination.

Table 3: Visibility and legibility of positive combinations with Avantgarde Book BT and Arial typeface

E – Avantgarde Book BT, positive	F – Arial, positive
29.1%	70.9%

The fourth comparison was conducted between two inverse combinations (cf. Figure 4), where the Avantgarde Book BT typeface (G) and Arial typeface (H) are used.

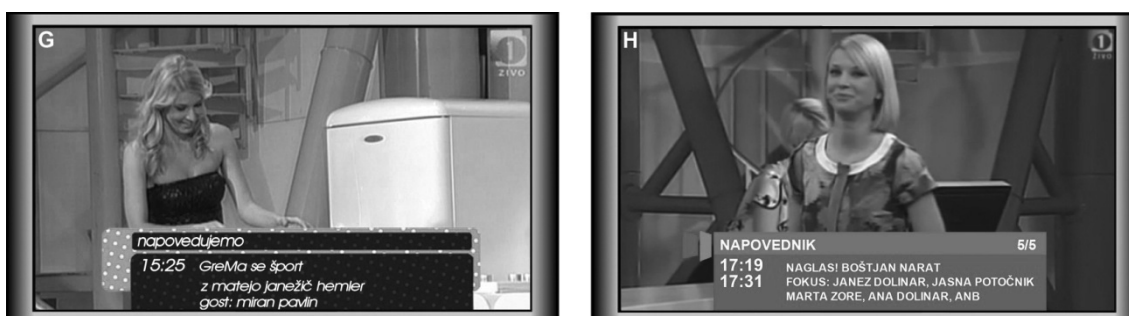


Figure 4: G – positive combination with Avantgarde Book BT typeface;  
H – positive combination with Arial typeface

The positive combinations from the third part of the study were changed into inverse. When the colour combination was changed, the visibility and legibility of the Arial typeface deteriorated in comparison with the Avantgarde Book BT typeface (cf. Table 4). The visibility and legibility of both inverse combinations were quite similar, the difference between the two examples being less than 2%. The difference between lower case letters and capital letters was minimal.

Table 4: Visibility and legibility of inverse combinations with Avantgarde Book BT and Arial typeface

G – Avantgarde Book BT, inverse	H – Arial, inverse
49.1%	50.9%



The fifth comparison was made among four examples, Examples E, F, G, H being taken from previous comparisons. In this case, the purpose was to establish how the surroundings affect visibility.

The results were as expected (cf. Figure 5), since the surroundings did not affect much the decision of respondents. In both comparisons, the Arial typeface was recognized as more visible and legible, which can be a consequence of the design of letters.

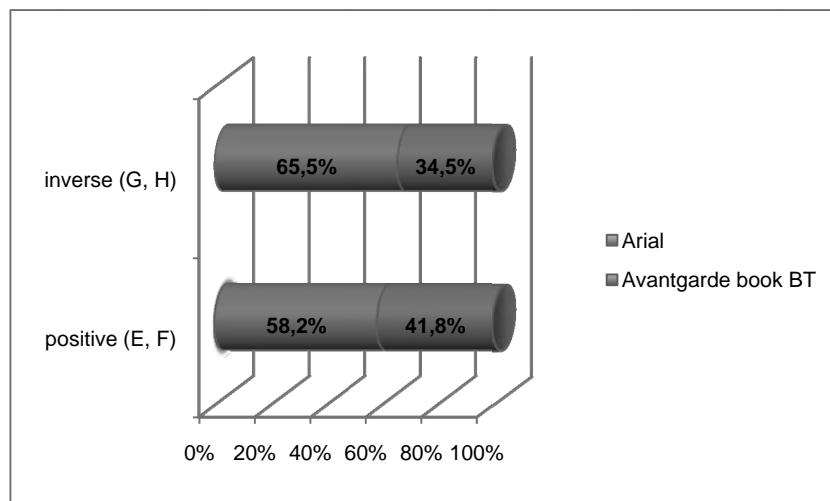


Figure 5: Visibility and legibility of Avantgarde Book BT and Arial typefaces in positive and inverse combination

In the sixth case, the respondents were grading the same colour combination of graphic design (both examples are in the positive combination) with different typefaces. The Arial typeface was used in Example I and the Tahoma typeface in Example J.

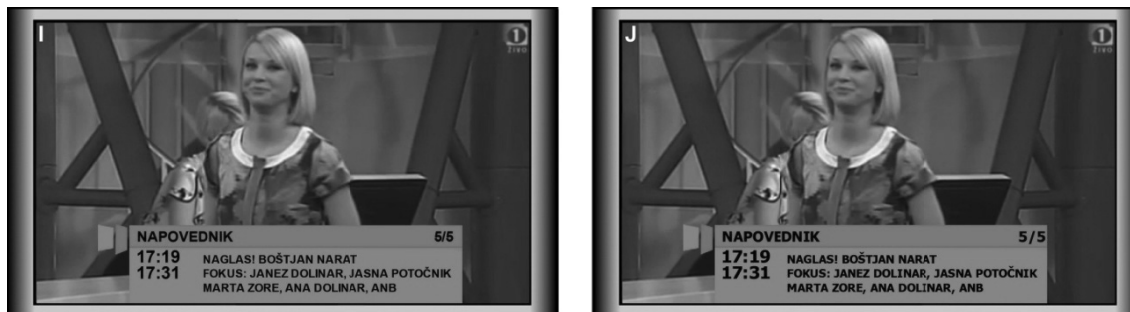


Figure 6: I – positive combination with Arial typeface;

J – positive combination with Tahoma typeface

In previous researches on visibility and legibility of typefaces for television screen (Pušnik, Možina, 2009; Pušnik, Možina, 2010), the Tahoma typeface was accepted most favourably. However, unfortunately in this case, the Tahoma typeface was not accepted as expected. The respondents' opinion was that when the positive colour combination is in use, the Arial typeface is more visible and legible (cf. Table 5). The reason for the latter can be found in rather thick strokes of the Tahoma typeface.

Table 5: Visibility and legibility of positive combinations with Arial and Tahoma typeface

I – Arial, positive	J – Tahoma, positive
56.4%	43.6%

The seventh comparison was performed between two inverse combinations (cf. Figure 7). The Arial typeface was used for Example K and the Tahoma typeface for Example L.

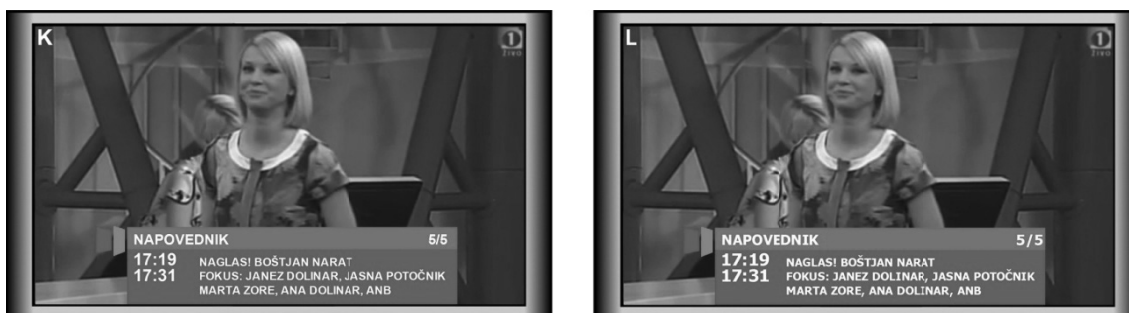


Figure 7: K – inverse combination with Arial typeface;  
L – inverse combination with Tahoma typeface

The predictions about good visibility and legibility of the Tahoma typeface proved to be true in this case (cf. Table 6). Due to the thick strokes of the Tahoma typeface, the inverse combination with this typeface is more visible and legible. The main reason for this can be found in the colour combination (darker colour for background and lighter colour for typeface) and in the thickness of typeface strokes.

Table 6: Visibility and legibility of inverse combinations with Arial and Tahoma typeface

K – Arial, inverse	L – Tahoma, inverse
25.5%	74.5%

The last comparison was among four examples, two positive and two inverse ones. The Arial typeface was used in Examples I and K, and the Tahoma typeface in Examples J and L.

The results show (cf. Figure 8) that the Arial typeface is more suitable for the positive combination, while on the other side, the Tahoma typeface is more appropriate for the inverse combination. The reason for the latter is in the thickness of individual features, which together with the inverse combination made the signage more visible and legible (Götz, 1998; White, 1996).

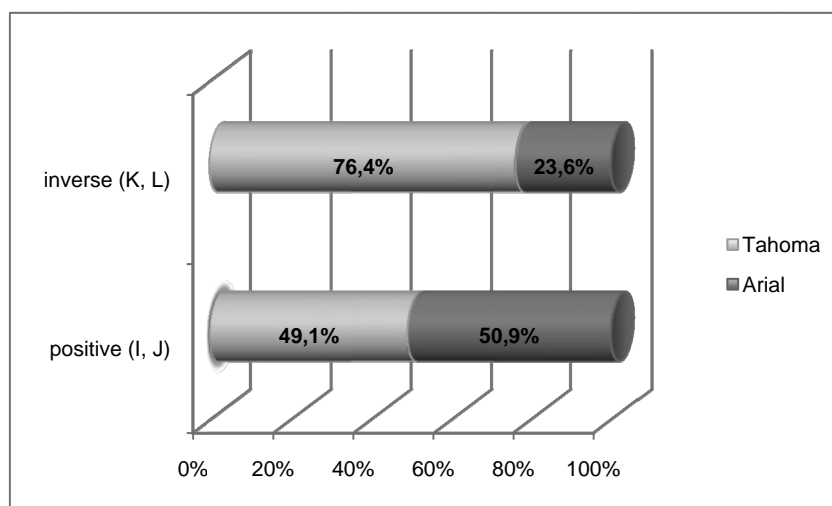


Figure 8: Visibility and legibility of Arial and Tahoma typeface in positive and inverse combination

#### 4. Conclusion

The results show that our choice and predictions were correct. Regardless of the previous researches being made for the television screen of aspect ratio 4 : 3, they show along with this study that the use of an inverse combination is a better solution for television screens. The new standard of television screens does not change the facts about good visibility and legibility of typefaces for television screens. The picture in the new aspect ratio is quite different; however, it does not affect the area of our research. The use of graphic elements for entertainment broadcasts is the same as for television of the previous aspect ratio standard 4 : 3. Only a slight

change can be observed now in the transitional period when the picture of the aspect ratio 16 : 9 is being converted to be used on television screens of the aspect ratio of 4 : 3. In this period, the positive colour combination of the background and typeface is being better accepted (Pušnik, Možina, 2010). Since the transitional period is short, the work with the new aspect ratio again leads to the use of inverse combinations for television broadcasts.

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## VISUAL IMPACT OF PACKAGING SIGNS FOR RECYCLING AND WASTE MANAGEMENT

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**Abstract:** *This article examines visual representation of recycling and waste management signs printed on packaging and its relation to the consumer. Since the life cycle of packaging is short, proper labeling of packaging is important because it serves as a visual guide to the consumer during the process of sorting waste. Since introduction of the Mobius loop sign by the Container Corporation of America in 1970, there has been a growing trend of increased environmental awareness. During the years, many new signs with environmental claims have been introduced to consumers, and their numbers are increasing every year. It is therefore important that the design of these signs is easily understandable to consumers and that their meaning is clear and unambiguous. This article is aimed to determine how the Croatian consumers interpret recycling and waste management signs and how their design and connotative meaning affect consumer decisions. It also examines impact of multiple sign interactions, and how they affect consumer interpretation.*

**Key words:** *Recycling signs, recycling symbols, environmental symbol design, environmental awareness*

### 1. Introduction

Product packaging is regarded as an essential part of the modern lifestyle. It contains, identifies and protects the product, while also communicating product characteristics to the consumer. But, despite many of packaging's favorable characteristics, its life cycle usually ends shortly after it reaches consumer, or after the product is used up. It then becomes waste, or more precisely, an environmental problem. In 2008, yearly production of municipal waste in Croatia was 1,78 million metric tons, which is almost double compared to 0,98 million in 1997 (Croatian environment agency, 2008). Increased waste generation and other environmental issues have led to an increase of environmental awareness amongst modern consumers. One of the more popular measures used for countering increased waste generation is recycling, which is formally supported in many countries, including Croatia.

Recycling of packaging waste, which is part of municipal waste, begins with separation of packaging types which are recyclable from the general, non-recyclable waste and sorting them in several categories, based on material the packaging is made of. This process requires consumer's motivation, since the only reward for the invested time will be personal satisfaction by knowing that they are doing their share in protecting the environment. This excludes PET packaging, because there is a collection fee for this type of packaging introduced by Croatian government in 2006. This has caused an instant growth in PET packaging recycling. Since recycling is a voluntary process, it should be made as easy as possible for the consumer. Several researches conducted in England have pointed out that a reasonably large portion (between 25 and 30 percent) of consumer population would recycle if it would be made easier (Marks/Spencer, 2008; Smallbone, 2005).

One of the most direct ways to point the consumer on which pile to separate the used packaging and therefore making the waste separation process easier, is through package labeling. Although producers have began labeling their packages with various information in 1660s (Berger, 2002), recycling and waste management signs have been introduced just in second half of the 20<sup>th</sup> century. Following the "boom" in environmental awareness amongst American population, Container Corporation of America, then big producer of recycled paper and carton, sponsored a contest for the first anniversary of Earth Day in 1970. The aim of the contest was to create a design which would symbolize the process of recycling. The winning design was a three-chasing-arrows constructing a Mobius loop made by Gary Anderson. Container Corporation of America made several versions of the sign to mark products which are recyclable, and those which are made from recycled content to aid consumers in their purchase decisions and waste sorting. Because of the good reception of the sign amongst American consumers, many other producers began to use the symbol on their product packaging. This sign, known as Universal recycling symbol, or Mobius loop, is the most recognized visual

representation of recycling process. It was registered and inserted into the catalogue of symbols ISO 7000, and it's use is regulated by ISO 14021 norm (Bracun, 2009).

Following the success of the Mobius loop sign, many companies, organizations and governments have issued signs linked with recycling and waste management. Many of them feature designs based on the concept of chasing arrows, like the Green Dot symbol or Universal Recycling Codes. In 2005, Ministry of environmental protection, landscaping and construction of the Republic of Croatia introduced "Recyclable packaging" sign, which use is obligatory by law for recyclable products on the Croatian market.

Since many of producers distribute same products to multiple countries, it is common that these products feature several signs linked to recycling and waste management. This situation makes used product packaging "harder to read" to the consumer, and waste sorting more lengthy and demanding task. There is also a demand for a certain level of education in recycling and waste management sign meaning, so consumer can make better judgment which signs are relevant when sorting waste.

The main aim of this paper is to research how Croatian consumers perceive recycling and waste management symbols that are used on product packaging, and how do those symbols influence waste sorting.

## 2. Methods

This study used a self-administered questionnaire as the research method to investigate consumer attitudes toward environment and recycling, their recycling habits and perception of recycling and waste management signs. Survey was conducted in the city of Zagreb from 15<sup>th</sup> August till 6<sup>th</sup> September 2010, on the sample of 106 consumers. The questionnaire was issued semi-randomly by hand to the targeted working (N=56) and student (N=55) population. The age span was from 20 to 59, and the gender ratio was 63% female(N=67) and 37% male(N=39) consumers.

The questionnaire was divided in two parts:

- evaluation of ecological consciousness and recycling habits
- perception of recycling and waste management symbols in regard of waste sorting

First part of the questionnaire consists of four questions using dichotomous and nominal-polytomous response scales, while Likert Scaling with 1-to-5 rating scale was used to determine the level of ecological consciousness and the level of caution while sorting waste.

In the second part of the questionnaire participants have been given four sign combinations taken from products on the Croatian market. Based on those signs they had to determine in which kind of waste (recyclable, litter, neither) would they sort the product bearing the respective signs. Offered symbol combinations are shown in Figure 1: 1. Green Dot, 2. Tidyman and Resin Identification Code for Polyethylene Terephthalate packaging, 3. Tidyman, Recyclable packaging and Green Dot, 4. Tidyman, Resin Identification Code marking "OTHER" plastics, Green Dot.

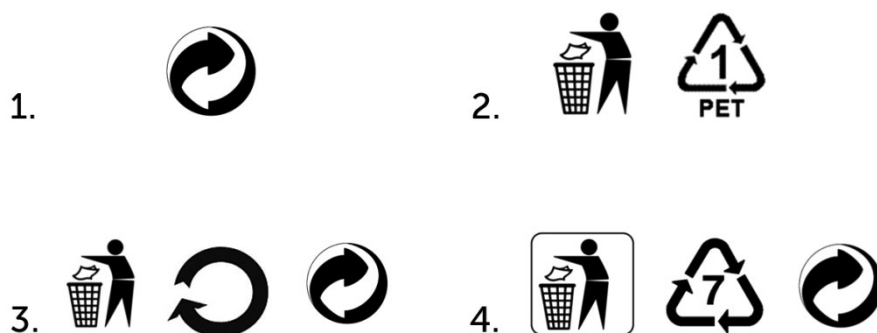
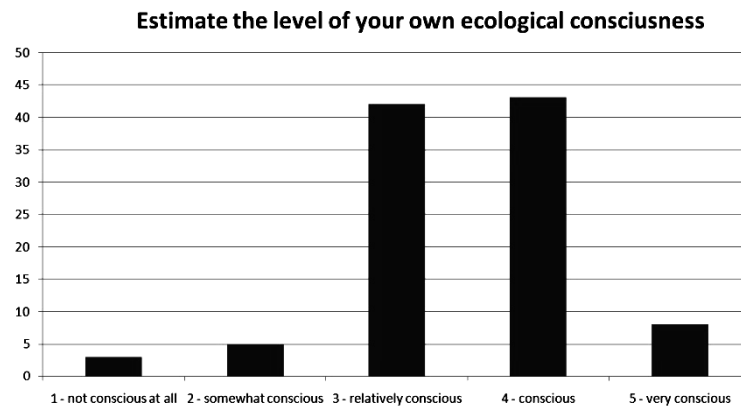


Figure 1: Sign combinations from the second part of the questionnaire

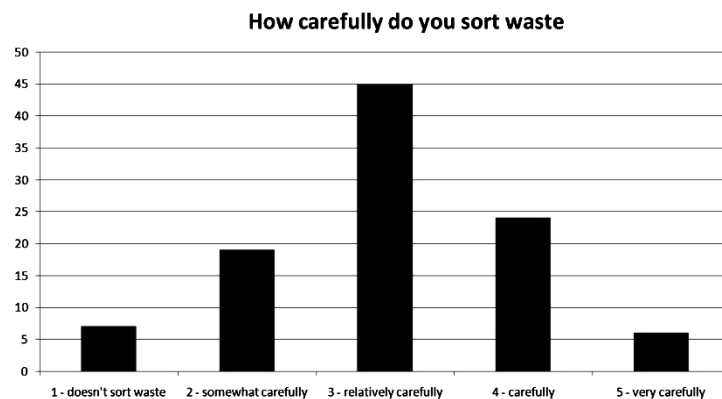
### 3. Results and discussion

All results are presented in percentages (%). Most participants consider themselves relatively conscious (42%) and conscious (43%) regarding to environment, while there are only few (3%) without any ecological conscience (Figure 2).



*Figure 2: Level of ecological conscience of participants*

Majority of respondents (75%) claim they are putting effort in recycling their household waste, while the rest (25%) aren't recycling in their households. These results, combined with the results of the first question (Figure 2), indicate that there is motivation for tackling waste problems, which is a great potential for increasing recycling rates through government and organization sponsored campaigns.



*Figure 3: How carefully respondents claim to sort their waste*

Most respondents claim that they are “relatively careful” (45%) when sorting waste, while only 6% of them being “very careful” during that process. This might be an indication that respondents aren't properly informed of the importance of proper waste sorting in the recycling process. Majority of respondents pay some attention to signs on packaging (74%), and most of them find the information sometimes useful (Table 1). Respondents aren't keen on buying products made of recycled materials, and 45% of them claim that environmental symbols of packaging doesn't have influence on their purchase, while only 12% of respondents are influenced by the symbols during their purchase. Most of the respondents are trying to reuse packaging.

Table 1: Results of questions using nominal-polytomous response scales

Question	Yes (%)	No (%)	sometimes (%)	don't pay attention (%)
Do signs marked on packaging help you when sorting waste for recycling?	13	17	44	26
Do you try to buy products made of recycled materials or products with packaging made of recycled materials?	8	31	61	
Do enviromental symbols on packaging have influence on you purchase?	12	45	43	
Do you try to reuse packaging?	40	19	41	

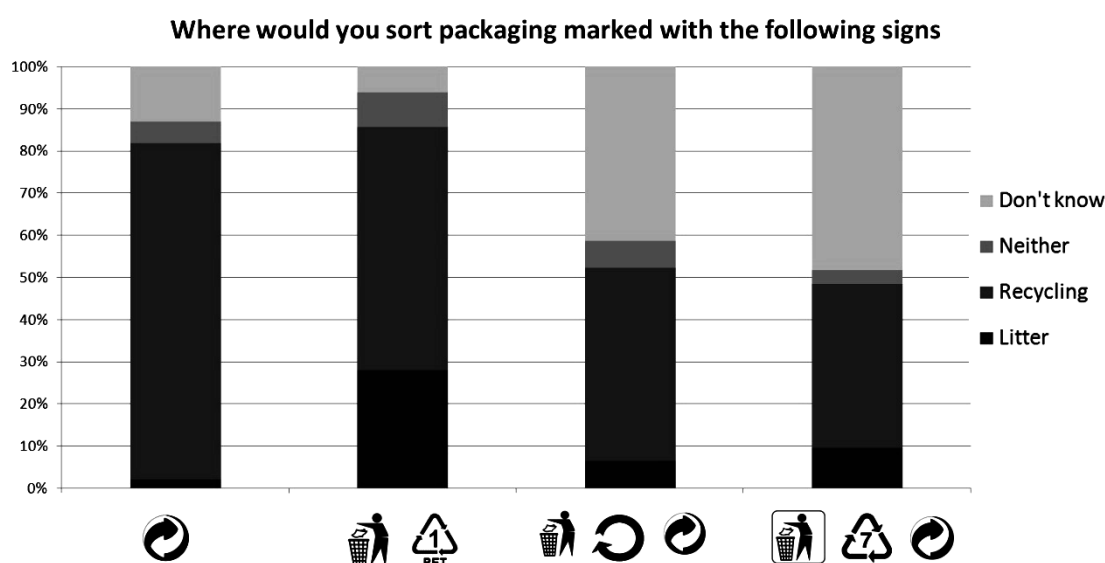


Figure 3: Results of the second part of the questionnaire

Results in the second part of the questionnaire (Figure 3) show that the vast majority of respondents would sort packaging marked solely with Green Dot symbol for recycling (79%). That answer is wrong, because the meaning of the symbol is that the producer has paid a fee for packaging waste disposal in those countries where the Green Dot packaging waste collection scheme is in operation. Since Green Dot collection scheme doesn't operate in Croatia, this symbol is irrelevant to Croatian market, but it can be found on numerous products. Even if the Green Dot Scheme would exist in Croatia, the sign can be applied to almost any kind of packaging, recyclable or not, as long the producer pays the fee. Only 2% of respondents have answered correctly ("Litter") to this question. That result can indicate lack of education about recycling and waste management symbol amongst respondents. It also shows that the symbol might be perceived as a recycling symbol due it's visual concept of chasing arrows, which is also featured in widely known Mobius loop.

In the second example, featuring Tidyman sign and PET Resin Identification Code, most respondents would also sort packaging marked with those signs in the recycle bin (56%), while 27% would sort it in litter. By the regulations, this package would properly be sorted in the litter because there is no obligatory "Recyclable packaging" sign, most Croats are familiar with the PET recycling scheme, and some PET collecting containers are marked with PET Resin Identification Code, so both answers are somehow correct.

Third example, featuring Tidyman, "Recyclable packaging" and Green Dot signs have caused increase in number of respondents that "don't know" (39%), while 43% opted for recyclable waste, which is correct. The increase in insecurity can be attributed to the growth in number of featured symbols (3), or because "Recyclable packaging" sign still isn't widely known.

In the final example, featuring Tidyman sign, "OTHER" Resin Identification Code and Green Dot signs, there was a further increase in "don't know" answers (46%), while only 9% of respondents answered correctly ("litter").

#### 4. Conclusion

Effective household waste recycling program relies solely on the consumer for correctly sorting waste. It is therefore crucial that the consumer is properly educated for that task. According to results of this study, consumers have the motivation for environmental protection, but they lack the knowledge to conduct proper household recycling process. While it is uncertain whether the respondents follow stated actions and attitudes in reality, it is almost certain that they are in dire need for useful information regarding meaning of recycling and waste management symbols. Further research will be necessary in order to determine the most efficient way of consumer education about recycling and waste management signs used on packaging.



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## USING EYETRACKING IN THE FIELD OF MEDIA AND PACKAGING DESIGN

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**Abstract:** *Visual communication doesn't exist just for itself. It bears a message and expects reactions. A successful promotion campaign is created by teams coming from different fields, e.g. analysts, psychologists, designers and others. Designing visual communication is also an important economic segment.*

*Recently the eye tracking method has begun to play an important role in researching visual communication. It is used to analyse and precisely define the specifics of a future buyer. The buyer may be an internet user or services user or a buyer buying goods in a store where he or she comes in contact with packaging. The important role of a precise analysis of eyetracking and what consulting the changes means for the end user.*

**Key words:** *visual communication, eyetracking, media design, packaging design.*

### 1. Introduction

Design should never be destined for itself – the end product is always expected to be usable and responsive. Design simply doesn't mean designing a product, a packaging etc. but it also means the whole strategy of pretesting. Today design also means a very important business field.

It is necessary to include the potential end-user into the particular testing phases of the contemporary designing process. It may be a user of industrial products, a potential buyer of food and packaged industrial products or a webpage user.

We distinguish between a buyer and a user, although eventually a buyer becomes a user and a user becomes a buyer. If we are caught by a product or even by packaging while shopping, which mostly happens with food, we speak about a buyer. We speak about a user if we use a product we have bought because of its being nice, functional, high-quality or because it simply was a must have. We are users while using e.g. a webpage if only to buy particular products or services the webpage offers.

Although we speak about designing media and packaging we mustn't overlook industrial design because it is a design philosophy with the help of which we try to introduce elements to the product that will persuade the buyer. Next to industrial design we are going to discover packaging design and packaging redesign and one of the media – webpages in the following text.

### 2. Design and redesign

#### 2.1 Industrial design

Next to the much needed functionality and innovations of products it is necessary to pay much attention to design that may help to make products more attractive and recognizable on the market. The designing phase must include materials that end-users like and environment friendly colours. The company leaders and employees need to view the designing process as an added value and not as a burden. Designing is not an expense, designing is an investment, which really leads to lowering a company's costs by making its products more attractive. Designers bear a huge responsibility because companies expect to get back the design costs through sales. Nowadays companies that hesitate about design cannot expect to be successful on the market.

#### 2.2 Packaging design

In 1973 James Pilditch wrote a book called *The Silent Salesman*. Its title has become a synonym for a different view of packaging. Today packaging is one of the key and most powerful components of product marketing.

Packaging as one of the factors that is influenced by decisions within the product policy framework, may improve the quality of market supply of a company considerably. The importance of successfully designed packaging is therefore huge. Apart from advertising it is the most powerful medium of product marketing.

The basic objective of a successful packaging is that a buyer recognizes it and next time finds it again and buys it. We buy a product and a brand name where a package is not just a part of a product but it has the power to inform, which influences the buying. A brand name and packaging court us, their goal is to make us loyal, to make us fond of them. The packaging phenomenon means trusting the packaging and buyers' identification with it. Being loyal to a package and being loyal to a brand name may show as being loyal to certain social groups, which may have a huge social impact. Packaging may therefore symbolize not only a brand name but also a country and a social system.

Convincingness of the exterior of packaging:

- While buyers are shopping it is the last chance to convince them to buy a product.
- From 60 to 80 % buying decisions happen in shops.
- More than 60 % of decisions are based on packaging.
- A half of all new products on the market are unsuccessful.
- A package usually has 2 to 3 seconds to convince buyers if they have noticed it.

## 2. 3 Packaging redesign

Also when speaking about the redesigning phase we cannot avoid extensive testing. If companies selling consumer products continually change their packaging, the end results are usually not good. According to the research which was carried out by Perception Research Services, 10 % of packaging redesigns increase sales of a product, while 20 % of redesigns decrease its sales. We have even seen packaging of some well known brand names unsuccessfully redesigned, which has made consumers to turn away from them while at the same time choosing from among the competition categories of products. We would like to remind you of the case of the dramatic redesign of the Pepsi brand name Tropicana, which by using a new package and a new logo for the orange juice had become totally unrecognizable for the consumers. This change meant a huge problem for the existing buyers because they were not able to find the product on the shelves. In that period the sales of Tropicana decreased by 20 %, while the sales of the competition line of drinks Minute Maid by Coca-Cola increased twice. Coca-Cola then clearly avoided the bad impact Tropicana suffered and started to redesign the brand name Minute Maid. The marketing manager of the Coca-Cola soft drinks division Venkatesh Kini wrote in the public report that they had been testing new packaging designs among consumers for almost two years and they based the selected key elements of the packaging that needed to be kept on these testings.

Clear and simple elements which don't include dramatic changes compared to the old packaging and give consumers key messages make a brand name persuasive and enable it to position itself on the market well because consumers are able to recognize it easily. It is also important to mention that the common effort of the company (the brand name owner) designers and the outside designing consultants may help to ensure the balance between maintaining the original brand name and the new creativity which may improve the brand name position. This is what companies selling consumer products should bear in mind when launching projects of packaging "rejuvenating".

## 2. 4 Designing media – webpages

When designing information which should be shown on the world wide net and therefore on the screen the designers have countless possibilities. The net has surely become irreplaceable media that has to attract visitors during their first visit and to try to hold them with well arranged and attractive contents. Any too lengthy searching with your eyes and useless clicking with the mouse shows us that the webpage is bad. Bad webpages with useless stuff present a wrong picture of the company and are a nightmare for visitors. Too many options how to design a webpage quickly mislead a designer who introduces unnecessary elements into the webpage that drive a visitor away in a couple of clicks.

### 3. Pretesting and eyetracking

Preliminary testing measures various different elements, such as the level of concentration, transmitting information, receiving and summoning a message, creativity and credibility of visual information, positive emotional reactions to following a product, packaging, visual information, brand name and buying intentions. The technologies are therefore divided into three huge groups, which are inner evaluation and communication and behavioral impacts. We also use eyetracker measurements during preliminary testing.

We know that there is a difference between the actual behaviour of buyers and their feedback, there is a difference between what buyers say they do and what they really do. When observing a buyer using the method of eyetracking we precisely record and make a report about a buyer's behaviour while in visual contact with a certain packaging. The modern technology of eyetracking enables us to understand visual recognition together with eye movements when looking for information on a packaging

Once there is an advertisement, a packaging or a web page, through testing we can acquire some useful information that suggests the way consumers see the visual information and react to it. Acquired data are especially useful when the client has to decide which of the prepared models should be used.

#### 3. 1 Basic methods of eyetracking measurements

The human eyes are constantly moving until they stop and focus on a point. There are over ten different types of eye movements, of which the most important ones are *saccades*, *fixations*, and *smooth pursuit*. When the eyes stop to focus it is called a *fixation* and the movements between these fixations are called *saccades* (Figure 1). Out of the above methods we acquire the so called *heatmaps*, areas on which the eyes focus the longest.



Figure 1. Fixation points and saccades with 1-2° of sharp vision.



Figure 2. Heatmaps.

### 3. 2 Using eyetracking for industrial products design

Apart from testing product ergonomics and quality of materials, eyetracking measurements are used for testing products for the touch of particular materials and their colours. An eyetracker in the shape of glasses is used for these purposes, it enables us to follow and test prototypical industrial products with ease. We make a study using an adequate sample of possible end-users that shows us the visual responsiveness during particular testing phases. Although we cannot measure kinesthetic feelings we are able to give particular results about the feeling for the touch of materials based on the visual measurements. We test the corrected and supplemented prototypes again and compare the results.

### 3. 3 Using eyetracking for packaging design

Visual impacts transmitted by packaging are of key importance if we want to sell a product well. To make a product easily recognizable on the shelves it is more effectual to use simpler and clearer elements. When designing packaging we have to bear in mind not only the image of the packaging itself but also its image among the multitude of other products. It will only be successful enough if it attracts the attention better than other products. The task of a designer is therefore difficult. He or she has to design a package that will catch our attention among the multitude of other products but at the same time the package must function on itself, it must be nice and convincing enough.



*Figure 3. Fixation points on packaging with 3 participants.*

#### 3. 3. 1 Visual impact and usability of packaging

Visual impacts transmitted by packaging are of key importance if we want to sell a product well. To make a product easily recognizable on the shelves it is more effectual to use simpler and clearer elements. On the other side, minimization of the key elements, their indistinctiveness and indiscriminability lead to chaos and total rejection from consumers.

Updating and redesigning packaging has to be a well considered process. Designers must endeavour to keep some original concepts that may be very important for the discriminability of a product on the shelves. The most important thing is that a buyer is able to find the desired product in a shop easily and quickly. Companies very often wish to “rejuvenate” a product and change its packaging but often the result is that a consumer simply doesn’t find the product and looks for the competition product – just because he or she didn’t recognize the new packaging. The final goal of packaging redesign must always be growing sales, better experience and obligatory cooperation with consumers, otherwise “rejuvenating” packaging makes no sense. The product is meant for the consumer after all.

## 4. Example method of testing

A producer of alcoholic drinks decided to market two new alcoholic drinks with orange and flavoured. We tested the samples with an eye tracking device Tobii T120 Eyetracker. Twenty-eight adult persons who knew the other drinks of the same producer were included in the testing.

Standard lighting conditions were ensured in the experiment area. Monitors were calibrated. The screen was calibrated for every single tested observer.

We tested the likableness of the new package and recognition of the new package in a group of products of the same producer. Moreover we tested the colour of the drink in connection to its taste. We also use the eye tracking technology when testing the colour of the drink in connection to its taste. A participant is asked which colour he or she would choose for an alcoholic drink with orange flavour and pictures of fifteen drinks in different shades of orange are shown on the screen. At the end of the testing the possible colour of the drink is chosen.

#### 4. 1 Results

We tested fifteen different samples of orange colour (orange flavour) that we labelled from O1 to O15. Using the eye tracking device we chose five most frequently chosen samples and repeated the process. That is how we got the final colour of the drink.

We tested also the new line of products in relation with known line of products.

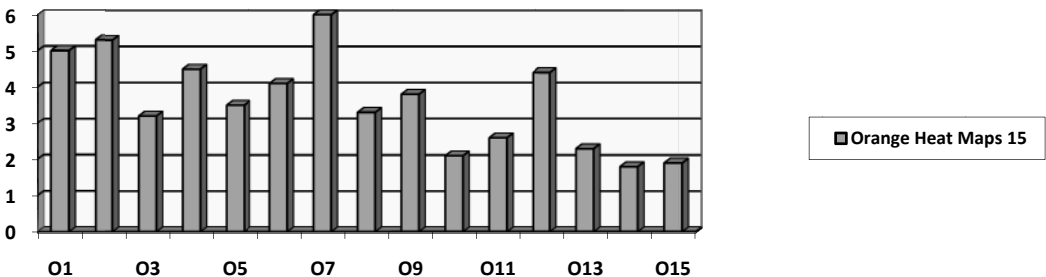


Table 1: The table 1 shows that sample O7 is the most frequently chosen one in samples of 15.

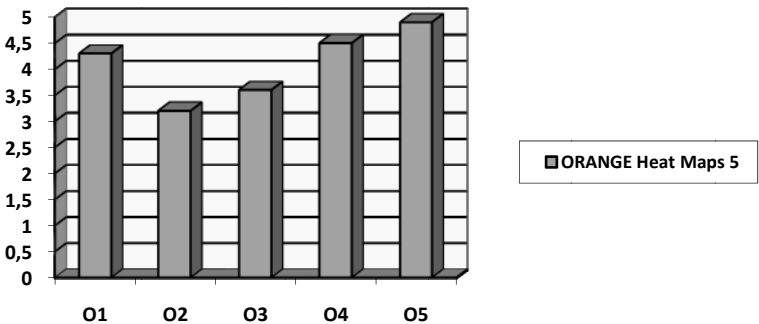


Table 2: The table 2 shows that sample O5 is the most frequently chosen one in samples of 5.

Certain results of packaging testing are not mentioned because they are always the ordering party's property and it is a business secret.

#### 5. Summary

Media and packaging are visual communication media about the design of which a number of researches about market culture, market laws, buyer behaviour, buyer psychology and user psychology etc. has been carried out. Packaging is definitely a factor with a huge impact on sales. If the results of testing different target groups are counted with, the sales usually grow for 15 %. Designer teams are therefore forced to design a larger number of different types of packaging so that later the company and its potential buyers decide about the most suitable packaging while testing different samples. We know the story about well designed products and their functionality. It would be nice if companies were aware of it as well as they usually view design as unnecessary costs let alone the need to include prototypes in pretesting.

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## TYPEFACE LEGIBILITY ON KINDLE, KINDLE FOR MAC AND KINDLE FOR iPhone

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**Abstract:** Amazon.com is an American-based multinational e-commerce company, known as one of the largest online retailers worldwide. One of their additions is Amazon Kindle, a software and hardware platform for rendering and displaying e-books and other digital media. Three Kindle hardware devices support this platform and a Kindle software application for the existing six types of different hardware users to read Kindle contents on these devices.

The purpose of the research was to analyze typeface legibility on an Amazon Kindle, iPhone (Kindle for iPhone) and Mac (Kindle for Mac). These are three different devices of different screen sizes and screen resolutions, however, with the same software, displaying the same contents.

**Keywords:** Amazon Kindle, Kindle for Mac, Kindle for iPhone, legibility, typography

### 1. Introduction

Amazon.com started as an online bookstore; however, soon DVDs, music CDs and MP3s, video games etc complemented Amazon's daily offer. One of their latest additions is Amazon Kindle (3<sup>rd</sup> generation) – the newest technological achievement in the area of e-books launched recently. Amazon Kindle 3 is the “bigger” brother of Amazon Kindle 2, released in February 2009, merely one year after the first Kindle generation (Kindle Wireless Reading Device, 2010). Three Kindle hardware devices support this platform and a Kindle software application for the existing six types of different hardware, *inter alia* Kindle for Mac and Kindle for iPhone. Kindle for iPhone allows iPhone, iPad and iPod Touch users to read Kindle contents on these devices. The same as Kindle for iPhone, Kindle for Mac is free of charge as well, allowing users to read Kindle books on a Mac, this being a desktop or notebook computer.

The purpose of the research was to analyze typeface legibility on an Amazon Kindle, iPhone (Kindle for iPhone) and Mac (Kindle for Mac). These are three different devices of different screen sizes and screen resolutions, however, with the same software, displaying the same contents. The goal was to check the suitability of the displayed contents, screen characteristics and legibility of fonts.

### 2. Hardware and software

#### 2.1 Amazon Kindle

The device enables contents presentation in a specific way with no colours present (only a 16-level greyscale) and five buttons for the navigation. Amazon Kindle is based on an electrophoretic display, which forms visible images by rearranging the charged pigment particles using an applied electric field. Each particle comprises the negatively charged black plastic on one side and positively charged white plastic on the other. The spheres are embedded in a transparent silicone sheet, each sphere being suspended in an oil bubble enabling free rotation. The voltage polarity applied to each pair of electrodes then determines whether the white or the black side is face-up, giving the pixel white or black appearance.

On Amazon Kindle, the contents can be shown in different file formats (.pdf, .txt, .html and .mobi); however, the default format is .azw (Amazon Whispernet), which is at the same time the format of more than 400,000 e-books, e-magazines etc available at Amazon.com (Kindle Wireless Reading Device, 2010). This format includes information that enables Amazon Kindle to show contents as text (or graphics) in a predefined typeface, eight different font sizes and three possible line adjustments.

#### 2.2 Apple iPhone

The company Apple Inc. expanded in 2007 their business into the telephony, music and video industry area. Their wide offer includes iPod players and a multimedia mobile phone



iPhone, the most recent generation of which is called iPhone 4. The latter is the newest technological achievement of mobile technology and was introduced in the middle of 2010 (Video calls, multitasking, HD video, and more, 2010). The device enables the presentation of information and contents in a special way. It is not only about the visual appearance of the applications, usage of colours and animations, but also about the selection of typography. The newest version of iPhone has a touch screen display, which is a 3.5-inch (89 mm) liquid crystal display from scratch-resistant glass. The capacitive touch screen is designed for a bare finger, or multiple fingers for multi-touch sensing. The screens of the first three iPhone generations have the resolution of 320 × 480 pixels (HVGA) at 163 ppi, while the display on iPhone 4 has the resolution of 640 × 960 pixels at 326 ppi (Video calls, multitasking, HD video, and more, 2010), which was also used for our testing.

### 2.3 Apple MacBook Pro

In the research, as a device for testing the Kindle contents on a computer, MacBook Pro was used, which is a line of Macintosh portable computers, first introduced in January 2006 by Apple Inc. MacBook Pro is currently produced in three sizes, i.e. 13", 15", and 17", and there are two display versions for MacBook Pro 15". There are standard LCD displays (for 1.83 GHz, 2.0 GHz, 2.16 GHz and 2.33 GHz models), and there are LED displays (compatible with 2.2 GHz, 2.4 GHz, 2.5 and 2.6 GHz Santa Rosa and Penryn models). In our research, a 15" antiglare display was used, with the screen resolution of 1680 × 1050 pixels (Meet the MacBook Pro Laptop Family, 2010). Currently, this is a common screen resolution for either a desktop or notebook, PC or Mac computer.



*Figure 1.: Devices used in research (Amazon Kindle, iPhone 4 and MacBook Pro 15")*

### 2.4. Software

Regardless of the device we used instead of Amazon Kindle, all of them use the same software or at least its basics. Some changes occur in scripts, since different devices have different specifications. Consequently, also the name of the software changes regarding the device we want to install to. We can choose among Kindle for Mac, Kindle for PC, Kindle for iPhone (also for iPod Touch) and Kindle for iPad. Almost on a daily basis, new software solutions are released, a brand new one being Kindle for BlackBerry and Kindle for Android (Kindle for iPhone: Read Kindle Books on your iPhone or iPod Touch, 2010).

Common characteristics of all of them is that no Kindle device is required, that we can enjoy the best reading experience, that Kindle books are easily accessible, and that they automatically synchronize among the devices with Amazon Whispersync. Whispersync is a technology which saves and synchronizes your last page read, bookmarks, notes and highlights among your devices.

To run a Kindle application on an iPhone, iPod touch or iPad only an iOS 3.0 is required. To read e-books on a PC or Mac, at least a 500 MHz Intel or AMD processor, 128MB of RAM, screen resolution of 800 × 600 pixels, Windows XP (Service Pack 2) or Mac OS X 10.5, and 100MB of available disk space is required (Gabrijelčič, 2009; Mele, 2010).

The user interface is the same for all devices. Home screen is used to display all the books we have purchased and stored into the device library, and after selecting one, we can see their contents. The latter is displayed in a full screen mode, which depends on the device display size, namely the smaller the device, the smaller the display. Another matter is the performance

of the display, and as already mentioned, Amazon Kindle uses 600 × 800 pixels at 167 ppi, iPhone 640 × 960 pixels at 326 ppi, while MacBook Pro uses 1680 × 1050 pixels (with LED backlighting).

The software is very easy to install after being downloaded from Amazon.com, as only one click is required from the installation to the point when we can start reading e-books.

### 3. Anti-aliasing

Anti-aliasing enables the user or reader to experience the same feeling by looking at a screen as they would by looking at a printed page. This method is based on the description of the font outline, considering repeated colour shades that appear against background colour. The parts where the font outline united with the background were joined using middle hue values. In this way, we can create more smooth-looking fonts, especially when using bigger font sizes (Götz, 1998; Kommer, Mersin, 2002). When working with smaller font sizes, anti-aliasing influences the entire letter, which makes the letter appear soft and blurred.

When the horizontal and vertical lines align with the pixel frame, the font looks sharp and solid; however, if the deviation from the pixel frame occurs and the font stretches over two or more lines, it seems foggy. In practice, a larger amount of text rarely aligns with the pixel frame in more than just a few parts, therefore, the rest of the text looks blurred. The quality of anti-aliasing depends on numerous factors. Software developers use various technologies, techniques and algorithms to calculate the optimal hue values for middle colour values of anti-aliased font outlines (Gillespie, 2010).

Due to the conformity with the pixel frame, the pixel fonts adjust to the screen, and there are no anomalies or worse readability of the text, respectively. With other fonts, it is just the opposite. The letters are made also of lines which are different from the angles 0°, 45° or 90°, which requires additional adjustment (Gillespie, 2010). The letters the parts of which do not align with the pixel frame require additional time for processing and additional capacity of the device. The adjustment is mostly made with the use of colour and shade that make the edges appear smooth. Therefore, from 16 to 20 intermediate shades of grey colour are used for such smoothing for a black letter on white background, which gives the letter the right image to be viewed from a normal distance. The process is the same for colour versions of font and background. This is possible only if the screen of the device supports 16-byte colour display. If the screen shows 8-byte display or only 256 colours (Götz, 1998; Kommer, Mersin 2002; Zwick, Schmitz, 2003), all intermediate shades are lost and replaced with colours that correspond to the so-called web palette.

The suggested solution is completely acceptable for large-sized fonts and bold versions; the problem between the pixel frame and font appears when decreasing the font size. However, iPhone has already took a step further in this field and designed the so-called Retina Display (cf. Figures 2 and 3), in which the engineers at Apple were able to pack four times the number of pixels into the same 3.5-inch (diagonal) screen found on earlier iPhone models. The resulting pixel density on iPhone 4 (326 pixels per inch) makes the text and graphics look smooth, and continuous at any size (Learn about the High-Resolution Retina Display, 2010).

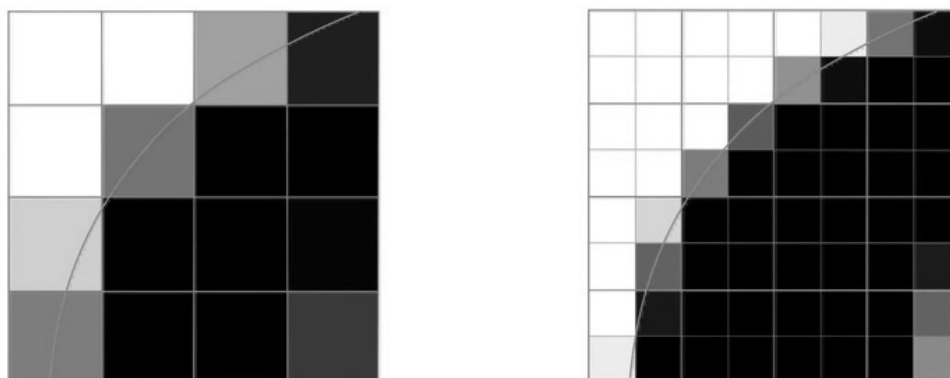


Figure 2: Magnified view of arrangement of individual pixels on pixel frame for letter “a” on earlier iPhone models (left) and new iPhone 4 model with Retina display (right)

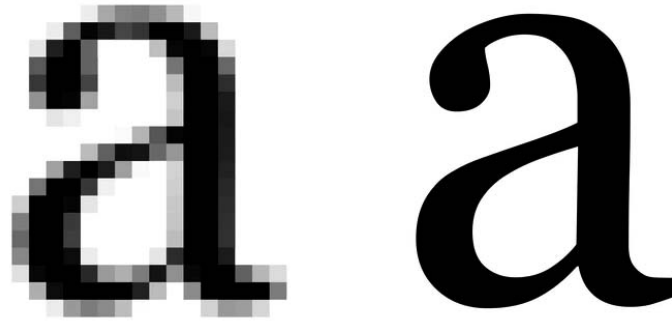


Figure 3: Normal view of letter “a” on earlier iPhone models (left) and new iPhone 4 model with Retina display (right)

#### 4. Methods

Different devices and different screen sizes were the reason for our research. We wanted to check the suitability of individual text sizes regarding the device, screen and displayed contents. Kindle software application enables the adjustment of the text size, addition of bookmarks and the overview of annotations we created on Kindle. Besides the text size adjustments, which can make reading more comfortable, we can change the colour of the text and background (only on iPhone, iPod Touch or iPad). We can choose between *black* (black letters, white background), *white* (white letters, black background) and *sepia* (dark brown letters, light brown background). Since colour modes are not available on Amazon Kindle (due to the 16-level greyscale) and Kindle for Mac, we tested only the black (black letters, white background) option (cf. Figure 4).

The purpose of the research was to establish whether devices with small screens are competitive with bigger-screen devices, and what factors influence such a decision. The research was conducted through an experiment, testing legibility and text comprehension. The comparison of devices was performed with Amazon Kindle, Apple iPhone 4 and Apple MacBook Pro, showing different texts with the same contents in three text sizes, but in the same colour mode. Amazon Kindle has the possibility for eight, Kindle for iPhone five and Kindle for Mac ten different text sizes. Nevertheless, we decided to test three of them. First, we selected the middle value and called it “normal”, and then we chose one text size smaller (called “small”) and one larger (called “large”) than the “normal” value. On each device, we measured the time of reading and how well the text was comprehended.

The research was undertaken among a group of people ( $n = 17$ ), male and female, aged 21–50 with different knowledge of technology, typography and with various reading habits. A diverse group of people allowed us to draw conclusions that are more representative. The collected data were analyzed and statistics were elaborated with the interpretation of the gathered data.

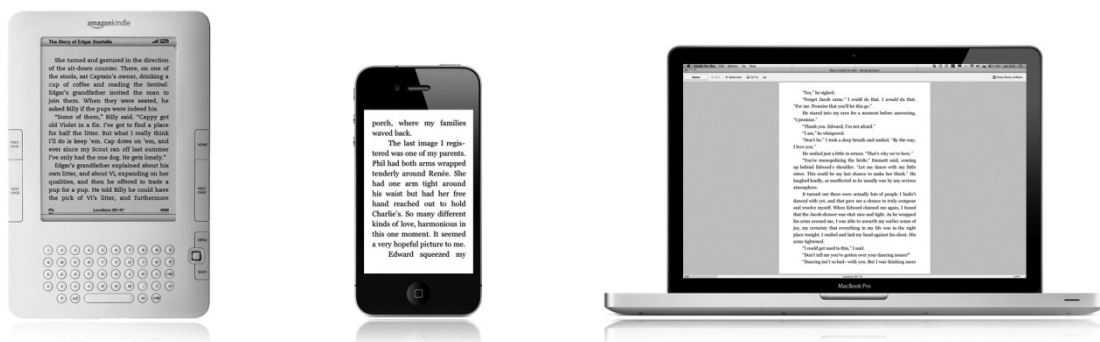


Figure 4: Example of Amazon Kindle, Apple iPhone 4 and MacBook Pro screens, showing different texts with same contents at “normal” text size and in black colour mode

## 5. Results and discussion

The survey was conducted among a group of people, almost equally represented by both genders (47% male, 53% female). 23.5% of interviewees were aged 21–25, 17.6% 26–30, 23.5% 31–35, 17.6% 36–40 and 5.9% 41–45 years. The remaining 11.9% was represented by interviewees aged 46–50 years. In accordance with our expectations, the results revealed that the majority of interviewees are familiar with all devices, since the use of them was not problematic.

The next question examined the opinion of the default typefaces. The results revealed that the selection of typefaces for electronic devices is a well thought-out decision, based on many trials and research. While all interviewees believed that the selection of typeface matters, 64.7% of them were satisfied with the default typeface used on Amazon Kindle, 76.4% on iPhone and 88.2% with that on MacBook Pro (cf. Figure 5). In contrast (cf. Figure 6), on average 17.6% thought the combination of the typeface and background to be excellent, 70.6% good and 11.8% decent, which leads to the conclusion that the combination of the typeface and background is appropriate and considerably influences text legibility.

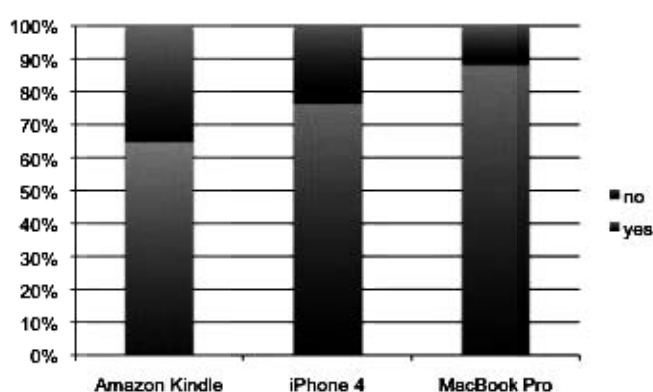


Figure 5: Satisfaction with default typeface

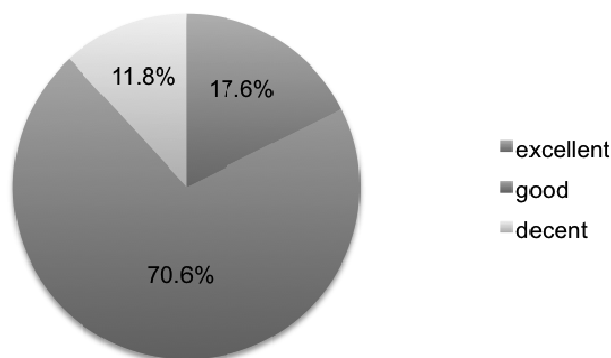


Figure 6: Combination of typeface and background

Text legibility and reading comprehension were tested with time measuring and questions regarding the contents. The text (different texts with the same contents and of similar length) was displayed in three different text sizes.

The text classified as “small” in size (cf. Figure 7) was read on Amazon Kindle in 16–20 seconds by 29.4% of interviewees, while the same percentage of interviewees read the contents in 31–35 seconds. The rest read the contents in 21–25 and 26–30 seconds (17.6% each), and 5.9% in 36–40 seconds. On iPhone, the text was read in 16–20, 21–25 and 31–35 seconds by the same percentage of interviewees (23.5% each), in 26–30 seconds by 17.6% and in 36–40 seconds by 11.9%. On MacBook Pro, 47.1% of interviewees read the text in 16–20 seconds, 29.4% in 21–25 seconds, 17.6% in 26–30 seconds and 5.9% of interviewees in 31–35 seconds.

The results for the text “normal” in size (cf. Figure 8) on Amazon Kindle were: 16–20 seconds by 41.2%, 21–25 seconds by 35.3% and 26–30 seconds by 23.5% of interviewees. None of the interviewees needed more than 30 seconds to read the contents on Amazon Kindle. On the other hand, on Kindle for iPhone, 5.9% of interviewees read the contents in 31–35 seconds, 23.5% in 26–30 seconds, and the rest in 21–25 and 16–20 seconds (35.3% each). On Kindle for Mac, the contents were read even faster, since 64.7% of interviewees read it in 16–20 seconds and the rest 35.3% read it in 21–25 seconds.

The contents displayed in the text size “large” (cf. Figure 9) were read on Amazon Kindle by the same percentage of interviewees (35.3%) in 16–20 and 21–25 seconds. The rest read the contents in 26–30 (23.5%) and in 31–35 seconds (5.9%). On iPhone, there were more interviewees who needed a longer period time to read the contents, as 23.5% of them read it in 26–30 seconds and 17.7% in 31–35 seconds. On MacBook Pro, the contents displayed in the “large” size were generally read faster than on the other two devices, for 52.9% of interviewees read the text in 16–20 and 35.3% in 21–25 seconds. The rest (i.e. 11.8%) needed between 26 and 30 seconds.

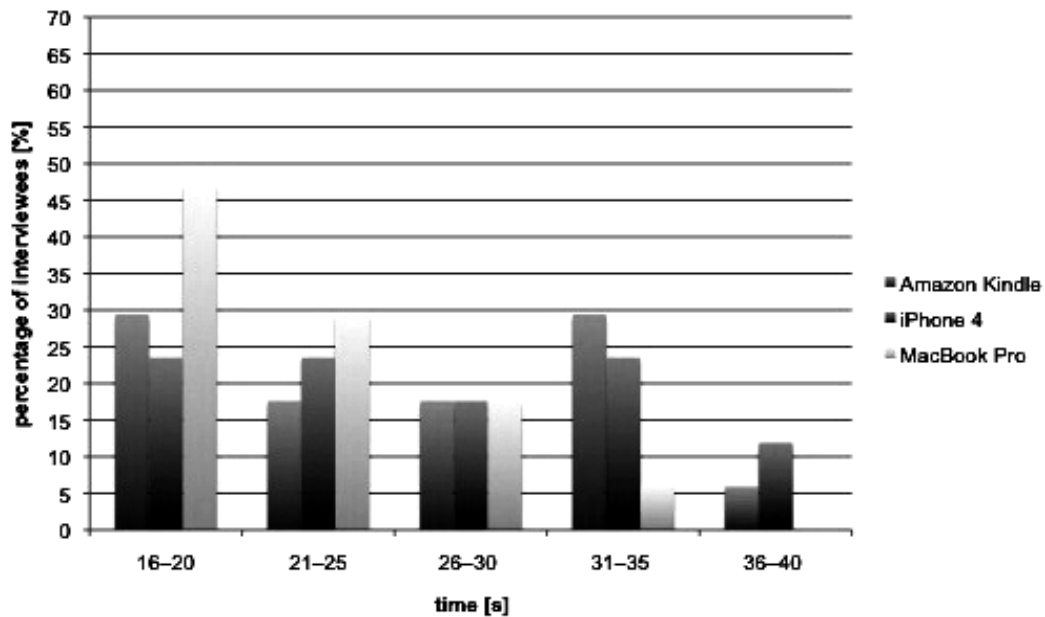


Figure 7: Text legibility on devices using text size “small” tested with time measuring

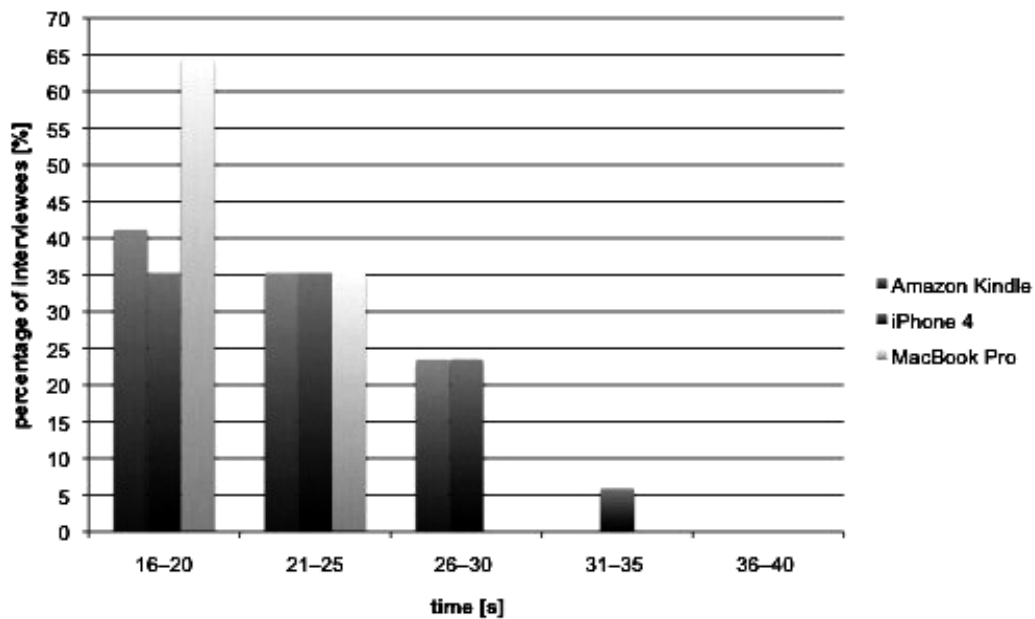


Figure 8: Text legibility on devices using text size “normal” tested with time measuring

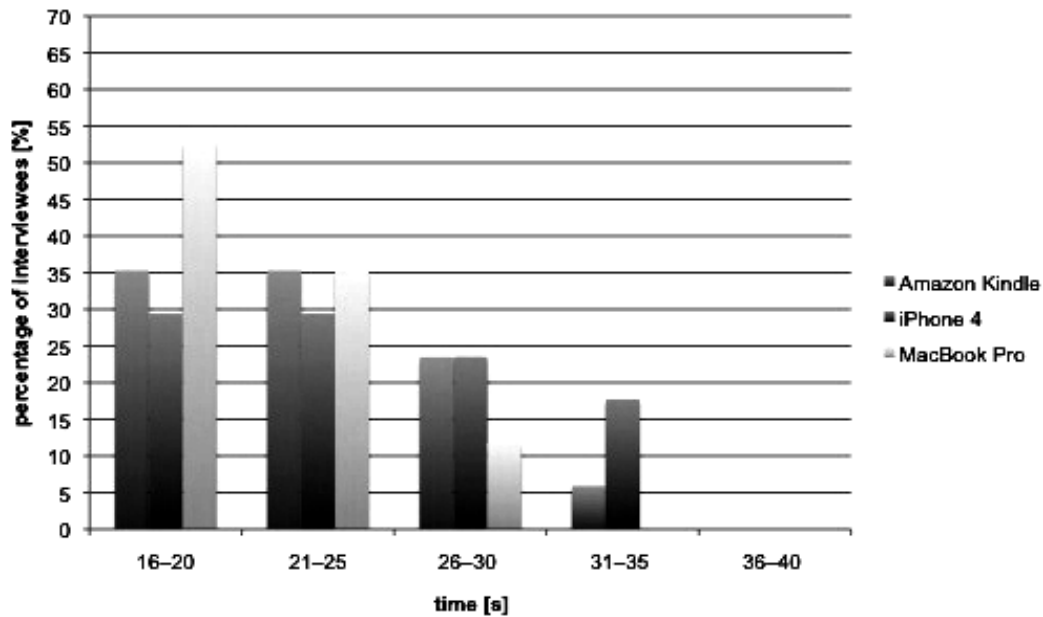


Figure 9: Text legibility on devices using text size “large” tested with time measuring

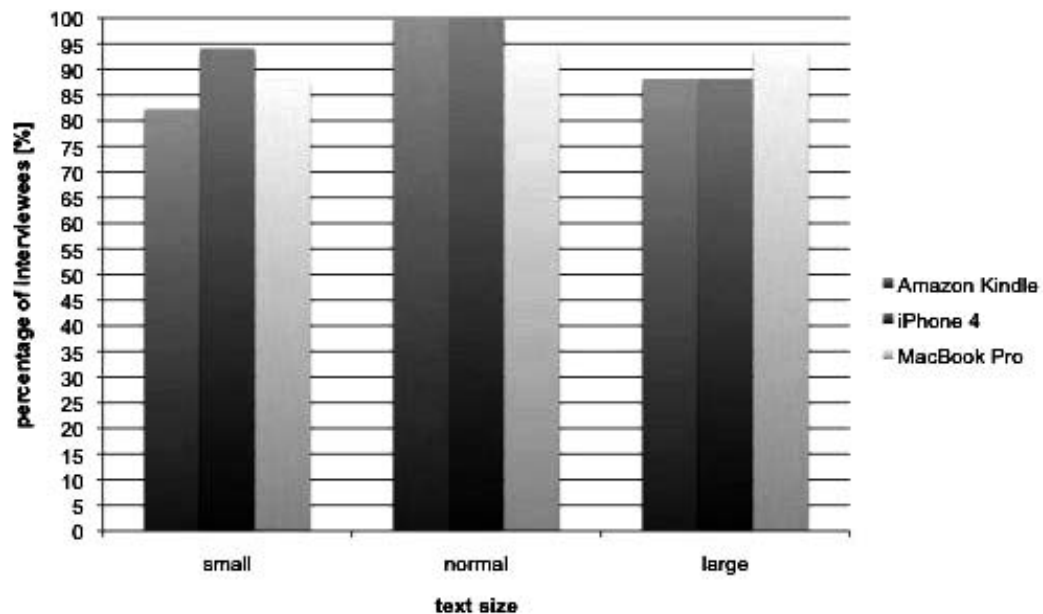


Figure 10: Percentage of interviewees answering correctly text comprehension questions

After the time measuring for each text size, a set of questions regarding the read contents were posed. The results of text comprehension were rather expected (cf. Figure 10). For the text size “small”, 82.3% of interviewees answered correctly after using Amazon Kindle, 94.1% using iPhone and 88.2% MacBook Pro. For the text size “normal”, all answers were correct after using Amazon Kindle and iPhone, and 94.1% answered correctly after reading the contents on Kindle for Mac. The questions regarding the contents were displayed in the size “large”, 88.2% of interviewees answering correctly after using Amazon Kindle and iPhone, and 94.1% after using MacBook Pro.

The results of correctly answered questions are similar to the time measuring results for different text sizes. The highest number of correctly answered questions was given after reading the contents in the text size “normal”, which was also the size, when the contents were read the fastest. Slightly fewer correct answers were given after reading the contents in the text size “small” and “large”, as this were also the sizes when the reading time was slightly longer than for the text “normal” in size.

## 5. Conclusion

The results show that in general, the contents displayed in the text size “normal” were read slightly faster on all devices than the contents displayed in “small” and “large”, which proves that setting the middle text size value as “normal” was correct. From the results, it can also be seen that the screen size, as well as the screen resolution is important for comfortable reading, since the reading time on iPhone was on average slightly longer than on the other two devices. Bigger screen sizes can improve legibility or even reading comprehension; however, that does not mean that on smaller screens, e.g. iPhone, the reading experience is substantially impaired. Due to the devices with bigger screens having some advantages regarding the reading experience in comparison to smaller devices, the portability factor needs to be considered as well. iPhone is easily portable; however, it does have some reading disadvantages associated with a smaller screen size. On the other hand, while MacBook Pro provides the best reading experience, it is less portable-friendly. This may lead to the conclusion that the best choice would be Amazon Kindle, which is easy to carry around and generally gives very satisfying reading results.

For our research, this might be the conclusion; nevertheless, it is important to know that we have not only conducted the analysis of the current situation, but also of the future, which is already bringing us new, easily portable products with large screens, long-lasting battery life (very important in the effort to near e-book readers to normal books) and entertainment options, which make the reading experience even more interesting.

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## DESIGNING THE GRID SANS REGULAR WITH TITLING ALTERNATES

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**Abstract:** *Some technological influences, such as: the fast turning printing presses, and before that, letterpress technique, both made different demands for type designers to design peculiar typefaces for newspapers printing process. But technological influences also forced them into avant-garde design projects, and the perfect example of it is still Herbert Bayer's Universal type inspired by bent plywood and tubular steel Marcel Breuer's designs, and never the fewer elementary constructivist principles which also guided Paul Renner into designing Futura. Furthermore, later modernist idea followed with general modernistic growth advocates clarity with so-called invisible typefaces. Studying the works of all the modernist heroes, and later the heroes of postmodernism, along with all their attempts to create a universal typography in a various sense, I have been prompted to endeavor to design a ultimate sublimation of all ideas and aspect of universality in one single font named Grid.*

**Key words:** *Universal typography, legibility, readability*

### 1. Introduction

My very first thoughts after the close observation of Bayer's Universal type and Renner's first Futura trials, was that the modernist approach must be reformed. If I want to design a contemporary typeface, I must move away from calligraphic heritage, that was also Renner's thoughts, but after his big steps nothing else has been done.

Our printing type is not the expression of a movement like hand writing; every thing deriving from a left-to-right dynamic, all thicks and thins, which only entered into script with quill, make no sense in printing type. (Renner, 1927)

All those Grotesque and Neogrotesque fonts from the end of the 19th century were not designed with the modernistic approach. All of them had the unbeatable core in the ductus, and as a matter of fact nowadays fonts still have the same core. The most popular typefaces from late modernism through the postmodernism to the digital era were so-called Human Grotesque (from Frutiger to Calibri) which was introduced in 1930 by the traditionalists (Gill Sans). After all the efforts that were made in early modernism, we are stuck in a long dialectical interval with "Antiqua Linealen".

"The impression of our printing types is not thrown onto the paper from left to right like handwriting; rather it descends with an impression from above. The script of the future will have to be honest expression of all these technical processes". (Renner, 1927)

If we understand circumstances of our time – as Renner understood the technology from the beginning of printing type – with all those gadgets and our ultimate DTP machines, what more can I say in addition to this explanation?

Renner succeeded in his basic attempt to reflect geometrical structure of the capitals on the small letters. The combination of capitals derived from the ancient inscriptional forms and the small letters developed from cursive writing shapes was so different for such a long time. His approach was so different, so analogical. He designed glyphs with perfect balance in two different alphabetical cases, he curtailed lowercase and defer them to the governed capitals. Finally that made such a big difference from Futura and the others typefaces of the period.

But Renner failed in his another basic attempt which is noticeable in his very first Futura trials and articles. (figure 1) In the article of 1930 entitled 'The problems of form in printing type' he revealed an observation of optical phenomena in typefaces. He was very keen on his own earlier statements and attempts to design monolinear typeface. (Burke, 1998)

Furthermore, we demand from a printing type a regular, pearl grey; no letter should be blacker than any other and no part of a letter should appear as a fleck. This grey on the opened pages of a book arises from the optical mixture of black letterforms with white paper.

... Generally, where two heavy bars intersect at a right angle or meet in pointed angle, a zone forms that is not lightened by irradiation, or less strongly so. Dark flecks arise; one can notice them in almost all printing types. Only a few designers and punccutters succeed in avoiding them. (Renner, 1927)



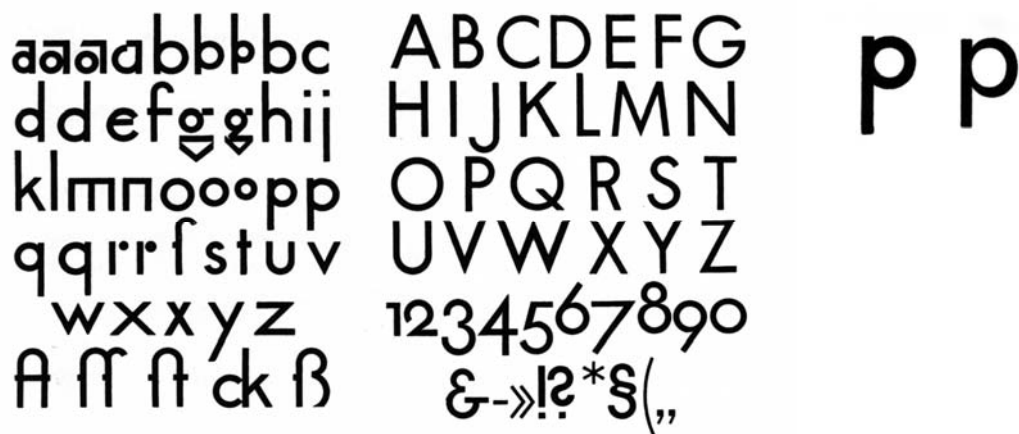


Figure 1

Besides all those constructivistic experimental glyphs, monolinearity in the Futura first design trials is pervasive. Calligraphic heritage was dismissed in every aspect but the technical core of these glyphs, the absence of thin stress and junctions were later rejected (right image).



Figure 2

Probably the prime example for all authors of Modern Grotesque typefaces was Sütterlin-Schrift, a model for schoolchildren handwriting, and as a matter of fact Renner was involved in the campaign to replace it in Munich schools with the more geometric model. (Burke, 1998)

## 2. The Method

The huge efforts had been made to establish modern Grotesque as the only truly modernistic type, yet the rules for legibility continue to proliferate. The ideal sans serif was not there yet – although Paul Renner's Futura was a step in the right direction, it didn't fit the essence of the 'New Typography'. The essence of the New Typography is clarity.

All the attempts up to now to produce a type for our time are merely 'improvements' on the previous sans serifs: they are still too artistic, too artificial, in the old sense, to fulfil what we need today. (Tschichold, 1928)

Jan Tschichold in his book *The New Typography* traced the path for the new generation of Swiss typographers who followed the essential principles as a blind doctrine. The typeface used for the typesetting of the book was Akzidenz Grotesk. Tschichold was satisfied with it and recommended it as the best readable sans serif typeface of the time. Furthermore, the generation of Swiss typographers accepted the Berthold's typeface from the 1898. as the recommendation of their "highest priest".

In 1950s Adrian Frutiger started a revolutionary project of universal typography. Once again universality was considered but from a different point.<sup>1</sup> Adrian Frutiger designed Univers as a grid of possibilities contained within a single type family. In place of Bayer's attempt to economize with fewer characters, Univers expanded outward, aiming to solve numerous typographic problems within a single, coordinated system, building letters along a spatial grid of variables. (Lupton, 2006) Frutiger's design of Univers was the answer to the demand as well as it was Helvetica (Eduard Hoffman, Max Miedinger) at the same time. These two typefaces were actually an improvement of Neo-grotesque form, both referring to Akzidenz Grotesk as the almost ultimate font and actually they were two derivatives of it.

Readability was followed simultaneously by both modernists and traditionalists. Both wings accepted "invisible typefaces" as the best readable. But, according to a Swiss style, every typography should work on the same principle that the typeface shouldn't be in use if it expresses something, particularly if it expresses spiritual matters, and that was the unique quality of Neo-grotesque novelty.

When I started with first drawings, I had a several goals in my mind. In the essence of the Grid font should be universality, that has been my main goal. I have striven to study universal typography in every sense, and that has prompted me to start with the design of the project which will be (one day) an ultimate sublimation of all ideas and the aspect of universality in one single font named Grid. So I have considered Bayer Universal type as a certain postulate; My first attempts have been to design an unicas font (figure 3) and that has been easy. I have just followed with the principles I published and presented on Grid '08 symposium. (Nedeljkovć, 2008) But at the same time I have had to define some basics; Basic glyphs and groups for the Grid font. I believe (still with no experimental proof), that types designed with the principle of elementary constructivism we cannot consider that is readable for a body text because they have a very large base group of glyphs which are also very wide, and designed on an aesthetic principle of the harmony of similarity.



*Figure 3: Word typeset in Grid Unicas.*

Therefore the reading problems have come with difficulties with recognizing characters especially when they are so close to each other (figure 4). (Nedeljkovć, 2008)



*Figure 4: Words typeset in Futura.*

Consequently the basic shapes of the Grid font have been designed in attempt to form a large number of compound shapes (figure 6) which can produce a functional glyphs. Yet for the regular font which is intended for a body text I have decided to remove a lowercase 'a' from the base group 1 (figure 5) for the reason I have mentioned above. According to any other Modern Grotesque typeface Grid sans has a narrower loops, which makes it difficult to observe through such kind of a prism, but it makes it easier to read.

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<sup>1</sup> Universality of Bayer's Universal type was followed with futile orthographical reform of typography.

Figure 5: Base group 1

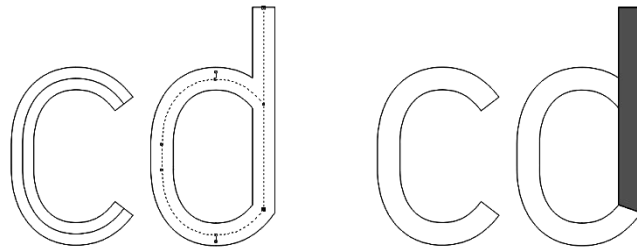


Figure 6

I have been delighted with the intentions of Renner of producing monolinear typefaces. Truly monolinear fonts are still very rare, and it's just because of the bad humanistic habitude which type designers cannot rid of. I have mentioned above about the popularity of Human Grotesque, there are so many beautiful of them; But! One of the reasons why there is a constant demand for new typefaces is the fact that we get used to the peculiarities of older typefaces. What you see too often doesn't work anymore. This is how typefaces play their double role we're fed up with them. (Unger, 1992) Frutiger, probably the most legible typeface, has been designed for the signs of the Charles de Gaulle Airport in Paris in 1968 by Adrian Frutiger, and it has become the model for almost all later Human Grotesque forms. Nowadays there are so many of them very similar to Frutiger that we could almost come with a new group named after him.

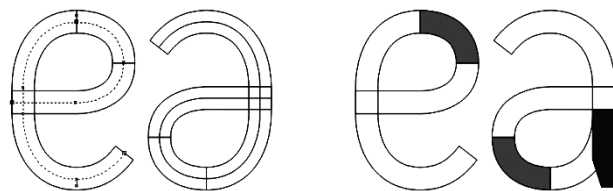


Figure 7

In a lowercase character "e" and "a", are the best examples of compounding shapes (strokes). All the characters are developed on the same matrix. Strokes are just welded and expanded when they have been done well.

Every designer has particular habits that ooze through into the typeface designs: typical curves and corners, idiosyncratic transitions from thick to thin, a personal approach to endings, a peculiar movement through-out all letters and elements. (Unger, 1992)

The ideas of the type designer dipped in the styles of the times, which help define characteristics of the letters. (Unger, 1992) Typefaces which could probably best fit our times are those with more technical face such as Klavika (2004) by Eric Olson, Neo Sans and Neo Tech (2004) by Sebastian Lester, Geogrotesque Regular (2009) by Eduardo Manso and, truly monolinear FF Netto (2008) by Daniel Utz. In the Grid sans I have striven for monolinearity and managed to avoid changing thickness in junctions. However, there are no junctions, actually I have done it the same as Daniel Utz did but unlike FF Netto, Grid sans has those chin strokes

from the capital 'G'. That has been done in favor of readability. (figure 7) Chin stroke has become a compound shape on all the letters where it has been put to ensure better legibility (figure 8).



*Figure 8: Base group 2*



*Figure 9: Base group 3*



*Figure 10: Base group 4*



*Figure 11: Base group 5*

The second aspect of universality which I consider is the opportunities being started with Univers font family. But nowadays we have an infinitive cosmopolitan idea. A single, coordinated system for building letters in different typeface styles in a spatial grid of variables today is being proliferated in Unicode system. Whereas the ASCII standard has room for only 256 characters, Unicode promotes both globalization and localization, allowing Web browsers, word processors, and other applications to recognize and transmit thousands of different characters. [Unicode 4.0 is said to encode 96,248 characters] This allows written languages with smaller user groups to not only survive locally but to be exist across the face of the entire planet. (Lupton, 2006)

Unicode will never completely map the linguistic terrain, as there will always be new characters. This universality, again, is an open one: universal without totality. (Lupton, 2006) Yet

[illegible]

BB DD JJ  
PP RR aa

### 3. Conclusion

In forthcoming experimental testings in the field of legibility of didactic resources and teaching aids in service of improvement cognition, the good results are predictable because the letters have been formed as an eclectic mixture of former forms of Grotesque, that should

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ensure that the font remains striking and readable at the same time, but not invisible. The final process of understanding of the read, Gerard Unger illustrated in the beautiful rhetorical figure: "The black, printed letters dissolve in your minde like an effervent pill in a glass of water. For the short moment, all those black signs disappear off the stage, change their outfits and return as ideas, as presentations, and sometimes even as real images". For that I am counting to happen every time like visual mneme based on both graphemic and semantic criteria when students follow the same sentences in the same typography in different kinds of didactic resources and teaching aids during the learning process (Kolers, 1973).

ABCDEFGHIJKL  
MNOPQRSTUVWXYZ  
abcdefghijklm  
nopqrstuvwxyz  
0123456789  
! ? & @ \* \$ € # ™ © ®  
% = + - × ÷ ° < >  
() [] {} " ' " ' . .  
, , . ,

Figure 14: Grid Sans Regular with titling alternates.

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## INFLUENCE OF EFFECT PIGMENTS BASED ON SiO<sub>2</sub> FLAKES PRINTED ON SYNTHETIC PAPER ON THE COLORIMETRIC VALUES

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**Abstract:** The investigation was focused on the influence of effect pigments based on silicon dioxide flakes (SiO<sub>2</sub>) on the colorimetric values and print gloss. Two effect pigments were used: Colorstream T10-01 and Colorstream T10-03, which were overprinted on dried CMYK offset inks. As a printing substrate, a fiber synthetic paper was used. The properties of prints were determined with the measurements of CIELAB values before and after applying effect pigments on CMYK offset inks. On the bases of those measurements the differences in colour, chroma and hue have been calculated. The estimated results show that the colorimetric values and print gloss of overprinted CMYK offset inks by effect pigments varies with the observation at different angles. The most obvious differences in color and in hue of CMYK offset inks were seen at angle of 15° at both overprinted pigments, while the differences in chroma changed the most at observation angle of 25°. The overprinted effect pigment Colorstream T10-03 resulted in the higher print gloss than Colorstream T10-01 at all CMYK offset inks.

**Key words:** effect pigments, silicon dioxide (SiO<sub>2</sub>) flakes, offset prints, synthetic paper, colorimetric values, print gloss.

### 1. Introduction

Ultraviolet light (UV) reactive ink jet printing has become well known as a reliable printing method for graphic printed products. Areas of interest for UV ink jet are also packaging materials. Advancement in ultraviolet (UV) curing technology, i.e. the processes of transforming a liquid into a solid by using UV light, is responsible for some of the recent changes in the printing industry. Some advantages are: inks do not dry in the nozzles, they have good adhesion to non-porous substrates and they do not have high volatile organic solvent emissions. After printing there is a cure stage, where photoinitiators interact with the UV light to form free-radicals, which then attack double bonds in the acrylate monomers creating a coloured image polymeric coating (Hartley, 2009). Once the UV light comes in the contact with the ink, polymerization occurs instantaneously, unlike polymerization with oxidation inks which takes several hours to cure (Hoff, 1997). Cured UV inks offer vibrant, high opacity, high gloss color, and superior print definition on a variety of substrates, including packaging materials (Kipphan, 2001). UV printing has become pervasive in the label printing market and is a good choice for applications like luxury cosmetics and wine labels (Hershey, 2007).

Synthetic papers are being used as multi-layer bags of high strength, outdoor tags, labels and flexible packaging materials for many applications. Their usage in the pharmaceutical field is expected to increase, especially with the products that are known to have a high and expensive pilferage rate (Polischuk, 2008).

### 2. Methods

In this study, two different effect pigments, both based on synthetically manufactured silicon dioxide platelets coated with titanium dioxide, were examined: Colorstream T10-01 Viola Fantasy (further as Pigment 1) and Colorstream T10-03 TropicSunrise (further as Pigment 2), manufactured from the Merck company. These pigments were overprinted in offset technique on dried CMYK inks on fiber synthetic paper Pretex.

The colorimetric and print gloss measurements were performed on the paper printed in offset technique. CIEL\*a\*b\* values before and after applying effect pigments on CMYK inks were measured by X-Rite MA68II multi-angle spectrophotometer. Measurements were made at 15°, 25°, 45°, 17° and 110°. On the bases of those measurements the differences in color, chroma and hue have been calculated between CMYK offset inks (standard) and overprinted pigments on them (trial).



The total CIELAB color difference,  $\Delta E^*_{ab}$ , is given by:

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2},$$

where:

$$\Delta L^* = L^*_{trial} - L^*_{standard}, \Delta a^* = a^*_{trial} - a^*_{standard}, \text{ and } \Delta b^* = b^*_{trial} - b^*_{standard}$$

The chroma difference,  $\Delta C^*_{ab}$ , is given by:

$$\Delta C^*_{ab} = C^*_{ab,trial} - C^*_{ab,standard}$$

The hue difference,  $\Delta H^*_{ab}$ , is that part of the color difference that is left after accounting for lightness and chroma differences and is given by:

$$\Delta H^*_{ab} = [(\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*_{ab})^2]^{1/2}$$

The sign h is positive if the hue angle of the trial is higher than that of the standard and is negative if the hue angle is smaller than that of the standard (Nassau, 1998).

The print gloss was measured according to the ASTM D523 standard at angles of 20°, 60° and 85°, using GlossMaster.

### 3. Results

The research was focused on the influence of overprinted pigments on the colorimetric values of CMYK inks and print gloss.

#### 3.1 Differences in colorimetric values

In Figures 1-3 the color, chroma and hue differences between CMYK offset inks and overprinted pigments on them are presented.

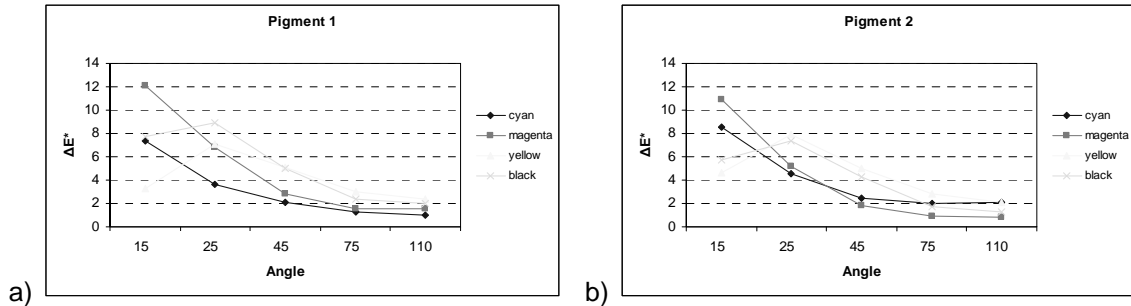


Figure 1: Color differences between CMYK offset inks and overprinted effect pigments on them: a) Pigment 1, b) Pigment 2.

Colorstream pigment is one of the second-generation innovative types based on thin flakes of silica ( $\text{SiO}_2$ ). A characteristic of the Colorstream effect pigments is the “flowing” play of colors that is dependent on the angle of observation and the incidence of light (Measuring special effects, website). In our experiment significant discrepancies between the different observation angles were noticed, too. Figure 1 shows that the most obvious color differences between CMYK offset inks and both overprinted effect pigments on them were seen at angle of 15° and the smallest at angle of 110°. Both pigments overprinted on magenta and cyan offset inks obtained the highest color difference at angle of observation of 15°, while overprinted on yellow and black offset inks at angle of 25°. In the case of overprinted cyan and magenta offset inks, the color differences decrease at higher observation angles. Color differences of overprinted yellow and black offset inks increase till angle of 25° and then decrease.

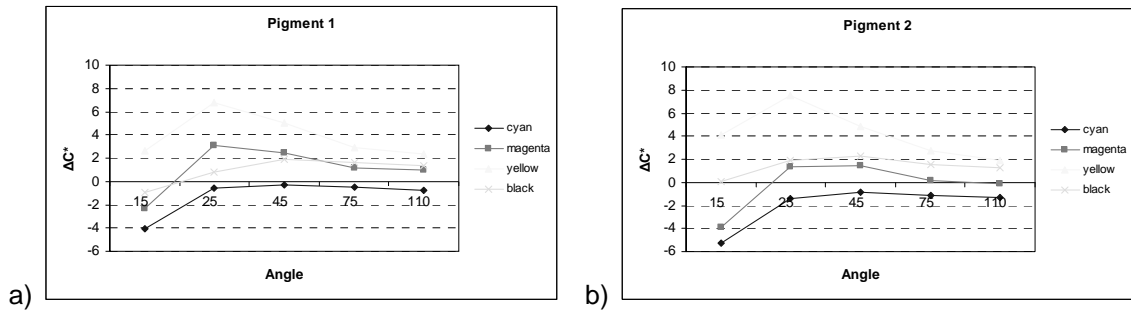


Figure 2: Chroma difference between CMYK offset inks and overprinted effect pigments on them: a) Pigment 1, b) Pigment 2.

A color's purity describes its chromaticity or chroma. This property of color tells us how pure a hue is. That means there is no white, black, or gray present in a color that has high chroma (*Color Glossary*, website). The influence of multi-angles measurement on chroma differences between CMYK offset inks and overprinted pigments on them has shown the highest deviation at observation angle of 25°. Chroma difference was the most noticed at yellow offset ink. Cyan offset ink has a lower chroma as other inks. A negative value of  $\Delta C^*$  indicates that the trial (overprinted CMYK offset inks by effect pigments) has a lower chroma and a positive value indicates that the trial has a higher chroma (Nassau, 1998). On average Pigment 2 had greater influence on chroma differences than Pigment 1.

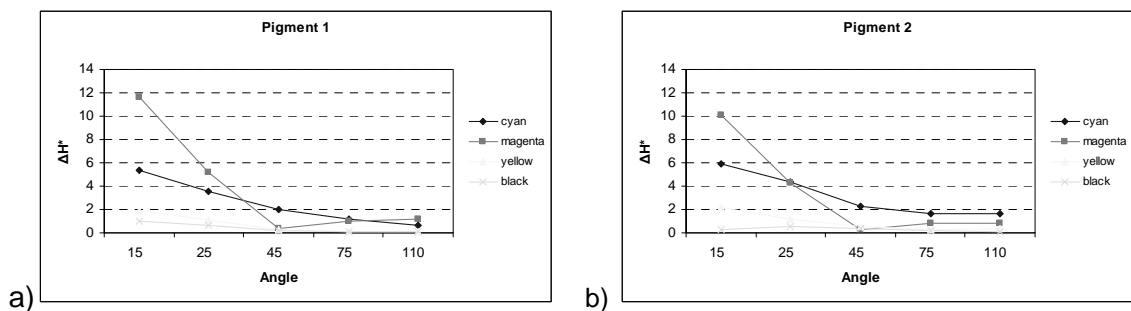


Figure 3: Hue difference between CMYK offset inks and overprinted effect pigments on them: a) Pigment 1, b) Pigment 2.

As can be seen from the Figure 3, the hue difference between CMYK offset inks and overprinted effect pigments on them varies with the measurement at different angles. The difference in hue was noticed the most at observation angle of 15°, and the least at angle of 110°. At magenta offset ink the highest hue difference was observed. Hue differences for yellow and black offset inks are only imperceptible.

### 3.2 Print gloss

Print gloss is the property of a printed surface to reflect light specularly, which imparts the surface shiny appearance. Gloss can increase after printing by applying an overprint varnish or lamination and is also influenced by effect pigments (Romano, 1999). Print gloss of CMYK offset inks without and with overprinted pigments measured at 20°, 60° and 85° is presented in the Figure 4.

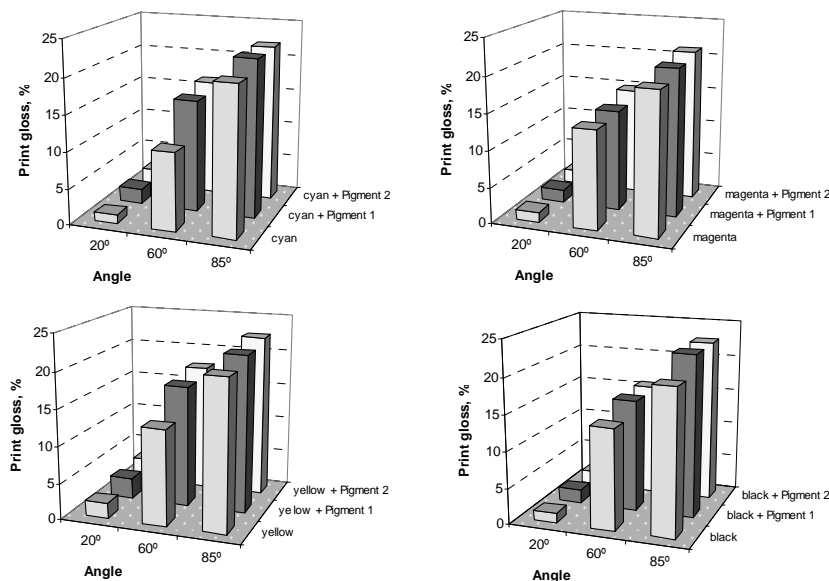


Figure 4: Print gloss at 20°, 60° and 85° of CMYK offset inks without and with applied pigments on them.

Different measurement angle gives a different result of print gloss as can be seen in Figure 4. By increasing the angle also the print gloss increases. It was found that yellow offset ink obtained the highest print gloss (2.13 at angle 20°, 13.13 at angle 60°, 20.63 at angle 85°), while cyan offset ink the smallest (1.20 at angle 20°, 10.8 at angle 60°, 20.43 at angle 85°). After printing the pigments on dried CMYK offset inks, the print gloss increased. Pigment 2 contributed to a little higher print gloss than Pigment 1 at all CMYK offset inks. In the case of both overprinted pigments on yellow offset ink, the values of print gloss were the highest, while on magenta offset ink the smallest.

#### 4. Conclusions

In the present study was confirmed, that colorimetric values of overprinted CMYK offset inks by effect pigments varied at different observation angles. The most obvious color and hue differences after applying effect pigments on CMYK offset inks were seen at angle of 15°, while the chroma changed the most at observation angle of 25°. The highest color differences were noticed at black offset ink overprinted by Pigment 1 and on yellow offset ink overprinted by Pigment 2. Chroma difference was the highest at yellow offset ink, while hue difference was the highest at magenta offset ink overprinted with both pigments. It was also established that both overprinted effect pigments improve print gloss of offset prints to some extent. The highest print gloss gave overprinted yellow offset ink. Pigment 2 contributed to higher print gloss.

#### Acknowledgement:

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# THE COLOUR MAPPING METHOD BASED ON THE LCH COLOUR SPACE FOR SIMULATING TEXTILE PRINTED TEXTURE IMAGES

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**Abstract:** In nowadays graphic industry, the implemented colour management system ensures highly accurate visual match between the printed reproduction and the soft proof. However, in textile industry, custom soft proofing using solid colour patches is not suitable for the texture samples (especially heavy-textured) due to their spatial colour non-uniformity. In order to achieve the high colour fidelity visualization of the printed textile products on the display, the colour mapping of solid (uniform) colours to various texture patterns should be applied. In this study, a colour mapping method is developed based on the spatial and statistical (histogram) distribution of the luminance (L), chroma (C) and hue (H) channels (CIE LCH colour space). The original textile samples with three different texture patterns were simulated using the developed colour mapping method and the results were compared with the ones that are obtained using the gray-to-colour mapping method (GCM). Measured CIELAB colour difference values ( $\Delta E_{94}$ ) indicate that the colour mapping method based on the LCH colour space has better performance in the terms of image similarity between the target and the generated texture images. Same conclusion is confirmed with the visual evaluation of the original and the simulated samples. Based on the results, the satisfactorily precise soft proof of the printed textile products can be obtained using the LCH colour mapping method with a texture pattern and a target solid colour as the input parameters.

**Keywords:** colour mapping, texture simulation, pattern

## 1. Introduction

The colour management system (CMS), assuming that all the input and output devices included in the system are properly calibrated and characterized, ensures the colour accuracy through the whole colour reproduction workflow. In these circumstances, soft proofing is highly reliable in predicting appearance of the colour printed on a paper. The fundament of CMS are ICC device profiles, obtained by spectrophotometric measurements, which store information how color characteristics of specific device are mapped within the CIE Lab colour space (Homann, 2009).

In textile industry, the colour accuracy has the same importance as in the paper printing industry. However, despite the existence of the colour management system, soft proofing can't give satisfying results. The reason for that is in spectrophotometric measuring technology, where a spectrophotometer measures the summation of an input light reflected from the certain part of printed surface and gives for the result the average colour of that part (Xin and Shen, 2006). As a consequence, the same measurement results are possible to obtain from textured substrates with different appearance, which means that the soft proofing is not suitable for non-uniformly coloured substrate. The inadequacy of custom soft proofing technique based on solid colour patches is even more noticeable in the case of heavily textured textiles, since their colour appearance is highly influenced by spatial colour distribution (especially luminance distribution) (Xin and Shen, 2006). In order to provide simulation of colour appearance on specific surface, methods for mapping solid colours to different texture patterns are developed. The algorithm of colour mapping on texture samples is shown in Figure 1.

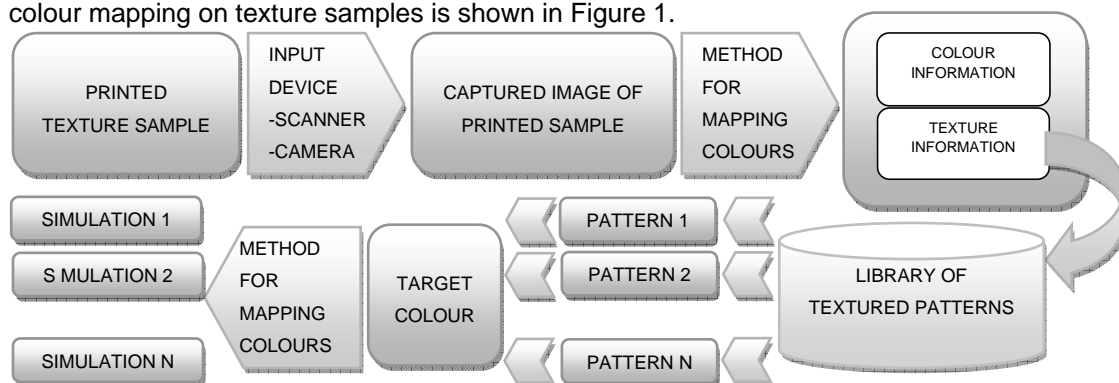


Figure 1: The algorithm of colour mapping on texture samples

Using the colour mapping method with an original texture pattern and a target solid colour as the input parameters, the image of the target colour printed on that specific texture can be generated. The appropriate method can give satisfactorily visual match between the generated and original image.

Hong et al. (2000) suggested mapping method based on the assumptions that chromacity of the colour printed on textured substrate will stay constant while luminance value will vary. Montag and Berns (2000) presented a method to generate neutral textile images in CIE LCH colour space, using a singular value decomposition technique.

Xin and Schen (2003, 2005, 2006) developed the gray-to-color (GCM) and color-to-color mapping (CCM) methods, both based on the RGB colour space.

In this study, a new method, based on the CIE LCH colour space, for mapping colour on the texture patterns is developed in order to simulate the appearance of printed textiles on a monitor with high colour fidelity. The developed method is compared with the GCM method suggested by authors Xin and Shen (2003, 2005, 2006). The colour difference between the images generated with this two methods is evaluated both in the visual (subjective) and numerical ( $\Delta E_{94}$ ) way. Methods, as well as presentation and discussion of results, are defined below.

## 2. Method

Three printed textile materials (wool, cotton-polyester and wool – acryl) are scanned in at a resolution of 360 dpi using a Linotype - Hell scanner. Chosen backing for scanning was black. The sRGB ICC profile is assigned to the scanned images.

### 2.1 The spatial and statistical distribution of texture image channels

For the purpose of examining colour distribution of texture samples, the spatial and statistical distributions of image channels are analyzed. The histogram demonstrates the global statistical distribution of each channel (global analysis). Figure 2 presents the RGB and LCH histograms of texture sample. However, in order to simulate a texture image on a pixel-by-pixel basis, the spatial distribution also should be included (local analysis). Figure 3 shows the spatial distribution of texture image channels.

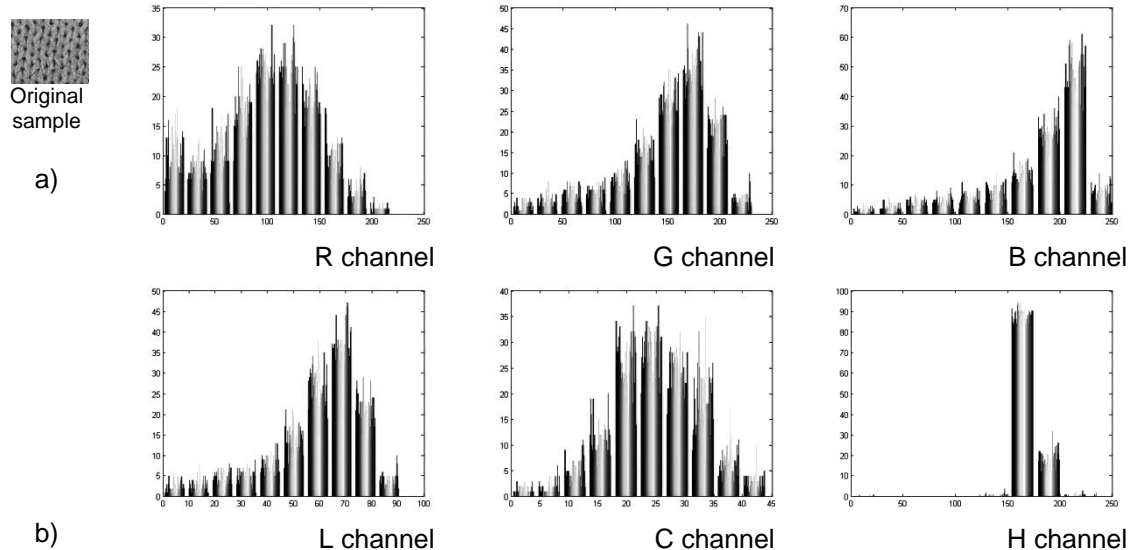


Figure 2: The statistical distribution (histograms) of texture sample: a) RGB, b) LCH channels

From Figure 2a can be noticed that woven pattern of sample affects all of the RGB channels significantly, where width of the histogram is in correlation with the mean channel value- the histogram with smaller mean value will have larger standard deviation. Due to the dominant blue channel of observed sample, the histogram of B channel has the lowest width and vice versa.

From Figure 2b can be noticed that texture nature of sample has the greatest influence on the L channel in the way that L value can be higher than target value due the unprinted parts of textile fabrics and lower due to the fabrics crossings and holes. The influence on chroma value is, also, significant with the difference that printed colour can only be less saturated due to the nature of textile materials, while the variation of hue has a very limited range and, thus, hue can be considered to be approximately constant. The same conclusions can be deduced from Figure 3.

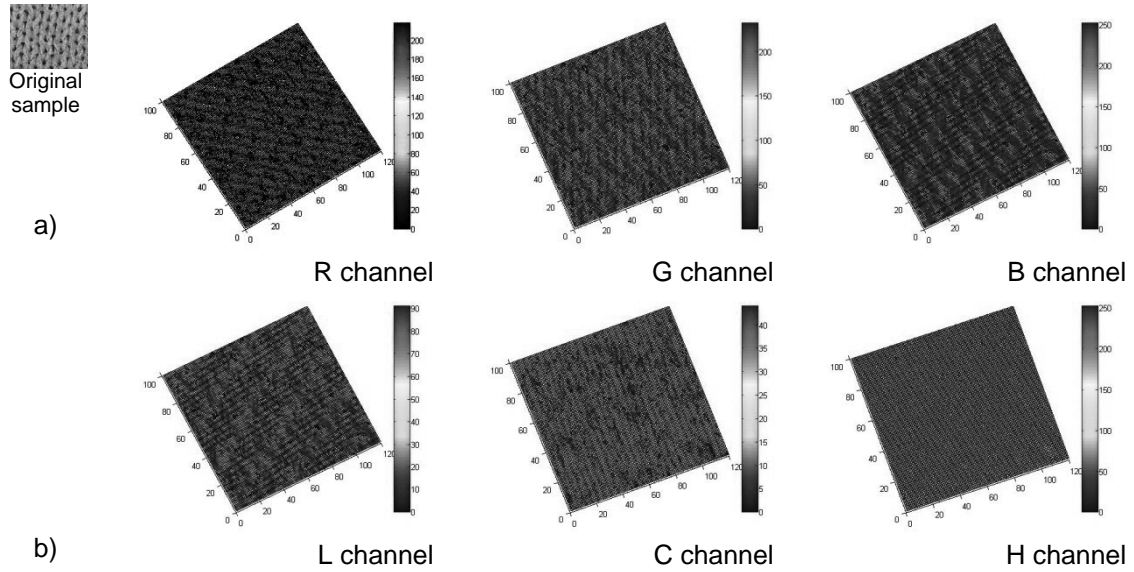


Figure 3: The spatial colour distribution of texture sample: a) RGB, b) LCH channels

## 2.2 GCM mapping method

The gray-to-colour mapping method is based on the RGB colour space and the luminance (Y) channel derived from RGB channels (Xin and Shen, 2003, 2005, 2006):

$$Y = 0.299 R + 0.587 G + 0.114 B. \quad (1)$$

According to this method, the generated colour,  $V_n$  ( $n=R,G,B$ ), of pixel with coordinates  $(x,y)$  can be deduced from the spatial distribution and the mean value of Y channel using the following equation:

$$V_n(x,y) = S_n + \Delta Y(x,y) = S_n + (Y(x,y) - Y_{\text{mean}}), \quad (2)$$

where  $S_n$  ( $n=R,G,B$ ) is the user-specified target RGB colour and  $\Delta Y(x,y)$  is the pixel deviation to the mean luminance. The short-coming of this method is that the different  $(R(x,y), G(x,y), B(x,y))$  combinations can produce the same  $Y(x,y)$  value (Equation 1). Since the pixel deviations in RGB channels are not exactly the same as that in the luminance channel, Equation 2 is corrected:

$$V_n(x,y) = S_n + (\delta_n/\delta_Y)\Delta Y(x,y), \quad (3)$$

where  $\delta_n$  is the standard deviation of the  $n^{\text{th}}$  channel and  $\delta_Y$  is standard deviation of the luminance channel. In the case of perfect (theoretic) correlation between RGB and Y spatial distributions, the value  $\delta_n/\delta_Y$  would be equal to 1.

## 2.3 LCH method

Based on the analysis of LCH channels of scanned texture samples, a new method for mapping colours on the texture patterns is developed.

Using this method, the generated colour ( $L_T, C_T, H_T$ ) at pixel with coordinates  $(x,y)$  can be calculated as:

$$L_T(x,y) = L_t + \Delta L(x,y) = L_t + (L(x,y) - L_{\text{mean}}), \quad (4)$$

$$C_T(x,y) = C_t * (C(x,y)/C_{\text{max}}), \quad (5)$$

$$H_T(x,y) = H_t. \quad (6)$$

where  $(L_t, C_t, H_t)$  is the user-specified target RGB colour,  $\Delta L(x,y)$  is the pixel deviation to the mean luminance value and  $C_{\text{max}}$  is the maximum chroma value. The chroma value can be, also, calculated analogue to L value as:

$$C_T(x,y) = C_t + \Delta C(x,y) = C_t + (C(x,y) - C_{\text{mean}}), \quad (7)$$

where  $\Delta C(x,y)$  is the pixel deviation to the mean chroma value.

Both equations (Eq. 5 and Eq. 7) give the approximately same result and which one is appropriate to use depends whether the target colour is determined with mean or maximum chroma value. For example, if target image is already converted to ICC CMYK printer profile which is created based on the measurement of average light reflected from sample- the chroma channel should be calculated using Equation 7. In the case where target colour is defined before converting to CMYK colour space, then Equation 5 should be used.

### 3. Results

For the purpose of comparing the colour accuracy of the GCM and LCH methods, mean colour of the scanned image is used as a target colour to generate a new texture image. The colour difference E94 between the original and generated image is calculated on the pixel-per-pixel bases. The images that simulate the original samples and the spatial distribution of the colour difference value are presented in Figure 4.

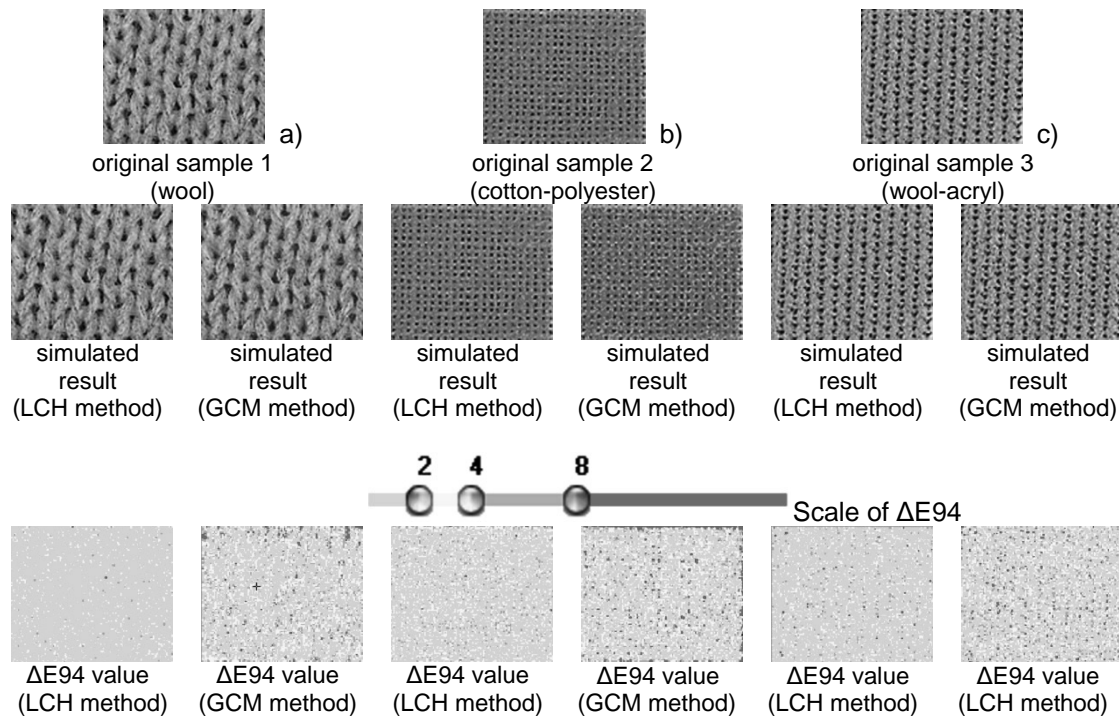


Figure 4: Colour mapping results with LCH and GCM methods using the mean colour of the original image as a target colour and the spatial distribution of the colour difference ( $\Delta E_{94}$ ) between the generated images and original sample: a) wool, b) cotton-polyester, c) wool-acryl

For the overall performance evaluation of presented colour mapping methods, the statistical values (mean, max, min and standard deviation) of  $\Delta E_{94}$  colour difference are calculated and presented in Table 1.

Table 1: Values of  $\Delta E_{94}$  colour difference between simulated results

$\Delta E_{94}$		SAMPLE 1		SAMPLE 2		SAMPLE 3		
		LCH	GCM	LCH	GCM	LCH	GCM	
All	mean	1.35	3.21	2.42	3.50	2.04	3.34	
	max	11.67	22.19	13.5	30.66	19.44	23.49	
	min	0.00	0.00	0.00	0.00	0.00	0.00	
	std	1.17	2.18	1.76	2.57	1.75	2.29	
Best 90%	mean	1.07	2.67	2.03	2.88	1.62	2.78	
Worst 10%	mean	3.86	7.97	6.00	9.06	5.84	8.37	

The GCM and LCH colour mapping methods are, also, comparatively investigated in the terms of colour similarity between the generated images created by mapping target colour to scanned texture image and the samples printed with that target colour. The simulation results are presented in Figure 5.

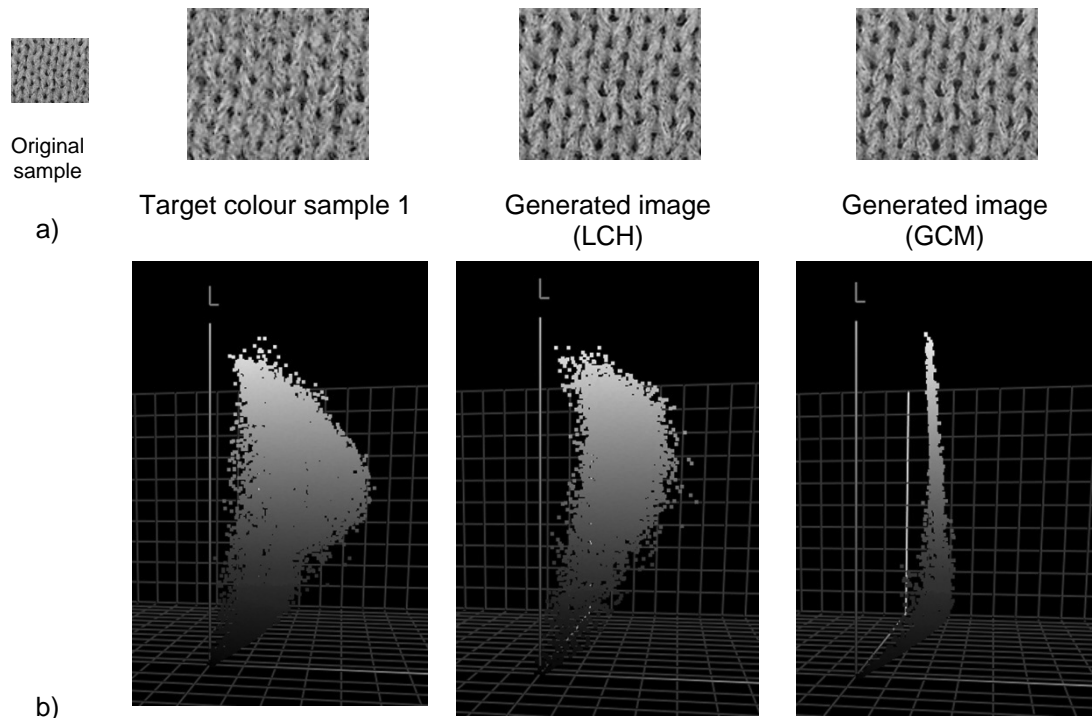


Figure 5: Results of mapping the colour of the target sample to original sample texture:  
a) the generated images , b) 3D colour gamut of images in the LAB colour space

#### 4. Discussion

From Figure 3 it can be noticed that printed areas are not ideally covered with ink (especially in a case of wool material). This numerous white, unprinted fabrics increase luminance and decrease chroma of the selected area and, therefore, have the influence on colour appearance.

The fabric crossings and holes in textile pattern, on the other side, decrease both luminance and chroma, while hue value is not significantly influenced by woven pattern.

Based on the obtained results presented in Figure 4, the developed LCH colour mapping method has better performance in simulating all three different textiles, which is confirmed with numerical calculations of colour different values showed in Table 1.

Same conclusion is confirmed with the visual evaluation of the original and the simulated samples viewed in the scaled size (20%) that give approximately equal visual appearances to those of the physical samples when viewed under normal viewing distance ( 25 to 30 cm) (Xin and Chen, 2006).

The original physical samples used in Figure 4 were scanned using black backing. Change of backing would cause changes in image histograms and, thus, the changes in the colour appearance. This indicates that backing parameters should remain the same as ones used in spectrophotographic measurements of printed textile material, which colour distribution is been simulated. Besides backing, the parameter that should be also carefully controlled is scanning resolution.

From Figure 5 can be seen that LCH colour method maps the chosen colour to original texture with more success and better approximation of original colour gamut. The reason for low performance of the GCM method is due to absence of predicting the right  $\delta_r/\delta_y$  value for the target colour based on this value for original image (Equation 2).

Based on the results, the satisfactorily precise soft proof of the printed textile products can be obtained using the LCH colour mapping method with a texture pattern and a target solid colour as the input parameters.

#### 5. Conclusion

In textile industry, the existence of standard colour management system does not ensure the colour accuracy since the influence of woven pattern nature on the colour appearance is not included (especially in the case of heavily textured textiles). As a consequence, the custom soft proofing is not reliable technique for this rapidly developing industry. On the other hand,



evaluation of the colours printed on the textile materials by making hard proofs for every design change is very expensive and time consuming process.

All this indicates that, in addition to standard CMS, certain technique of color mapping on texture images is needed in order to provide the final appearance of colour reproduction printed on textile before it is actually produced.

In this work is developed colour mapping method based on the spatial and statistical distribution of the LCH channels, which gives satisfactorily visual match between the generated and original scanned version of texture image. By applying the colour management, the image generated with the LCH mapping method can visually match the printed physical textile sample itself.

The directions for future work include integration of the developed LCH color mapping method and library of texture patterns in existing colour management system that includes separate ICC printer profiles for every used textile material, along with the other profiles ( for scanner, camera, monitor etc.).

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## DETERMINATION OF HALFTONE DOT AREA BY COLOR SPACE SEGMENTATION

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**Abstract:** Optical quality control in print industry utilizes various measurement devices for the analysis of prints and printing plates. Besides the traditional optical and sensory modules detector arrays and image processing methods are being integrated into such devices for the past decade. Industry standard devices used mostly for measuring control strips have an aperture size of 3-4 mms in diameter usually; however the observation of samples of smaller size would also be desired in many cases.

The aim of this study was to determine dot area coverage of small details of halftone images based on digital photomicrographs. A video microscope was used to capture digital images taken with a CMYK filtered interline-transfer CCD camera. The pixel values of the digital image were transformed to CIELAB color space. A segmentation method was applied to separate the color space to segments representing primary and multiple colorants. The method was tested on a series of samples. Results were compared to measured values as reference, reasonable agreement was found in case of samples with low tone values.

**Key words:** color space, segmentation, video microscope

### 1. Introduction

Optical measurement devices comprise a major group of print quality control tools. Densitometers are being replaced by spectrophotometers providing more versatile data for the measurement and management of color, as the emphasis shifts from density to colour difference in international standardization and practice. Some devices are so popular, they can be considered industry standard for scanning spatially uniform samples of media wedges and test charts. Device manufacturers adapt the aperture size to this practical task, resulting in a typically 3-4 mms in diameter. However human visual acuity allows for the investigation of much smaller color targets.

Images acquired by a digital camera combined with color filters are a source of valuable data regarding the microstructure of the investigated sample; geometric morphologic, colorimetric, and other types of information can be extracted.

In the area of color management spectral and colorimetric printer models predict the spectral reflectance or colorimetric values using colorant levels as input values. Using such models in inverse way it is possible to determine CMY values necessary to reproduce a certain color – this task is performed by a color management system using a printer device profile.

Dot area measurement is important to verify tone reproduction quality, that screens or film tints are correct and have unchanged during duplication. Tone value increase is inherent to printing processes producing the tonal range by halftone dot structure, its extent is specific to technological parameters desired values are determined in international standards[1]. Tone value increase and apparent dot area is determined based on optical density measurement, according to the Murray-Davis and Yule-Nielsen or other formulas [2].

The AM offset print is comprised of cyan, magenta, and yellow halftone dots separated by the unprinted areas of the substrate. If the fraction of the relative area  $a_{ijk}$  occupied by each of the possible ink superposition is known, then based on the additive colour matching principle, the XYZ tristimulus values of the sample are predictable by means of the following formulas, known as the Neugebauer equations:

$$\begin{aligned} X &= a_{000}X_{000} + a_{001}X_{001} + \dots + a_{111}X_{111}, \\ Y &= a_{000}Y_{000} + a_{001}Y_{001} + \dots + a_{111}Y_{111}, \\ Z &= a_{000}Z_{000} + a_{001}Z_{001} + \dots + a_{111}Z_{111}, \end{aligned} \tag{1}$$

The corresponding surface fractions are defined by the Demichel equations:

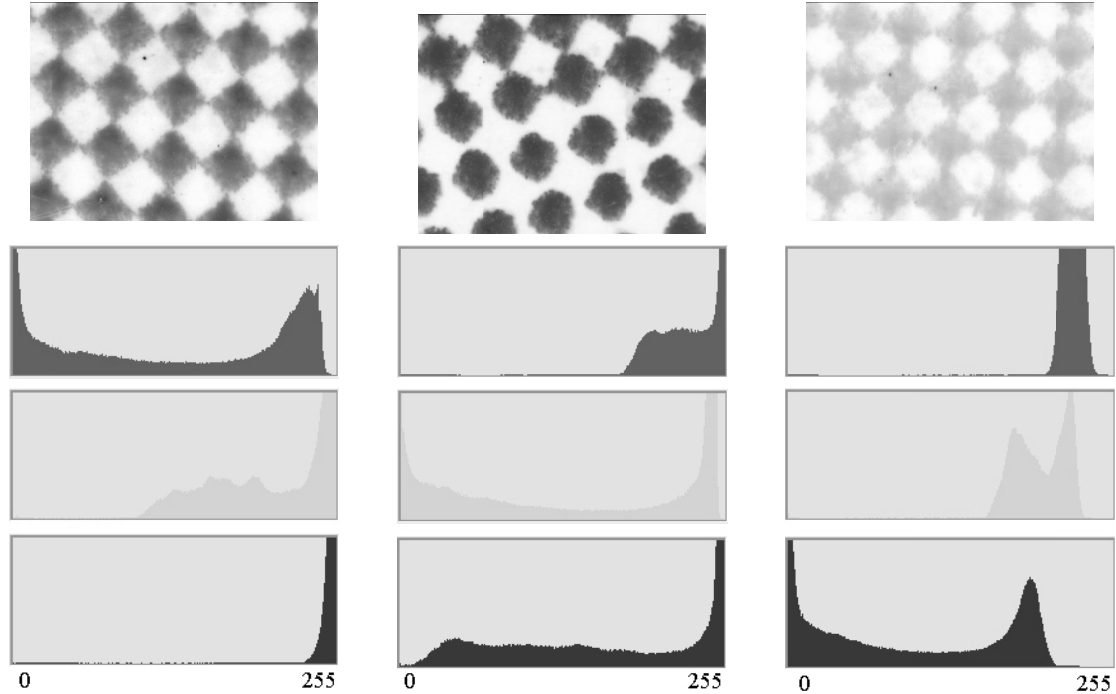
$$\begin{aligned}
 a_{000} &= (1-c)(1-m)(1-y), \\
 a_{100} &= c(1-m)(1-y), \\
 a_{010} &= (1-c)m(1-y), \\
 a_{001} &= (1-c)(1-m)y, \\
 a_{011} &= (1-c)my, \\
 a_{101} &= c(1-m)y, \\
 a_{110} &= cm(1-y), \\
 a_{111} &= cmy.
 \end{aligned} \tag{2}$$

where  $c$ ,  $m$ ,  $y$  denotes areas where cyan, magenta and yellow inks were deposited,  $(1-x)$  notation is used if the unit area is not covered by ink  $x$  [3].

The aim of this study was to establish a method for determine dot area on a small portion of halftone prints based on its digital image captured by a video microscope.

## 2. Method

A video microscope was used to capture digital images taken with a CMYG filtered interline-transfer CCD camera type WAT 250D with 748 x 568 effective pixels. The advantage of this complementary color filter arrangement over the RGB filter matrix is that it transmits more light at the expense of noise level. The optical setup together with correction methods of the application software rendered a spatially uniform image. Appropriate lighting conditions are important to exploit the achievable largest dynamic range for the separation of overprinted dots. In order to achieve good color rendering a fiber coupled incandescent light source was used to illuminate the samples in 45/0 measurement geometry. Camera white point was adjusted to substrate white, gain control was set manually and “gamma” was set to 1, resulting a linear tone transfer function.



*Figure 1: Digital images of cyan, magenta and yellow AM dot structure (152 LPI) with 50% nominal coverage (upper row) and their R, G, B histograms (lower rows), offset prints on coated substrate*

The Yule-Nielsen effect becomes visible on microscopic level, the printed dots appear as non-uniform patches, the interaction of light with substrate and ink (optical dot gain) result broadband histograms (Figure 1.).

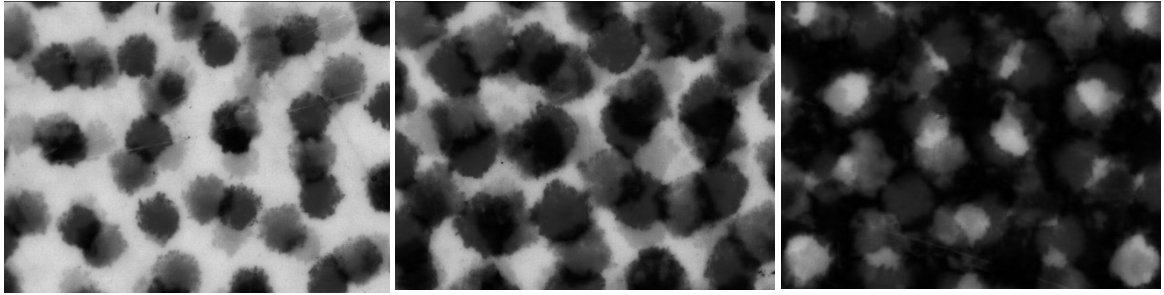


Figure 2: Microscopic images of AM offset CMY chromatic grey samples, nominal dot area coverages are 30%, 50% and 70%

Segmentation is a process to decompose an image into regions representing characteristic areas. Segmentation on a transformed image, in a color space with psychophysical axis is an approach that exploits the nature of halftone dot images.

Individual pixel values of the digital image were transformed to CIELAB color space. As a first step image pixel RGB values were transformed to CIE XYZ tristimulus values using the sRGB transform [4]. However this transformation does not provide accurate tristimulus values, it has been shown previously, that applying a transformation which uses a standard RGB color space introduces errors of tens of  $\Delta E_{ab}$  in magnitude between measured and calculated tristimulus values of color patches [5]. The XYZ values were used to calculate  $L^*$ ,  $a^*$ ,  $b^*$  using the camera white point as a reference.

The distribution of the points representing the image pixels in the color space reveal a structure brought forth by the combined halftone pattern (figure 3). It made possible to separate the color space to segments representing the primary and multiple colorants. In case of four color prints nine segments were determined: substrate white, C, M, Y, R, G, B, CMY, K: the eight Neugebauer primaries plus achromatic black. Segmentation parameters were set using samples of the same substrate and ink set, on offset prints with standard rotated AM screens. Theoretically this method can be applied to images printed with more primary colors, however in this study only three color prints were considered.

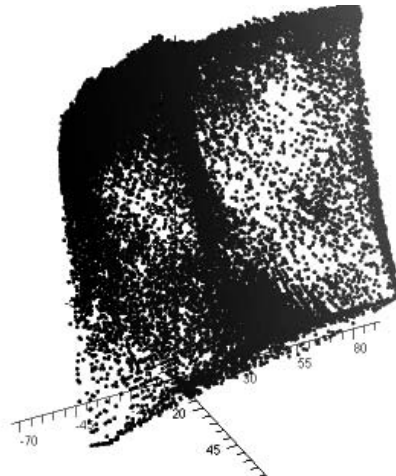


Figure 3: Distribution of the pixels of a CMY halftone print digital image transformed into  $L^*a^*b^*$  color space the boundary of the color solid represents the gamut

### 3. Results and discussion

The group of pixels of the digital image representing the white substrate are obtained by applying a threshold on the lightness ( $L^*$ ) axis. Image pixels of black pigmented areas can be found similarly, however only CMY prints were used in this study with 30%, 50%, 70% nominal tone values. Segmentation was based on hue and lightness features of the color solid of the digital images of the CMY prints. Maximum chroma ( $C^*_{ab}$ ) values plotted as a function of hue angle ( $h^*_{ab}$ ) (Figure 4) indicate which hue region correspond to primary colors in the upper part and the two color overprints in the low lightness region of the color solid. Hue histograms (the number of pixels as a function of hue angle) show similar characteristics.

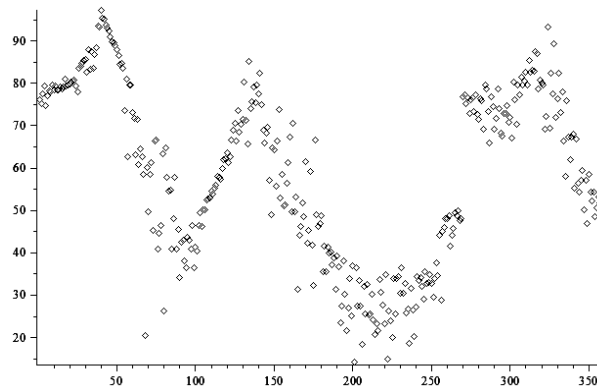


Figure 4: Maximum chroma ( $C^*_{ab}$ ) values (vertical axis) plotted as a function of hue angle ( $h^*_{ab}$ , horizontal axis) for the lower part of the color solid

In the evaluation magnified portions of three chromatic grey samples were used as test images. In case of high tone values overprinted areas appear reasonably dark on the image making the segmentation inaccurate in comparison with measured data (table 1 and 2). This artifact was presumably due to low level of illumination. The accurate definition of the magnified image of the printed dot is also limited by the lack of real edges, sharp, high contrast boundaries.

Table 1: Measured dot area values by reference device, header shows the nominal values for CMY offset print

CMY	30%	50%	70%
C	39,2	62,5	79,9
M	40,5	64,8	82,5
Y	37,9	60,4	80

Table 2: Calculated dot area values based on transformation and segmentation in CIELAB color space

CMY	30%	50%	70%
C	40,1	60,4	69,4
M	30,8	50,2	71,1
Y	31,9	45,3	63,1

#### 4. Conclusion

Segmentation of magnified portions of digital images of offset prints transformed to a color space with psychophysical axis may offer a solution of determining dot area on small scale. Prediction of dot area percentage performs better in case of low tone values; the success of the segmentation process heavily depends on the image acquisition parameters.

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## SPATIALLY UNIFORM AND VARYING HDR TONE MAPPING TECHNIQUES EVALUATION

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**Abstract:** High dynamic range (HDR) imaging is a set of techniques that enable achieving very high difference between the lightest and darkest area of an image. With these techniques it is possible to obtain higher dynamic range than with standard digital imaging or photographic methods, so HDR images more accurately represent the extensive range of lightness levels that can be found in real scenes. However, reproducing HDR images properly can be a problem, because they contain broader dynamic range than most of today's display devices. To ensure that tones and, more important, relations between them will be preserved after range clipping, the so-called tone mapping operators are being developed. These rendering techniques can be classified in two categories: spatially uniform (usually termed as global) and spatially varying (local operators). Global operators apply the same transformation to every pixel of an image, while local mapping use different algorithm for each pixel based on its local spatial content. The aim of this work was to define which tone mapping technique enables better reproduction of HDR image in term of noise and dynamic range i.e. less noise while maintaining most of the initial dynamic range. HDR images are generated from 3 photos of Kodak Q60 24-step gray scale which were taken by Canon 500D DSLR camera with exposures of -2 EV, 0 EV and 2 EV. Images are generated and tone mapped using Dynamic Photo HDR 4.8, Photomatix Pro 3 and Artizen HDR 2.8. softwares. From noise and dynamic range assessment, which was conducted inside Imatest 3.1 software, it was concluded that spatially uniform operators ensures reproduction with less noise and higher dynamic range.

**Key words:** HDR, tone mapping, noise, dynamic range

### 1. Introduction

Dynamic range is a ratio between maximum and a minimum of any physical measure. For a natural scene, it is the ratio between the darkest and lightest parts of a scene. In order to obtain the dynamic range of visual stimuli, HDR (high dynamic range) imaging has been introduced. Natural scenes contain a large amount of luminance variation, often spanning a range of 10000:1 (Kuang et al, 2008). This ratio can even reach 100000:1 for the outdoor scenes that contain luminance values from shadows to bright sunlit. Human eyes has a narrower DR and are capable of distinguishing details at any given adaptation level within a contrast of 10000:1 (Ledda, 2007). With the development of image detectors and technologies for image generation this range can be obtained and can linearly be displayed only on HDR displays. Since these devices are expensive and still not widely used, in practice some clipping of image DR must occur in order to present it on current LCD monitors (which usually have DR limitations of 300:1). Printed images have an even narrower dynamic range (Kuang et al, 2008).

The problem of dynamic range gap has been solved by developing different tone mapping methods whose purpose is to clip the high dynamic range of images into the range that can be reproduced by certain device. The most common classification of these rendering techniques takes into account whether the same mapping function is used for all pixels (spatially uniform or global operators) or if the mapping function varies depending on a given pixel neighborhood (spatially varying or local operators) (Krawczyk et al, 2007). In the former case tone reproduction curve is constructed in a way that for a given HDR pixel luminance always assigns the same output pixel intensity. For local operators output pixel intensity can vary quite significantly even for pixels with same luminance level since it depends on the scene surround. As stated by Kuang et. al (2008): "The main advantage of spatially uniform mapping lies in the simplicity and computational efficiency, although there is a fundamental difficulty in keeping the appropriate local contrast in each region of the image. Spatially varying mapping is more flexible in controlling local contrast, since a specific mapping tactic is used for each pixel based on its local spatial content."

There are plenty of approaches in developing algorithms for both global and local operators. Global tone mapping techniques were initially inspired by psychophysical models of brightness and contrast perception (Tumblin and Rushmeier method), and also by models of retinal

photoreceptors (version of this model was introduced by Reinhard and Devlin). Today, the most used are logarithmic mapping (adaptive version of this model was introduced by Drago et. al., 2003) and histogram adjustment method (derived by Larson). Local operators tend to maximize local contrast in order to compress scene illumination, while preserving surface details (texture). Photographic tone reproduction (presented by Reinhard et. al), perceptually uniform JND space, bilateral filtering method (presented by Durand and Dorsey), gradient methods and other are just some of the local operators which are (together with globals) usually incorporated in softwares for HDR image generation.

Using certain operator, approach and particular algorithm for tone mapping of HDR images depend of the effect which is to be obtained. The goal can be maximizing the image contrast, maintaining as many details as possible or producing the realistic images i.e. obtaining a perceptual match between the real scene and a displayed image. Local operators are mostly used when the goal is to maintain and emphasize details (maximizing local contrast), while global are better choice when producing photorealistic images is important.

When a new rendering algorithm is proposed, the rendering performance may be compared with some of the previous HDR image rendering algorithms (Kuang et al, 2008). Usually, tone compression performance, colour appearance and other image attributes are taken into account and overall rendering performance is ranged by human observers. Defining these factors as the important ones, Kuang et. al, (2008) showed that better result can be achieved with local operators (even though only one global operator was tested). Yoshida et al. (2005) proved that operators efficiency depend also on luminance levels, where local operators are perceived with significantly more detail reproductions in bright regions than global.

Image quality after tone mapping can also be evaluated in order to define whether certain operator produces satisfying results. In their study Čadík et al. (2006) proposed simple equation to define image quality as the combination of image attributes given as:

$$OIQ = 0.327 \text{ Bri} + 0.267 \text{ Con} + 0.102 \text{ Det} + 0.230 \text{ Col} \quad (1)$$

where: OIQ is an overall image quality function in the interval of 0-1 (1 being the best quality), Bri is brightness, Con – contrast, Det are details and Col are colours all in the interval 0-1 (0 means the worst reproduction of the appropriate attribute).

By using this formula and the results obtained from perceptual test it was summarized that the best rendering can be achieved with photographic tone reproduction proposed by Reinhard (local operator). Very good results produce also global operator defined by Larson (histogram adjustments method).

In practice, HDR images are usually generated by merging of multiple photographs captured with different exposure (0, minus and plus), where at least three photographs are needed. During the merging process exposure blending works pretty well, while further tone mapping often produces images with a lot of noise (especially in dark areas of the scene). Noise is defined as the random variations of brightness or colour information in images and it is usually undesirable by-product of image capturing. Causes of its appearance in photographs can be pixel size, sensor technology and manufacturing, ISO speed, exposure time, digital processing and raw conversion. Noise will, in certain extent, always exist in images, but if it increases significantly due to tone mapping algorithm, it can affect final appearance of HDR image. Since noise affects image quality (especially details perception) it should be considered as one of the important factors for evaluating tone mapping algorithms.

Noise magnitude can be defined as amplitude distribution or as noise frequency spectrum, where the first representation is mostly used. It is based on standard deviation which quantifies the typical variation a pixel will have from its “true” value. Noise is usually measured in RMS (root mean square) voltage or pixel level, where RMS is equivalent to standard deviation. Lower the standard deviation, lower the noise magnitude will be. Figure 1a shows image that has a low noise magnitude and hence low standard deviation value, while in Figure 1b image with higher noise is presented. In Figure 1. RGB histogram is shown, but the same comparison can be made for the luminosity and individual colour histograms.

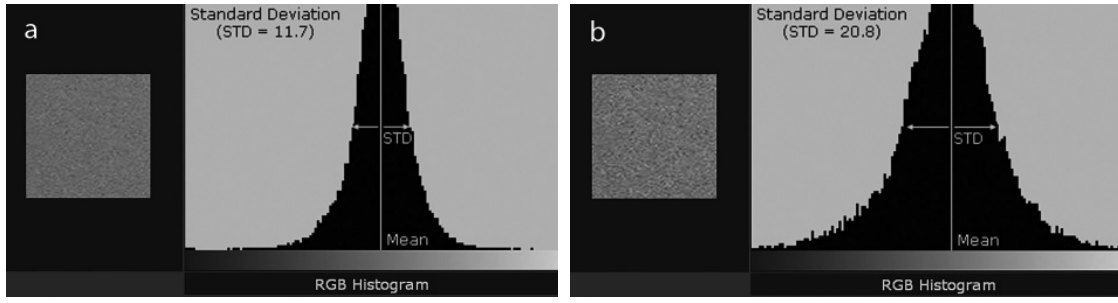


Figure 1: Image (left) and corresponding standard deviation representing noise magnitude (right) for image with: a. low amount of noise, b. high amount of noise

When evaluating photographs, noise is often expressed in relative luminance units, such as f-stops, which corresponds more closely to the eye's response than standard pixel or voltage units. F-stop describes the ratio between a lens's focal length and aperture diameter. For a given focal length, larger f-numbers have smaller apertures, letting less light into the camera, also deepening the depth of field (Carr and Corell, 2009). Since from exposure value depend how much light will be let into camera, hence how many luminance levels can be captured it is a good indicator of both dynamic range and noise. Noise in f-stops is obtained by dividing the noise in pixels by the number of pixels per f-stop:

$$\text{Noise in f-stops} = \text{noise in pixels} / (d(\text{pixel}) / d(\text{f-stop})) \quad (2)$$

where  $d(\text{pixel})/d(\text{f-stop})$  is the derivative of the pixel level with respect to luminance measured in f-stops ( $\log_2(\text{luminance})$ ).

Since luminance noise (measured in f-stops) is referenced to relative scene luminance, independently of electronic processing or pixel levels, it is a universal measurement that can be used to compare digital sensor quality when sensor RAW data is unavailable.

Important factor to be considered while evaluating tone mapping operators is also the degree of initial dynamic range clipping. DR is usually expressed as contrast ratio, but it can also be measured in density or f-stops. One f-stop correspond to 0.301 density units, while contrast value can be obtained as:

$$2^{\text{f-stop value}} = \text{contrast value} \quad (3)$$

Dynamic range is limited by the lightest and also the darkest tone where texture can no longer be discerned (the black level). Since black level itself is limited by image noise, dynamic range generally increases for lower ISO speeds and cameras with less measurement noise.

## 2. Method

In order to evaluate tone mapping techniques 3 photos of stepwedge from Kodak Q60 test chart are obtained by Canon 500D DSLR camera (15.1 MP, CMOS sensor). Images are taken under standard illuminant D65 using the auto-exposure bracketing (-2 EV, 0 EV and 2 EV). Due to the surroundings aperture of f/8 and ISO 1600 were used. Images (shown on Figure 2) are saved as jpg files and imported into softwares for HDR images generation.

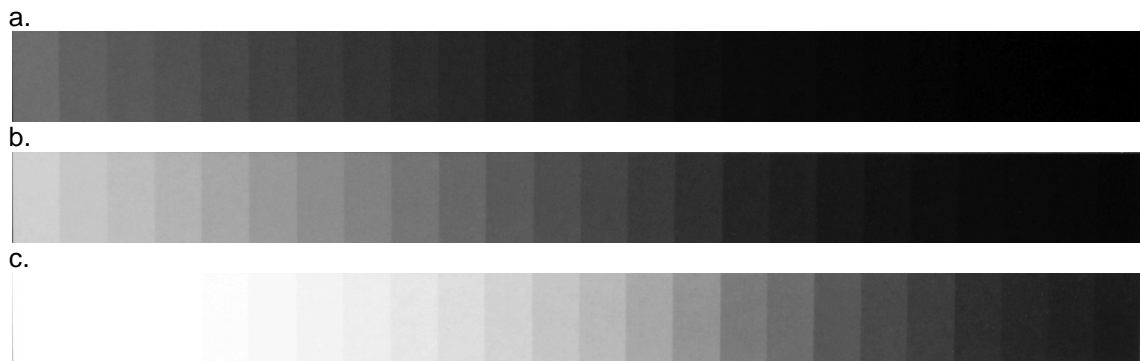


Figure 2: Images of Kodak Q60 stepwedge taken with exposure of: a. -2 EV, b. 0 EV and c. 2 EV



Three softwares are used for image generation and mapping - Dynamic Photo HDR 4.8, Photomatix Pro 3 and Artizen HDR 2.8. Prior the tone mapping images are aligned and merged into one HDR photo, which was then processed by using certain operator. In Dynamic Photo HDR 7 rendering methods can be chosen depending of an effect which is to be achieved. First three methods (*Eye-Catching*, *Ultra Contrast* and *Halo Matix*) use local operators, third (defined as *Smooth Compressor*) use both local and global operators in order to produce vivid, but yet smooth images, while the others (*Auto-Adaptive*, *Photographic* and *Human Eye*) use only global operator. The main difference between methods that use the same operator is in contrast and saturation levels which are calculated by different algorithms. Tone mapping in Photomatix Pro 3 can be performed by using two mapping methods defined as: *Details Enhancer* (local) and *Tone Compressor* (global operator), while in Artizen HDR 2.8 three methods can be used: *Display* and *Natural* methods are using global operators, *Dramatic* creates more contrasty and saturated images by using local operator.

In each software default settings for every tone mapping method were used, without changing any of the parameter available. After mapping, images are saved as 16-bit TIFF files and imported into Imatest 3.1 Master (option: *Stepchart*) for further evaluation. Imatest detects chart zones using the smallest density step that results in uniformly spaced detected zones, where the dynamic range is the difference in density between the zone where the pixel level is 98% of its maximum value (250 for 24-bit color, where the maximum is 255), estimated by interpolation, and the darkest zone that meets the measurement criterion. Total dynamic range is expressed in f-stops, which describes total light range by powers of 2. From this number contrast ratio can and density units can easily be obtained as shown earlier.

In Imatest noise can be defined as a function of pixel level or exposure expressed in pixels or f-stops, signal-to-noise ratio (SNR or S/N) as a function of pixel level or exposure and also as one single number which represent the average noise value. Noise expressed in relative units (f-stops) is observed both for the original image (photographed with 0 EV) and also for the tone mapped images. Noise in pixels over the whole density range is also observed, as well as the average luminance channel noise.

### 3. Results and discussion

As mentioned earlier, grayscale stepwedge was photographed 3 times in order to obtain minimum number of images for HDR image generation. Exposure difference was 2 EV. Figure 3 shows density response curve for image taken with 0 EV, while Figure 4a and 4b. shows noise in pixels (Figure 4a) and f-stops (Figure 4b) as a function of exposure logarithm (or negative target density).

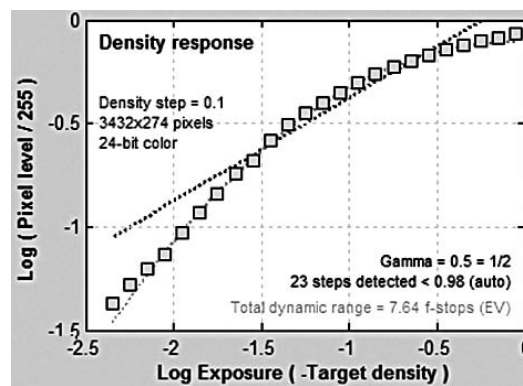


Figure 3: Density response curve for photo of Kodak Q60 stepwedge taken with 0 EV

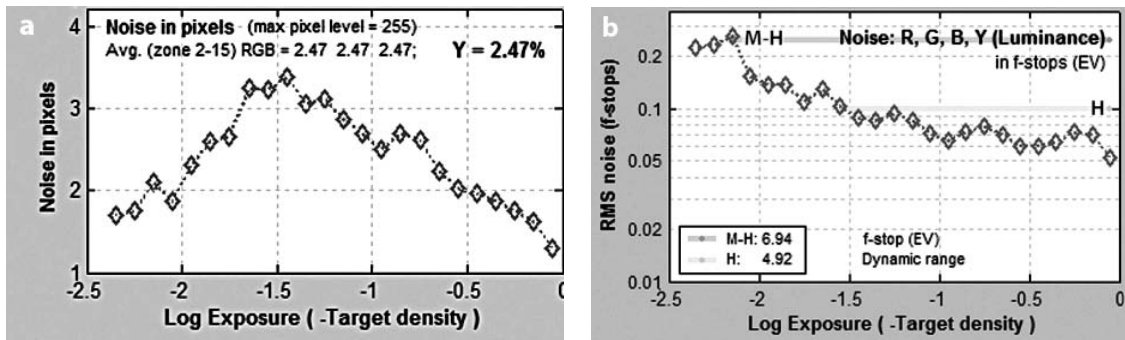


Figure 4: Noise in an image taken with 0 EV expressed as: a. noise in pixels, b. noise in f-stops

From Figure 3. it can be seen that density curve follows the gamma curve of 0,5 with the small deviations in dark areas of an image. Total dynamic range of image is 7,64 f-stops which correspond to the contrast ratio of 200:1 or maximum density of 2,3. Noise is highest in midtones, but acceptable - average luminance channel noise is 2,47%. From Figure 4b where noise is scaled to the difference in pixel levels between f-stops, it can be seen that most of the tones of an image correspond to high quality scale (marked with yellow or H). Here only two quality levels exist and the maximum noise within each range is defined (for high quality level maximum noise is at 1,48 density value (4,92 f-stop), while for medium-to-high level (M-H) maximum is at 2.09). Regarding the results, quality of basic image (taken with 0 EV) is defined as good, so no additional photographs are made.

Evaluation of dynamic range and noise for images created and tone mapped in Dynamic Photo HDR software shows that density response curve usually follows logarithmic function (with different gamma values) except in dark tones. Noise is mainly constant and most of the tones on an images belong to high quality scale. Exceptions are images mapped with *Halo Matix* and *Ultra Contrast* methods which shows significant deviations. In first case (as shown on Figure 5) density response curve follows an S-shape which means that highlights will be shifted toward dark tones and that darkest tones of an image will be reproduced lighter. This can be easily noticed in processed image (Figure 7a). With *Ultra Contrast* mapping method only 21 steps of stepwedge are detected, as seen on Figure 6.

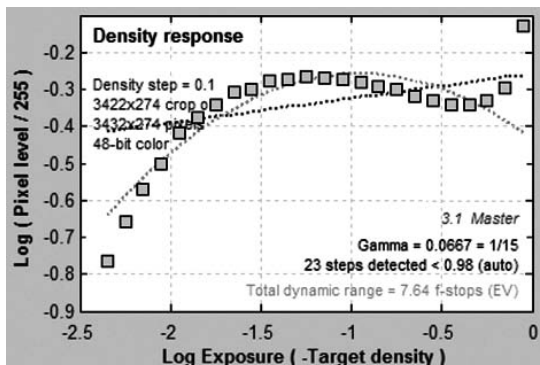


Figure 5: Density response curve for image tone mapped inside Dynamic Photo HDR by local operator Halo Matix

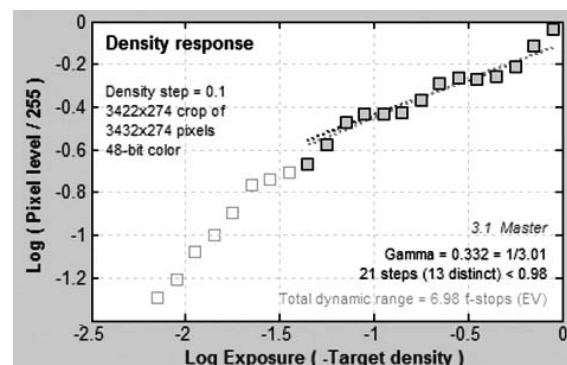


Figure 6: Density response curve for image tone mapped inside Dynamic Photo HDR by local operator Ultra Contrast

In dark areas of an image different density levels will be perceived as one (Figure 7b).

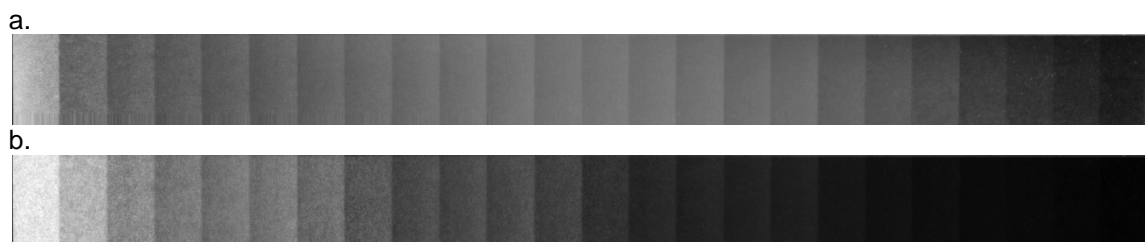


Figure 7: Images after tone mapping in Dynamic Photo HDR by local operator: a. Halo Matix, b. Ultra Contrast

Beside the bad rendering, dynamic range and smoothness in tonal transition, using these techniques also leads to noise increasing as seen on Figure 8 and 9.

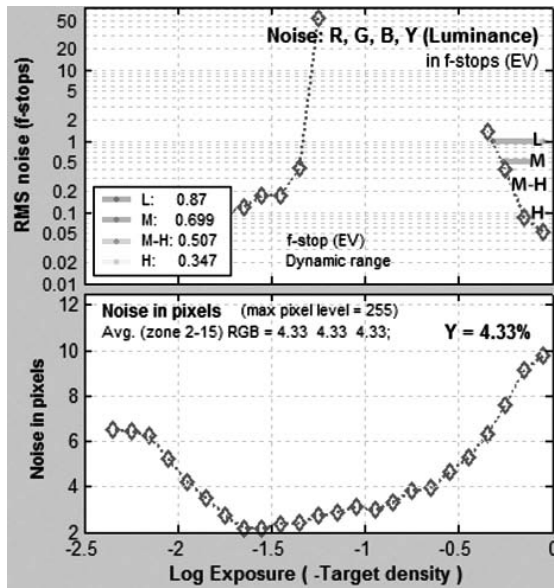


Figure 8: Noise in f-stops and pixels in image tone mapped with Halo Matix operator

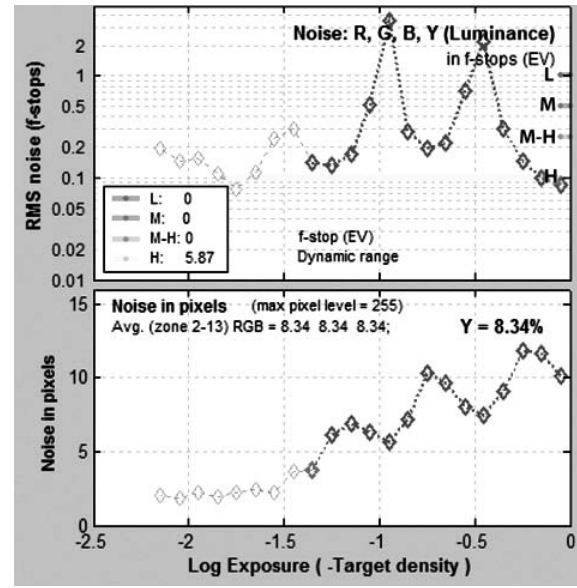


Figure 9: Noise in f-stops and pixels in image tone mapped with Ultra Contrast operator

Both images contain areas of low image quality, usually in midtones. In case where *Halo Matix* operator is used, noise is most obvious in highlights and dark tones, while with *Ultra Contrast* method it can be seen in highlights and the midtones. These methods belong to spatially varying (local) operators class.

With *Photomatix Pro 3 Detail Enhancer* method density response curve follows linear, rather than logarithmic law (Figure 10). Comparing to *Tone Compressor* method (Figure 11) this curve will produce tonal transition which does not correspond to the human eye response. Total dynamic range, however, is very similar in both techniques used.

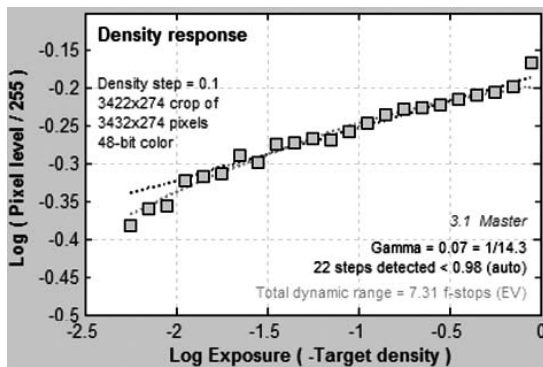


Figure 10: Density response curve for image tone mapped inside Photomatix Pro 3 by local operator Detail Enhancer

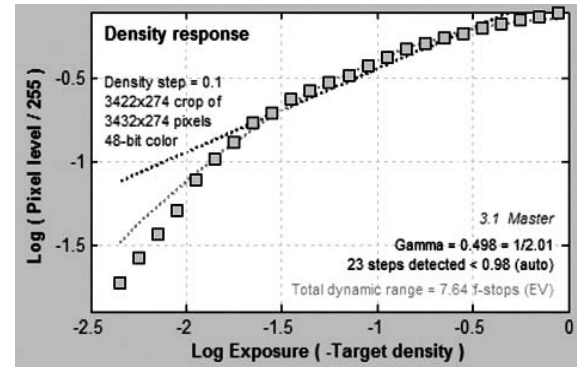


Figure 11: Density response curve for image tone mapped inside Photomatix Pro 3 by local operator Tone Compressor

Noise is much higher for *Detail Enhancer* method as can be seen from Figures 12 and 13, where noise in f-stops is shown. Here, levels of medium and low quality can easily be distinguish from the high quality levels. With *Tone Compressor* method only high quality levels exists.

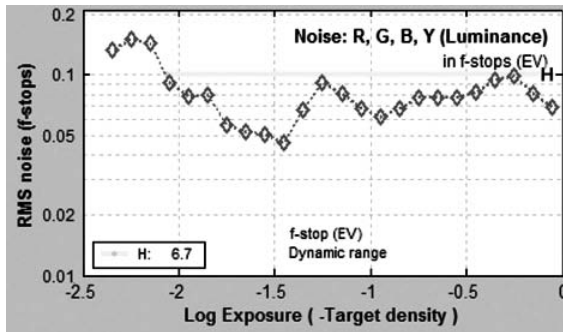


Figure 12: Noise in f-stops in image tone mapped with Detail Enhancer method

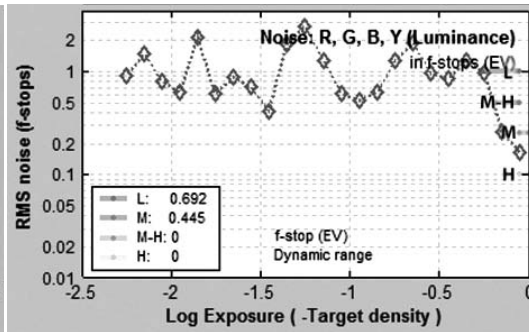


Figure 13: Noise in f-stops in image tone mapped with Tone Compressor method

In Artizen software, density variations and noise are only considerable from *Dramatic* tone mapping technique as seen in Figure 14 and 15. Density response values are very scattered and hence neighbour luminance levels on an image will not be perceived properly. Noise is also very high, as can be seen on Figure 15 and perceived visually in Figure 16.

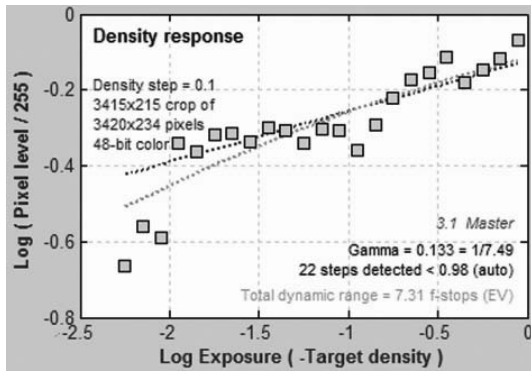


Figure 14: Density response curve for image tone mapped inside Artizen by local operator Dramatic

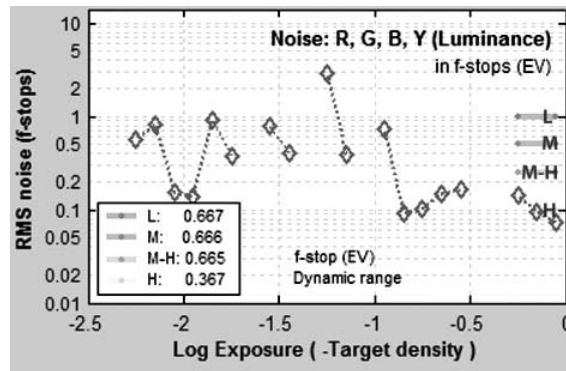


Figure 15: Noise in f-stops in image tone mapped with Dramatic method in Artizen

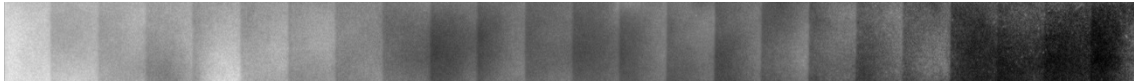


Figure 16: Basic image after tone mapping in Artizen with Dramatic tone mapping method

Figure 17. shows total dynamic range values (expressed in f-stops) of images tone mapped within Dynamic Photo HDR 4.8 for all mapping techniques. First three methods (marked with blue) use local operators, fourth method use combination of local and global operators, while last three (marked with red) use global operator. Same colours are used to mark average luminance channel noise values obtained from images mapped with different Dynamic Photo techniques (Figure 18).

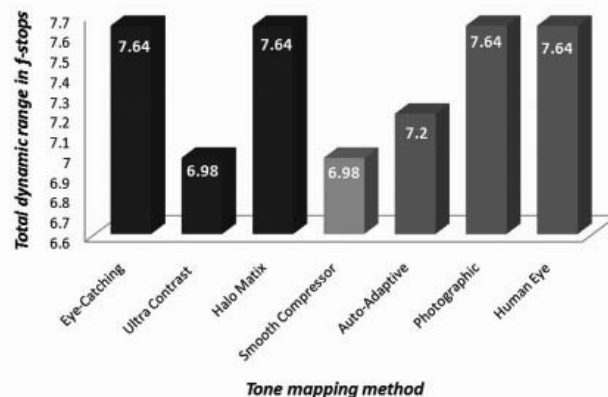


Figure 17: Dynamic range of images tone mapped in Dynamic Photo HDR 4.8 (local operators marked blue, global red, and operator that use combination of global and local mapping marked green)

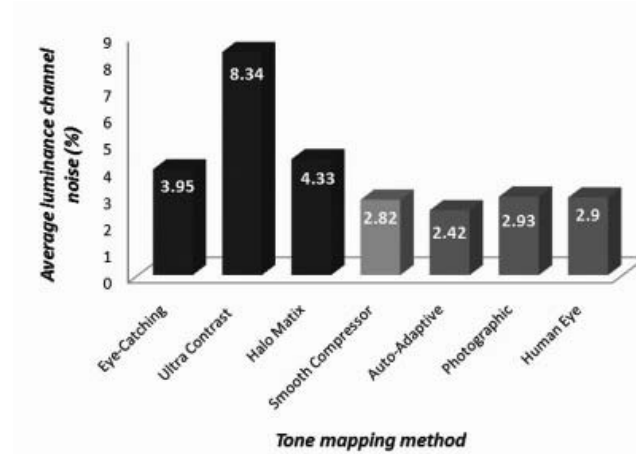


Figure 18: Average luminance channel noise in images mapped within Dynamic Photo HDR 4.8 (local operators marked blue, global red, and operator that use combination of global and local mapping marked green)

Comparing local and global operators in Dynamic Photo (Figures 17 and 18) it can be seen that local operators usually produce higher average noise in mapped image, while dynamic range is not so affected. *Smooth compressor* method which is a combination of local and global operators ensures reduction of both noise and dynamic range, while minimum noise is obtained by mapping images with global operators.

Dynamic range and average luminance noise in images mapped with Photomatix Pro 3 and Artizen HDR 2.8 are shown in Figure 19 and 20, respectively. Local operators in every software are marked blue, global red (first two methods in each graph belong to local operator class).

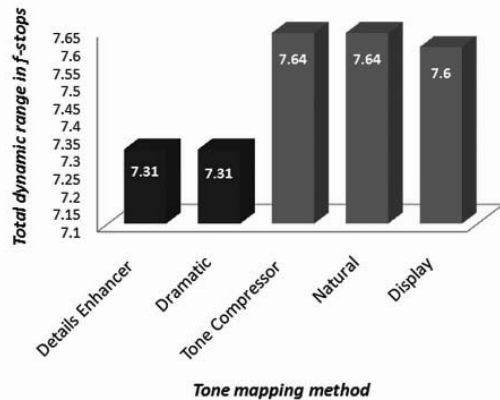


Figure 19: Dynamic range of images tone mapped in Photomatix Pro 3 and Artizen HDR 2.8

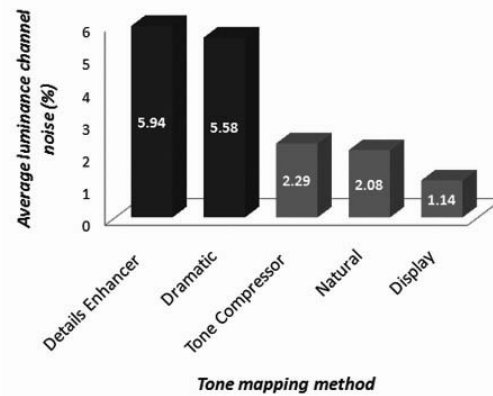


Figure 20: Average luminance channel noise in images mapped within Photomatix Pro 3

From Figures 19 and 20 it can be concluded that using local instead of global operators in both Photomatix Pro 3 and Artizen HDR 2.8 will lead to lower dynamic range and hence, higher noise in mapped images.

#### 4. Conclusion

In this work evaluation of spatially uniform and spatially varying HDR tone mapping techniques was performed. As a parameters of interest, noise and dynamic range in HDR images generated and mapped within three different softwares were observed. In every software we have used (i.e. different tone mapping algorithms applied for calculations) we obtain the same results showing that spatially varying methods (local operators) produce images with considerable amount of noise. Spatially uniform methods, on the other hand, tends to maintain high dynamic range where most of them even reduce amount of noise that exist in original photo (taken with 0 EV). Since principle that stands behind global operators is that overall, rather than local, contrast should be preserved, the results were expected.

Tone mapping techniques enable maintaining local contrast in order to facilitate displaying HDR images on devices with lower dynamic range. Today, these methods are mostly used for creation of artistic images, where improved contrast and vivid tones can produce pretty much unreal results. If creating an artistic HDR photo is the goal, image quality is not an important issue. But, if HDR imaging is used with intention to improve drawbacks in images, which may occur due to bad shooting conditions, objective reproduction is important and image quality can not be neglected. Development of new generation of HDR displays will ensure that images with high dynamic range are presented without range clipping, and hence tone mapping will no longer be mandatory step in HDR image generation. But before these devices became widely used, choosing the right tone mapping technique can make a difference in quality of final image. Without taking into consideration which of the tone mapping methods tend to produce more realistic images (images that correspond better with the real scenes) and focus only on dynamic range and amount of noise as important factors of image quality, spatially uniform methods comparing to spatially varying surely produce much better results.

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## STUDY OF SAMPLE CHOICE INFLUENCE ON THE ESTIMATED COLOR REPRODUCTION SYSTEM ACCURACY

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**Abstract:** The growing demands for quality and well defined product quality levels encourage the printing houses to align their production processes to the specifications defined by the international standards. Those standards prescribe the use of certain tools. As the tools, such as characterization and process control charts are standardized, they may be more or less suitable for certain color reproduction processes, as many studies have shown that the choice of training set values has a great impact on the characterization model accuracy. This study investigates the impact of the test set values choice on the estimated color reproduction system accuracy. Three random RGB value samples in each of the three different sample sizes have been taken, and their corresponding  $L^*a^*b^*$  values predicted by the standard ICC profile were compared to the empirical values on the laser electrophotographic printer with RGB driver. The results obtained with different sample sizes and different random samples were compared using the analysis of variance to find whether the samples are significantly different.

**Key words:** CRS evaluation, test set size

### 1. Introduction

General process and quality control methods can be applied to any kind of production processes. Their aim is to quantify relevant quality parameters in terms of their aimed values and tolerances, and to quantify the capabilities of given production processes to produce products within the specification limits (tolerance). Only unambiguous acceptability criteria in the case of attributive characteristics, and defined quantities in the case of measurable characteristics can lead to legal liability and avoid misunderstandings between the producer and the consumer. However, tools and methods used for inspection must also be defined as they can affect the results and increase the alpha and beta risks which are always present in the case of statistical quality control.

Beside the general quality control tools and methods, different production processes use special tools adapted to their demands. Specifically, in color reproduction processes color charts are used to characterize them and to estimate their accuracy. For example, the current ISO process control standard specifies the process parameters such as the aimed colorimetric values and tolerances for solid patches of primary, secondary and tertiary colors and TVI curves, and the aimed values for all of the patches of the corresponding test charts (IT8/7.3 or ECI2002) are provided by FOGRA in the form of characterization data. A subset of the device space values contained in ECI2002 chart is used as process control tool known as Ugra/FOGRA media wedge. It is commonly used to evaluate the ability of digital proofing systems to simulate production prints. The tolerated mean and maximum of errors are specified, and processes exceeding those values are considered to be unsuitable for use. Using the independent data set when evaluating device characterization models is necessary to obtain objective measures of model accuracy. The error can be modeled by  $\chi^2$  distribution and median is therefore more accurate central tendency measure than the mean. This study investigates the influence of the test set values choice on the estimated color reproduction system accuracy, and analyzes differences between sets of data using the analysis of variance.

### 2. Experimental

The experiment was conducted on a laser electrophotographic printer using the plain paper and RGB driver. A standard characterization chart (supplied with commercial profiling package) containing 918 patches was printed on the printer, and the patches were measured using a reflection spectrophotometer with  $45^\circ/0^\circ$  measuring geometry. The measurement data was used to create the ICC profile by commercial software package. In order to investigate the influence of the test set data on the system accuracy, nine independent test sets were created. RGB values different from those contained in the characterization chart were selected, and their permutations used to sample the device space. From those values, three different sets for each



of the three different set sizes were selected, making nine different sets in total. Test charts of those nine RGB data sets were printed and corresponding L\*a\*b\* device responses were measured. Images of nine RGB charts were converted to L\*a\*b\* space using the device profile and absolute colorimetric rendering intent, and L\*a\*b\* values predicted by the profile were compared to measured device responses. It should be noted that profile's AtoB1, colorimetric device to profile connection space transformation table is used in this process in order to obtain colorimetric values which can be used to express the  $\Delta E$  colorimetric differences. Although the accuracy of BtoA, profile connection space to device transformation table is more important, transformation to device values does not provide suitable error metric, and the forward and reverse transformations are considered to be similarly accurate. The  $\Delta E$  error histograms were plotted to inspect possible differences in the error distribution, and other measures such as minimum, maximum, central tendency and confidence interval were used to compare the samples. Finally, the analysis of variance was conducted to compare whether the mean values of different samples are significantly different.

### 3. Results

Figures 1 to 3 and Tables 1 to 3 show the distributions of the  $\Delta E$  error between the colorimetric values predicted by the profile and those measured on the device, as described in previous section. The results in Tables 1 to 3 appear to be similar for central tendency measures. However, the maximum error seems to differ significantly both between samples of the same size, and between samples of different sizes.

Table 1:  $\Delta E$  statistics for three different random samples of 144 values

N – # patches	min	median	mean	max	95% C.I.
144	1,90	5,47	5,54	11,35	0,60
144	1,48	5,36	5,68	13,66	0,69
144	1,37	5,27	5,44	10,50	0,60

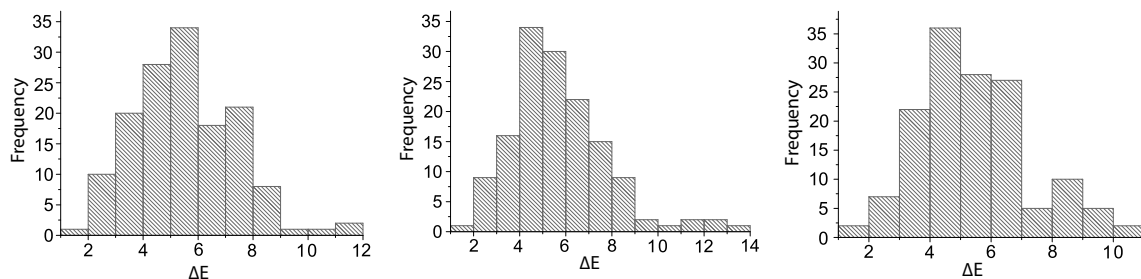


Figure 1: Three different random samples of 144 values

Table 2:  $\Delta E$  statistics for three different random samples of 288 values

N – # patches	min	median	mean	max	95% C.I.
288	1,23	5,39	5,89	17,75	0,57
288	0,78	5,12	5,49	13,54	0,50
288	1,34	5,54	5,95	16,15	0,55

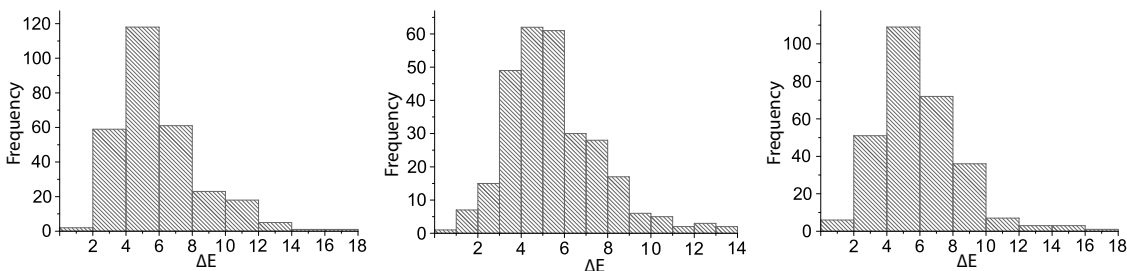


Figure 2: Three different random samples of 288 values

Table 3:  $\Delta E$  statistics for three different random samples of 576 values

N – # patches	min	median	mean	max	95% C.I.
576	0,84	5,31	5,62	17,66	0,34
576	1,06	5,31	5,80	16,86	0,37
576	0,57	5,66	5,81	14,74	0,33

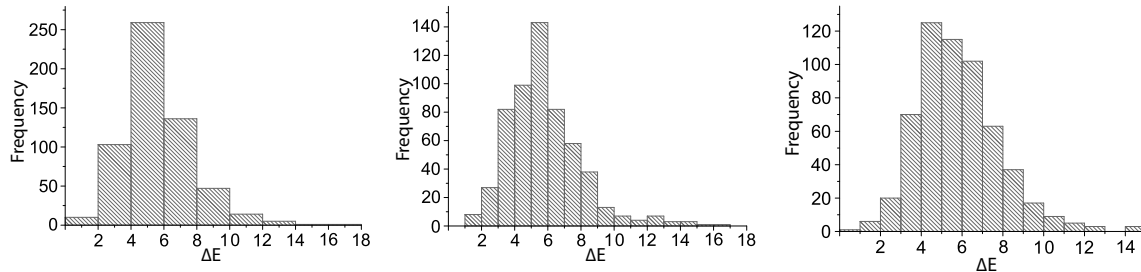


Figure 3: Three different random samples of 576 values

The analysis of variance was used to compare the three different random samples of 288 values as they appear to have largest differences between means with respect to the width of confidence intervals. It was also used to compare differences between the three samples of different sizes (Table 2). The analysis of variance tests whether means of compared groups of data are equal. It assumes that the variances of groups of data are equal. To test the equality of variances, Levene test was conducted. In the case of different sets of 288 values, Levene test significance equaled 0,213 (Table 4), and as  $0,213 > 0,05$ , the null hypothesis of equal variances is accepted. The ANOVA results (Table 5) show that the probability that differences between groups have occurred by chance is very small  $0,038 < 0,05$ . The ANOVA does not provide the information which group is significantly different, so Tukey's HSD test was also conducted. The results (Table 6) show that the difference between group two and three were barely significant at 0,05 significance level as  $0,049 < 0,05$ , while differences between other groups were insignificant.

Table 4: Levene test of equality of variances for three different groups of 288 values

Levene test	df1	df2	Significance
1,551	2	861	0,213

Table 5: ANOVA for three different groups of 288 values

	Sum of squares	df	Mean square	F	Significance
Between Groups	36,039	2	18,020	3,289	,038
Within Groups	4717,040	861	5,479		
Total	4753,079	863			

Table 6: Tukey HSD for three different groups of 288 values

(I)	(J)				95% C.I.	
		Difference between means (I-J)	Standard error	Significance	Lower limit	Upper limit
1,00	2,00	,40041	,19505	,100	-,0575	,8583
	3,00	-,05952	,19505	,950	-,5175	,3984
2,00	1,00	-,40041	,19505	,100	-,8583	,0575
	3,00	-,45993*	,19505	,049	-,9179	-,0020
3,00	1,00	,05952	,19505	,950	-,3984	,5175
	2,00	,45993*	,19505	,049	,0020	,9179

*Table 7: Levene test of equality of variances for three groups of different sizes*

Levene test	df1	df2	Significance
5,893	2	1005	0,003

*Table 8: Welch and Brown-Forsythe tests for three groups of different sizes*

	Statistic	df1	df2	Significance
Welch	1,661	2	384,559	0,191
Brown-Forsythe	1,940	2	644,871	0,145

Three groups of different sizes could not be compared using the analysis of variance as the variances of those groups were not homogeneous (Table 7),  $0,003 < 0,05$ . Therefore, test robust to this condition were used and showed that the means of groups of data are not significantly different as  $0,191 > 0,05$  and  $0,145 > 0,05$  (Table 8).

#### 4. Discussion

The results of the conducted experiment showed that the choice of random values can result in small differences in mean values on the 0,05 significance level. The choice of sample size did not have significant effect on the 0,05 level. However, the maximum errors which are very important criteria for the evaluation of a color reproduction system were considerably different both between different samples of the same size and between samples of different sizes.

#### 5. Conclusion

It is known that color reproduction device models are less accurate in some regions of color space, depending on the model type and constraints. Therefore, careful choice of test set values is necessary in order to estimate the maximum error more accurately. However, including those values inevitably increases the central tendency measures and larger test sets may be necessary in order to estimate them more accurately.

#### 5. Literature

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## EMERGING SUBSTANCES OF CONCERN IN THE GRAPHICAL INDUSTRY

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**Abstract:** Emerging contaminants of concern are commonly derived from municipal, agricultural, and industrial wastewater sources and pathways. These newly recognized contaminants represent a shift in traditional thinking as many are produced or generated industrially, are dispersed to the environment from domestic, commercial, and industrial/graphical uses. In the paper the results of residues of emerging heavy metals in printing wastewater are presented. To our experimental research emerging heavy metals were detected to after the wastewater printing industry was threat by commercial zeolit sorbent. The wastewater of selected X graphical company.

**Key words:** emerging substances of concern, emerging metals, graphical industry

### 1. Introduction

Emerging contaminants are commonly derived from municipal, agricultural, and industrial/graphical wastewater sources and pathways. These newly recognized contaminants represent a shift in traditional thinking as many are produced industrially yet are dispersed to the environment from domestic, commercial, and industrial uses.

According to NORMAN (Network of reference laboratories for monitoring of emerging environmental pollutants) "Emerging substances" can be defined as substances that have been detected in the environment, but which are currently not included in routine monitoring programmes at EU level and whose fate, behavior and (eco)toxicological effects are not well understood. Emerging pollutant as the new term is used and could be defined as pollutants that are currently not included in routine monitoring programmes at the European level and which may be candidates for future regulation, depending on research on their (eco)toxicity, potential health effects and public perception and on monitoring data regarding their occurrence in the various environmental compartments/water, air, soil, biota, humans.

More than 32 million substances were registered with the American Chemical Society's Chemical Abstract Service, with over 15 million of them being commercially available. Unfortunately, regulatory controls only exist for approximately 250,000 (1.6%) of these substances. Therefore, around 98% of the commercially available compounds are **NOT** inventoried and are essentially unregulated substances, some having a high degree of uncertainty associated with their environmental fate, transport, and toxicological effects. In less than two years, more than 5 million new chemicals were added to the registry, and 5 million additional chemicals became commercially available. At the current rate of chemical development, the fraction of unregulated to regulated chemicals will continue to increase exponentially. Once available in the marketplace, many of these substances are released into the environment, where they pose an unknown level of risk to humans, animals, and plants.

EmS are chemicals found in a wide array of consumer goods, including pharmaceuticals and personal care products. EmS may be found in very low concentrations between 0.0001 and 0.001 mg/L in surface water, ground water, domestic wastewater, industrial wastewater, agricultural runoff, reclaimed water, and other waters. Many of these compounds also may be found in soils and in the air. They are a fact of modern, industrialized living.

The major aim of these paper is to provide first information in our research area on EmS for evaluation of their potential threat to environmental and human health. To accomplish this goal, the research activities of this project are to: [1] develop analytical methods to measure chemicals and microorganisms or their genes in a variety of matrices (e.g. water, sediment, waste) down to trace levels, [2] determine the environmental occurrence of these potential contaminants, [3] characterize the myriad of sources and source pathways that determine contaminant release to the environment, [4] define and quantify processes that determine their transport and fate through the environment, and [5] identify potential ecologic effects from exposure to these chemicals or microorganisms. The goal of this paper was to determine emerging heavy metals before and after treatment wastewater in graphical industry.

## 2. Theoretical approach

An important component of emerging contaminant research is to determine the environmental occurrence by answering the fundamental questions: What compounds enter the environment? How often and at what levels do they occur? In what mixtures do they occur? These questions are addressed by field reconnaissance studies at national, regional, and local scales.

## 3. Transport and Fate

Transport and fate provides a basic understanding of the biologic, chemical, and hydrologic processes that affect partitioning into various environmental media (e.g. water, sediment and tissue) and chemical and microbial transformation (Figure 1). These processes can have a significant effect on the potential toxicity of a contaminant.

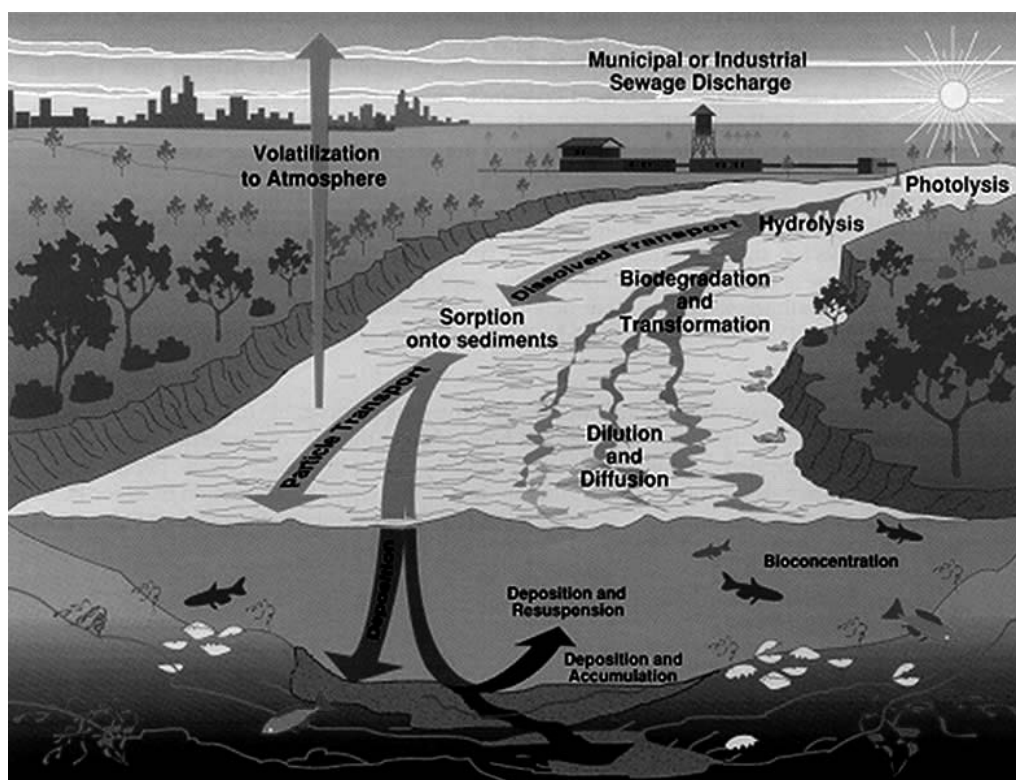


Figure 1: Transport and fate of emerging chemical contaminants

## 4. Ecological Effects

For most emerging contaminants and emerging metals in trace, nanogram level, there is currently little information regarding their potential toxicological significance in ecosystems, particularly effects from long-term, low-level environmental exposures. Correlations between occurrence of emerging contaminants in the environment with occurrence in the tissue of aquatic biota are investigated and used where possible in development and testing of hypotheses on biological effects. Evaluating ecological effects of environmental contamination goes beyond observing co-occurrence of contaminants/metals and adverse effects to documenting cause and effect relationships. Research to characterize cause-and-effect relationships requires documentation of contaminant uptake, modes of action, and biological endpoints.

For convenience, EmS are categorized seven general classes: Global organic contaminants; Pharmaceuticals and personal care products; Endocrine-modulating compounds; Nanoparticles; Industrial chemicals (new and recently recognized); and Biological metabolites and toxins.

It should be recognized that these categories are not absolute and that many compounds fit into multiple categories.

**Global Organic Contaminants** include polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and siloxanes. PBDEs and HBCDs are flame-retardant chemicals that are applied to items such as clothing, upholstery, foam cushions, electronics, and automobile interiors. PBDEs do not chemically strongly bind to the substrates to which they are applied, and so they are easily liberated. These moderately long-lived molecules are primarily released into the atmosphere, where they can be transported globally and readily bioaccumulate and biomagnify in biological tissues. Recent research shows that PBDE tissue burdens are doubling in humans and animals every two to five years, with levels in human breast milk recently showing dramatic increases. PBDE concentrations as high as 419 nanograms per gram (ng/g) lipid weight have been reported in a sample of human breast milk from an Austin. To this category/class of emerging organic contaminants the different synthesized aromatic dyes substances are belong which are using in printing graphical industry.

Biomagnification factors for PBDEs ranged from 3:1 to 85:1 in sharks and dolphins. PBDEs have been shown to have adverse effects (e.g., interfering with reproduction and development) in mammals, birds, and invertebrates at “environmentally relevant exposures”. In this sense, “environmentally relevant exposure” means that concentrations similar to those shown to have adverse effects in laboratory experiments have also been measured in the environment. Additionally, PBDEs have been shown to produce carcinogenic, endocrine-modulating, developmental, reproductive, and neurotoxicological effects.

**Pharmaceuticals and Personal Care Products (PPCPs)** include all prescription and over-the-counter drugs, diagnostic agents, dietary supplements, fragrances, soaps, conditioners, sunscreens, cosmetics, caffeine, and nicotine. PPCPs also include antibiotics. This diverse category of ESOC includes many water-soluble compounds. The most common mechanism for their entry into the environment, especially surface water, is through wastewater discharges (municipal and septic drainage), land application of sewage sludge and manure, and landfill leachate. Depending on the type of treatment employed and the specific chemical(s) involved, wastewater or drinking water facilities may or may not be effective at removing these compounds from the effluent or drinking water. Receiving water concentrations of PPCPs typically range from nanograms per liter (ng/L) (parts per trillion) to low micrograms per liter (g/L) (parts per billion), with caffeine and common pain relievers (e.g., ibuprofen) typically found in the highest concentrations.

Past laboratory studies suggested that environmental effects due to PPCPs were not likely at environmentally relevant concentrations; however, most of these studies were conducted with single compounds and did not account for interactions (additive, synergistic, or antagonistic) between ESOC, and may not have been of sufficient duration to capture adverse effects in the environment. More recent field studies suggest that estrogenic effects from PPCPs are occurring at observed environmental concentrations. More research is needed on the fate and effects of PPCPs in complex effluents and their receiving waters.

**Endocrine-Modulating Chemicals** include natural and synthetic hormones, surfactants, pesticides, tributyltin, polychlorinated biphenyls (PCBs), and dioxins/furans. Estrogens are excreted by humans and are readily degradable under aerobic conditions, but they degrade slowly under anaerobic conditions. Conjugated estrogens, which are formed as the body eliminates estrogens, are not estrogenically active. However, these conjugated estrogens can be deconjugated in wastewater treatment systems, liberating active estrogenic compounds in the discharge. The research studies documented significant declines in a fathead minnow population in a lake dosed with only 5 to 6 parts per trillion of the synthetic birth control hormone 17 $\alpha$ -ethinylestradiol, when compared with an undosed control lake fathead minnow population. This concentration of ethinylestradiol has been reported in wastewater effluents in Canada and the United States. Potential effects from wastewater discharges could be even greater due to the additive or synergistic effects of other estrogenic compounds in the wastewater (e.g., natural estrogen, pesticides, surfactants, etc.) and should be studied. Industrial EmS include phthalates (plasticizers), nonylphenol and alkylphenol ethoxylates (surfactants, antifoaming agents, and plasticizers or ultraviolet stabilizers in plastics), bisphenol A (an ingredient in lacquers used to treat cans used for food goods), PCBs, dioxins/furans, PBDEs (flame retardants), and parabens (preservatives used in cosmetics and antibacterial toothpastes). Unmetabolized livestock growth regulators, along with prophylactic antibiotics are excreted in animal urine and manure. A commonly used surfactant, nonylphenol ethoxylate, was recently banned in Europe due to its persistence, high bioaccumulation potential, and strong estrogenic effects (1/10,000 of Estrogen

Equivalent, or EE). The EPA is in the process of recommending water quality criteria for nonylphenol ethoxylate (which may be as low as 1.4 g/L in salt water) (EPA, 2003).

Besides being toxic at recommended application rates, many currently used or legacy pesticides—such as aldicarb, atrazine, chlordane, DDT, diazinon, lindane, mirex, parathion, permethrin, simazine, toxaphene, and tributyltin—may have endocrine-modulating effects on aquatic organisms. These EMCs can alter neural input to the endocrine system; interfere with the hormonal modulation of the nervous system; and adversely affect the regulation of hormone and receptor biosynthesis, secretion, and metabolism.

**Nanomaterials** are natural and man-made structures, ranging in size from 1 nanometer (nm) to 100 nm, that are widely used in nanotherapeutic pharmaceuticals, drug delivery, cosmetics, personal care products, energy storage products, fabrics, lubricants, and even recreational equipment such as golf balls. Their use is already so ubiquitous that one would find it very difficult to avoid exposure to at least some form of nanomaterials. Due to their extremely small size, nanomaterials can pass through biological membranes and the blood/brain barrier. Additionally, nanomaterials display different physical and chemical properties than their parent compounds. For example, nonferrous metals such as gold or silver may become magnetized. Other nanoscale materials can act as catalysts or semiconductors. These properties only increase the likelihood that nanomaterials could produce unanticipated toxicological effects.

## 5. High-Risk Characteristics

Many millions of unregulated chemicals may be potentially associated with environmental risk, including items long thought to be benign, such as PPCPs. Improved analytical chemistry methods have resulted in the identification of many more chemicals in ambient waters or the tissues of organisms than were previously thought to occur. Considering the current information on EmS, those with the highest propensity for adverse biological effects include those that are: Persistent (structurally stable or consistent release); Bioaccumulative; Carcinogenic; Lipophilic; Acutely or chronic toxic; Endocrine disruptors, and/or Sized in the nanoscale range.

Persistence may be caused by the structural stability of the chemical (e.g., a long half-life) or it may be a result of consistent loading to the environment. The latter is the case for many PPCPs, alkylphenols, and hormones/steroids that are consistently being released to the environment via wastewater effluents, landfill leachate, feedlot operations, or the land application of sewage sludges. Persistent, lipophilic, bioaccumulative, endocrine-disrupting compounds that may also be carcinogenic—such as PBDEs, aromatic dyes and pesticides (and their associated breakdown products)—should therefore be the highest priority for regulatory control. Recent research suggests that some nanomaterials also possess many of these high-risk properties.

Research to date indicates that many of the nonorganic nanomaterials (ceramics, metals, and metal oxides) are inherently nonbiodegradable and are stable and persistent (EPA, 2007). They are also capable of bioaccumulating in the food chain. A number of researchers have reported acute and chronic toxicity of various nanomaterials.

In NORMAN Project EmS are divided into 23 categories (classes) with 79 subcategories/subclasses with examples of individual emerging substances, Table 1.

*Table 1: Emerging substances – most frequently discussed*

Category / class	Sub-class	Individual substances
<b>Algal toxins</b>	Cyanotoxins	Microcystin-LR, Microcystin-RR, Microcystin-YR
<b>Antifoaming agents</b>	Antifoaming agents	Surfinol-104
<b>Antioxidants</b>	Antioxidants	2,6-Di-tert-butylphenol, 4-tert-Butylphenol, BHA, BHQ, BHT
<b>Antifouling compounds</b>	Antifouling compounds	Irgarol
	Organotin compounds	Dibutyl tin ion, Monobutyl tin ion, Tetrabutyl tin ion, Diphenyltin ion, Triphenyltin ion
<b>Bio-terrorism/sabotage agents</b>	Bio-terrorism/ sabotage agents	Chloropicrin
<b>Complexing agents</b>	Complexing agents	DTPA, EDTA, NTA, Oxadixyl, TAED
<b>Detergents</b>	Aromatic sulphonates	Naphthalene sulphonic acid

	Alcohol ethoxylates (Aes), Alkanol amides, Alkyl glucamides (Ags), Alkyl polyglucosides (APGs), Alkyl sulfates (AS), Alkylether sulfates (AES), Alkylphenol ethoxylates (APEOs), alpha-Olefin sulfonates (AOS), Amine ethoxylates, Cocamidopropyl betaine, Fatty acid diethanolamides (FADAs), Organosilicones, Polyethylene glycols, Secondary alkane sulfonates (LAS)	
	Linear alkylbenzene sulfonates (LAS)	C10-C14-LAS, C12-LAS
	Ethoxylates/carboxylates of octyl/nonyl phenols	4-Nonylphenol di-ethoxylate (NPE2O), 4-Nonylphenol mono-ethoxylate (NPE1O), 4-Nonylphenoxy acetic acid (NPE1C), 4-Nonylphenoxyethoxy acetic acid (NPE2C), 4-Octylphenol di-ethoxylate (OPE2O), 4-Octylphenol mono-ethoxylate (OPE1O), 4-Octylphenoxy acetic acid (OPE1C), 4-Octylphenoxyethoxy acetic acid (OPE2C)
<b>Disinfection by-products (drinking water)</b>	Iodo-trihalomethanes, Bromoacids, Bromoacetonitriles, Bromoaldehydes, Haloacetic acids (chloro-, bromo-, iodo-)	
	Other disinfection by-products	Bromate, Cyanoformaldehyde, Decabromodiphenyl ethane, Hexabromocyclododecane (HBCD), NDMA
<b>Plasticizers</b>	Phthalates	Benzylbutylphthalate (BBP), Diethylphthalate (DEP), Dimethylphthalate (DMP), Di-n-butylphthalate (DBP), Di-n-octylphthalate (DOP)
	Other	Bisphenol A, Triphenyl phosphate
	Benzophenone derivatives	2,4-Dihydroxybenzophenone
<b>Flame retardants</b>	Brominated flame retardants	1,2,5,6,9,10-Hexabromocyclododecane (HBCD), Tetrabromo bisphenol A (TBBPA), Tetrabromo bisphenol A bis (2,3 dibromopropylether), Hexabromocyclododecane (isomers), Decabromodiphenyl ethane
	Polybrominated diphenylethers	2,2',3,4,4',5',6-Heptabromodiphenyl ether (BDE 183) 2,2',4,4',5,5',6-Hexabromodiphenyl ether (BDE-153) 2,2',4,4',5,6',6'-Hexabromodiphenyl ether (BDE-154) 2,2',4,4',5-Pentabromodiphenyl ether (BDE-99) 2,2',4,4',6-Pentabromodiphenyl ether (BDE-100) 2,2',4,4'-Tetrabromodiphenyl ether (BDE-47) 2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether (BDE-209) Technical Decabromodiphenyl ether, Technical Octabromodiphenyl ether Technical Pentabromodiphenyl ether
	Organophosphates	Tri-(dichlorisopropyl)phosphate, Triethylphosphate, Tri-n-butylphosphate, Triphenylphosphate Tris(2-chloroethyl)phosphate
	Chlorinated paraffins	Long chain PCAs (IPCAs, C>17), Medium chain PCAs (mPCAs, C14-17), Technical PCA products
<b>Fragrances</b>	Fragrances	Acetylcedrene, Benzylacetate, Benzylsalicylate,



		Camphor, g-Methylionone, Hexylcinnamaldehyde, Isoborneol, Isobornylacetate, Isoquinoline, d-Limonene, Methylidihydrojasmonate, Methylsalicylate, p-t-Bucinal, Terpeneol
	Nitro musks	Musketone, Muskxylene, Musk ambrette
	Macrocyclic musks	
	Polycyclic musks	AHTN (Tonalide), Galaxolide, OTNE, AHDl (Phantolide), ADBI (Celestolide), ATII (Traseolide)
<b>Gasoline additives</b>	Dialkyl ethers	Methyl-tert-butyl ether (MTBE)
<b>Industrial chemicals</b>	Industrial chemicals	TCEP, Triphenyl phosphine oxide
<b>Nanoparticles</b>	Carbon fullerenes	Buckyballs (Fullerene C-60)
	Carbon nanotubes	Carbon nanotubes – single-wall, Carbon nanotubes – multi-wall, Carbon nanotubes – coated
	Carbon black	Carbon black
	Silicon-based	Silicon Carbide, Silica
	Titanium dioxide	Titanium dioxide
	Aluminium Oxide	Aluminium Oxide (powder), Aluminium Oxide (fibre)
<b>Perfluoroalkylated substances and their transformation products</b>	Perfluoroalkylated substances	2-(N-ethylperfluorooctanesulfonamido)-ethyl alcohol (N-Et-FOSE) 2-(N-methylperfluorooctanesulfonamido)-ethyl alcohol (N-Me-FOSE) 6:2 Fluorotelomer sulfonate (6:2 FTS) Alcohol N-methylperfluorooctane sulfonamidoethanol (N-MeFOSE) N-ethylperfluorooctanesulfonamide (EtFOSA) N-methylperfluorooctanesulfonamide (MeFOSA) N-methylperfluorooctanesulfonamidoethyl acrylate (N-MeFOSEA) Perfluorobutanesulfonate anion (PFBS), Perfluorodecane sulfonate (PFDS) Perfluorodecanoic acid (PFDA), Perfluorododecanoic acid (PFDoA) Perfluorododecanoic acid (PFDoA), Perfluoroheptanoic acid (PFHpA) Perfluoroheptanoic acid (PFHxA), Perfluorohexane sulfonate (PFHS) Perfluorononanoic acid (PFNA), Perfluorooctane sulfonamide (PFOSA) Perfluorooctane sulfonamidoethanol (FOSE), Perfluorooctane sulfonate (PFOS) Perfluorooctanesulfonyl fluoride (POSF), Perfluorooctanoic acid (PFOA) Perfluorosulfonamide, Perfluorotetradecanoic acid (PFTDA) Perfluoroundecanoic acid (PFUnA)
	Fluorotelomer alcohols	4:2 FTOH, 6:2 FTOH, 8:2 FTOH, 10:2 FTOH, 12:2 FTOH
	Perfluorosulfonamido alcohols	
<b>Personal care products</b>	Sun-screen agents	4-Methylbenzylidene camphor, Benzophenone, Benzophenone-3, Butyl methoxydibenzoylmethane, Ethylhexyl methoxycinnamate, Eusolex, Homosalate, N,N-Diethyltoluamide, Octocrylene, Oxybenzone
	Insect repellents	N,N-diethyl-m-toluamide (DEET), Bayrepel
	Carriers	Octamethylcyclotetrasiloxane (D4), Decamethylcyclopentasiloxane (D5) Dodecamethylcyclohexasiloxane (D6),

		Hexamethyldisiloxane (HM or HMDS) Octamethyltrisiloxane (MDM), Decamethyltetrasiloxane (MD2M) Dodecamethylpentasiloxane (MD3M)
	Parabens (hydroxybenzoic acid esters)	Methyl-paraben, Ethyl-paraben, Propyl-paraben, Isobutyl-paraben
<b>Pesticides</b>	Polar pesticides and their degradation products	Amitrole, Bentazone, Bromofos-ethyl, Carbazole, Carbendazim, Carboxin, Glyphosate, Chloridazon, Clopyralid, Chlorpropham, Chlorpyrifos, Chlorotoluron, 2,4 D, Dicamba, Desethylterbutylazine, Desmedipham, Desmetryn, Diazinon, Diclobenil, d-Dichlorvos, Dinoterb, Endosulfan-sulfate, Ethoprophos, Ethofumesate, Fluroxypyr, Heptenophos, Iodofenphos, Imidacloprid, MCPA, MCPB, MCPP (Mecoprop), Metalaxyl, Methomyl, Metamitron, Mevinphos, Phenmedipham, Prometryn, Prometon, Secbumeton, Terbutryn, Terbutylazine, Thiabendazyl, Triadimefon
	Other pesticides	Cypermethrin, Deltamethrin, Permethrin
	New pesticides	Sulfonyl urea
	Degradation products of pesticides	Desisopropylatrazine, Desethylatrazine
	Antimicrobial agents	Dichlofluanide
<b>Biocides</b>	Biocides	Triclosan, Methyltriclosan, Chlorophene
<b>Pharmaceuticals</b>	Analgesic	Acetaminophen (paracetamol), Codeine, Hydrocodone
	Anorexic	Fenfluramine
	Anthelmintic	Ivermectin
	Antibacterial	Amoxicillin, Ampicillin, Azithromycin, Chloramphenicol, Chlortetracycline, Ciprofloxacin, Clarithromycin, Cloxacillin, Danofloxacin, Dicloxacillin, Doxycycline (anhydrous), Doxycycline (monohydrate), Enoxacin, Enrofloxacin, Erythromycin, Flumequine, Josamycin, Lincomycin, Methicillin, Minocycline, Norfloxacin, Novobiocin, Ofloxacin, Oleandomycin, Oxacillin, Oxytetracycline, Penicillin G, Penicillin V, Roxithromycin, Spiramycin, Sulfadiazine, Sulfamerazine, Sulfamethazine
	Anticonvulsant	Sulfamethoxazole, Sulfapyridine, Carbamazepine, Primidone
	Antidepressant	Tetracycline, Tiamulin, Citalopram, Escitalopram, Sertraline, Fluoxetine, Fluvoxamine, Paroxetine
	Antidiabetic	Glyburide (glibenclamid; glybenzcyclamide), Metformin
	Antiemetic	Diphenhydramine
	Antihistaminic	Loratadine
	Antihypertensive	Nadolol, Verapamil
	Anti-inflammatory	Aceclofenac, Acemetacin, Acetylsalicylic acid (aspirin), Alclofenac, Diclofenac, Fenoprofen, Fenoprofen calcium salt dihydrate, Ibuprofen, Indomethacin, Ketoprofen, Meclofenamic acid, Mefenamic acid, Naproxen, Phenylbutazone, Phenazone, Propyphenazone, Tolfenamic acid
	Antimicrobial agent	Clotrimazole
	Antineoplastic	Cyclophosphamide, Cyclophosphamide (anhydrous form), Daunorubicin, Doxorubicin, Epirubicin, Fluorouracil, Ifosfamide
	Antiulcerative	Famotidine, Lansoprazole, Omeprazole,

		Ranitidine
	Antiviral	Acyclovir
	Anxiolytic	Alprazolam, Bromazepam, Diazepam, Lorazepam, Medazepam, Meprobamate, Nordiazepam, Oxazepam, Temazepam
	Beta-Blockers	Acebutolol, Atenolol, Betaxolol, Bisoprolol, Carazolol, Metoprolol, Oxprenolol, Pindolol, Propranolol, Sotalol, Timolol
	Blood viscosity agents	Pentoxifylline
	Bronchodilators	Albuterol, Albuterol sulfate, Clenbuterol, Fenoterol, Salbutamol, Terbutaline
	Diuretic	Caffeine, Furosemide, Hydrochlorothiazide
	Lipid regulators	Bezafibrate, Clofibric acid, Etofibrate, Fenofibrate, Fenofibric acid, Gemfibrozil, Lovastatin, Mevastatin, Pravastatin, Simvastatin
	Sedatives, hypnotics	Acecarbromal, Allobarbitol, Amobarbital, Butalbital, Hexobarbital, Pentobarbital, Aprobital, Secobarbital sodium
	Steroids and hormones	17-alpha-Estradiol, 17-alpha-Ethinylestradiol, 17-beta-Estradiol, Beta-sitosterol, Cholesterol, Diethylstilbestrol, Estriol, Estrone, Estrone 3-sulphate, Prednisolone, Dexamethasone, Bethametasone, Mestranol
	Psychiatric drugs	Amitryptiline, Doxepine, Imipramine, Nordiazepam, Zolpidem
	X-ray contrast media	Diatrizoate, Iohexol, Iomeprol, Iopamidol, Iopromide
<b>Trace metals and their compounds</b>	Trace metals and their compounds	Tetramethyllead, Tetraethyllead
<b>Anticorrosives</b>	Benzotriazoles	
	Methylbenzotriazoles (MBT)	4-Methyl-1H-benzotriazole, 5-Methyl-1H-benzotriazole, 5,6-Dimethyl-1-H-benzotriazole
	Tolyltriazoles (TT)	Tolyltriazole, 4-/5-Tolyltriazole (Ttri)
<b>Wood preservatives</b>	Phenols	para-Cresol
<b>Other</b>	Drugs of abuse	Cocaine, Codeine, Dihydrocodeine, Heroin, Hydrocodone, Morphine, Oxycodone
	Benzothiazoles (BT)	Benzothiazole, 2-Mercapto-benzothiazole, Benzothiazole sulfonic acid
	Nicotine metabolite	Cotinine

## 6. Results

The most common mechanism for emerging contaminants of concern and emerging metals and dyes from graphical industry entry into the environment, especially surface water, is through wastewater discharges, land application of sewage sludge and manure, and landfill leachate. Depending on the type of treatment employed and the specific chemical(s) involved, wastewater or drinking water facilities may or may not be effective at removing these compounds from the effluent or drinking water. Receiving water concentrations of EmS typically range from nanograms per liter (ng/L) (parts per trillion) to low micrograms per liter (g/L) (parts per billion).

In the wastewater of the graphical industry tree emerging metals Cu (II), total Cr, Zn (II) were detected by zeolit as the adsorbed concentration the residues of examined metals were reduced but the concentration levels are detectable.

## 7. Conclusion

Emerging substances of concern as the newly recognized contaminants in a very low ppm, ppb and ppt concentrations could be defined as substances that have been detected in the environment, but which are currently not included in routine monitoring programmes at EU level and whose fate, behavior and (eco)toxicological effects are not well understood.

Emerging contaminants imperatively need to be candidates for future regulation, depending on research on their (eco)toxicity, potential health effects and public perception and on monitoring data regarding their occurrence in the various environmental compartments. In wastewater of graphical and printing industry the residues of three emerging metal contaminants were detected. Emerging metals were determined in wastewater before and after treatment processes by zeolite sorber.

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## THE INTERACTION OF THE ALKALINE SOLUTION AND THE ALUMINIUM-OXIDE FILM DURING THE PRINTING PLATE MAKING PROCESS

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**Abstract:** The non-image areas on the lithographic printing plate are built from roughened and porous aluminium-oxide film. During the plate making process the printing plate is immersed in alkaline solution to dissolve part of the photoactive layer. In this process it is impossible to avoid contact between alkaline solution and aluminium-oxide layer, which is also soluble in this kind of solution. The aim of this paper was to determine the influence of the alkaline solution on the surface properties of the aluminium-oxide film. Measurement of the contact angle was made by applying the defined chemical substances for calculation of surface free energy of aluminium-oxide. Roughness parameters were defined by topographical measurement to determine aluminium-oxide's surface characteristics. The results showed that alkaline solutions cause significant change of the aluminium-oxide surfaces. This leads to conclusion that determination of developing process parameters must be precisely define in order to achieve printing plates of high quality level.

**Key words:** plate making process, alkaline solution, aluminium oxide, surface free energy, roughness parameters

### 1. Introduction

Aluminium foils suitable for use as an offset printing plate consists of two different areas: ink-receptive image areas which carry a photosensitive coating and fountain solution-retaining non-image areas. In order to improve the fountain solution adhesion on the aluminium oxide film and to enhance the adhesion of the photosensitive coating during the printing process [1-2] the foil needs to be roughened by electrochemical graining and anodic oxidation [3].

Roughening of the aluminium surface and forming the thin aluminium oxide film are necessary for a number of reasons:

- It enlarges the functional properties of the surface and causes better fountain solution adsorption.
- It enlarges the better adsorption of the photosensitive coating.
- It enlarges the functional properties and causes better ink adhesion.
- It increases stability of the fountain solution and printing ink on the non-image and image surfaces during the reproduction process.
- It ensures the better mechanical properties of the printing plates and thus, longer print runs with the plates.

After the electrochemical graining process the rough aluminium surface has to be covered with a thin (less than 2  $\mu\text{m}$ ) photosensitive coating, which will be receptive for printing ink in the printing process and present the image areas on the printing plate surface. Due to the fact that aluminium oxide layer on the printing plates is a thin and an extremely porous and that the standardized plate making process requires immersing of the plate in the alkaline solution, significant changes in the structure occurred during the immersion. These changes are the consequence of the amorphous properties of aluminium oxide that is soluble in different alkaline solutions.

### 2. Plate making process

Printing plate making process for offset technique consists of several in-line processes which have to be controlled and standardised. In the first stage, the printing plate surface has to be exposed to certain radiation which causes physical and chemical changes in the photosensitive coating. The result of this process is that exposed areas become soluble in alkaline solutions. In the next stage, the exposed parts of coating have to be removed from aluminium oxide by immersing the printing plate in alkaline solution. This process should not significantly affect the roughness of the substrate because it is essential for its function. Nevertheless, recent studies [4-5] have been confirmed that the chemical processing can also affect the micro-structural roughness inducing changes that impair the quality of printing plate. It has been detected that the extent of these undesired effects depends the working age of the processing solution.

This paper is a step forward in investigation of changes in aluminium oxide surfaces during the chemical processing phase. The main object is directed to the immersion time-depending changes in the structure, and the second one is related to processing solution concentrations and its influence on the oxide structure.

### 3. Experimental part

The changes in the structure of the printing plate surface can indirectly be detected by measuring the wetting properties of observed surfaces [6] and directly, by measuring the changes of the roughness parameters on the printing plates surfaces [7].

In this paper the influence of the alkaline solution on the surface properties of the aluminium-oxide film (non-image areas) was investigated. Measurement of the contact angle was made by applying the defined chemical substances for calculation of surface free energy of aluminium-oxide. Roughness parameters were defined by topographical measurement to determine aluminium-oxide's surface characteristics.

#### 3.1 Preparation of samples

The samples of the printing plates used in this paper were uncoated aluminium foils (Cinkarna Celje). The samples were immersed in sodium hydroxide of different concentrations: 0.20, 0.45, 0.70 moldm<sup>-3</sup> and in a different time periods of 5, 9, 13, 17 and 21 sec.

#### 3.2 Surface characterisation

A measurement of the roughness characteristics of the printing plate surface was performed by electronically-mechanical device surface roughness tester TR200. The surface structure of aluminium plates is a very complex and its estimation demands necessary simplification. It is revealed through the quantification system of surface roughness condition by one-dimensional parameters based on shot of two-dimensional profile on the part of the investigated surface. In regard to the amplitude and the horizontal characteristics of the profile, there are horizontal surface parameters, vertical ones and hybrid ones. The modern equipment for measuring the surface roughness enables measurements of great numbers of parameters, each describing a single characteristic of the surface roughness [8]. The choice of the roughness parameters which will give the optimal characteristics of the surface depends firstly on the process of its elaboration and the function of investigated surface.

In this paper, the printing plate surface was evaluated through following parameters:

- $R_a$  – arithmetical mean of the roughness, (roughness average);
- $R_p$  – the highest peak inside the reference length;
- $R_k$  – core roughness depth, working surface which will influence the consistency of the material (printing plate).

The investigated roughness parameters are defined according to the ISO/DIS 13565-2 (1994) standard on the curve of relative length carrying capacity, so called Abbott's curve [9-10]. Abbott's curve (Figure 1) gives the relative share of the material as a function of the line high cross section and describes relative growth of the material share with the increasing profile.

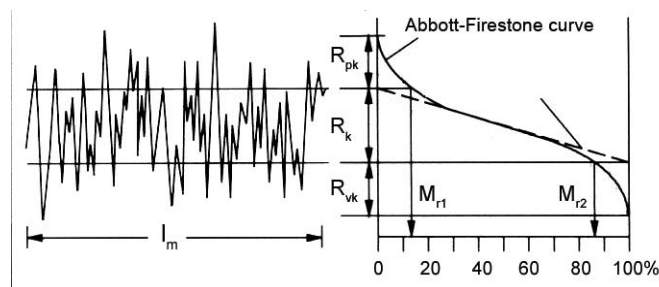


Figure 1: Abbott-Firestone curve

Contact angle measurement and calculation of surface free energy (SFE) was performed by video based DataPhysics OCA30 device. It ensures the static and the dynamic characterization of liquid/solid interfaces by contact angle measurement procedure, the requirement for the calculation of surface free energy. By determination of contact angle between the defined liquid and certain surface it is possible to get the wetting properties of the solid surface [11],

information about the homogeneity of the surface, roughness characteristics of the surface and an information about the interaction between the liquid and the solid.

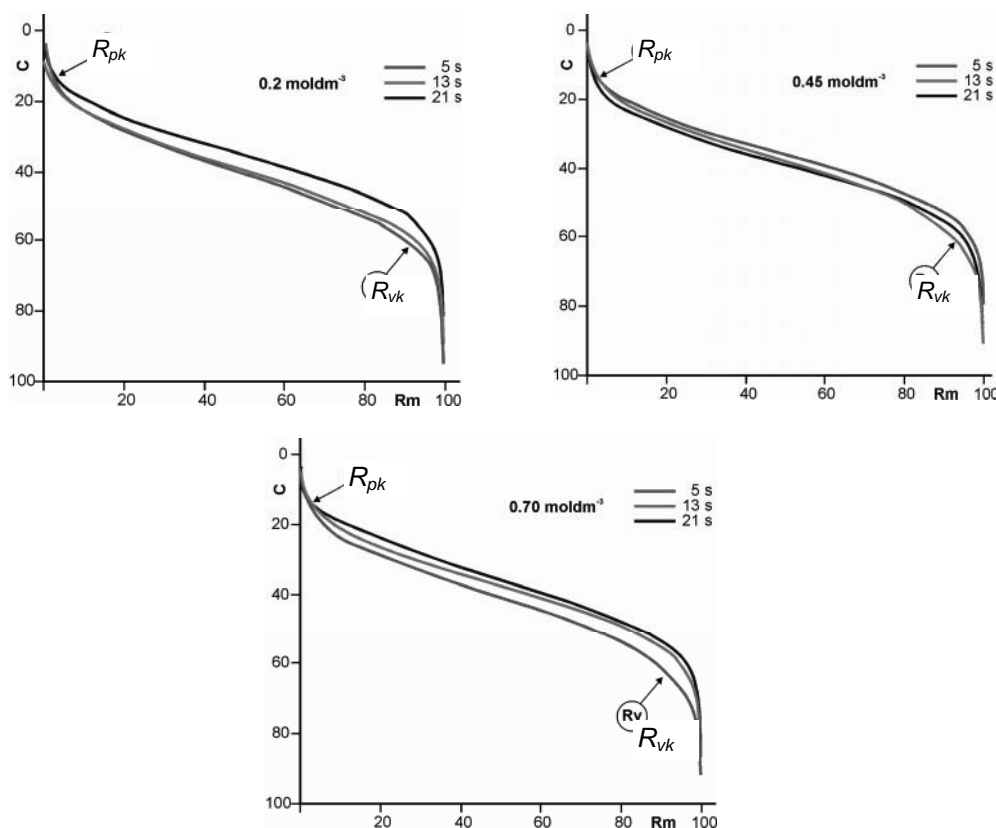
In this paper surface free energy of the aluminium oxide surfaces was calculated by measuring the contact angle with three liquids of known surface tension: diiodomethane (Merck), glycerol (alkaloid) and water (El-TO) (Table 1) [10]. Surface free energies of the aluminium oxide printing plate samples were calculated by using harmonic mean equation [12].

*Table 1. Surface free energy ( $\gamma_{lv}$ ) and their dispersive ( $\gamma_{dlv}$ ) and polar ( $\gamma_{plv}$ ) components and viscosity of liquids*

Liquid	Surface free energy $\gamma$ (mNm <sup>-1</sup> )			Viscosity (mPas)
	$\gamma_{lv}$	$\gamma_{dlv}$	$\gamma_{plv}$	
Diiodomethane (Ström)	50.8	50.8	0.0	2.78
Glycerol (van Oss)	64.0	34.0	30.0	1412
Water (Ström)	72.8	21.8	51.0	1.002

#### 4. Results and discussion

Results of the relative share of the aluminium foil samples as a function of the line high cross section (Abbott's curve) are presented in Figure 2. One can see that there are some differences in interaction of alkaline solution with aluminium foil in relation to the immersion time and conc. of NaOH. Conc. of 0.2 moldm<sup>-3</sup> causes the higher differences in the oxide structure for the period of 21 sec. These results were expected because longer immersion of plate sample cause higher dissolution of aluminium oxide structure and higher values of the parameters presented in Abbott's curve. Higher NaOH conc. (0.45 moldm<sup>-3</sup>) has resulted with similar profile within observed immersion time. One can say that changes in the profile have happened, but they are similar for all observed parameters, i.e. in core roughness depth, peak height and valley depth of the structure. Alkaline conc. of 0.70 moldm<sup>-3</sup> has caused increased values for the period of 13 and 21 sec. Obviously higher conc. cause faster reaction between solution and aluminium oxide structure and increased values in relative length carrying capacity of observed surface.



*Figure 2: Abbott's curve for NaOH conc. 0.20, 0.45 i 0.70 moldm<sup>-3</sup>*



Results of the calculated surface free energy ( $\gamma_{lv}$ ) and dispersive ( $\gamma_{div}$ ) and polar ( $\gamma_{plv}$ ) components of the aluminium oxide surface have been presented in Figure 3. The results have shown that by immersing of the aluminium plate, porous structure of the oxide has been significantly changed. Consequently, the surface free energy of the oxide, as well as contact angles of adsorbed liquids has been different. One can see that the SFE has the highest values on the samples immersed in conc. of  $0.2 \text{ moldm}^{-3}$  NaOH and lowest values on the samples immersed in  $0.7 \text{ moldm}^{-3}$ . On the other hand, by the increasing period of immersion the results of the SFE are lowering. Those results were expected because SPE is in correlation with the observed surface:

$$E = \sigma \cdot A \quad (1)$$

Where  $E$  is energy of the substance,  $\sigma$  is surface tension and  $A$  is substance area.

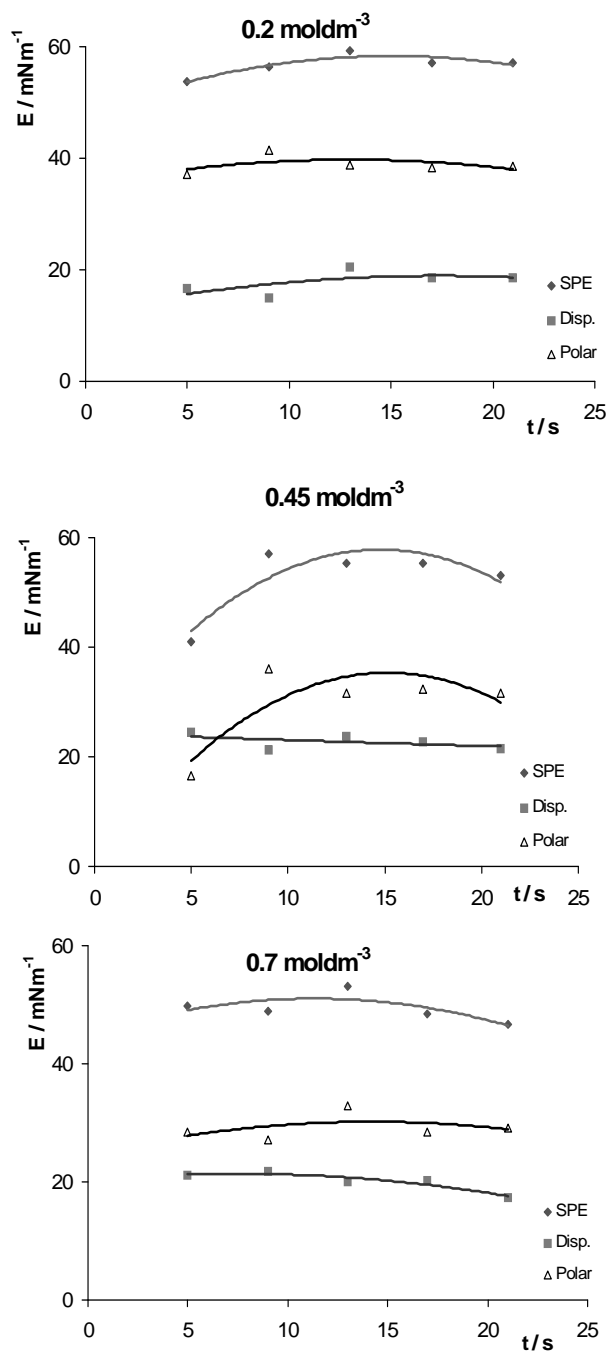


Figure 3: Surface free energy, dispersive and polar components of the aluminium oxide surface (NaOH conc. 0.20, 0.45 i 0.70 moldm<sup>-3</sup>)

According to the results one can see that the dispersive component of SFE has not been particularly changed within the time period of immersion. On the other hand, the polar component of the SFE has been changed. For all observed conc. the polar phase has been increased with the immersion period, and decreased after the 20 sec of immersion. This is the consequence of structural changes which have happened in the aluminium oxide film.

## 5. Conclusion

The aim of this paper was to determine the influence of the alkaline solution on the surface properties of the aluminium-oxide film. Measurement of the contact angle was made by applying the defined chemical substances for calculation of surface free energy of aluminium-oxide. Roughness parameters were defined by topographical measurement to determine aluminium-oxide's surface characteristics. The results showed that alkaline solutions cause significant change of the aluminium-oxide surfaces. This leads to conclusion that determination of chemical processing phase must be precisely defined in order to achieve printing plates of high quality level. Changes in aluminium oxide surfaces, during the plate making phase, could cause the alterations in the adsorption process of the fountain solution on the non-image areas in the reproduction process, and consequently result with imprints of lower quality level. Those results are in correlation with other investigations of the aluminium porous structure published in [5-6].

This paper is another contribution in investigations related to changes in aluminium oxide surfaces during the chemical processing phase. The results of the experimental are repeatable because of the complete definition of the printing plate samples preparation and strictly controlled and defined chemical processing conditions.

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# WASTE PRINTING INKS AS A POLLUTANT OF GRAPHIC ENVIRONMENT

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**Abstract.** The concentration levels of target metals (Cd, Cr, Co, Zn, Fe and Cu) in sheet-fed offset fresh and waste printing inks (cyan, magenta, yellow, and black) were determined by using atomic absorption spectrophotometer (AAS). The concentration levels of Co, Zn, Fe, and Cu in waste printing ink were significant higher than in the fresh printing ink samples. The variations of the metal concentrations in waste and fresh printing inks (cyan, magenta, yellow and black) are in the following range:  $Co > Zn > Cu > Fe$  and  $Co > Cu > Zn > Fe$ , respectively. The presence of Co and Cr in all the samples was not detected. Due to the determined levels of metals, waste printing inks could be classified as hazardous waste.

**Key words:** waste printing inks, metals pollution, graphic environment

## 1. Introduction

Reactive inks have greater use in printing industry, due to their good fastness properties their provision of a wide range of bright colours and the flexibility in their application methods. However, reactive printing inks have been considered to be basis of more environmental problematic compounds that arise from printing ink effluents. Often, only 50-90% of the ink will react with the substrate, depending on the ink and on the application method. As a result, the highly concentrated wastewater produced is a considerable pollution concern [1]. There is currently a renewed interest in the environmental impact and safety of a whole range of manufactured materials including printing inks. The recent media attention concerning the detection of toxic metals in pigmented coatings (paints and inks) applied to imported products has led to a plethora of published information as well as posted information on a variety of internet sites. In many instances this information is incorrect, inaccurate or misleading as there is a tendency to make generalizations about metals of all types [2, 3].

Metals can be present in printing inks in the form of metal-based pigments, dyes and through impurities and contaminants in the raw materials used in printing process. Emergency Planning and Community Right to Know Act (EPCRA) includes barium compounds, copper compounds, zinc compounds and cobalt compounds which are reportable under Section 313 of EPCRA.

The objective of this work is to provide current and accurate information regarding the origins, presence and usage of metals in printing inks.

## 2. Materials

We analyzed eight printing ink samples, four fresh and four waste printing ink samples. All inks were sheet-fed offset printing inks (cyan, magenta, yellow and black) from the same Heidelberg SM 74 2-P-H printing machine. All the ink samples were from same printing facility in Novi Sad (Serbia). Fresh printing inks have the same chemical composition (Table 1), from the same ink manufacturer, Toyo Ink MFG CO. LTD., Japan [4].

Table 1: Chemical composition of fresh printing inks

Composition (%)		Background concentration of heavy metals (ppm) [3]	
Pigment	10 - 30	As	3 - 12
Rosin modified phenolic resin	20 - 40	Pb	4 - 61
Vegetable oil	20 - 30	Cd	0.1 - 1
Petroleum oil	20 - 30	Cr	1.5 - 40
Additives	10 >	Se	0.1 - 3.9
Naphthenic acids, cobalt salts	0 - 1		
Carbon black	0 - 20		

Petroleum-based raw materials used in printing inks can also contain background concentrations of toxic heavy metals at similar or greater than natural background

concentrations depending on the source of the raw materials, processing operations and other variables [2, 3].

### 3. Method

Analysis of priority pollutant metals is conducted by atomic absorption spectrophotometry (AAS) method. Samples are prepared by digestion with 0.1 mol/dm<sup>3</sup> hydrochloric acid (HCl) using the EPA method 3020 for aqueous samples wastes that contain suspended solids and mobility – procedure extracts. Samples were analysed for the requested metals Cd, Cr, Co, Zn, Fe, and Cu. After extraction method, the concentrations of metal ions were determined by using PerkinElmer's AAnalyst 300 Spectrometer. Analytical values less than the method detection limit (MDL) are represented as not detected.

### 4. Results and discussion

The application of AAS technique confirmed the presence of zinc, copper, iron and cobalt in all the samples (fresh and waste). The concentration levels of cadmium and chromium were below the instrument detection limits in all the printing ink. The metal concentration levels in printing inks are given in Table 2.

Table 2: Metal concentrations in fresh and waste printing inks

		Concentration [mg/kg]					
		Cd	Cr	Co	Zn	Cu	Fe
Fresh inks	C <sub>F</sub> (cyan)	ND	ND	17.00	1.16	2.12	0.44
	M <sub>F</sub> (magenta)	ND	ND	6.48	0.29	0.40	0.54
	Y <sub>F</sub> (yellow)	ND	ND	1.38	0.42	0.06	0.28
	B <sub>F</sub> (black)	ND	ND	19.60	ND	0.36	0.66
Waste inks	C <sub>w</sub> (cyan)	ND	ND	20.00	12.22	3.19	0.71
	M <sub>w</sub> (magenta)	ND	ND	103.78	9.82	0.88	2.19
	Y <sub>w</sub> (yellow)	ND	ND	2.80	4.17	0.06	1.35
	B <sub>w</sub> (black)	ND	ND	30.48	5.90	0.84	2.21

ND - not detected

The detected metal concentrations in fresh printing ink samples, confirmed the manufacturer specifications about the maximum allowed concentrations (MAC) in sheet-fed offset printing inks. Namely, the total amount of heavy metals in fresh printing inks should not exceed the value of 100mg/kg [5]. The metal concentrations in fresh printing inks can be used as a indicator for the metal concentration changes in the waste printing ink.

The variations of the metal concentrations in waste printing ink (cyan, magenta, yellow and black) are in the following range: Co>Zn>Cu>Fe and for fresh inks are in the following range: Co>Cu>Zn>Fe.

In the Republic of Serbia, the Regulation for maximum allowed concentrations (MACs) of heavy metals in printing ink has not been adopted. Unfortunately, in Serbia and other undeveloped countries are still in practice that the waste printing ink is directly discharged into the municipal sewage without any treatment.

The Regulation of hazardous matters in water recipients ("Official Gazette of Socialist Republic of Serbia" No. 31/82) gives the maximum allowed concentrations (MAC) for target metals (Table 3).

Table 3: The maximum allowed concentrations (MACs)

Metal	MAC [mg/l]
Cd	0.01
Cr	0.6
Co	2.0
Zn	1.0
Fe	1.0
Cu	0.1

It is evident that the concentrations of all heavy metals in waste printing inks, except for Fe in cyan ink, exceed much the MAC level.

The variations of metal concentrations in the fresh and waste printing inks in order to MAC values are shown in Figure 1. As can be observed from Figure 1, the target metals have different concentration levels in various printing ink (cyan, magenta, yellow and black), due to the type of pigments and other compounds used for production of inks. The average concentration levels of each metals (Co, Zn, Fe, and Cu) in waste ink samples were higher than MAC approximately almost to 2-20 times.

The concentration levels of Cd and Cr in all the printing ink were under instrument detection limits.

As can be seen from Figure 1, the concentrations of Co and Cu in all waste printing ink were above the MAC values. Thus, the Zn concentration in waste printing ink (cyan, magenta, yellow and black) were approximately 13 times higher than the concentration level in fresh inks, and 8 times higher than the MAC value.

The concentration levels of Cu in all printing ink samples were below the MAC values prescribed by the Regulation of hazardous matters in water recipients ("Official Gazette of Socialist Republic of Serbia" No. 31/82). Thus, the average concentration level of Cu in waste printing ink samples was 1.5 times higher than the concentration level in fresh inks, and 15 times higher than the MAC value.

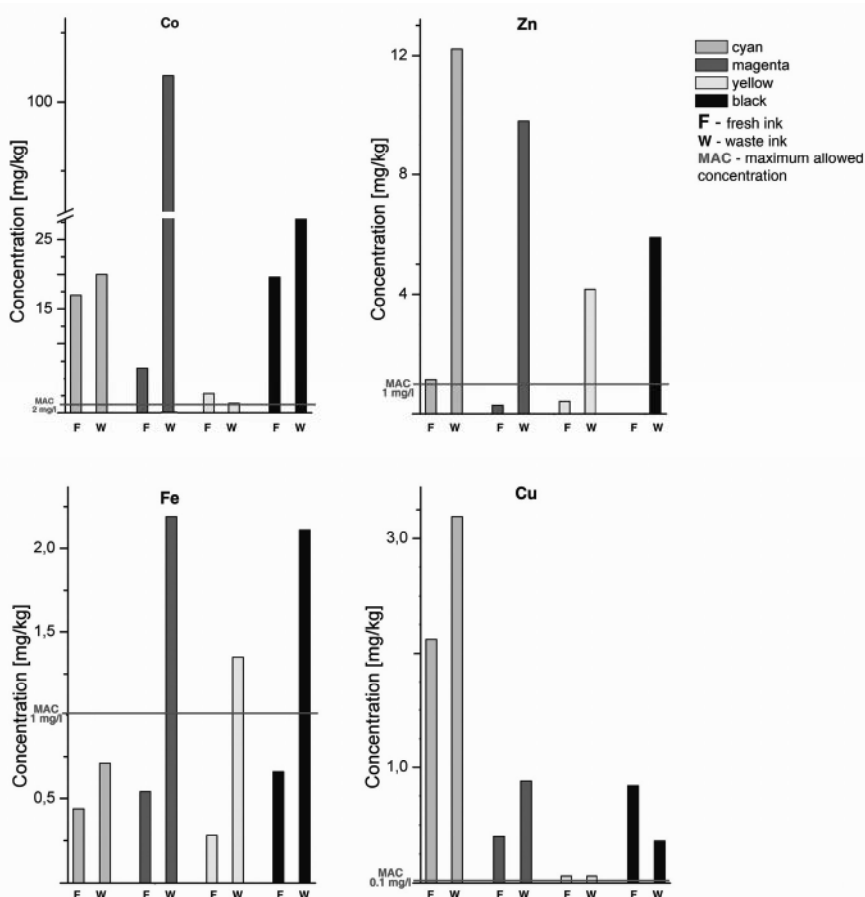


Figure 1: The comparison of Co, Zn, Fe and Cu concentrations in fresh and waste printing inks with MAC values for each metal

#### 4.1 The adsorption method as a possibility of printing wastewater

After the printing process, waste printing inks present very serious problem and it should be found the appropriate solution for management of this toxic waste. One of the possibilities for waste ink management is the recycling of waste ink, but it can be very expensive because it requires the investment in expensive equipment [6]. Another way for reducing of printing inks pollution is the application of alternative replacement of conventional printing ink. Earlier comparative testing between conventional and alternative replacement of conventional printing

ink ("eco-friendly" printing ink) was confirmed that the "eco-friendly" inks contain much less concentration of toxic metals but much of these are still in the use.

Therefore, heavy metals must be removed from the polluted streams in order to meet increasingly stringent environmental quality standards. Various treatment techniques and processes have been used to remove the pollutants from contaminated waters. Among all the approaches proposed, adsorption is one of the most popular methods, and it is currently considered as an effective, efficient and economic method for water purification [7, 8]. Numerous studies in the past two decades have been focused on using low-cost effective sorbents for heavy metal adsorption, like natural zeolite and activated carbon [9, 10, 11]. Clinoptilolite, as a most common natural zeolite, has a high sorption capacity and selectivity, resulting from its porosity and sieving properties. Due to its high adsorption capacity, it is often used as an adsorbent in the industry. This capacity is related to the pore structure and chemical nature of the zeolite surface [9]. The adsorption efficiency of heavy metals achieved using natural zeolites and activated carbon could be approximately 50%.

## 5. Conclusion

Based on the experimental data we concluded that the concentration levels of the target metals (Co, Zn, Fe, and Cu) were significant higher in waste printing ink than in fresh printing ink samples. The significant concentration changes were observed for Co and Zn in waste magenta and cyan samples, respectively. The concentration levels of Cd and Cr in all the samples were below the instrument detection limits and the MAC values prescribed by the Regulation of hazardous matters in water recipients ("Official Gazette of Socialist Republic of Serbia" No. 31/82). While, the concentration levels of Co, Zn, Fe, and Cu were significantly above the MAC values. Moreover, heavy metals (Co, Zn, Fe, and Cu) as emerging substances must be removed from waste printing inks, because they tend to accumulate in living and working environment and represent a harmful to employee's health.

## 6. Acknowledgement

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## WETTING OF OFFSET PRINTING PLATE'S NON-PRINTING AREAS AS A FUNCTION OF PRINT RUN

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**Abstract:** One of the main issues in graphic reproduction is to ensure high quality level of imprints throughout whole print run. There are many factors which could cause degradation of the imprints quality, among other is quality of the printing plate. Essential in achieving high quality imprints in lithography, where difference of the printing and non-printing areas of the printing plate is achieved through opposite physical-chemical properties, is to ensure optimal thin film of fountain solution on non-printing areas before application of printing ink on printing plate.

The aim of this paper was to determine wetting properties of the non-printing areas of the printing plate in relation to the duration of the print run.

Measurement of the surface free energy of investigated surfaces was made to characterize non-printing areas. In addition, to determine functionality of those surfaces, measurement of contact angle by applying fountain solution has been done.

Results of the measurement showed that print run has significantly influenced functionality of non-printing areas.

**Key words:** lithography, printing plate, contact angle, surface free energy

### 1. Introduction

Printing plates used in offset have a flat surface with printing and non-printing areas are in the same level. The distinctive feature of this printing technique to others is the fact that the printing and non-printing areas have opponent physical and chemical properties. In order to achieve the ink-repellent effect on the non-printing areas, a water based solution (fountain solution) that contains certain additives is used. A vital factor in achieving high quality level of imprints in offset is to establish the optimal water-ink balance, since higher or lower amount of water can have negative effect on the final product quality. This is one of the reasons why physical and chemical surface properties of the substances used in offset have to be carefully monitored. The most important physical phenomenon which is important on the surface of the printing plate in printing and non-printing areas, as well as in transfer of the ink on the printing substrate, is adsorption. Adsorption is accumulation of particles of one phase on the boundary between two phases [1]. In this case, solid phase is the aluminium-oxide film from which non-printing areas of the printing plate are built, and the other phase is the liquid water based solution.

The next important characteristic of the non-printing areas is surface roughness, which is directly related to the adsorption, amount of adsorbed particles and velocity of adsorption. Roughness of the printing plate's non-printing areas determines amount of the fountain solution which must be adsorbed [2].

To ensure needed roughness, first step in production of aluminium substrate used for printing plates is graining which could be mechanical or chemical. A degree of micro-roughness varies depending on how the graining has been done, but is defined by printing plate's exploitation. The grained non-printing areas have its peaks and recessions, whose features are defined by certain roughness parameters [3] (Fig. 1). In general, the salient surface points (peaks) of the wrinkles absorb more water based solution due to the higher level of free surface energy in those areas. All the substances tend to minimize their energy state as it is the most stable state. To minimize their energy state, they have to minimize their number of boundary molecules and, therefore, have to minimize their surface area [4]. On the other hand, for better wetting and thinner film of fountain solution, one must make fountain solution's surface tension lower (base for fountain solution is water which has high surface tension,  $72.8 \text{ mNm}^{-1}$ ). 2-propanol is commonly used in graphic industry to reduce surface tension of water.

During printing process, printing plate is in contact with offset cylinder, rollers which cause friction and consequently changes of the printing plate's surface characteristics [5]. Therefore it



is necessary to monitor printing plate's behaviour through whole printing run and make needed adjustments to obtain desired quality level of imprints.

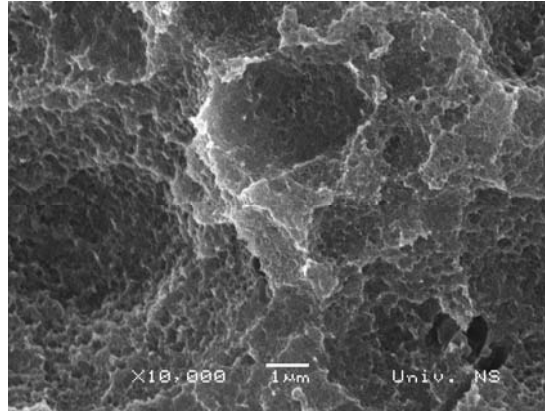


Fig. 1. SEM image of non-printing area of printing plate

## 2. Theory

Surface phenomena are caused by difference of molecules, ions or atoms on the surface of a chemical substance compared to the same particles in the middle of the same substance. Molecules, ions or atoms in the middle of the chemical substances are surrounded with same particles (molecules, ions or atoms) and attractive forces between them are compensated which makes resultant force equal zero. On the other hand, particles on the substance's surface are surrounded with other equal particles only from one side that leads to the resultant force which is trying to pull them to the middle or giving those particles ability to attract molecules, ions or atoms from neighbour phase. The energy of particles in surface layer in comparison to the particles in the middle of the chemical substance is called surface free energy [5]. Surface free energy has many direct consequences like adsorption, surface tension, wetting which are exploited in graphic arts and many other industries.

Adsorption is surface attraction of particles of one phase to the surface of neighbour phase. Particles of first phase, which are chaotically moving, are on distance of round 1nm attracted by van der Waals or electrostatic forces to the surface of second phase. Adsorption forces are directly proportional to the value of surface free energy of the substance. Largest adsorption forces have solid state ionic structures.

Beside surface free energy which is property of the chemical compounds, forces between atoms in molecules, roughness of the solid phase is very important factor that influences substance's ability to adsorb particles of neighbour phase. A smooth surface would adsorb lower amount of the particles than rough one (Fig. 2).

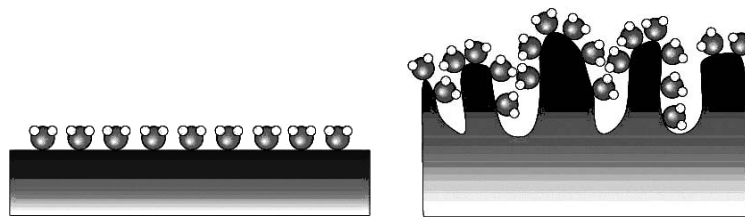


Fig. 2. Water adsorption on a smooth and rough surface

Second phenomenon caused by surface free energy is surface tension ( $\sigma$  / Nm<sup>-1</sup>). Surface tension is a force which acts vertically on a substance's surface and tries to decrease its size. The value of the surface tension is equal to the value of the surface free energy.

According to the Owens, Wendt, Rabel and Kaelble, surface tension could be divided to polar component ( $\sigma^P$ ) and dispersive component ( $\sigma^D$ ):

$$\sigma_l = \sigma_l^P + \sigma_l^D \quad (1)$$

$$\sigma_s = \sigma_s^P + \sigma_s^D \quad (2)$$

where  $\sigma_l$  is surface tension of a liquid phase and  $\sigma_s$  is a surface tension of a solid phase,  $\sigma_s^P$  and  $\sigma_l^P$  are polar parts of the surface tension,  $\sigma_s^D$  and  $\sigma_l^D$  are dispersive parts of the surface tension.

Owens and Wendt combined two equations, surface tension (3) and Young equation (4) to solve equation system using contact angle ( $\theta$ ) of two referent liquids of known dispersive and polar component of their surface tension.

$$\gamma_{sl} = \sigma_s + \sigma_l - 2\left(\sqrt{\sigma_s^D \cdot \sigma_l^D} + \sqrt{\sigma_s^P \cdot \sigma_l^P}\right) \quad (3)$$

where  $\gamma_{sl}$  is surface free energy on solid – liquid phase interface,  $\sigma_l$  is surface tension of a liquid phase and  $\sigma_s$  is a surface tension of a solid phase,  $\sigma_s^P$  and  $\sigma_l^P$  are polar parts of the surface tension,  $\sigma_s^D$  and  $\sigma_l^D$  are dispersive parts of the surface tension.

$$\sigma_s = \gamma_{sl} + \sigma_l \cdot \cos \theta \quad (4)$$

where  $\sigma_s$  is a surface tension of a solid phase,  $\gamma_{sl}$  is surface free energy on solid – liquid phase interface,  $\sigma_l$  is surface tension of a liquid phase and  $\theta$  is contact angle between liquid and solid phase.

Kaeble solved equation combining two liquids of known surface tension to calculate average value of surface free energy. Finally, Rabel had enabled calculation of polar and dispersive component of surface free energy using linear regression knowing contact angles of various liquids [6]. Combining (3) and (4) result is linear dependence  $y = mx + b$  (Fig. 3.):

$$\frac{(1 + \cos \theta) \cdot \sigma_l}{2\sqrt{\sigma_l^D}} = \sqrt{\sigma_s^P} \sqrt{\frac{\sigma_l^P}{\sigma_l^D}} + \sqrt{\sigma_s^D} \quad (5)$$

where  $\theta$  is contact angle between liquid and solid phase,  $\sigma_l$  is surface tension of a liquid phase,  $\sigma_s^P$  and  $\sigma_l^P$  are polar parts of the surface tension,  $\sigma_s^D$  and  $\sigma_l^D$  are dispersive parts of the surface tension.

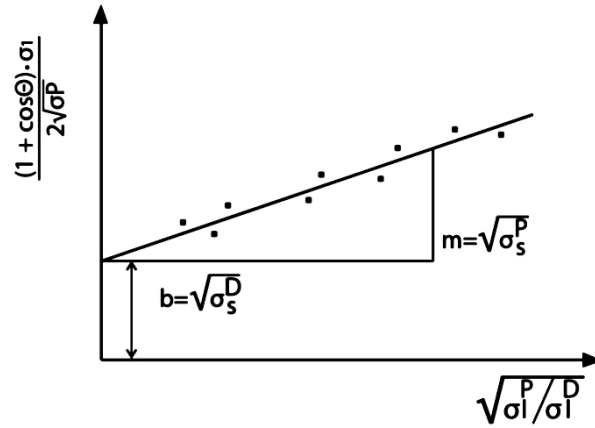


Fig. 3. Determination of dispersive and polar component of surface free energy according to Rabel

Wetting is physical phenomenon conditioned by decrease of surface tension in system solid – liquid. A liquid will wet a solid surface only if it would lead to the reduction of free surface energy value. One can determine the quality of wetting by observing liquid drop shape. Contact angle is angle between two tangents, one touching solid surface and second touching a drop of liquid in intersection point of three phases (solid, liquid and vapour). By measuring contact angle one can determine wetting degree of investigated system.

Contact angle is defined by angle between two tangents, one on the liquid drop ( $t_1$ ) and second on the solid surface ( $t_2$ ) in the point where all three phases (solid, liquid and vapour) are in touch (Fig. 4).

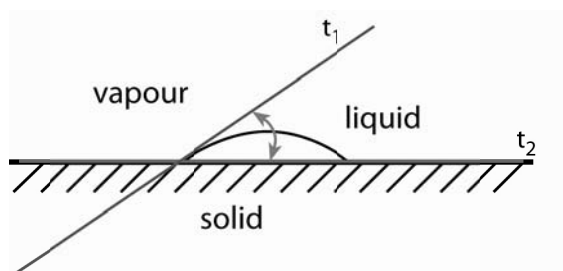


Fig. 4. Definition of the contact angle

When measuring contact angle one must keep in mind that its value is also influenced by time passed from formation of a drop on solid surface to the time because contact angle decreases (Fig. 5.) This decrease is caused by gravitation force which acts on the liquid drop [7].

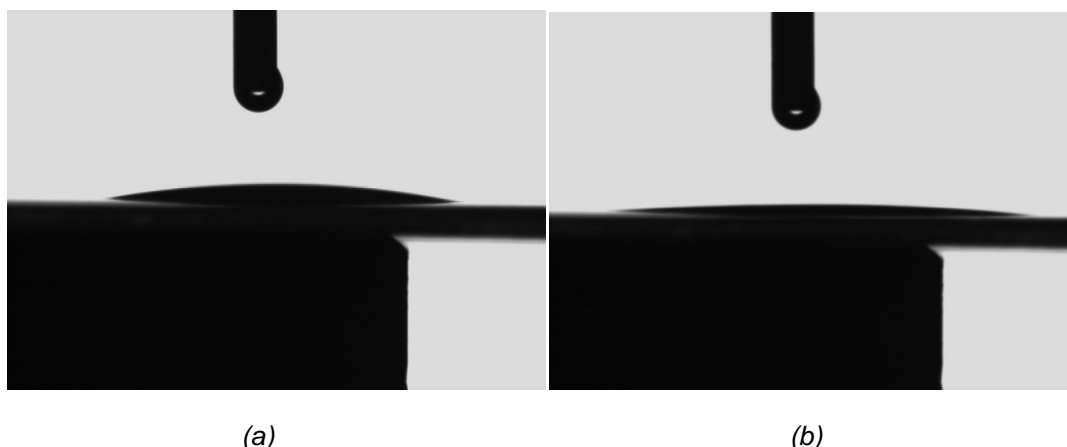


Fig. 5. Contact angle at 0.1 seconds (a) and at 0.5 sec.(b) after liquid-solid contact

### 3. Materials and method

#### 3.1 Sample preparation

The investigated lithographic printing plates used in this study were Kodak Sword Ultra, positive thermal CtP plates 0,3 mm thick. The plates have been exposed on plate imager Kodak Magnus VLF (with external drum) by same laser sensitivity or exposure energy approx. 140mJ/cm. After the exposition photosensitive layer was removed from exposed (non-printing) areas of the plate. The removal has been achieved by chemical processing in alkaline Kodak Goldstar premium developer. The developing have been made according to the standardized processing procedure: at the temperature of processing solution  $22 \pm 3$  °C, processing speed in the range of 0,7 – 1,2 m/min and the processing time of  $18 \pm 4$  s. All examined samples of printing forms were developed in identical conditions to avoid influence of laser power and difference in temperature and saturation of the developer [8,9].

Printing process was conducted on a 32 page Komori 38 D web-fed heat-set printing machine, producing colour reproductions, 56 g/m<sup>2</sup> UPM Ultra H web gloss-coated paper and Sun Chemical heat-set top gloss colours were used.

Samples for measurement were: Sample0 printing plate which was not used for printing, Sample1 printing plate after 123,000 imprints, Sample2 printing plate after 177,000 imprints and Sample3 printing plate after 300,000 imprints. Five samples were taken from each printing plate ( $R=1.5$ cm), positioned along the line of printing pressure in the printing units and with center-to-center interval of 20 cm, with the aim of analyzing its affect and diversity on the different position of the non-printing surface (Fig. 6) [10].



Fig. 6. Positions of the taken samples on the printing plate

To determine changes in wetting properties, two types of fountain solution were prepared. Solution1 was a commercial fountain solution which is used in web offset, distilled water with additives and Solution2 was also web offset fountain solution, prepared with substitutes for 2-propanol as a additive which decrease solutions surface tension ("Eco friendlier fountain solution").

### 3.2 Measuring methods

To determine surface properties of the investigated samples, measurement of the contact angle was performed. Videobased, optical contact angle measurement was performed by DataPhysics OCA30 device. It ensures the static and the dynamic characterization of liquid/solid interfaces by contact angle measurement procedure, the requirement for the calculation of surface free energy. In this paper contact angle was measured by using the sessile drop method and surface free energy were calculated by using Owens-Wendt-Rabel and Kaelble (OWRK) analysis method. [11].

Wetting properties of non-printing of printing plate samples were calculated by measuring the contact angle of three liquids of known surface free energy and viscosity (Tab. 1) [12]. Contact angles of liquids were defined from average values of seven liquid droplets placed on different areas of the same printing plate sample.

Tab. 1. Surface free energy ( $\gamma_{lv}$ ) and their dispersive ( $\gamma_{div}$ ) and polar ( $\gamma_{plv}$ ) components and viscosity of liquids

Liquid	Surface free energy $\gamma$ (mNm <sup>-1</sup> )			Viscosity (mPas)
	$\gamma_{lv}$	$\gamma_{div}$	$\gamma_{plv}$	
Diiodomethane (Ström)	50.8	50.8	0.0	2.78
Glycerol (van Oss)	64.0	34.0	30.0	1412
Water (Ström)	72.8	21.8	51.0	1.002

Functionality of the non-printing areas was investigated by applying two different types of fountain solutions. Measurement of contact angles were performed in the same way as when measuring test liquids.

## 4. Results and discussion

In Fig. 7 one can see change of the contact angle value of standard liquids on investigated samples of printing plate.

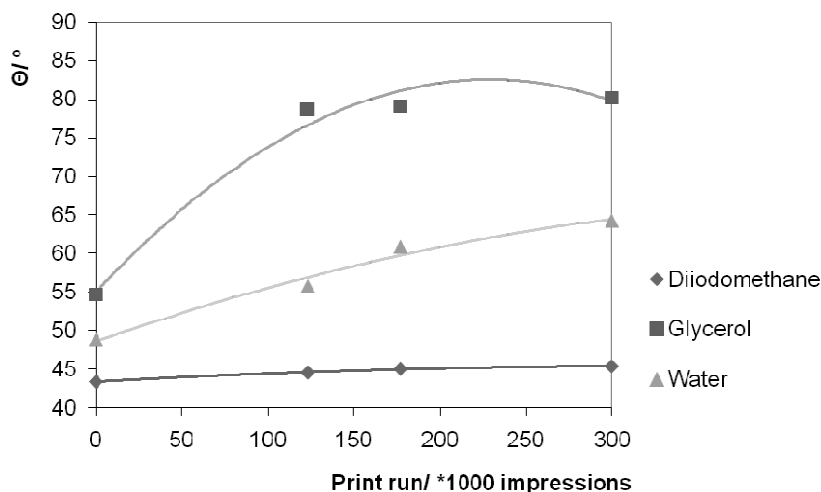


Fig. 7. Contact angle value of standard liquids

Observing Fig. 7 it could be seen that increase of the print run causes constant increase of the contact angle between printing plate's non-printing areas and water. Furthermore, increase of the glycerol contact angle is substantially higher than the one with water but this increase is not constant. Contact angle with glycerol reaches nearly maximal value even at first printing plate that was in printing process (Sample1), but then stays at this value. Contact angle with diiodomethane is slightly rising with increase of the print run, but the value is nearly unchanged (less than  $2^\circ$ ).

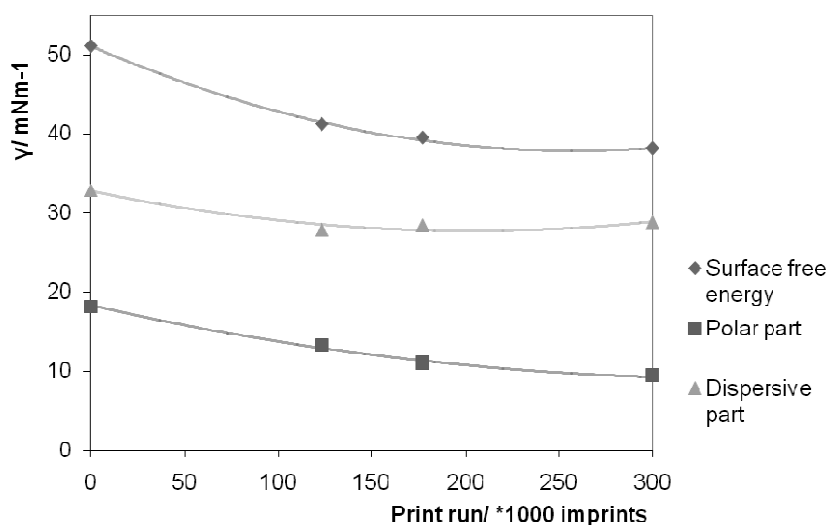


Fig. 8. Surface free energy value as function of print run

Surface free energy calculation was made to the Owens, Wendt, Rabel and Kaelbe method which is used to characterisation oxid films [13]. Obtained results are presented in Fig. 8. Surface free energy decreases with the increase of the print run. Observing paths in Fig. 8. it could be seen that although value of surface free energy is significantly decreased (round 20% from Sample0 to Sample3), dispersive part of it stays nearly unchanged, that is decrease of surface free energy is consequence of decrease of its polar part.

Having in mind printing process and friction between printing plate and rollers, offset cylinder surface properties must change. Peaks of the aluminium-oxide layer certainly wear during exploitation of the printing plate. On the other hand, printing plate is in constant contact with fountain solution and particles of paper dust. This could lead to the filling of recessions with  $\text{CaCO}_3$  [14] or paper particles which causes decrease of polar part of aluminium-oxide layer.

In Fig. 9. one could observe functionality of non-printing areas as a function of print run. Functionality of the printing plate is determined by application of fountain solution on the printing plate samples.

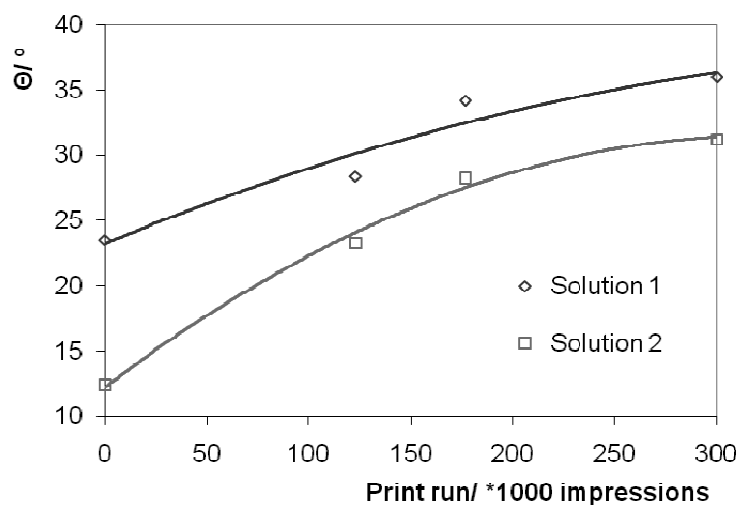


Fig. 9. Contact angle of fountain solutions in dependence on print run

As it could be expected, increase of the print run causes decrease of wetting ability. One could see that contact angle of Solution1 is higher on all printing plate samples, but in the same time it is more stable. Contact angle of Solution2 is significantly lower at the Sample0 than the one of Solution1, but difference between them is constantly decreasing with increase of the print run.

This behaviour of both investigated fountain solutions is connected with prior results of surface free energy. Fountain solutions is mainly composed of water and they are wetting better polar solid surfaces and as it could have been seen in Fig. 8. polar part of surface free energy of non-printing areas is decreasing with print run length.

## 5. Conclusion

The aim of this paper was to determine changes of the surface characteristics and wetting ability of the non-printing areas that occur when printing plate is exploited. The investigation was made under the assumption that contact of printing plate with ink and water rollers as well as offset cylinder causes wearing of aluminium-oxide layer.

Determination of the surface characteristics was made by measuring contact angle of three standard liquids which enabled to calculate surface free energy. To control functionality of the non-printing areas, contact angle of two different fountain solutions was measured.

Obtained results confirmed our assumption. Surface free energy of the investigated printing plates decreases with increase of the print run. This decrease is due to the decrease of polar part of surface free energy. Results of contact angle measurement of fountain solutions showed that wetting ability of non-printing areas is deteriorating with number of imprints made. These results imply that investigation and monitoring of surface characteristics is very important and must be done to make needed corrections which would enable same quality level of products through entire print run.

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## COMPARISON OF FREQUENCY CHARACTERISTICS FOR FOLDERS AND CUTTERS IN PRINTING COMPANIES

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**Abstract:** The objective of this paper was to determine the extent of noise in some printing companies in Novi Sad. The noise level of two different types of machines – folders and cutters, in five printing companies, was investigated using TES-1358A Sound Level Meter (SLM), with RS-232 Interface. The data on equivalent A-level [dBA], as well as the maximum and minimum sound pressure levels (SPL) were collected. The average value of  $L_{eq}$  was 87,66 dBA for folders, and 80,21 dBA for paper cutters. It was found that the folders are the predominant noise sources, with the maximum  $L_{eq}$  levels at 2000 Hz and 4000 Hz. For this type of the machines the means of  $L_{eq}$  levels exceeded the permissible levels given by NR-80 curve at higher frequencies. For the paper cutters the means of  $L_{eq}$  levels were below the acceptable values given by NR-80 curve at all frequencies, but the levels were very close to the values registered at 2kHz and above.

**Keywords:** Noise level, frequency analysis, folders, cutters

### 1. Introduction

Noise, or undesirable sound, is one of the outcomes of rapid urbanization and technological development. The main sources of noise are the means of transport and industrial processes. Mechanical industry creates serious noise problems. It is responsible for intense noise indoor as well as outdoor. In industrial settings, in most machines, there is a continual and sometimes also intermittent type of noise. The noise may contain predominantly low or high frequencies, tonal components, be impulsive or have unpleasant and disruptive temporal sounds patterns. In printing industry, noise occurs during printing, binding, folding and cutting processes. The sources of noise are all moving parts of the machines and the elements of the machinery drive such as motors, compressors and vacuum pumps, which supply mechanical energy, air under pressure or vacuum [1].

Occupational exposure to excessive noise is commonly encountered in a great variety of industrial processes. The impact of noise will primarily be localised on hearing damage called noise induced hearing loss (NIHL) and that is often the cause of an occupational disease [2]. Besides the hearing impairment, non-auditory effects of noise may also include lack of concentration, irritation, fatigue, headache, cardiovascular problems, etc. [3]. Hearing damages from excessive noise are usually generated when noise exceeds permanently 85 dB(A) and the workers reject or misuse personal hearing protection [4]. Noise does more harm than just to damage hearing. In the work-place even levels are just low enough not to damage hearing may nevertheless be high enough to interfere with communication, to interfere with the hearing of warning signals and to be stressful. They produce what some authors describes as “an ergonomically extreme condition”. It has been shown long ago that productivity improves if workplace noise levels are moderated [5].

### 2. Methods

The aim of this investigation was to determine noise level and noise spectrum of some machines in a few printing companies in Novi Sad. The noise level measurement of two types of the machines, cutters and folders, was performed using TES -1358A Sound Level Meter (SLM), with RS-232 Interface. For conducting the noise survey, Serbian guidelines for noise measuring were followed [6]. The desired response of SLM was set at “fast”. When the measurements were made, the microphone was located in such a way as not to be in the acoustic shadow of any obstacle in appreciable field of reflected waves. The noise levels were measured about 1.5 m above the floor and the measurements were taken over a period of 30s for folders and 10s for paper cutting machines. The A-weighted levels on  $L_{eq}$ ,  $L_{max}$  and  $L_{min}$  Sound Pressure Level (SPL) in dBA were collected. At the end of experiment, the data were downloaded to a personal computer and, with the help of utility software, the equivalent SPL and noise spectrum at each reading were obtained. The data were statistically analysed using Microsoft Excel.



### 3. Results and discussion

Noise measurements were conducted for folders and cutters. The mean levels of  $L_{eq}$ ,  $L_{min}$  and  $L_{max}$  (in dBA) with their variances are given in Table 1. The measured  $L_{eq}$  values for all machines generally varied between 75-95 dBA.

The highest noise level was measured for folders with the mean value of 87.66 (3.14) dBA. For cutters the mean value was 80.21 (6.87) dBA. The noise levels produced by 7 of 11 machines exceed the limiting threshold level of 85 dBA, tolerated by law. It can be noticed that the great range of noise levels (75.2-94.8) dBA and the high variance (6.87) were obtained for the cutters, which is due to the different type of cutting material used.

Table 1. Noise levels of  $L_{eq}$ ,  $L_{min}$  and  $L_{max}$  ( in dBA) for folders and cutters with average levels and variances

Type of machine	$L_{min}$ [dBA]	$L_{max}$ [dBA]	$L_{eq}$ [dBA]
<b>Cutters</b>			
Zünd XL-3000	86.2	100.7	94.8
Polar 92	75.4	89	81.3
Perfecta	70.3	91.8	76.4
Perfecta	65.5	75	86.8
Polar 92	66.1	78.6	89.9
Wohlenberg 92	63.2	86.6	75.2
Average (SD)	71.12 (7.81)	90.8 (4.77)	80.21 (6.87)
<b>Folders</b>			
STAHL Gmbh & Co	85.5	88.3	86.8
Cantrad	81.7	82.7	84.1
STAHL Heidelberg	78	96.6	90.9
MBO KTL 67	83	88.8	86.7
HORIZONTAL CROSS FOLDER	78	104.2	91.2
Average (SD)	81.24 (2.91)	92.4 (7.15)	87.66 (3.14)

Frequency analysis of the means of SPL ( $L_{eq}$ ,  $L_{min}$ ,  $L_{max}$ , ) at 1/3 octave bands for folders and cutters is presented in Figures 1-2. It reveals that noise levels for both type of the machines increases with higher frequencies and the highest noise levels are in the frequency range of 2-8 kHz.

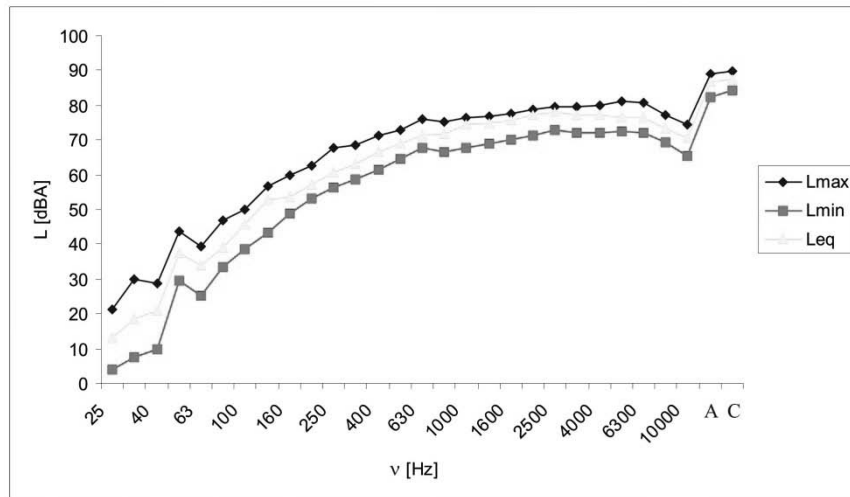


Figure 1. Folders: Means of  $L_{eq}$ ,  $L_{min}$ ,  $L_{max}$  at 1/3 octave bands

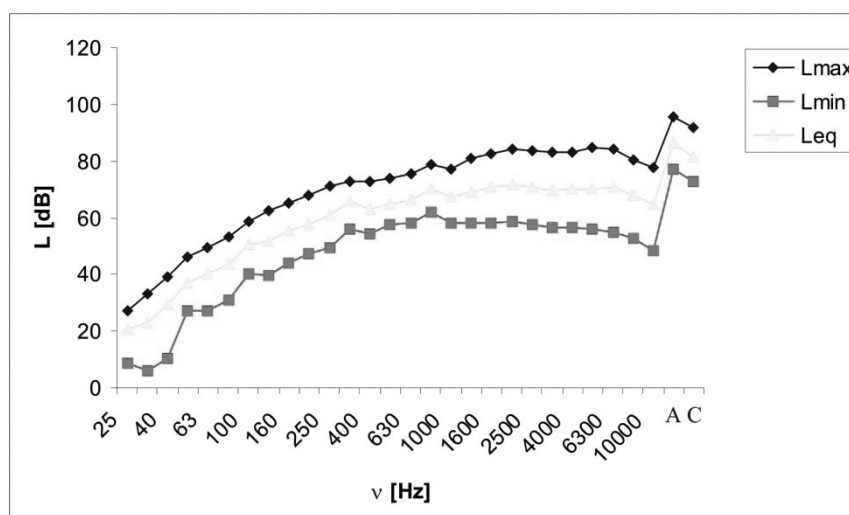


Figure 2. Cutters: Means of  $L_{eq}$ ,  $L_{min}$ ,  $L_{max}$  at 1/3 octave bands

High noise levels at frequencies below 1 kHz produced interference with workers communication, since much of the human speech is between 300 and 700 Hz [7]. Hearing damage from excessive noise usually occurs at high frequencies (3, 4, 6 kHz) and then spreads to lower frequencies (0.5, 1, 2 kHz) which limits the working capacity and social adequacy of workers [8]. For effective noise induced hearing loss prevention, it is important to consider the spectral content of noise as the personal protective equipment is often designed according to the noise spectrum.

The dBA means of  $L_{eq}$  (SPL) at 1/1 octave bands for each type of the machines in comparison with NR-80 curve<sup>1</sup> at 1/1 octave bands, as a histogram, are presented in Figures 3-4.

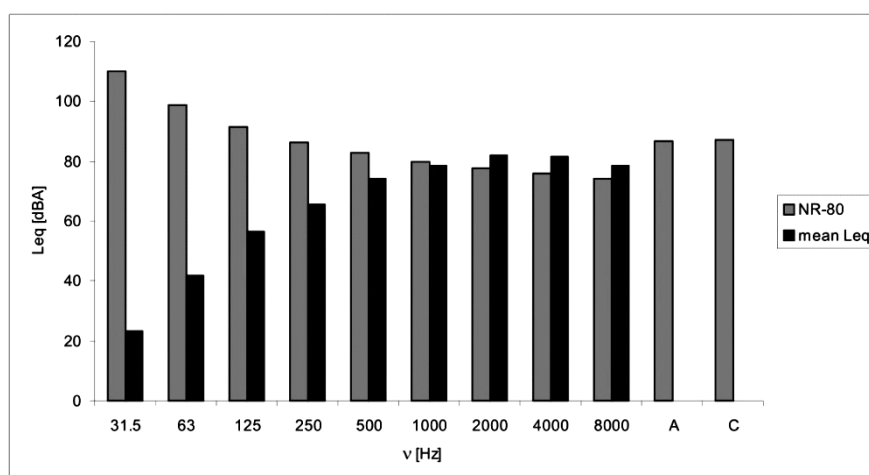


Figure 3. Folders: The means of  $L_{eq}$  in dBA at 1/1 octave bands in comparison with NR-80 curve

It was found that the means of  $L_{eq}$  levels for folders were considerably greater than the permissible at higher frequencies (2kHz and above). It was also found that for cutters the means of  $L_{eq}$  levels did not exceed NR-80 curve values, but the levels were very close to those values at 2kHz and above.

<sup>1</sup> The noise rating – NR–curves are developed by International Organisation for Standardization (ISO) to determine the acceptable indoor environment for hearing preservation, speech communication and annoyance. The Noise Rating level for industrial noise should not exceed the levels of NR-80 curve.

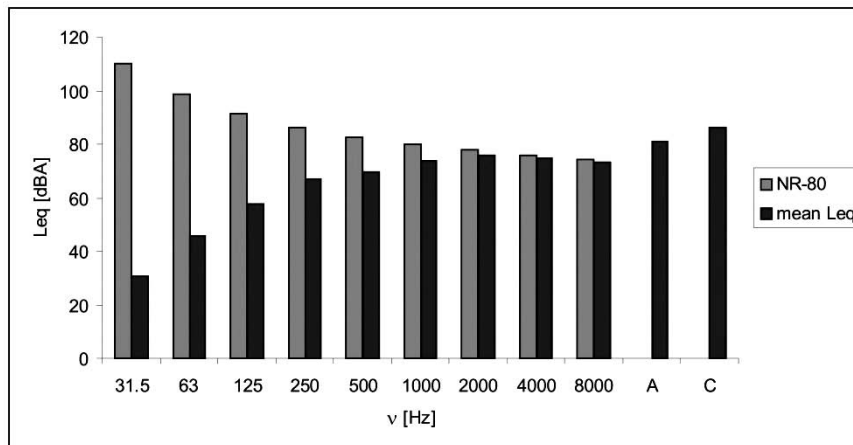


Figure 4. Cutters: The means of  $L_{eq}$  in dBA at 1/1 octave bands in comparison with NR-80 curve

#### 4. Conclusion

The noise measurement conducted in printing companies showed that 64 % of the machines produce  $L_{eq}$  levels which exceed the limiting threshold level of 85 dBA. The frequency analysis of the means of SPL revealed, for both types of the machines, that the noise was dominated by higher frequency noise. It was found that the folders are the predominant noise sources, with the maximum  $L_{eq}$  levels at 2000 Hz and 4000 Hz. For this type of the machines the means of  $L_{eq}$  levels exceeded the permissible levels given by NR-80 curve at higher frequencies. For the paper cutters the means of  $L_{eq}$  levels were below the acceptable values given by NR-80 curve at all frequencies, but the levels were very close to the values registered at 2kHz and above.

The high levels of noise obtained in this study suggest that a hearing conservation programme (HCP) to protect workers from the effects of hazardous noise exposure in the workplace should be integrated into printing companies. In the application of noise reduction techniques special care should be concentrated on higher frequencies (2kHz and above), since it was at those frequencies that the maximum of noise level was found. Noise reduction techniques such as redesigning walls and ceilings, using noise absorbing materials etc. could be used. The workers should have personal protection measures and should be rotated to reduce their exposure level.

#### 5. Acknowledgment

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## WEB PAGES ADAPTATION FOR VIEWING ON MOBILE DEVICES, THE SYSTEM OF DIFFERENT CSS DOCUMENTS

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**Abstract:** *In step with rapid development of mobile devices and similar handheld wireless devices, a large amount of devices gained capability to access internet. Content providers had to find a way how to serve all mentioned platforms at the same time. This paper introduces a sort of web documents static layout adaptation method. Related methods were discussed in order to compare them to this paper introduced method. Elements selection recommendations were given. An application of this method is also discussed and presented in this paper.*

**Keywords:** *internet, adaptation, browsing, navigation, CSS*

### 1. Introduction

In recent years it has become normal that mobile devices support internet access. As a result, hosting providers and web designers face a new problem - how to make a site equally well be displayed on computer screens and screens of portable wireless devices. It is necessary to serve a large number of different devices at the same time (Beszteri and Vuorimaa, 2007). During the ninetieth years, most of the internet users used personal computers for browsing the Internet. They all had similar screen sizes, and thus 640x480, 800x600, and 1024x768. Web page designers designed the web document layouts for these standards. With the appearance of new terminals, supporting one dedicated resolution is not sufficient anymore. The diversity of displays is so high that manually re-authoring the same document for all possible clients is not effective, if possible at all (Beszteri and Vuorimaa, 2007).

There are intensions to classify the client terminals to different categories and adapt the documents for those classes. A good example is the "media type" of Cascading Style Sheets (CSS). It specifies categories like handheld, or screen, and the author can define different styles for the document objects in each category. Unfortunately, there are no standard display sizes for handheld computers or mobile phones. Even the different models of the same brand can have extremely different displays. So, it is hard to define a common style within a certain category (Beszteri and Vuorimaa, 2007, Bos, 1998).

Content providers need dynamic layout adaptation methods to serve any clients with any display sizes. Static methods, like providing XSL Transformations (XSLT) (Clark, 1999) for each supported devices or device groups may give the most satisfactory results, but they limit the usage of the documents to a predefined set of clients. There are already a couple of solutions, which adapt existing web pages, typically HyperText Markup Language (HTML) (Ragett, 1999) documents for devices with small displays. For instance, the Wireless Application Protocol (WAP) (WAP Forum, 2001) Gateway of Google (Google, 2005) adapts HTML pages to WAP enabled mobile phones. The most effective adaptation algorithms in this area are based on heuristic rules. Therefore, they cannot work perfectly for all documents. They adapt documents written in a certain description language and they use the language elements for adaptation purposes (Beszteri et al., 2007, Clark, 1999, Ragett, 1999, WAP Forum, 2001, Google, 2005).

### 2. Related work

Layout adaptation algorithms need architectural and sizing information about the document. According to Beszteri, 2007, first of all we need a way to describe the architectural structure of the document. Our adaptable documents will be built up from basic and compound objects (Beszteri and Vuorimaa, 2007).

Basic objects are document fragments which are not decomposed further by the adaptation algorithm. It is the designer's responsibility to decompose the document to small enough fragments (Beszteri and Vuorimaa, 2007).

Compound objects are the placeholders for basic and other compound objects. A compound object has one or more cells. Each cell contains one and only one basic or compound object. (Beszteri and Vuorimaa, 2007). Figure 1 shows object types present inside documents.



Figure 1. Document object types. a) a horizontal compound object and b) a vertical compound object.

A modified XML language version was used for page description. XFrames language of World Wide Web Consortium (W3C) was user as a model for modified XML language (Pemberton, 2003).

The syntax of a basic object can be seen from the following example:

```
<basic class = "anything" title = "Basic object" source = "http://any.server.com/basic.alt"/>
```

Chen et al. 2003 used similar principle. Every page is split to several parts. Adaptation algorithm finds the best way for element fragmentation based on pages free space. Page is analyzed through three steps: 1. higher level blocks detection, 2. explicit dividers detection, 3. implicit dividers detection. Globally, pages consist of header, body and footer (Chen et al. 2003).

System used by Penn, 2001 represents heuristic table detection method inside HTML documents. Given method was used to gather important information from pages to be forwarded to mobile devices (Penn, 2001).

All method here presented try to adapt existing web documents. All of them give relatively good results, but are limited to existing markup languages properties. Aim of this paper is to show one similar and a lot easier way to adapt web pages to common mobile device screen resolutions and is interesting for non experienced users who posses small or no programming or XML knowledge.

### 3. Suggestion of different CSS documents adaptation model

CSS represents Cascading Style Sheets. Styles are used to define HTML elements look. First time CSS used was inside HTML 4.0 version. They can be inline, built-in and external. In our case external type shall be used (W3schools.com, website).

Aim of this method is to present different site versions depending on type of client used to access server. Client detection should be performed server-side. After client detection, an adequate CSS document version is used to define web page look. That CSS document is also adequate to client device.

Client device screen resolution plays significant role to this system. Web page designer should create several simple additional CSS documents which should support major mobile device screen (hereinafter MDS) resolutions.

Developing site shall have one primary CSS document to be used for displaying pages on PC screens. For MDS who posses significantly smaller screens, a special CSS document shall be used which shall adapt page to aimed MDS resolution. Key point is that page displayed on MDS won't contain all elements displayed on PC screen. Designers responsibility is to, based on site theme, choose elements to be shown on all devices screens.

#### 3.1. Client detection

Client detection would be performed server-side by using simple script. Based on client type detected, certain CSS document is used. In case that detected operating system is a kind of PC operating system, basic CSS document version is used. In other case, if mobile device operating system is detected, an adequate CSS document is used. It is up to designer to decide how wide resolution range shall be supported. Table 1 shows some commonly used clients (*user agents*) by What's my user agent, website:

Table 1. Most common user agents (What's my user agent, website)

Client	Source
Mozilla/5.0 (Windows; U; Windows NT 5.1; en-GB; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6	Firefox 2.0, Windows XP
Mozilla/4.0 (compatible; MSIE 7.0; Windows NT 5.1)	Internet Explorer 7, Windows Vista
Mozilla/4.0 (compatible; MSIE 7.0; Windows NT 5.1; .NET CLR 1.1.4322; .NET CLR 2.0.50727; .NET CLR 3.0.04506.30)	Internet Explorer 7, Windows XP
Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; .NET CLR 1.1.4322)	Internet Explorer 6, Windows XP
Mozilla/4.0 (compatible; MSIE 5.0; Windows NT 5.1; .NET CLR 1.1.4322)	Internet Explorer 5, Windows XP
Opera/9.20 (Windows NT 6.0; U; en)	Opera 9.2, Windows Vista
Opera/9.00 (Windows NT 5.1; U; en)	Opera 9.0, Windows XP
Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; en) Opera 8.50	Opera 8.5, Windows XP
Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; en) Opera 8.0	Opera 8.0, Windows XP
Mozilla/4.0 (compatible; MSIE 6.0; MSIE 5.5; Windows NT 5.1) Opera 7.02 [en]	Opera 7.02, Windows XP
Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.7.5) Gecko/20060127 Netscape/8.1	Netscape 8.1, Windows XP
Googlebot/2.1 ( <a href="http://www.googlebot.com/bot.html">http://www.googlebot.com/bot.html</a> )	Googlebot 2.1 (search engine bot)
Googlebot-Image/1.0 ( <a href="http://www.googlebot.com/bot.html">http://www.googlebot.com/bot.html</a> )	Googlebot Image 1.0 (search engine image bot)
Mozilla/2.0 (compatible; Ask Jeeves)	Ask Jeeves (search engine bot)
msnbot-Products/1.0 (+ <a href="http://search.msn.com/msnbot.htm">http://search.msn.com/msnbot.htm</a> )	Windows Live (search engine bot)

### 3.2. Page elements choice propositions

Based on site theme, there are different patterns / element layouts which are in use. Every site shown on MDS must possess visual identity (logo), site name or company name etc. Also a sort of navigation is a must-have element. No site is usable without any kind of navigation or some sort of visual identity. If present on desktop version of site, a Search field is recommended to include if it is an important factor in site function. Last, but not least important, is page content. A certain amount of important page data should be included. These are elements that should be present in every MDS site version. The rest of content is up-to designer to decide whether to include or not.

### 3.3. MDS dedicated CSS document formation principle

In case of building MDS adaptable site, designer should decide which parts of page are to be displayed on MDS according to some priorities. From previous chapter one can conclude that indispensable page elements are:

- site visual identity (logo, site or company name),
- navigation,
- selected page body content,

while the rest of elements (like Search field) are optional and their appearance depends on designer and site theme.

After choosing a certain number of elements to be shown on MDS, adaptation is performed the following way:

- all page elements should be hidden
- absolute positioning property is given to them. If it is possible it can be relative depending on page structure and complexity.
- all elements should be positioned to upper left browser window corner
- chosen elements to show on MDS should now be revealed
- previously chosen elements properties are now set based on client version

Inside MDS CSS documents, absolute units are available to use too (most often px units), but also usage of relative units (like percentage, em, ex, etc.) is not excluded.

### 3.4. Solution presented on existing search engine Google

Practical example of this method which was described in last chapter shall be presented on existing search engine Google (Figure 2).

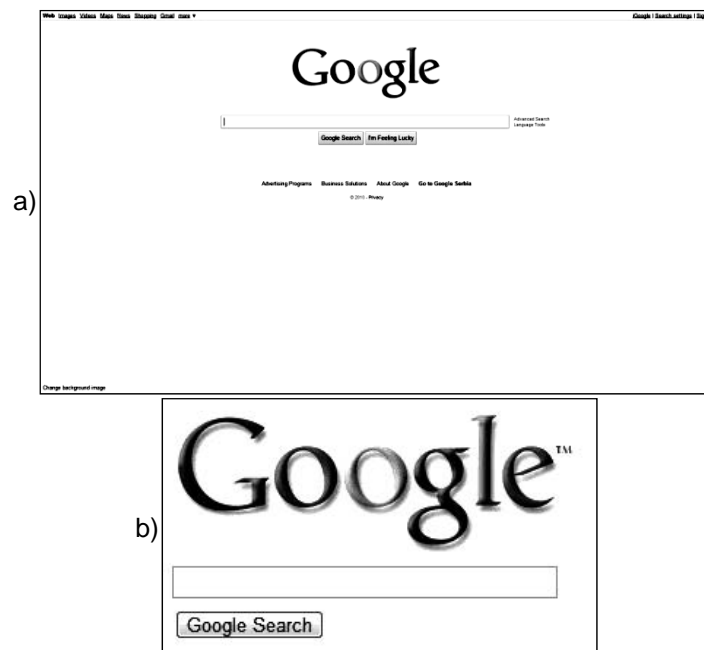


Figure 2. Example solution for Google site: a) PC screen version, b) MDS version

For adapted site version, a CSS document was created with the following content:

```
@charset "utf-8";  
/* CSS Document */
```

```
* {  
    visibility: hidden;  
    position: absolute;  
    left: 0;  
    top: 0;
```

```

}

#logo {
    visibility: visible;
}

.lst {
    visibility: visible;
    width: 260px;
    top: 110px;
}

#butGo {
    visibility: visible;
    top: 140px;
}

```

The page has been adapted for MDS according to rules stated in previous chapter of the paper. Important page elements were separated. Their properties were adjusted for (in this case) one screen size case. It is up-to designer to define different CSS documents for common MDS resolutions.

#### 4. Conclusions

This web page adaptation method hasn't got many touching points with the rest of existing adaptation models. This model is considered static unlike other described models which are considered dynamic and use markup languages, JavaScript, etc. The method offers satisfying results although it can not be applied on all kinds of sites. Site adaptation using this method becomes easier to apply if it is considered during site creation process.

The disadvantage of this model is a fact that all site changes in process of adaptation are only made inside external CSS document. That implies that, no matter of platform, whole HTML code will be loaded regardless that only small number of elements is displayed. Google example (Figure 6) CSS shows that only logo, search field and "Google search" button will be visible. Regardless, all HTML elements shall be loaded.

It is up-to designer to generate a satisfactory number of CSS documents for adaptation to cover most of common MDS resolutions used the present day.



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## EXTENDED PACKAGING AND 2D CODES

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**Abstract:** 2D codes are one of the automatic identification technologies. Compared to the conventional barcode technology, 2D codes can encode larger amount of data on a smaller area and besides numerical, alphanumerical data can be also encoded. For this reason there are lots of possibilities to use them for different applications like advertising purposes. Especially on packaging there is frequently not enough space even for printing all obligatory or additional information about specific product. 2D codes are one of the possible solutions. Additional information about the product, manufacturer or usage of the product is main priority that 2D codes can provide on the product where printing space is limited. While these codes can be decoded with every newer mobile phone, the technology is becoming more and more accessible and popular. 2D code can cross links the printed matter with interactive internet and can represent a contact between seller and costumer. In the article 2D codes (especially QR and EZ code) are described and the presentation of their applications on the packaging and other printed products are shown. Besides that the comparison of code largeness regarding to the different encoded information and different code type was done. At the end the readability of QR and EZ codes printed in 100 % and 30 % of raster tone value in process printing inks was determined.

**Key words:** 2D code, QR code, EZ code, extended packaging

### 1. Introduction

Since 1949 (Keyword.com), when Norman Joseph Woodland and Bernard Silver (the most often credited as having originally invented the barcode), filed the patent application, the identification of the products is much faster. Though Woodland and Silver pioneered the concept of a symbol and a reader, it was not until 1974 that the first UPC bar code was actually used in a supermarket (Keyword.com). But today we cannot imagine the world without barcodes, while queues in front of the cashier's desk are smaller, the inventories are made quicker and the data are captured more precisely almost without any mistakes.

Despite the fact that barcodes facilitates our lives a lot, there are some imperfections. Linear barcodes can encode just small amount of data and have to be quite big if we want them to be readable. Because of that in the late 80's (Intermec) 2D matrix codes were developed. Besides quick and precise encoding and decoding process, 2D codes can encode much more information or data (even several thousand characters) to a very small area compared to barcodes. Furthermore, 2D codes can be decoded with mobile phones, what open new opportunities for code usage not only for identification but also for advertising while the content of the code become accessible to everyone.

There are several types of 2D codes, but we will be focused only on QR code and EZ code. Both are used for identification and in advertising. QR code, developed by Denso in 1994 (QR code.com), is used for advertising and especially for labeling small items such as products in medical, pharmaceutical, mechanical and computer industry. QR codes can be decoded by code readers as well as by mobile phones in case of advertising.

EZ code was developed by Scanbuy in 2005 (Scanbuy). That symbology was created specifically for the mobile camera phone while its simple, highly effective design allows it to be read at a smaller size, by a higher number of mobile devices (Scanbuy).

Since 2D codes can be really small with encoded larger amount of data than barcodes, they are particularly suitable for use in packaging, where the space for additional information is limited. Consequently the code on packaging or advertising material does not serve only for identification on the cashier's desk, but can also offers an additional value with connection of the static printed media with interactive World Wide Web which can be reached through scanning of 2D code by mobile phone.

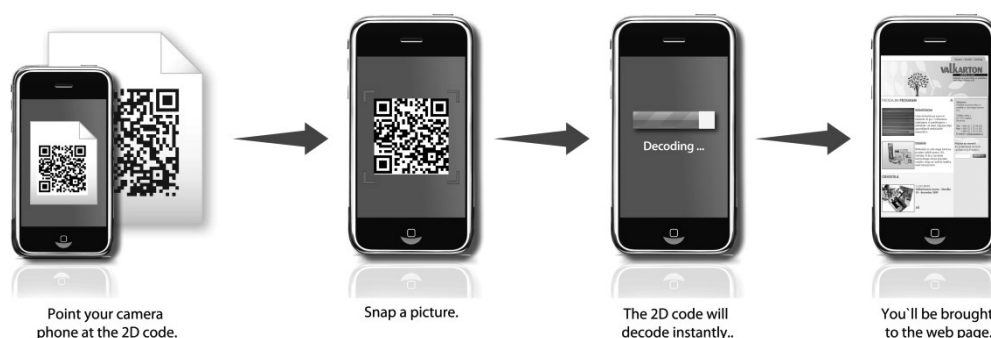
The aim of our study was to present as much information about QR and EZ codes, their usage and extended packaging. In addition, we wanted to compare these two codes among

one other according to largeness and we create codes in process printing inks and determine their readability.

## 2. Extended packaging

Packaging has a lot of different roles. It has to protect the content against external influences and against the scatter, to offer protection during the transportation and to inform the users about the content of the packaging. (Vujković, 2007). And the most important role for the extended packaging is the last mentioned. For good and informative packaging we need additional space to print additional information on. As nice and elegant solution 2D codes can be used. In them the information or link to the information can be encoded.

On that way we can add additional information to printed media and consequently connect the printed media with the interactive internet. The packaging has to have the ability for the consumer to know that additional information is available (GS1, 2009). So, besides printing the 2D code on the packaging there has to be also some information (Figure 1) that will inform costumers how they can get additional information through their mobile phones.



*Figure 1: An example of how can we get the information from 2D code.*

Extended packaging has the benefits for customer and also for the retailer. Customer gets more information about product ingredients, can check if products are genuine, gets further product instructions, gets information about allergens and picks up coupons electronically (GS1). On the other hand brand and retailer understand consumers better, develop another sales channel, strengthen loyalty programs, add value to brands and increase trust (GS1).

When the consumer has scanned the barcode from the packaging or from other media there are two possible modes of information exchange; direct and indirect (GS1, 2009):

- Direct mode - all information is read directly from the barcode and the mobile phone is able to send the request directly to the brand owner. Systems like that is mobile web portal or a web service, which returns the extended data when connected to.
- The most common example of direct mode access is when a URL is embedded in a 2D code. Direct mode of access enables the brands to engage in a direct dialogue with the consumer without any intermediaries.
- Indirect mode - the information exchange occurs through an intermediate. The consumers' mobile device engages in information exchange through a lookup/resolution service that maps the scanned GTIN in the code to its trusted source of information.

## 3. Experimental part

Our experimental part was divided in two steps. Firstly we were focused on discovering the applicability spreading of QR and EZ codes. Secondly we made the virtual experiment, in which we test how the amount of data influences the largeness of 2D codes. We made some additional test also on the area how color influences the code readability.

### 3. 1 QR code



Figure 2: QR code (Kaywa).

QR (Quick Response) code (QR code.com) is 2D matrix code that contains *information in both vertical and horizontal directions*. Because of that QR code holds a considerably greater volume of information than a bar code. It can encode up to 7,089 numeric, 4,296 alphanumeric or 2,953 binary data. Its main features are large capacity, small printout size and high speed scan. Reed-Solomon error correction enables the code to be successfully read even it is partially torn, damage or dirty. Because of three position detection patterns (squares in three of four corners of the code) code can be read from all 360° directions. QR code exists in 40 different versions from 21 × 21 to 177 × 177 modules.

Some applications of QR code are shown on the Figure 3.



Figure 3: Examples of QR code usage (2D code, Mobile Kaywa).

### 3. 2 EZ code

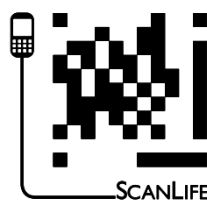


Figure 4: EZ code (ScanLife).

EZ code (Scanbuy) is a 2D code that was created specifically for the usage with mobile phone. It has a simple, highly effective design that allows it to be read at a smaller size, by a higher number of mobile devices. The EZ code features three distortion correction features (single modules in three of the code corners), and two guide bars (on the right and on the bottom side of code) which allows more flexible decoding. Codes can be created and edited using the ScanLife platform. EZ code is not a global standard yet, but they are doing on that to facilitate the growth of this symbology.

The size of EZ code is equal no matter how much information you encode, that is 11×11 modules, and the payload area is 83 modules large. Total physical size of code is 1,27 cm.

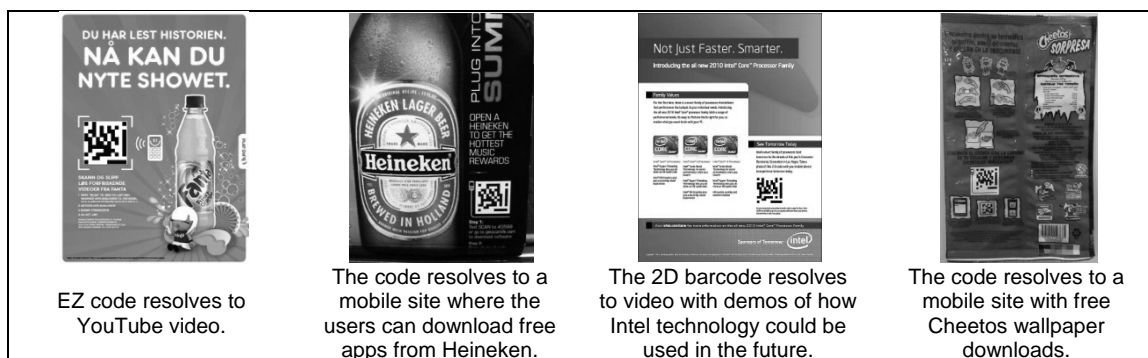


Figure 4: Examples of EZ code usage (2D code).










## 4. Results and discussion

Code samples were generated with different code generators and prepared in Adobe Photoshop to have the same module size in all codes and appropriate raster tone value. Printing was done using laser printer (HP Color LaserJet 3550) with default settings for plain paper preference and resolution 600 x 600 dpi. As printing substrate the packaging cardboard Reno de Medici 230 g/m<sup>2</sup> (Italy) was used. For reading measurements all samples were exposed to standard daylight in The Judge II (Gretag Macbeth) chamber and illuminated at 45° angle. The readability or non-readability of codes was determined using mobile phone Nokia N86 8MP and i-nigma (for QR codes) or ScanLife (for EZ codes) software was used. The code readability or non-readability was determined.

### 4. 1 Largeness of codes depending on data encoded

At first the largeness of codes in dependence of encoded data was investigated. EZ code was generated with ScanLife (Scanlife) generator, while QR code was generated with ScanLife and Kaywa (Kaywa) generators. The largeness of the module (the smallest element of the code) was set to 1 mm, so all codes were comparable in largeness among each other.

Table 1: Comparison of the largeness of codes with same data encoded.

Code - generator			Encoded data
EZ - ScanLife	QR - ScanLife	QR - Kaywa	
			World Wide Web address <a href="http://www.valkarton.si">http://www.valkarton.si</a>
			Telephone number 041234567
			SMS to the telephone number 041234567 with message "An experimental solar-powered aircraft launched on Wednesday has landed safely in Switzerland after successfully flying"




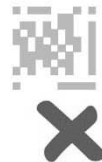

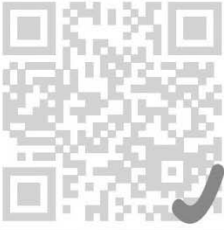

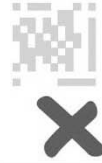

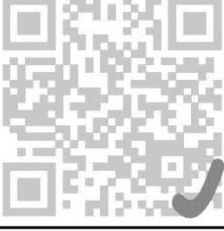


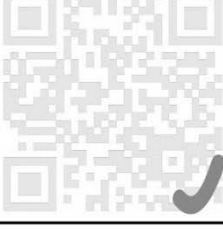



The comparison of the largeness of the codes was done and the readability of codes was determined. The largeness of the codes is very different as it is seen from the table 1. It is noticeable that EZ code has always the same size regardless on the amount of encoded data. On the other hand QR code generated with Kaywa generator changes its largeness very much and becomes larger as more information is encoded. Even though QR code generated with Kaywa changes its size according to amount of data, the QR code generated with ScanLife generator remains the same no matter of the data quantity. That is because ScanLife generator generates QR codes in indirect mode of information exchange while Kaywa generates codes in direct mode, so the information is encoded directly to the code.

The readability was determined and we realized that all codes presented in table 1 are readable irrespective to largeness or code type.

#### 4. 2 Influence of printing color to the code readability

While 2D codes are often used in the advertising and on packaging it is recommended that codes are not just in black but that the color could be the part of packaging design. We prepared codes in different process printing inks (cyan, magenta and yellow) at 100 % and 30 % raster tone value (A) and determine the readability of codes with mobile phone Nokia N86 8MP. For the experiment the EZ code and QR code (Kaywa) with World Wide Web address <http://www.valkarton.si> encoded was selected.

Table 2: QR and EZ codes printed in different printing color and different raster tone values. Codes with tick are readable and codes with cross are not readable.

Color	QR - Kaywa		EZ - ScanLife	
	100 % A	30 % A	100 % A	30 % A
Black				
Cyan				
Magenta				
Yellow				

We realized that all codes from table 2 that are printed in 100 % A are readable in the chamber at standard daylight illumination. The differences have been shown in the readability of the codes printed in 30 % A. Cyan, magenta and black QR codes printed in 30 % raster tone value were readable while the yellow codes printed with 30 % A were not. EZ codes were not readable even if the code was printed in 30 % black ink. The reason for non readability of EZ codes can be in the code design but probably the software ScanLife is not as good as the software i-nigma.

## 5. Conclusion

In comparison of QR and EZ code we realized lot of things (QR codes, Wikipedia). Each of codes has their own benefits and also limitations. For both codes a small camera on mobile phone is good enough to encode the code. Print resolution has not important effect on code readability.

While the size or density of the EZ code remains the same, independent of the amount of information associated with, the size of QR code increase with increasing the amount of data encoded if the code is encoded in the direct mode. Problems appear when we want to encode larger URL addresses and code become too large for printing on small media. Even though both codes are popular and used for advertising and in extended packaging, QR code is standardized and more known than EZ code, and consequently used in more different applications than EZ code. EZ code and its entire system stands and falls with the ability of Scanbuy, so it is dependent on it, while QR code do not have such a system behind it. The

users of EZ code will need to pay operator fees to make the connection to access the code, while QR code can be read even without the internet connection (depends on software you use). Furthermore the Scanbuy technology is a closed system and EZ code can only be read by Scanbuy reader, while so-called "open" format readers will not be able to interact with the code.

The business models of codes are quite different. ScanLife make their money by charging brands to create the codes, as well as every time a consumer scans one of their codes. This is a polar opposite of the "open" format model, where the printing, decoding and in some cases even the readers themselves are all essentially free.

2D codes and their usage are developing very fast. We can find them on packaging, in newspapers, on billboards and other posters, codes are used for identification of small products, they can be printed on different materials or engraved. As it is described in the article there are lots of different codes, one are standardized, other not, but all enable the communication between costumer and retailer. Besides that 2D codes can connect the static printed word into dynamic internet page and dynamic data about the product. QR code is better because we can encode or decode it with lots of different free softwares and their readability is good enough also at using different printing colors. EZ code is better choice if we need to encode information on small area. Comparing reader softwares the code reader ScanLife is worse than i-nigma, while EZ codes printed at lower raster tone values are not readable.

## 6. Acknowledgement

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## THE RENTABILITY RATION IN COLOUR AND BLACK AND WHITE WEB PRINTING FROM THE ASPECT OF ACQUISITION, EXPLOITATION

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**Abstract:** This paper is based on a short review, divisions DI technology and basic technical principles of work and today's applications in the industrial production of newsprint in obtaining variable printing black and white or multicoloured prints. From the point of purchase, the period of use and exploitation.

### 1. Introduction

Information and technical and technological trends starting twenty first century have led to significant improvement of information flow and business communications which may lead to dramatically accelerate the pace of life. General development of society is conditioned by the degree of development in the application of information technology that is significantly present in the printing industry itself. Graphic economy more broadly share bears to the total degree of social conditions in which the main prerequisite for a high degree of social progress. High level of social development can be encouraged a number of requests: An increase of social standards, growing need for various graphic products that dictate the trends of today, where they are reflected through "healthy" competition, [1]

- The necessity of human needs for various products will influence the development of the productive system with a high degree of flexibility,
- Implementation of new technologies in graphics systems,
- Implementation of new graphics technologies requires highly educated professionals,
- Involvement of highly educated professionals contributes to building a new advanced intuitive product that makes the feedback loop of a social development.

### 2. The basic division of digital printing

DI printing technology are the youngest type of printing or the processing of a print without conventional mechanical printing forms. The development of DI printing technologies were initiated by the Internet revolution is directly transferred to the development of this branch of the printing industry. Digital printing is still divided into laser and inkjet technology. It is necessary to specify some basic characteristics in common for both of these DI printing technology:

The concept of pressure in getting the impression there is no decisive role, "NIP",

- The process of printing forms occur in every work cycle, Diversity within a print circulation,
- Management techniques, different dynamics in the development of a specified number of copies can be seen best through the following benefits:

Personalisation of documents about Variable data printing Decentralization of the press from the preparation and management of data a wide range of circulations with different ratios of profitability depending on the form surfaces (sheets or rolls), the type of printing (colour or B/W, black / white) and finally in the choice of DI printing techniques (laser or inkjet technology) DI modern techniques can be subsumed under one common name that belong to the group for digital printing such as "computer to print" and carry certain characteristics:

#### 2.1 Tech electrophotography

##### **I Printers that use colour in dry powder form (technique electrophotography)**

It works by light selectively electrified positive electric charge on the surface of the drum, forming a latent electronic image that attracts negatively charged fine toner powder, the powder and then transferred to paper and melted on the surface using a heater. A laser printer the light source is digitally controlled. The laser beam is focused on photoactivator drum that turns on and off to form a picture on it. Light forms a positive charge on photoreceptor and creates an electrostatic latent image side. photoactivator moves, turns and passes through the unit to develop, which draws the necessary amount of toner to the developing unit. Photoactivator continues to spin and comes in very close contact with the paper, which will also move. Below is a paper transfer corona in the form of spirals or roller that creates in electric field. Paper attracts

the toner to the photoreceptor where the formed electrostatic latent image. Passing through a pair of heated rollers, synthetic toner to melt and permanently connected with fiber paper. The principle of operation of colour printers can be done in two ways: [3]

- a) The identical principle which requires a minimum of four basic CMYK colour printing section, this is a more complicated way of matching and control colours for print.
- b) The second way is specific in that four-CMYK image formed on the transfer drum and a four-colour image is created by passing paper through the printing unit. [2]

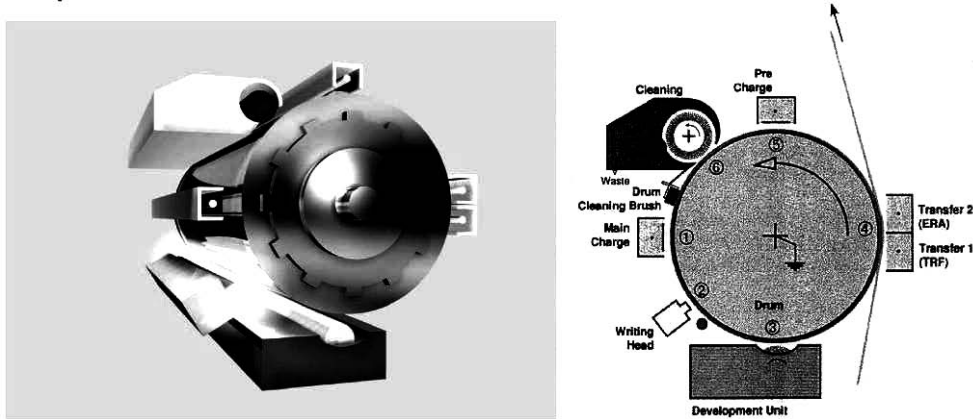


Image no. 1: Structural view of electrophotography printing system [2]

## 2.2 Tech spraying liquid paint (Inj jet printing)

### II Printers using the wet paint (ink jet printing) - cartridge colour

Because of its simple principle of the first models of these printers are used in the preparation of proofs of broken pages in large format for posters and sample sheets for the calibration of the press. The essence of all ink jet printer heads and nozzles seem to spray paint. Using spray paint to ensure overlap between two adjacent nozzles (nozzle) spray paint. With these printers, it is necessary to note that there are two principles of:

- a) Inkjet printers with continuous during the colour used in quick - industrial printer with high quality and sustainable level of print - printed from the roll. Representatives of these printers are: Scitex Realist, Du Pont Chromalin Digital, Kodak, Impika and their price is very high.
- b) Another type of ink jet printers with colour coating the drops in this way is presented to the first principle of operation of the ink jet printer. The use of these printers is enabled paging - sheetfed printing high resolution not very stable quality of the prints in an edition with a low cost of equipment purchase. A further principle of operation of these printers can be divided into heat and piezoelectric principle.

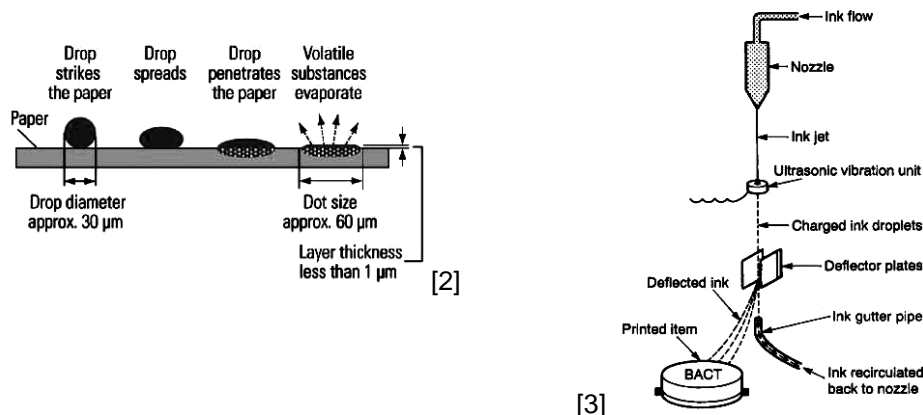


Image no. 2 and 3: Overview of Ink Jet droplets on the paper surface; schematic Inkjet principles

## 2.3 Printers with the principle of thermal

### III Printers using thermal STMP ie. thermal transfer technology, a printing surface with the appropriate

With the thermal technology is applied special paper whose surface is sensitive to heat and the image created by the so-called done. burning point electrode (low laser permanent or long-term point of burning). Through these special sensible thermal paper sheet is placed on the appropriate colour that fits the thermal printing head, when the head warm with colour film transferred to the paper surface. On the actual temperature depends on the intensity of sediment colour printing is extremely slow solid quality and can be used as a protective form of printing or printing art reproductions.

3. Setting requirements for new acquisition or upgrading existing production systems "DI technology" - Graphical Printing Center for printing - documents personalization variable, the examination profitability the transition from b/w (black/white) rotary laser printer on rotary colour printer

In solving the supply of Reference purchasing new production equipment and technological modernization of existing ones, is necessary to consider the current situation and the need to make a projection of future conditions optimized with reserve capacity of the industrial model of production in the coming eight to 10 years.

In the analysis of reference, I took as a typical form of the development of an industrial production, "Printing Center", starting its establishment and operation since 2002 year.

The formation of the first digital **printing centers** in the world and in our country began with the development of computer information technology to dictate trend of industrial printing digital printers from reel and related technological equipment for the further processing of printed materials. Further processing of the material was based on the operations of cutting, perforating, folding and insertion operations in the envelope. [3]

Late twentieth and early twenty-first century existence and application of rotating (b/w) was the only printer electrophotography technique, laser technique. The economic and functional reasons for these industrial printers reflected in the formation of "Printing Center". Their main activity was in the personalization of documents and variable data inprinting with great opportunities to perform market segmentation in direct communication with the user called. "Direct mailing. Past technological process required the use of preprint (Such cards) from the roll as a form of print media - materials, printed in offset technique (offset). The data were subsequently electro-technique - laser printing "imprinting" the zone already defined fields.

Current trends of development of digital printers have led to the starting positions - the reasonable cost of production and Polychrome - colour print on both sides (4/4) of the minimum of several hundred thousand, and to 5 - 6 million sheets of A4 monthly circulation. Way of obtaining fingerprints received an order to pass through a digital printing device. The work of the printing system can be achieved by electro-technology a laser or ink jet printing - technical solution to the continuous inflow of colour.

The fundamental difference separating the DI technology than conventional (offset) printing system is in addition to its basic technical principles of operation, high depreciation rates and repayment DI technology if they have approximately the same average cost of around 1.2 million euro. [4]

High depreciation rates of repayment of these printing systems is caused by the rapid development of computer information technologies representative key driver of its trend and development of new generations of printing systems. It can be shown through the following performance improvements:

- High-speed operation,
- Sustainability in the production of large print management capabilities,
- Shorter period of preparatory and final time,
- Increased flexibility of production which is reflected in the implementation of large scale formats and types of paper,
- Reduced the value of regular monthly maintenance
- A small number of raw-materials engaged in the process of production,
- Lower costs involved raw-material
- The use of organic colours and meeting the requirements of environmental standards,
- Lower noise, lower electrical consumption and smaller dimensions of the printing device

It must be noted next inevitable technological advantage in the preparation of the digital colour multi-colour (4/4) offset print with subsequent variable (b/w) inprinting content:

- Quick volatility prepress unite price. complete variable printing the entire document, a big advantage in the market with short response time to requests padded,
- Lack of technical waste caused by printing offset rolls - Such cards he refers to the elimination of stops on the rolls caused by the supplier. Any termination of the rolls is manifested in the form of technical waste transferred to the ratio of unplanned expenses which are then transmitted to each technological process (printing and mailing), a large economic advantage of saving material and labor in all phases that can be raised up to 12% per unit price the final product,
- Minor technical waste caused by transportation, which is reflected in the economic relationship between the number of sheets made cards will (x) «multiplication» the agreed unit price, **(the impact on the reduction of expenses in relation to the value of the material blank paper and finished Such cards 4/4 with a ratio of 45% on the unit value in exchange use blank paper)**
- Easier management of commodity and financial business - warehouse services due to a substantial number of different types of cards will and their aging facilities, **(a small number of employees and to prevent the ordering of unnecessary amounts of material - Such cards).**

#### 4. Economic calculation through analysis propositions

Economic calculations can be performed in two propositions:

I monthly production inprinting mutual colour (4/4) documents – use pre-printed substrates (paper sheats) as its procurement.

II (4/4) electro-technique or inkjet printing process, inclusive of variable data print.

It is necessary to start from the average monthly production of PC material above 5,000,000 A4/list.

**In consideration of proposition no. I** The monthly production of making cards will X «multiplication» Eq. Such cards cost X«multiplication» (percentage interruptions caused by technical management on roll +«sum» percentage increase in technical waste caused by the additional manipulation of materials by the time variable inprinting, X«multiplication» unite price imprinting impression (b/w) X«multiplication» reprint\* offset print with subsequent-backgroud monthly amortization rate + value + value of the maintenance involved in the process of printing material ( toner and developer). The last three factors make up the sum:  $\Sigma$  3.2% of the value of equipment (b/w) printing system which is 30% cheaper than colour printing system.

**In consideration of proposition no. II** The monthly production of digital printing X«multiplication» unite price per digital sheat colour\*printed digital prints X«multiplication» unite price of blank paper X«multiplication» monthly amortization rate +«sum» value +«sum» value of the maintenance involved in the process of printing materials. The last three factors make up the sum:  $\Sigma$  2% of the value of the purchased printers equipment. That printing equipment is 30% higher (b/w) black and white printer.

From the analysis set proposition following can be concluded that proposition **no. II** carries a greater benefit to be observed in the field the following savings:

- Total savings of materials 4.3% multiplied by the price difference of 45% of work blank paper developed in mutual colour tehcnical offset printing,
- Increased competitiveness in the market with a " for one step ahead " (because of the rapid response of finished product),
- Using InkJet Technology to create the ecological conditions of printing conditions,
- A more favorable value of maintenance, depreciation rates and raw materials for the benefit of ink jet printers of 1.2% higher,
- Relationship values on one side (offset print with subsequent-backgroud 4/4 + (b/w) imprint) and on the other side (the blank paper + colour digital 4/4 ink jet printing), in a comprehensive comparison about 7% in favor of colour multiple inkjet printing systems.

**The defined integrated Analytical reveals a trend of monthly benefit higher of 12.5% in favor of the acquisition of new technology Inkjet printing equipment for multicolour printing 4/4 (colour duplex impression), as well as changes in the current mode: the development and procurement of the reprint \* offset print with subsequent-backgroud. In addition to the percentage of benefits should not be forget out competition deletion in the market,**

**the establishment and development of environmental standards in graphic production, employee care, and reduce the number of employees.**

## 5. Conclusion

On the basis of the technological methods of production and economic performance carried out the analysis, the transition b/w variable inprinting<sup>\*digital printing on offset surface</sup> on colour data with previous multi-colour cards will use 4/4 from the roll, for different technology different approach new way of making the final variable document ink jet technology with a continual inflow of colours. The initial investment in the ink jet printing systems are 30% higher than laser (b / w) printing system. But with a monthly benefit ratio of 12.5% between the election mode, investments made payments in the short term of repayment. Because of these economic savings and the competitiveness of the final product on the market and strengthening the position in the business world of competition.

The accordingly graphic production ceter largest in the southeastern part of Europe in the field of digital printing with variable personalization of documents and insert envelope mailing with "in line" process finishing insert of mailing, it is worth investing in new technological equipment with new, modern production process work

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# THE COMPARISON OF PRINT GLOSS AND COLOUR DIFFERENCE OF CONVENTIONAL AND HYBRID INKS COATED WITH GLOSSY AQUEOUS AND UV COATINGS IN CORRELATION WITH SURFACE

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**Abstract:** The hybrid inks as the combination of UV ink and conventional ink technology have been developed with the goal to benefit from printing ink technologies. One of the advantages of hybrid ink technology is the possibility to use UV coatings which by the components provide higher print gloss and more saturated and vivid colours. In this paper we have measured the print gloss as the geometrical and colour difference values as the chromatic part of the light reflection which is both dependable on the inks, coatings and surface properties of printed sheets. We have printed colour samples with conventional inks on a four colour offset printing press with and additional coating tower which have been coated with two different anilox rollers (60L/cm and 90L/cm) with inline coating of aqueous coatings. The hybrid inks have been coated in similar way with UV coating using the same anilox rollers. The surfaces of the printed and coated samples were characterized by AFM surface scanning and the appropriate surface roughness values were calculated. The results indicate differences between average surface roughness after printing and subsequent coating between hybrid inks and conventional inks and higher gloss values for UV coatings and similar colour differences between coated hybrid and conventional inks.

**Key words:** hybrid, coating, surface roughness, gloss, colour difference

## 1. Introduction

Inline finishing and high gloss make hybrid inks attractive for using them as added value tools and enhancing the prints similar to UV ink technology but without the risk factors that carries the UV technology. Hybrid inks provide the benefits of UV coating without using additional water-based primer. Water-based primer prevents glossback, which occurs due to the incompatibility of UV coatings and conventional inks. Since hybrid inks accept a UV coating inline, the need for conventional offline coatings and water-based primers is eliminated, resulting in print quality that is closer to a conventional litho ink. Hybrid inks are based on binders selected to minimize the attack of ink rollers and blankets. The amount of photoinitiator is reduced for the same reason, resulting in a lower reactivity. The UV binders must of course be compatible with conventional binders. Basically, for this reason, the UV part of hybrid inks generally consists of polyesters acrylates, resulting in inks with lower scratch and chemical resistance. For the above mentioned reasons, hybrid inks are in practise often or almost exclusively used in combination with a UV overprint varnish.[1] Litho inks in order to be coated with UV coatings had to be dried with spray powder before applying the desired high gloss UV coating. To overcome this deficiency, printers found that they could aqueous-coat the sheets in line and minimize the use of spray powder. This type of surface enhancement also proved as very useful to produce high gloss printed products. Both of these technologies are used with success in today's printing technology.

## 2. Statement of the problem

One of the main functions of the UV or any other coating application beside the mechanical protection of prints and production optimization (drying) is the visual improvement of prints with vivid colours and especially gloss. Gloss is a complex issue and in papers [2] and [3], is defined not just as a material property but as a group of visual effects produced by properties of the underlying material. Surface properties that affect our impression of gloss are influenced by the substrate material, surface structure, smoothness, roughness, texture, and the degree of transparency as well the type of the materials which make these surfaces. The influence of the surface on the light reflection is a wide studied topic as can be seen from papers [4], [5] and [6] which introduce several theories of light reflection from rough surfaces. The reflection of the light from a coated sample also changes the colour values of coated surfaces as can be seen from



the experimental data found in [7] and [8]. The emerging new technologies and new types of coatings, as well their application methodology require the study of these new materials, their behavior and surface forming which influence the final visual appearance of printed products.

### 3. Materials and methods

For the experimental part we have printed a test chart on KBA Rapida 105 four colour offset printing machine which was equipped with an additional coating tower with closed chamber doctor blade system. The prints with the conventional inks from Sun Chemical World Series which comply to the ISO 2846-1:2006 were printed on a glossy paper 130g/m<sup>2</sup> which is defined as Type 1 by ISO 12647-2:2004 using the standard inking values defined by the same standard through Lab values. The hybrid ink prints were printed on the same substrate and have been printed with Sun Chemical HyBrite ink series, using the same inking values because at the moment there isn't any other specified standard for hybrid inks. We have used the KCMY colour sequence in the process as recommended by the ink producers. After printing the conventional printing inks were coated with aqueous glossy coating Prestofix Hochglanzlack H6055/55 in two quantities which were regulated with two anilox rollers (60L/cm and 90L/cm). The quantities were calculated through the weight measurement of the 10 x 10 cm samples taken on 6 positions on the sheets and were defined in g/m<sup>2</sup> which is a standard industry specification for calculating coating transfer and coverage. For the drying process we have used the machine's IR drying system which was at system settings specified by the press manufacturer. The hybrid ink prints were also coated using the two anilox rollers with and UV glossy coating VP 10532 from VEGRA and was dried by the UV lamps installed on the machine with also factory settings. After the drying we have used random sampling method to acquire the printed sheets from the OK sheets which conform to the inking standard to minimize the influence of ink film thickness. The print gloss on the sheet which were not coated and coated ones was measured with Glossmaster three angle glossmeter using the 60° angle specified by the ISO 2813:2004, while the colour difference was calculated using the Techkon SpectroDens measuring device which uses 0°/45° directional measurement geometry, D50 standard illuminant and the 2° standard observer. For the colour difference specification we have used the CIE D<sub>94</sub> colour difference formula. For the surface roughness characterization of surfaces on the prints we have used the CP - II SPM scanning microscope from Veeco. The scanned areas were 80 x 80 µm and were measured in three spots with two directions which resulted in six measurement values. The results presented are the average values for the measurements. The surface roughness parameters S<sub>a</sub> (average surface roughness) and S<sub>q</sub> (root mean square roughness) which are defined by the ISO/DIS 25178-2 standard draft were calculated by the Image Metrology SPIP software package. For the statistical data calculation we have used the Statistica software package.

### 4. Results

The print gloss of the conventional and hybrid inks was measured on the full tone colour patch (100% tone value) of the test forms to avoid any influence of the differences in ink densities on the measured print gloss. According to the used standard if the values of specular instrumental gloss was below 10 gloss units values in the 60° angle we have used the measured values from the 85° degrees and if it was over the 70 gloss unit value we have used the results from the 20° angle. The results of the measured print gloss are presented in Figure 1.

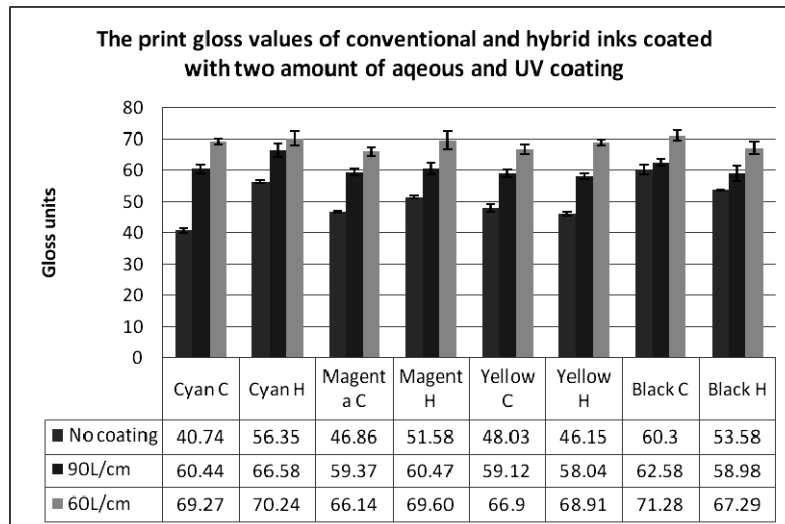


Figure 1. The print gloss values of conventional and hybrid prints coated with two amounts of coatings

As we can observe from the measured results in Figure 1. the gloss values of conventional inks was between 40.74 for the cyan with standard deviation value of  $\sigma=0.85$  and 60.3 for the black colour with  $\sigma=1.63$ . The hybrid inks with no coating applied yielded values from 46.15 for yellow colour with  $\sigma=0.59$  to 56.35 for the cyan patch with  $\sigma=0.49$ . The cyan and magenta patches of hybrid inks had larger print gloss values while the yellow and black patch yielded smaller values for the hybrid and larger for the conventional ink patches. For the first amount of coating transferred by the 90L/cm anilox roller the calculated amount of coating was  $1.95 \text{ g/m}^2$  for the UV coating used for the hybrid inks and  $1.9 \text{ g/m}^2$  for the aqueous coating used for the conventional inks. The gloss units values for the conventional ink prints coated with this amount varied from 59.12 with  $\sigma=1.1$  for the magenta and 62.58 for the black colour patch with standard deviation value of 1.07. The hybrid inks with UV coating resulted in higher values than non coated samples and varied from 66.58 for the cyan with  $\sigma=2.2$  to 58.04 for the yellow colour patch with  $\sigma=0.96$ . The second anilox roller with larger anilox cells yielded a transfer of  $3.96 \text{ g/m}^2$  for the aqueous coating and  $6.47 \text{ g/m}^2$  for the UV coating. The print gloss results for the aqueous coating were between 71.28 for the black colour patch with  $\sigma=1.5$  and 66.14 with  $\sigma=2.82$  for the magenta. The UV coatings were ranged between 70.24 with standard deviation of  $\sigma=2.2$  and 67.29 for the black colour patch with  $\sigma=2$ . We can observe that there is a rise in print gloss values for both the conventional inks coated with aqueous coating and hybrid inks coated with UV coatings using the same anilox rollers, but with different drying methods. We can also see that with highest coating amount transferred using the 90L/cm anilox roller the hybrid inks have higher values (except for the black colour patch), which can be partly explained by the larger amount of the transferred coating. For the characterization of the chromatic differences induced by the applied coating we have calculated the colour difference values between the initial non coated and coated samples of both ink and coating technologies. The results for the colour difference values are presented in Table 1 and 2 and in Figure 2.

Table 1. The colour difference values for the aqueous coated conventional inks

90 L/cm anilox roller						60 L/cm anilox roller					
Colour	$\Delta L$	$\Delta a$	$\Delta b$	$\Delta E_{94}$	$\sigma (\Delta E)$	Colour	$\Delta L$	$\Delta a$	$\Delta b$	$\Delta E_{94}$	$\sigma (\Delta E)$
Cyan	0.54	-0.99	1.24	0.96	0.09	Cyan	-1	-1.22	0.8	1.25	0.07
Magenta	-0.86	1.84	1.75	1.29	0.23	Magenta	-0.59	1.78	2.3	1.32	0.12
Yellow	0.29	0.11	2.87	0.63	0.2	Yellow	0.24	0.22	3.49	0.72	0.32
Black	-5.92	1.19	3.06	6.58	0.31	Black	-5.6	1.29	3.44	6.46	0.20

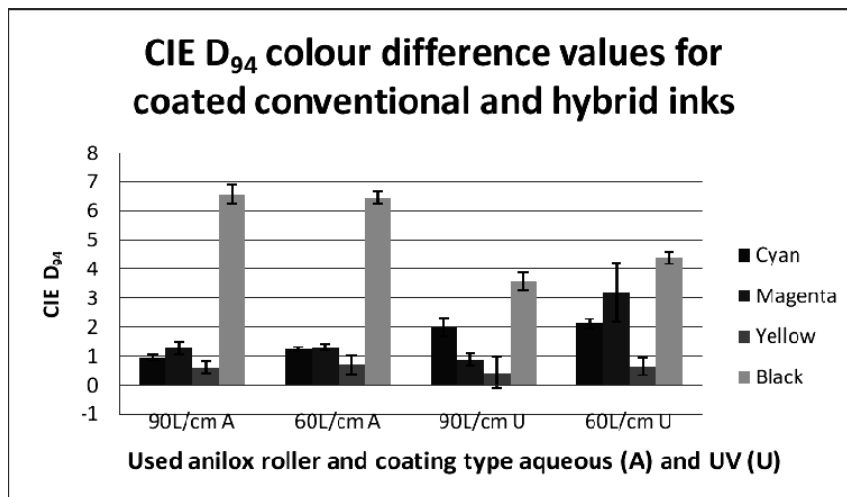
As we can see the changes for different colours in terms of lightness and hue differences the changes mainly occur in  $\Delta b$  which for both coating quantities indicate a shift to more saturated colours. The changes in lightness as quite low for all colours except for the black which showed

the largest changes in lightness and totally the largest changes in colour difference with values of 6.58 for the 90L/cm anilox roller and 6.46 for the 60L/cm anilox roller. All the other colours (cyan, magenta and yellow) had larger colour difference values for the larger amount of applied coating (3,96 g/m<sup>2</sup>), but were under visible difference threshold.

*Table 2. The colour difference values for the UV coated hybrid inks*

90 L/cm anilox roller						60 L/cm anilox roller					
Colour	$\Delta L$	$\Delta a$	$\Delta b$	$\Delta E_{94}$	$\sigma (\Delta E)$	Colour	$\Delta L$	$\Delta a$	$\Delta b$	$\Delta E_{94}$	$\sigma (\Delta E)$
Cyan	-1.94	-0.15	-1.45	2	0.32	Cyan	-2.1	-0.28	-1.34	2.12	0.18
Magenta	0.62	0.84	1.24	0.88	0.20	Magenta	-1.07	2	6.29	3.19	1.03
Yellow	0.67	-0.73	0.66	0.44	0.54	Yellow	0.28	-0.37	3.03	0.65	0.28
Black	-3.21	0.83	1.45	3.6	0.3	Black	-4.05	0.85	1.49	4.39	0.19

As we can see from Table 2. For coated hybrid inks the largest differences can be observed in lightness and chroma  $\Delta b$  values which indicate more saturated colours. The lightness changes indicate a darker colours especially for Cyan and Black. The chroma changes indicate more saturated colours but again the  $\Delta b$  values are much more dominant. The overall colour difference values are larger for the prints with larger amount of coating and 6,47 g/m<sup>2</sup> applied with the 60L/cm anilox roller.



*Figure 2. The colour difference values between the coated and non coated printed samples (conventional and hybrid)*

The surface roughness of the printed samples was measured with an AFM microscope and the average surface roughness  $S_a$  and the root mean square average roughness  $S_q$  parameters were calculated. The values presented in Table X. Are the arithmetic mean values of six measured positions. These values are based on the two dimensional standards and extended in three dimension.

*Table 3. The  $S_a$  and  $S_q$  surface roughness parameters of coated and non coated conventional and hybrid ink prints*

Surface type	$S_a$ (nm)	$S_q$ (nm)
Glossy paper no ink no coating	99.11	142.24
Conventional inks no coating	100.52	152.79
Glossy aqueous coating 90L/cm roller	66.41	93.44
Glossy aqueous coating 60L/cm roller	47.93	68.12
Hybrid inks no coating	166.61	218.54
Glossy UV coating 90L/cm roller	27.05	37.89
Glossy UV coating 60L/cm roller	15.85	22.26

As we can observe from table 3. after the initial inking the prints made with hybrid inks had a higher average surface roughness value of 166.61 nm compared to the conventional printing inks print of 100.52 nm. After the application of the coatings both type of surface had smaller surface roughness values, and with the additional application of the coating with larger cells of 60L/cm anilox rollers the values changed the surface roughness even more to smaller values of 47.93 nm for the aqueous and 15.85 nm for the UV coating. It can be clearly be observed that with the appplication of coatings and raising their quantity there is a decline in average and root mean square surface roughness. Even the hybrid inks with no coating had larger surface roughness values, the UV coating in the end produced a less rough surface than the aqueous coating. To further investigate the correlation between surface roughness and print gloss and colour difference we have calculated the appropriate correlation factors. These correlations are showed in Figure 3.

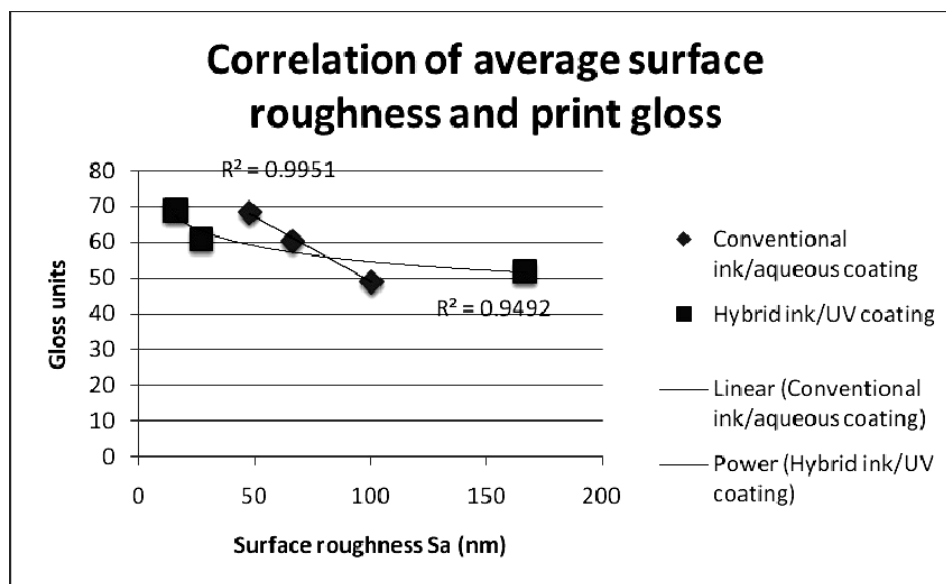


Figure 3. The correlation between average surface roughness and print gloss

From Figure 3. we can see that for the prints with conventional inks and aqueous coating there is a linear change in average surface roughness and average print gloss for all coloured patches. With the application of coating there is a decline in average surface roughness and linear type of increase of print gloss with  $R^2=0.995$ . The hybrid inks and UV varnish showed power type change ( $R^2=0.949$ ) of average surface roughness and print gloss where the application of additional coating quantity lowered the average surface roughness and raised the average print gloss value on these kind of prints. Because of small number of correlation points, and by looking to the measured results we can make an assumption that with the lowering of average and root mean square surface roughness there is an increase in colour differences.

## 5. Conclusion

On the basis of the measured results we can conclude that the additional amount of both type of coating has influence on average surface roughness, print gloss and colour difference. The highest values of print gloss and colour as well the smallest values of average surface roughness had the prints with UV coating over hybrid inks applied with the 60L/cm anilox roller. Conventional inks without any applied coating have a smoother surface than the hybrid inks, but as mentioned earlier the UV coating gives a smoother surface and thus greater specular reflection than the aqueous coating over conventional inks. There is a certain amount of variation between specific colours and the differences which are cleared by using the averaged values for all four process colours. This indicates that there is a constant need to monitor the production process (printing, drying, ink-coating compatibility) in order to produce a good quality added value printed product.

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## ANALYSIS OF ROUGHNESS CHANGES IN DIGITALLY PRINTED POLYESTER MATERIAL EXPOSED TO THERMAL LOAD

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**Abstract:** This paper presents the results of research on influence of heat on the printed textile material consisting of 100% polyester. It was assumed that thermal effects causes change in the structure of materials. In this case surface roughness was analyzed. In order to investigate this assumption the printed textile was treated with heating element, with three different degree of heat five times in a row and after every treatment surface roughness parameters  $R_a$  and  $R_p$  were measured. Thermal loads on a heating surface in contact with textile were analyzed using a special thermovision devices. Analysis showed that the heating value in measuring point were different. The reason is a consequence forms the heater in the heating element. Therefore, it is determined the arithmetic mean value for each heat input and the value of the deviation was quite high. Changes in surface roughness were measured by TR unit 200, and the results showed a correlation between the number of thermal effects and changes in surface roughness, regardless of the heat value. Although for further study it would be better to use the heating element that have smaller temperature difference on active surface, to make the results more precise.

**Key words:** printed textile material, thermal load, surface roughness,  $R_a$ ,  $R_p$ , thermovision camera, TR 200

### 1. Introduction

Digital ink jet printing is a newer technology that is increasingly attracting attention in the textiles printing industry, primarily because of the ability to adapt to the market demands and ability to print on many different materials, with a presentation of a satisfactory quality (Novaković, 2010). So today there is a great number of artificial textile materials on which to print. One of them is polyester, which is a hard, tough, synthetic material and it can be produced in various colors, shapes and sizes. It is made from chemical substances found in petroleum and is produced in three basic forms, as fiber, film and plastic.

All textile materials, including polyester, have distinctive properties, which differ from that of other materials, and their surface it is not absolutely flat. They have a certain roughness. At the very roughness affects both the mode of production, and their processing (Savvas, 2004, Naujokaityte, 2007), you can say that with the processing of raw materials of textile fiber surface roughness decreases (Naujokaityte, 2007) and that fibers of different origins have different roughness. On textile materials, printing can be done with digital or screen printing techniques, but as in the first (Merritt, 2005) in the second case also (Car, 2006), colour application will result in changes in surface roughness.

During exploitation the printed product is exposed to various treatments (washing, heat treatment during ironing, teardown during use, etc). Structure of material is changing due to thermal treatment, because in the process of ironing heating body affects simultaneously the color and the material (Novaković, 2010). There are three ways of heat transfer during thermal loads: conduction, convection, and electromagnetic radiation (Bomberg, 1983, Mao, 2007). Any of those heat transfer processes causes changes in fiber structure (Novaković, 2010) and surface roughness.

Effect of the same heat input does not cause the same changes in different textile materials because different materials have different thermal conductivity, which is actually a process where the energy is transmitted from place of greater to the place of lower temperatures, as a result of the direct impact of the molecules (Tavman, 1998). In addition, the thermal conductivity may also depend on the severity of fiber, thickness, porosity and structure, and the temperature, which act on the material (Mohammadi, 2003) that could be proved experimentally (Vingeswaran, 2009).

Thermal effect is very important and causes the changes on the surface of textile materials, so it needs to be measured. Most suitable and most precise method for measuring temperature on thermal field of heating element is contactless thermovision analysis (Sild, 2004). By means of contactless thermovision camera it is possible to obtain parameters of heating element,

temperature of the element with easily noticeable hot spots. Thermovision camera works on a principle of filtering infra red waves (Dudyik, 2009), these waves are carriers of heat and criteria for determining temperature of heating element. They measure mixture of emitted, reflected and transmitted radiation but only emitted radiation is relevant for bodies temperature measurement.

## 2. Experimental

Material used in the test is 100% polyester described in SRPS F.S3.112. For research purposes, the material is printed on a digital textile printing machine DTG Kiosk.

The surface roughness was measured on printed material as well as on the material before printing, where the reference length was 0.25 mm, by using TR 200, the product of company Portable Testers USA.

After analysis material was subjected to thermal load by heating element usually used Iron VIVAX IR-2000 T. Goal is to obtain information on influence of heat on surface roughness. Material was treated five times with three different degrees of heat and after each thermal treatment surface roughness was measured. For thermal load measurements latest generating of thermovision camera FLIR- type P65 was used.

## 3. Measurement results

Basic parameters for measuring surface roughness are as follows:

- Ra - arithmetic average of the absolute values of deviations of the profile inside the reference run,
- Rz - the arithmetic average of the deepest single file roughness measuring several adjacent tracks,
- Rt - total height profile,
- Rp - maximum height profile,
- Rv - deepest valley (Schubel, 2006).

Of all the above parameters were analyzed Ra, which in relation to the Rz gives a better correlation between subjective and measurement results, and that is reason why this unit was adopted as a principal in determining the surface roughness /17/, and Rp, because it is interesting to watch how the thermal effects influence to the maximum height profile.

The device used for measuring the roughness of TR 200, with settings shown in table 1.

*Table 1: Set up TR 200*

Cutoff	0.25 mm
Access	5L
Standard	ISO
Range	+/- 80 $\mu$ m
Filter	RC
Unit	metric

After printing the first analysis was analysis of Ra. We could say that ink application caused an increase in the arithmetic mean of the absolute value of deviation profile inside the reference run, and the same happened in the analysis parameters Rp, because after the printing process there was an increase in maximum height of profile (Table 2).

*Table 2: Values of parameters Ra and Rp for the material with 100% polyester before and after printing ( $\mu$ m)*

Condition	Ra ( $\mu$ m)	Rp ( $\mu$ m)
Before printing	3.721	3.78
After printing	4.655	4.68

After determining the surface roughness before and after printing, material was subjected to the thermal load. Printed surface was treated with heating element five times in 10 second intervals, using I, II and III degree thermal load. Thermal images of heating element are shown

in figure 1, 2 and 3. Figures 1a, 2a and 3a shows thermal field before thermal treatment of printed surface. During 10 seconds heat is transferred from heating element to the material which resulted in changes of thermal field of heating element as shown in figures 1b, 2b and 3b.

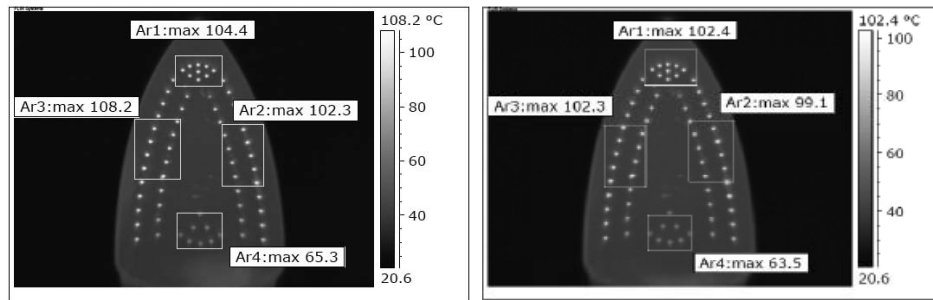


Figure 1. Thermovision shot of heating element before and after applying thermal load to the material (I degree)

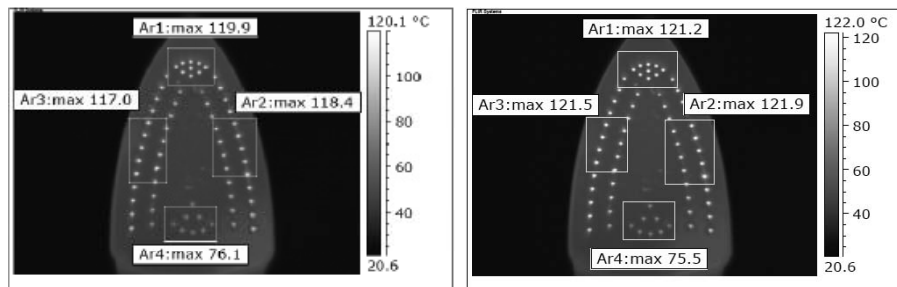


Figure 2. Thermovision shot of heating element before and after applying thermal load to the material (II degree)

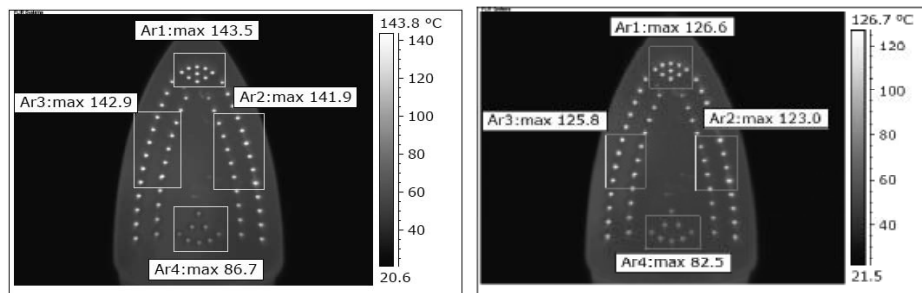


Figure 3. Thermovision shot of heating element before and after applying thermal load to the material (III degree)

Since the heating element after contact with the surface does not emit the same amount of heat, it is necessary to calculate the mean value of thermal load in all three cases. The difference between the highest and lowest temperatures was also determined, while the formula

$$\sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n-1}} \quad (1),$$

calculated assessment of the standard deviation.  $x_i$  is the amount of this effect,  $n$  - the number of historical data and  $\bar{X}$  is the mean value of historical data.

All values obtained are present in Table 3, Figure 4 is graphs of the mean value for thermal loads and standard deviation.

Table 3: Statistical analysis of data obtained by thermal imaging camera

Degree	Arithmetic mean (°C)	Sample range (°C)	Standard deviation ( $\sigma$ )
I	93.44	44.7	18.11
II	108.94	46.4	20.52
III	121.61	61	24.31



Based on the results presented in Table 3. it can be noticed that the I degree of thermal load has the lowest average temperature value, which is 93.44 °C, with standard deviation  $\sigma = 18.11$ . In the second case,  $\sigma = 20.52$  at a temperature of 108.94 °C, while the thermal load of grade III has a value of 121.61 °C and  $\sigma = 24.31$ . Deviations are high, primarily because there is a large temperature range of the measuring points on the surface of the heating element, which is due to shape of the heater located in the heating element. These values of deviations, the question is it possible to do the correct experiment.

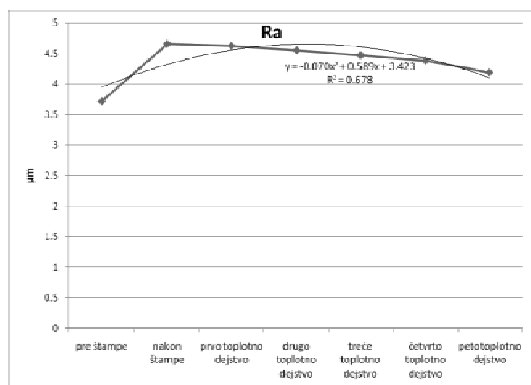
After that, the observed state of the material determined by the surface roughness of the same measurement point, as in the first two cases, and then analyzes the parameters Ra and Rp.

If we observe the parameter Ra (Table 4), we will find that each thermal load leads to his change, and then the surface becomes smoother. The heat input is also influential factor, and it can be concluded that the higher value the thermal load is decreasing Ra, but that regardless of the thermal effect, no value is lower than the initial value of surface roughness.

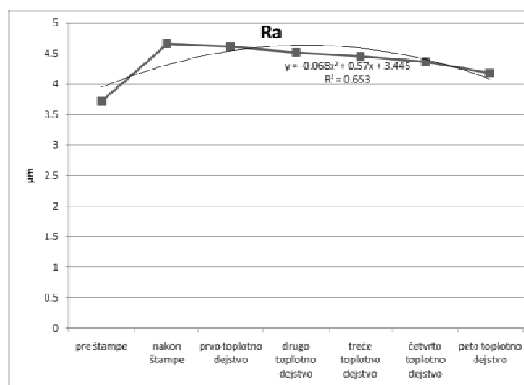
*Table 4: Values of the parameter Ra material with 100% polyester before and after printing, as well as after thermal loads (μm)*

Arithmetic mean (°C)	Before printing (μm)	After printing (μm)	First thermal load (μm)	Second thermal load (μm)	Third thermal load (μm)	Fourth thermal load (μm)	Fifth thermal load (μm)
93.44	3.721	4.655	4.623	4.55	4.47	4.383	4.191
108.94	3.721	4.655	4.612	4.513	4.451	4.364	4.177
121.61	3.721	4.655	4.601	4.501	4.411	4.337	4.141

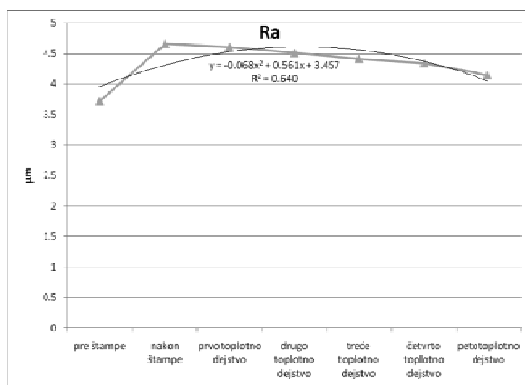
The obtained values for the Ra parameter are presented graphically in Figures 4, 5 and 6.



*Figure 5. Change the parameter Ra in thermal load of 93.44 °C*



*Figure 6. Change the parameter Ra in thermal load of 108.94 °C*



*Figure 7. Change the parameter Ra in thermal load of 121.61 °C*

Common to all the graphs is that the curve closest to the exponential form, with the value of the correlation coefficient ranged from 0.64 in the thermal load of 121.61 °C to 0.678 in the thermal load of 93.44 °C. For the thermal load of 108.94 °C correlation coefficient was 0.653. Based on these results, it could be argued that there is a correlation between the number

of thermal loads and changes in the parameter Ra, although the coefficient of correlation is not high. This may be interpreted as a consequence of large deviations, and showed that the lower value of the deviation increases the correlation coefficient (thermal load of 93.44 °C). Also, in next experiment we will use more measurement points.

Also, analysis of parameter Rp (Table 5), shows similar results to the analysis of Ra. After the thermal load, leads to lower the maximum height of profile, with a greater degree of heat stress caused a greater change in the value of Ra, but in this case the final value after the thermal effects is greater than the initial value.

Table 5: Rp values of the parameter for the material with 100% polyester before and after printing, as well as after thermal loads (μm)

Arithmetic mean (°C)	Before printing (μm)	After printing (μm)	First thermal load (μm)	Second thermal load (μm)	Third thermal load (μm)	Fourth thermal load (μm)	Fifth thermal load (μm)
93.44	3.78	4.68	4.65	4.58	4.49	4.4	4.26
108.94	3.78	4.68	4.63	4.543	4.461	4.35	4.197
121.61	3.78	4.68	4.615	4.512	4.423	4.31	4.181

Figures 8, 9 and 10 gives a graphical representation of parameter Rp for all three types of thermal load.

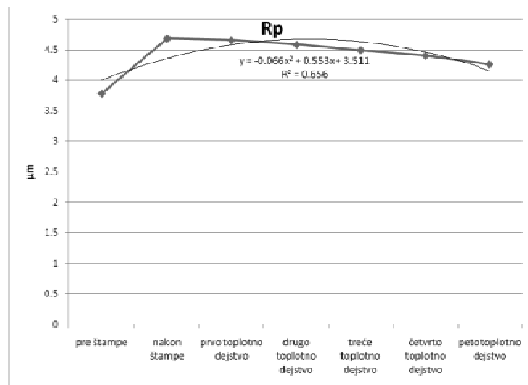


Figure 8. Change the parameter Rp in thermal load of 93.44 °C

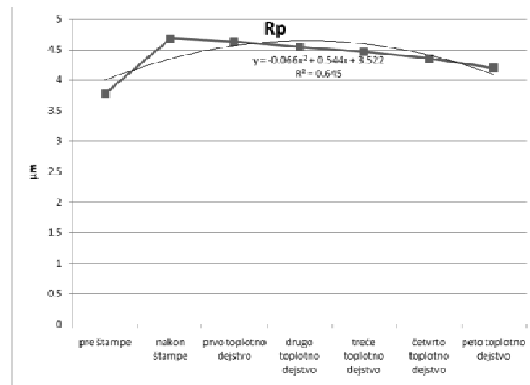


Figure 9. Change the parameter Rp in thermal load of 108.94 °C

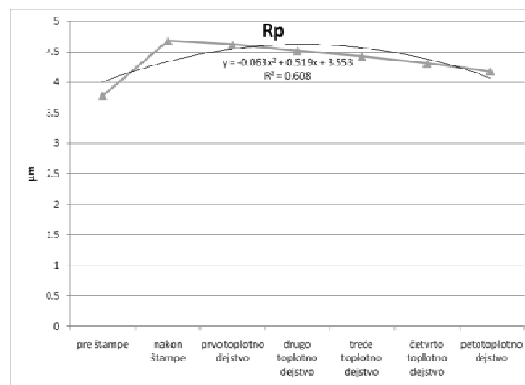


Figure 10. Change the parameter Rp in thermal load of 121.61 °C

As in the analysis of the parameters Ra and Rp parameter analysis, curves were the most likely exponential form, and the value of correlation coefficient was associated with a value of deviation, and is the first case when the minimum deviation, correlation coefficient was highest and was 0.656 (93.44 °C). Growth deviations, correlation coefficient was decreased, so in second case (121.61 °C) was 0.645 and 0.608 (121.61 °C). Like in the measurement Ra, also we will use more measurement points for next experiment.

## 4. Discussion

Experiment proves assumption that thermal treatment of printed textile material makes certain changes. These changes are reflected in changes of surface roughness of materials ie. changes in the arithmetic mean of the absolute value of deviation profile inside the reference run (Ra) and maximum height of the profile (Rp).

The surface roughness in both cases increased after the printing, because the surface ink inflicted, which is part of entering into the structure of the material, and partly remained on the surface (Novaković, 2010). Thermal load, affected the roughness of the analyzed material, because ink entered in the material structure, and that was resulted in reduced values for Ra and Rp, and those values of each thermal load were all lower. It is also important to note that the value of the thermal load associated with the change of surface roughness, mainly because the higher thermal load cause larger change of roughness. However, regardless of the thermal load ink remained on the surface, and surface roughness could not be reduced to the level before printing.

However, because of the high value of deviation in all three cases, the experiment should take the heating element, which has less thermal fluctuations on the surface, in order to get accurate results ie. the bigger value of the correlation coefficient.

## 5. Conclusion

Thermal effects on the textile material printed with digital printing technology changes surface roughness of 100% polyester materials. Applying ink in the printing process also changes surface roughness. Ink and thermal load will change the surface roughness, because of ink roughness will increase, and the surface roughness will decrease with thermal treatment of the printed surface. This will cause the part of ink to enter in the structure of the material and reduction of surface roughness of textile material of 100% polyester.

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# DESIGN ANALYSIS OF HOUSINGS OF UNIVERSAL MULTISTAGE HELICAL MOTOR GEAR UNITS

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**Abstract:** *Universal helical motor gear units do not belong in products whose selection is based on their looks, but on the basis of their technical characteristics (primarily load capacity –  $T$  and permitted overhung load –  $F_{Rperm}$  and axial load –  $F_{Aperm}$  at output shaft of gear unit), the range of gear units, quality, price, brand image and, very often, the delivery terms. However, it does not mean that their design is not paying great attention. On the contrary, design of universal helical gear units is paid great attention to ensure low consumption of material, high strength and rigidity, easy manufacturing, not complicate assembly, easy transportation, installation, service, maintenance and repair, simply disassemble and recycle, and finally nice looking of gear unit housing. For this reason, problematic of design of housings of universal multistage helical motor gear unit is detailed analysed in this paper in order to highlight the influence of some factors on the ultimate form of body of housing.*

**Key words:** *design, housing, universal motor gear unit*

## 1. Introduction

Universal helical motor gear units are among the mechanisms that have a very large application in mechanical engineering and whose construction is still paid very great attention. Special attention is given to defining the form of housing body, as the largest and most important component of gear unit. Beside of high strength and stiffness of housing, it must have a high universality, low consumption of materials, to be easy for manufacturing, easy installation (especially the simple installation of large gears), easy storage, transport, installation, supervision, service, maintenance and repair, simply disassemble and recycle, and finally, a nice aesthetic look of gear unit. Housings of universal helical motor gear units will be considered with all these aspects in order to highlight the procedure for selecting the best solution.

## 2. The Aim of the Study

The main objective of this paper is to point out some requirements which are set up to the housings of universal helical motor gear units and on usual ways of defining of their form.

## 3. Problem Description

Universal helical gear units can be delivered with motor or with free input shaft. If they are delivered with electric motors, they can be delivered with special motors, so called geared motors, or with standard (IEC) motors [1]. What electric motors will be used depends on the attitude of the manufacturers company as well as specific market demands.

If gear units are delivered with free input shaft, they can have usual solid input shaft and with IEC motors interface.

Large manufacturers usually use special motors, which are characterized by special flanges, special diameters of output shafts, stronger bearings and better sealing solution, so they have a number of advantages (easier, cheaper and more compact design, the possibility of achieving higher gear ratios, greater permitted force of the motor shaft and better tightness). Since they are buying large quantities of such motors, they get them quickly and at almost a price of standard motors, so that this procedure is completely payable to manufacturer. In addition, these manufacturers usually have their own factory of electric motors, so that they do not have practically this problem.

Small and medium manufacturers of gear units usually use standard IEC motors, although it is not the rule, mainly because of lower cost and short delivery time, and all the benefits of special motors they try to compensate by suitable way of installing motor to the gear unit. Since it is difficult to make up a lot of advantages of special motor, in practice there are different construction solutions of installing gear unit with standard IEC motors that are directly, or with IEC motors interface, connected for the housing of gear unit [1, 4].

The ponderous structure of the motor gear unit is special big problem in solutions with IEC motors, especially when using motors with high power (with a large flange shape B5) that are connected for the housing of gear unit. This particularly disorganizes the compact construction, so some manufacturers do not use large motors or use a form of B14 flanges.

Gear units with standard IEC motors are delivered by large manufacturers, who use special geared motors, especially when customers require. For example, when customer wants to install motors on purchased gear units by himself. It is usually case when they think they can do cheaper or faster service of their motors, or in case of export of gear units in the country, where there are factories of electric motors, which wants with a large taxes on motors to protect their products from foreign competition, and customers are payable to buy electric motors, so they buy gear units with free input shaft motor, usually, with IEC motors interface, which allow them much easier and more secure mounting IEC motors, so that there is no possibility to install motor incorrectly.

Universal gear units are usually made as single-, two-, three-stage and multistage units.

In order to avoid a problem that occurs when use a large gear ratio on the first gear pair, some manufacturers do not produce single-stage gear units. Since these products are relatively not interested for the market, it does not represent a specific problem, particularly because the higher values of gear ratios from single-stage gear unit can cover with smaller values of gear ratios of two-stage unit, but per some higher price.

As for the multistage gear units, which are the main issues of this paper, some manufacturers of universal gear units practice for example two-stage gear unit to made in special housings for the two-stage and the other in the universal housings for two- and three-stage gear units. The same case is with three-stage gear units that can be made in special housings for three-stage or in universal housings for two- and three-stage units, or a combination of two- and single- stage gear units is also possible. Universal four-stage units are rarely made in the special housing for four-stage units, but it is typically used combination of two two-stage gear units or very rare three- and one-stage gear unit, etc. In practice, it is present all the above solutions.

Regardless of the adopted concept, identical problems about the choice of housing form are present in all above solutions.

#### 4. Description of Ways for Solving Problems

Large number of factors influences on the final form of housing of gear unit and most of them must be satisfied, as follows:

**High strength** of housing of gear unit is required to ensure transmission with the largest torque ( $T_{\max} = T_N / f_{B\min}$ , where  $T_N$  - nominal torque and  $f_{B\min}$  - minimum value of the service factor) and permitted overhung and axial forces on the output shaft (and on the input shaft of gear units without motors). Nowadays, monoblock construction with large dimensions (construction in one part) is usually used to overcome this problem.

**High rigidity** is required for taking part the right position of gears (to ensure proper conjugate of gear teeth) and a peaceful and quiet operation, i.e. avoidance of work in the resonance field. Today gear units are sometimes driven by frequently regulated electric motors, and it is specific problem because gearboxes works in a wide range of speeds, so it is necessary to prevent the occurrence of resonance case in the whole range of speeds with corresponding stiffness of gear unit.

**Small consumption of materials.** All manufacturers of gear units solve this problem by making as smallest overall dimensions of housings and by proper defining of the walls thickness of the housings. Although there is no standard that defines the dimensions of the gear unit, most manufacturers take in consideration the dimensions defined by the leading manufacturers of gear units (for example SEW). The thickness of the walls is conditioned by the technological possibilities (casting) of individual producers, so they are also largely consistent. It is common opinion that the manufacturers that have their own foundries have somewhat thicker walls of housing and vice versa, although this is not the rule.

**Simple manufacturing** requires high manufacturing ability of gear unit housing, which is not a bigger problem today, as well as ability of gear unit housing for robotic production. However, the problem makes a simple removal of sand (casting cores) from the housing after casting, which is necessary to ensure by its proper form, so that it does not hold in the housing and later, during the operation, does not separate from the housing wall and thereby affects the bad operation of the bearings and gears, i.e. cause the premature breakdowns of gear units in a whole. In addition, well designed form of housing should provide its basic and decorative paint

to prevent corrosion and, in particular, this form should prevent separation of sand inside the housing. Producer color is usually used as decorative paint, and all the products in a factory are painted with it, while only on special request of customers producers use another color which customer must additionally pay. However, if the producer original color is not “lively”, then the housing or the whole gear unit should be painted with some more active color.

**High universality.** Almost all manufacturers of gear units produce specific housing types foot mounted and flange mounted, where there can be used small, large or flange for mixers. The existence of two types of housing for all producers is a heavy ballast, so some manufacturers are trying to overcome this problem by producing a single foot mounted housing or a universal housing which is primarily intended as foot mounted and can be used also as flange mounted (Fig.1), and since flange mounted housings are less required on the market that does not represent major problems for them. Producing only one type of housing significantly reduce production costs, particularly costs of storage of semi finished products. However, the cost of the universal housing is somewhat higher because it must be prepared for both methods of installation, although not necessarily, so they are prepared for only one type of installation and saving is done on the castings, but the weight of these castings is somewhat higher, especially when they are used only as flange mounted.

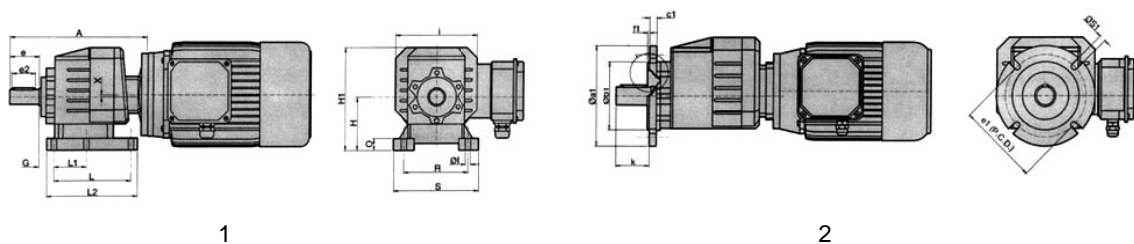


Figure 1: Characteristic design of universal housing types: (1) foot mounted and (2) flange mounted (Lenze solution)

Additionally, some manufacturers try to provide even greater universality gear units with a single housing, i.e. possibility of more complex assembly. This particularly complicates the form of housing, but manufacturer greatly increases the application possibility (Fig.2).

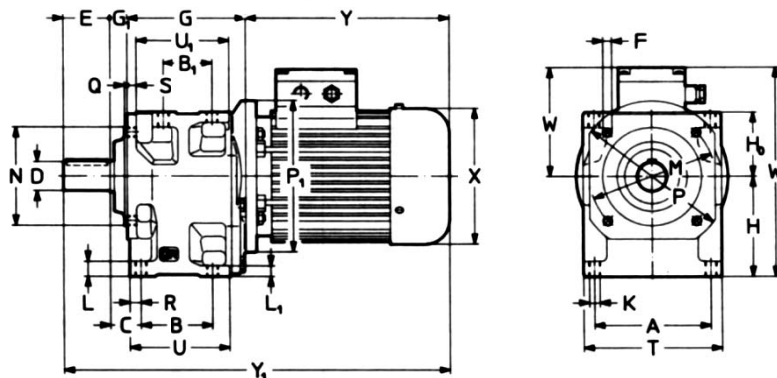


Figure 2: Characteristic design of the universal housing intended as foot and flange mounted solution (ROSSI)

**Easy installation** (especially simple installation of large gear wheels) represents the main problem which meets constructors and designers of gearboxes and they try to solve it in different ways (Fig.3). The classic way of installing gear wheels over frontal opening is now almost abandoned (Fig.4-1), because it does not allow installation of large gears due to the limited size of flanges. Nowadays two-piece housings are often used, so that one (smaller) part of housing is a part connected with motor flange (Fig.4-2) which usually has a seat for some bearing, while the second part of housing represent the rest of casing. This opening of high speed chambers allows the installation of large gear wheels of input gear pair with a slight reduction in strength and rigidity of the housing. Some manufacturers make opening from high speed chamber to low speed chamber, so that it is possible installation of large output gear

wheel (Fig.4-2). The most of manufacturers open only low speed chamber from the top, in order to keep a high strength and stiffness of their housing, and thus, by their way, they get a simpler way to install large gear (Fig.4-3). However, there are manufacturers that open high speed and low speed chamber from the top (Fig.4-4), which definitely reduces body stiffness but not to the extent that this decision was wrong.

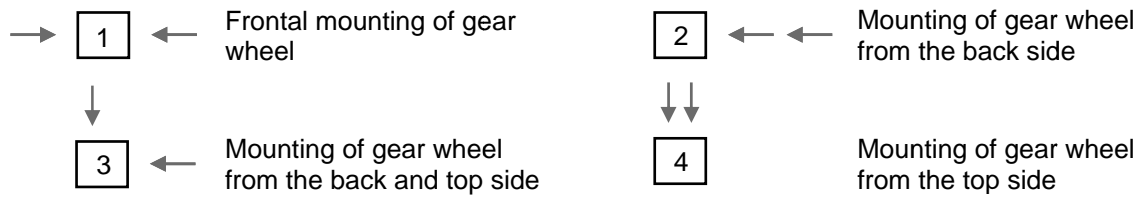


Figure 3: Characteristic solution of installing gear wheels in the gear housing: (1) frontal mounting gear wheel, (2) mounting of gear wheel from the back side, (3) mounting of gear wheel from the back and top side and (4) mounting of gear wheel from the top side

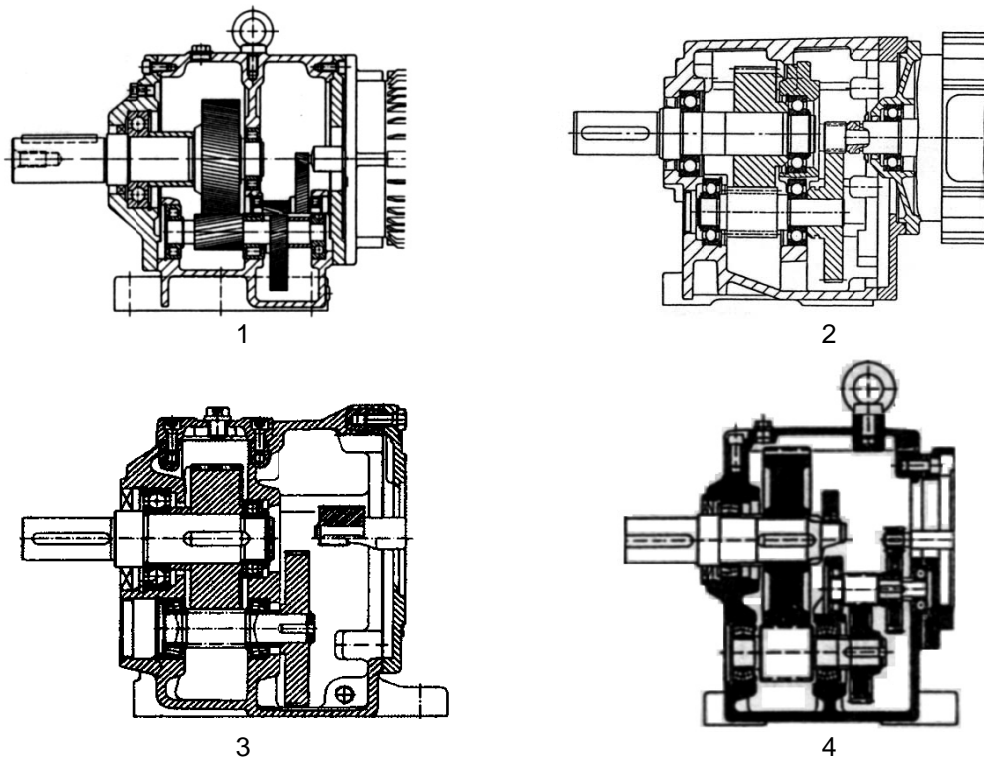


Figure 4: Typical mounting solutions: (1) frontal mounting of gear wheel (Horz), (2) mounting of gear wheel from the back side (Lenze), (3) mounting of gear wheel from the back and top side (Nord) and (4) mounting of gear wheel from the top side (Nord)

**Simple testing** is possible to do with any form of housing, so that the problem with the gearbox casing is not present.

**Simple conservation.** Housings of gear units have not special conservation. Protection, which provides basic painting and decorative color, is considered to be quite satisfied.

**Simple packaging** is possible to do with any form of housing so that the problem is not present. When gear reducers are packed, as a rule they should be put in the position of installation (in order to prevent leakage the oil out of the housing) and wrapped with plastic foil. Smaller sizes of gear units are placed in cardboard boxes, put on the pallets and wrapped with foil; while the larger size of gear units are just put on pallets and bolt-on to the pallet and wrapped with plastic foil.

**Easy transport** can be realized with any form of housing. Shipping and discharge of smaller sizes of gear units in/from transport carriage and so called micro transport is done manually. Larger size has a hook where gearbox is attached, and the largest size of gearboxes has even two hooks or special openings on the casing, so that this problem is not present. Transportation is done in the usual way by different transport conveyance.

**Easy storage** is possible to do with any form of housing, because it has prismatic shape which is suitable for storage (multi-level arranging), so this problem is not present.

**Simple deconservation.** Since gear unit housing is not usually conserved, this problem is not present.

**Easy installation** is available today by the usual “standard” form of housing that all manufacturers of universal gear reducer respect. So, in most cases, it is possible to replace gear unit of any manufacturer. However, it has to be emphasized that it is not enough to have the same installing dimensions for replacing of gear unit of different manufacturers.

**Simple supervision** of the universal gear units is not provided in the classical way through the so called audit opening, through which it can observe the condition of gears and bearings; but it is done by monitoring the surface of the housing, monitoring of possible leakage of oil, temperature monitoring and vibration activity of gear reducer, etc.

**Simple service** is provided for conventional forms of housing. It contains the level control of oil in the gearbox, replacing oil and, eventually, replacement of damaged components of gear reducer which is not so easy to do. Smaller repairs (replacement of seals, bearings or gears), unfortunately, is a major problem since the gearbox has to be disassembled, i.e. take it out from the machine and disassembled in a specialized workshop and replace the damaged components with the original parts, and so repaired gearbox turn back in the machine. With each installation it is necessary to additionally center the motor gear reducer which is not so easy for foot mounted housings.

**Simple maintenance** for universal gear housing provides the removal of accumulated dirt (mostly dust) from the surface of housing, to ensure smooth removal of heat and thus prevent excessive heating of gear reducer. Other activities implemented during the maintenance of gear unit (regular oil change which is carried out through special openings for inflow, control level and releasing the oil) require maintaining of these openings (hole threads) in a clean and proper condition. In the case of a damage of some part, similar problems occur that have already been described in the previous paragraph about the service.

**Simple repair.** In case that housing is damaged with small cracks or fractures, the welding of those details must be done in specialized workshops, because the housing is made of cast iron (usually SL200). In the case of major damage of housing, it must be replaced.

**Simply disassembling and recycling** is one of the main factors that adopted form of housing have to possess. In fact, only the housing of gear unit and some lids are made of cast iron and all other components (gears and bearings) are made of high quality alloy steel, and output shaft (and also input shaft for gear unit without motor) is made of high-quality carbon steel; so it is necessary to separate all these components and recycled them separately.

**Nice appearance of gear unit** is extremely important, although it is not crucial to placement on the market of gearboxes. However, designing and shaping of housing of gear unit is given great attention and today there are various shapes and colors of housing (Fig.5). The more successful design can be solutions of company Siemens (Flender), SEW, etc., where the plastic surface is provided which increases rigidity of casing and also active external surface is increased, which provides better cooling and increases heat capacity of gear units. A schedule of shadows on the casing has a major impact on nice appearance of housing because it creates a plastic surface. Also designation plates and some pictograms that show how to change the oil, etc. are interesting for the better appearance of gearboxes.

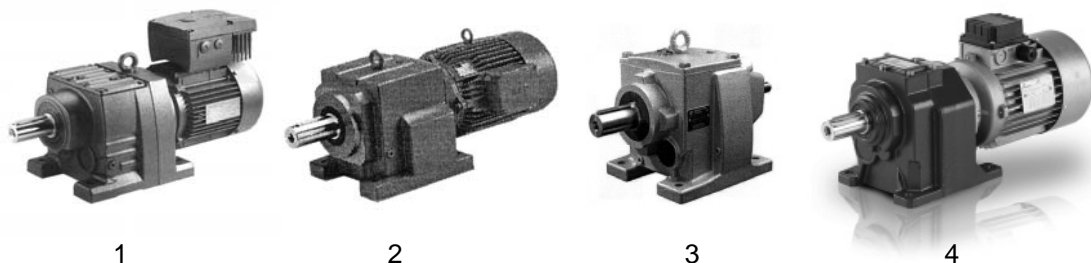


Figure 5: Characteristic appearances of housings of multistage universal gear units:  
(1) SEW, (2) Siemens (Flender), (3) Nord u (4) Bonfiglioli



## 5. Proposing solutions

Based on the carried out analysis, it can be concluded that the shapes of today's housing design of leading manufacturers of gear units are quite uniform and they meet all requirements placed in front of them. However, there are manufacturers who maintain classic forms of housing and therefore they have some weaker technical characteristics mainly low value of gear ratio. Solution of Siemens (Fig.6) today can be considered for the best and it would be adopted as a model which should be pursued.

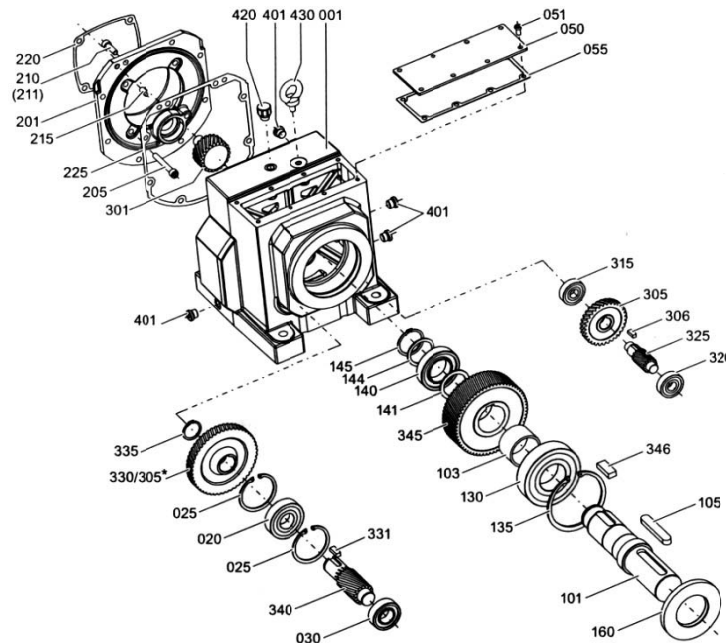


Figure 6: Characteristic solution of multistage universal gear units in the frame of expansion drawing of gear reducer (Siemens design)

## 6. Conclusion

Based on the carried out analysis, it can be seen that all the requirements, which multistage universal gear reducer have to meet, are met by the housing of most manufacturers. The casings are very well designed and very little can be done to improve them. Some minor design adjustments are certainly possible but they only depend on the designer's taste.

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## IMPROVEMENT OF IMPRINT REPRODUCTION BY FLEXOPRINTING

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**Abstract:** The Flexographic technology of printing is widely used for producing items for the packaging industry such as labels, different kinds of packs for food, drugs, etc. The technology gives the opportunity of using wide range of substrates – paper, polyethylene and aluminum foils are a small part of the previously mentioned. With the developing of the market the clients have started to require higher quality of printing, especially when talking about labeling industry. This is the reason why in 2009 Esko Artwork presented new technology for flexographic printing – High Definition Flexo (HD Flexo). The key to the high quality of HD Flexo is a combination of 4000dpi High Resolution optics along with unique screening technologies to take advantage of sharper and more accurate imaging. As a result of the applying the new technology, according to Esko Artwork, there are several improvements which can be accomplished, such as smooth vignettes (print to zero), the full tonal range of the offset and gravure technologies, high screen ruling with standard Anilox systems, increasing the tonal range achieved and etc. The current research is pointed to analyze the advantages of HD Flexo in a real production conditions, as well as to specify the optimal screen ruling, support dot size and etc. Important is also to define the dot gain, reproduction of fine line elements and high light vignettes achieved with HD flexo compared with other similar technologies.

**Key words:** HD Flexo, screen dots, dot gain, tonal range, printing plates and etc.

### 1.Introduction

Other benefits of applying the new method are the possibility of using wide range of printing plates; the longer print runs due to the rounder shape of the dots, which results in greater stability of the dots and the printing process as well; increasing the tonal range achieved using the HD Flexo technology.

The current research is pointed to the following:

- To understand whether the technology offers less dot gain due to the improved shape of the dots, using the 4000ppi HD optics;
- To study the accuracy accomplished while printing fine details, using the HD Flexo technology;
- To compare the smooth vignettes of HD Flexo with other technologies for imaging.

HD Flexo, smooth gradation, print quality, fine details, print element, package printing, imagin The flexography is a type of letterpress printing. The printing elements are raised above the non-printing surface of the printing plate. When using AM screening in flexography there is a limitation which doesn't occur with alternative technologies. The printing elements are formed from the material of the printing plate, which usually is a relatively soft photopolymer. When the printing elements are very thin (for example in highlights when using high resolution printing) they become weak and cannot stand on the contact pressure between the cylinders in the press. The printing elements get damaged and print inconstantly or don't print at all. The damaged printing elements are called scum dots.

The smallest stable printing element which can be formed on the plate during a certain workflow is called white point. The white point is applied to avoid the scum dots. It is measured in percents, where 0% responds to the areas of the initial image, where no ink is necessary, and 100% respond to the areas of the image, intended to be printed as solid color. Everything smaller than the white point is printed as white (there are no printing elements smaller than the white point, because they are removed in prepress). If the white point is 1%, then the image will be printed according to the expectations of the client. This kind of quality reproducing can be achieved easily using offset technology, for example. When using flexography the white point is usually set between 8% and 15% which causes loss of details in the highlights of the image due to the weak printing elements in these areas.

The value of the white point is in direct conflict with the acquirement of smooth gradation of the image. When low resolution is used, the value of the white point in percents is low, but the image seems grainy, the printing elements are visible with naked eye. For higher image quality

we would like to use higher resolution. In this case the size of the printing elements will decrease. The value of the white point will increase, which leads to great loss detail in the highlights of the image.

In package printing the white point should be at least 10-12 %. In label printing the conditions are friendlier, but the requirement is 200lpi to be used, so photographic quality can be achieved, which also leads to increasing the value of the white point to about 10%. There is no doubt that the quality of the printed image will decrease dramatically. The most noticeable effects are the loss of details in highlights of the photographs and the incorrect printing of graphics and details designed with gradation “to zero”. The image is printed with sharp, noticeable edges instead of smooth gradation from solid tone to the color of the substrate.

In flexography it is necessary the images to be retouched and changed, so they can be printed with satisfying quality. The extra converting of the images adds cost to the final product, requires additional time for prepress and the skills of qualified specialists.

The flexographic printing has some advantages to be considered:

- Cheaper presses;
- Water based inks can be used in flexography;
- There is better ink transfer between the ink and some substrates, compared with other technologies;
- Less consumption of materials (ink, substrate) for make-ready.

The HD Flexo is combination between two technological solutions.

HighRes Optics is technology, engineered to achieve 4000ppi resolution engraving of the printing plate while keeping the high productivity of the imager. When using 4000ppi the printing elements are formed from 3-4 times more pixels compared with using 2540ppi resolution. The using of 4000ppi leads to better dot shaping. The better dot shaping leads to greater stability of the printing elements and better color balance. Fine lines, barcodes and small letters are formed clearer.

The other technological solution is a specific screen, designed for decreasing the white point. The small and unstable printing elements on the printing plate have the potential to become scum dots. The screening in HD Flexo combines bigger and smaller printing elements in the highlights instead of fluent decreasing the size of all printing elements. The bigger dots are more stable and support the smaller dots, while the small dots transfer ass small quantity of ink as needed. The success of this technological solution is due to the balance between the neighbor printing elements.

The purpose of the current study was to analyze the parameters for applying the HD Flexo technology in real production conditions and to define the ability of increasing the resolution and improving the tonal gradation of reproducing without changing the currently used anilox cylinders.

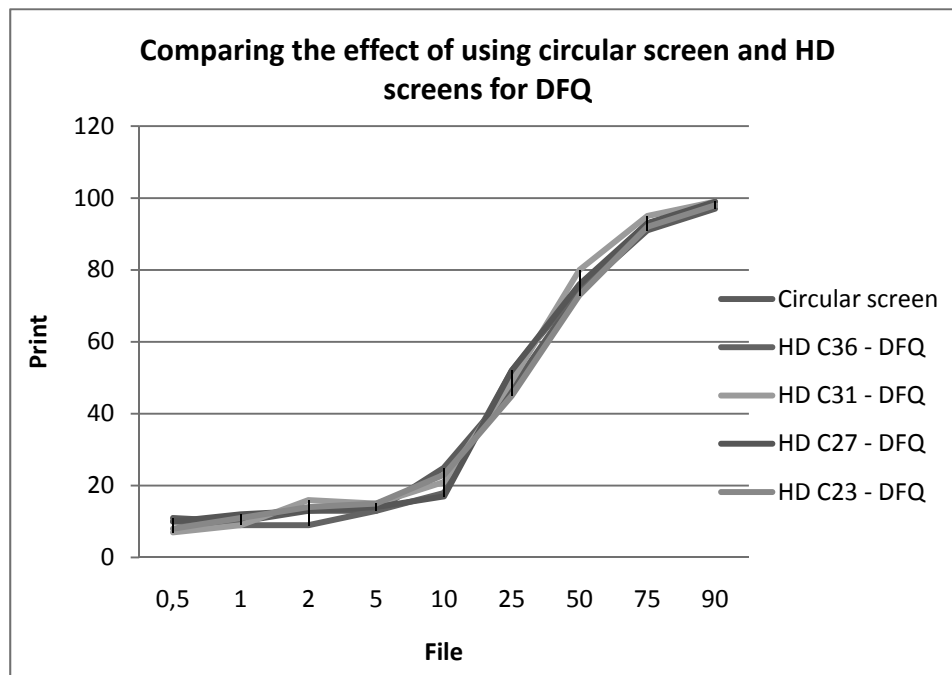
The experiment included printing of test forms to define the optimal characteristics for the HD Flexo technology. The test forms were made of Cyrel DFQ 45 printing plates with 198lpi resolution and 4000ppi imaging resolution. The screening profiles used were adapted to the Cyrel DFQ photopolymer.

The printing was made on PELD with printing press, constructed with central impression cylinder, anilox cylinders with 350lpcm resolution and ink transfer of  $5.2 \text{ cm}^3/\text{m}^2$ . The inks used were solvent-based.

Other parameters, such as speed, ink viscosity and substrate were the standard ones, used in the print house.

## 2. Results

- The prints were with visually improved gradation “to zero” without noticing jump in the gradation between the non-printed areas and the vignette.
- The smallest stable dot was reproduced.
- The optimal size of the supporting dots was defined.



Comparing the results of using circular screen and HD Flexo screens it can be concluded that with HD Flexo can be achieved lower dot gain, better reproducing of fine letters and lines and smoother gradation “to zero”. The optimal size of the supporting print elements is 36pix.

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## LETTER SIDE BEARING AND EMPIRICAL THEORY

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**Abstract:** Typefaces can be designed in many different ways. The typeface *Harmonia* was designed with the help of basic mathematical elements, i.e. straight and circular lines. In order to define the side bearing parameters for letters and other characters, we tried to follow the same – mathematically based – experiment. Therefore, the side bearings were to be determined with empirical equations. The size of the left- and right-side bearings can be different for different characters. Consequently, it was necessary to define individual segments and superficies of each character parts, calculate portions, define the predominating geometric character elements in each segment, initiate reductive factors, define reductive superficies of each character elements, transform the sum of reductive superficies of elements into side bearings, and define their minimum and maximum values. In the experiment, we started by defining the metrics between two characters. When satisfied with the space, we added a third character. However, when the letters were combined into words, the poorness of using merely the mathematical calculation came into expression. We realized that 56% of side bearings had minimum or maximum values, which was not acceptable. For our typeface to be useful, we had to move away from the empirical theory and in the end, define the character side bearings optically.

**Keywords:** empirical equation, letter side bearing, typography

### 1. Introduction

Straight and curved strokes or a combination of them is typical of most Latin small and capital letters. According to the letter design, they can be divided into groups, e.g. letters with a vertical upper part of the stroke (b, d, h, l, j, k, l, m, n, p, q, r, u; B, D, E, F, H, I, J, K, L, M, N, P, R, U), letters with a round stroke (b, c, č, d, e, o, p, q; B, C, Č, D, G, O, P, Q), letters with a dominant diagonal stroke – triangular letters (v, w, x, y; A, V, W, X, Y) and letters with a combination of different strokes (a, f, g, s, š, t, z, ž; S, Š, T, Z, Ž). Moreover, we distinguish symmetrical (e.g. l, o, A, H, U) and asymmetrical (e.g. a, d, k, B, G, R) letters (Cheng, 2005; Kunz, 2003; Tracy, 2003).

In order to use letters, numbers, punctuation signs, and other characters for reading, they need to have defined side bearings. The side bearing depends on the design of a letter or a character. Some letters and other characters can have different sizes of left- and right-side bearings (cf. Figure 1), e.g. straight-sided letters have larger side bearings than the curved ones, while smaller side bearing characterises triangular letters (Kunz, 2003; Tracy, 2003; Woolman, 1997). If the character spacing of letters is not appropriate, the legibility of a text deteriorates (cf. Figure 2). For setting an appropriate character spacing, typographers can use the system by Walter Tracy, where by placing side by side two letters, e.g. the capital “H” and “O” and small “n” and “o”, we get five (for capital letters) or six (for small letters) different sizes of side bearings. However, this system does not give the side bearing sizes for all letters, e.g. S, a, f, g, s, t, z (Baines, Haslam, 2002; Tracy, 2003). In the end, it is the typographer’s eye that it is the most important to optically define or modify the size of side bearings.

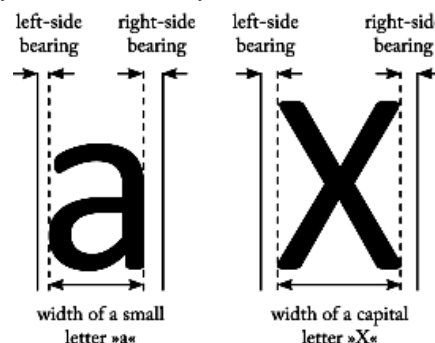


Figure 1: Example of different sizes of letter side bearings

abeceda

Figure 2: Example of incorrectly defined letter side bearings

It is important that both side bearings are appropriate for different letters and their combinations (e.g. in different languages). In consequence, the latter diminishes the work with kerning of some letter pairs. In the text, we have namely some letter pairs where the space between them is too big, e.g. Ta, Te, To, Va, AT, AV, FA, LV, LT, TA (Baines, Haslam, 2002; Tracy, 2003; Woolman, 1997). Such letter pairs should be kerned. Kerning of letters depends on the design of a letter or a character.

Typefaces can be designed in many different ways. In order to minimize the data required for defining letter shape, the typeface Harmonia was made by using the equations of two basic mathematical elements, i.e. of straight and circular line. The first one was (Berdajs, 1998) the equation of the straight line:

$$y = kx + n \quad (1),$$

where:

k – directional coefficient,

n – initial value (section on vertical axis),

and the second one was the equation of the circular line:

$$(x - p)^2 + (y - q)^2 = r^2 \quad (2),$$

where:

p – horizontal axis value of circle,

q – vertical axis value of circle,

r – radius.

In order to allocate the side bearing parameters to each small and capital letter, number, punctuation sign etc, we tried to follow the same – mathematically based – experiment.

## 2. Experimental

To attain the sizes of side bearings, it was necessary to define individual segments and superficieses of each character parts, calculate portions, define the predominating geometric character elements in each segment, initiate reductive factors, define reductive superficieses of each character elements, transform the sum of reductive superficieses of elements into side bearings, and define their minimum and maximum values.

### 2.1 Defining segments and element superficieses

Each character was divided into eight segments. The vertical distribution went through the middle of the character, while the horizontal distribution was performed according to the limits of the ascender and descender, and in the middle of x-height (cf. Figure 3).

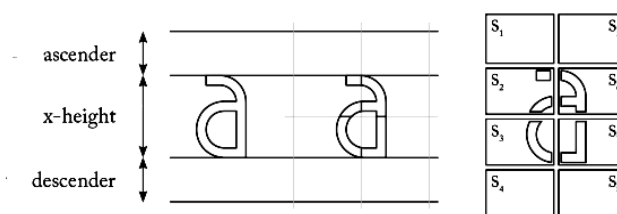


Figure 3: Example of letter divided into segments

The segments were marked with  $S_i$ , and the superficieses of elements with  $P_i$ . The sum of element superficieses was made as follows below.

The left side of a character:

$$P_L = \sum_{i=1}^4 P_i \quad (3),$$

where:

$P_L$  – superficies of character left side,

$P_i$  –  $i$  element superficies of character ( $i = 1 \dots 4$ ).

The right side of a character:

$$P_D = \sum_{i=5}^8 P_i \quad (4),$$

where:

$P_D$  – right side superficies of character,

$P_i$  –  $i$  element superficies of character ( $i = 5 \dots 8$ ).

## 2.2 Calculating portions

The calculation of portions was required, the ratio between the superficies of the element and the superficies of one half of the character being:

$$d_i = \begin{cases} \frac{P_i}{P_L}; & i = 1 \dots 4 \\ \frac{P_i}{P_D}; & i = 5 \dots 8 \end{cases} \quad (5),$$

where:

$d_i$  –  $i$  element portion,

$P_i$  –  $i$  element superficies of character,

$P_L$  – left side superficies of character,

$P_D$  – right side superficies of character.

## 2.3 Defining predominating geometric character elements in each segment and initiating reductive factors

For each segment, it was necessary to define which geometric element of a character is predominant. Such geometric elements can be straight ("rav"), diagonal ("dia"), curve ("okr"), or there can be a segment without an element ("brez"). For each geometric element, a reductive factor was defined, namely with:

$$f_i = \begin{cases} f_{okr} \\ f_{rav} \\ f_{dia} \\ f_{brez} \end{cases} \quad i = 1 \dots 8 \quad (6),$$

where:

$f_i$  – reductive factor for  $i$  predominant element of character,

$f_{okr}$  – reductive factor for curve element,

$f_{rav}$  – reductive factor for straight element,

$f_{dia}$  – reductive factor for diagonal element,

$f_{brez}$  – reductive factor for segment without element.

## 2.4 Initiating reductive superficies of each character element

With the help of element superficies, the portion of element superficies and reductive factors, it was possible to calculate the reductive superficies of elements:

$$R_i = P_i \cdot d_i \cdot f_i \quad (7),$$

where:

$R_i$  –  $i$  element reductive superficies of character ( $i = 1 \dots 8$ ),

$P_i$  –  $i$  element superficies of character ( $i = 1 \dots 8$ ),

$d_i$  –  $i$  element portion,

$f_i$  – corresponding reductive factor.

The left side of the character was calculated with:



$$R_L = \sum_{i=1}^4 R_i \quad (8),$$

where:

$R_L$  – reductive superficies of character left side,

$R_i$  –  $i$  element reductive superficies of character ( $i = 1 \dots 4$ ).

The right side of the character was calculated with:

$$R_D = \sum_{i=5}^8 R_i \quad (9),$$

where:

$R_D$  – reductive superficies of character right side,

$R_i$  –  $i$  element reductive superficies of character ( $i = 5 \dots 8$ ).

For both reductive superficies, it holds true that they are smaller than the superficies of each half of the character:  $R_L < P_L$  and  $R_D < P_D$ .

## 2.5 Transforming sum of reductive superficies of elements into side bearings

The next step was transforming the sum of element reductive superficies into the side bearings of characters.

The left side of the character was calculated with:

$$r'_L = R_L \cdot k \quad (10),$$

where:

$r'_L$  – left-side bearing of character,

$R_L$  – reductive superficies of character left side,

$k$  – factor for transformation of superficies into side bearings.

The right side of the character was calculated with:

$$r'_D = R_D \cdot k \quad (11),$$

where:

$r'_D$  – right-side bearing of character,

$R_D$  – reductive superficies of character right side,

$k$  – factor for transformation of superficies into side bearings.

## 2.6 Defining minimum and maximum values of side bearing

The calculated size of side bearing should meet the requirements for a suitable character spacing. Otherwise, the side bearing assumes the value of the minimum or maximum allowed side bearing size.

The value of the left-side bearing was calculated with:

$$r_L = \begin{cases} r'_L; & r_{\min} \leq r'_L \leq r_{\max} \\ r_{\min}; & r'_L < r_{\min} \\ r_{\max}; & r'_L > r_{\max} \end{cases} \quad (12),$$

where:

$r_{\min}$  – minimum allowed size of side bearing,

$r'_L$  – left-side bearing,

$r_{\max}$  – maximum allowed size of side bearing.

The value of the right-side bearing was calculated with:

$$r_D = \begin{cases} r'_D; & r_{\min} \leq r'_D \leq r_{\max} \\ r_{\min}; & r'_D < r_{\min} \\ r_{\max}; & r'_D > r_{\max} \end{cases} \quad (13),$$

where:

$r_{\min}$  – minimum allowed size of side bearing,

$r'_D$  – right-side bearing,

$r_{\max}$  – maximum allowed size of side bearing.

### 3. Results and discussion

During the experiment of empirical theory, the values of variable factors were changing. According to the results, it was found that the best size of side bearing was attained with the values of:

- factors for predominant geometrical elements, i.e.  $f_{okr} = 0.9$ ,  $f_{rav} = 1$ ,  $f_{dia} = 0.3$ ,  $f_{brez} = 0$ ;
- factor for transformation of superficies into side bearings, i.e.  $k = 0.35$ ;
- minimum and maximum allowed sizes of side bearings, i.e.  $r_{min} = 1.1$ ;  $r_{max} = 1.65$ .

The reductive factor for the diagonal element is the smallest, which means that its reduction of the element superficies is the biggest. The reductive factor for the curve element has a small reduction influence, while the reductive factor for the straight element does not influence the reduction of superficies.

Table 1 shows the superficies of elements in segments for some characters. In Table 2, the portions of superficies according to the left or right half of the character and the predominant geometric element in each segment are given. The values of reductive factors and reductive superficies are shown in Table 3. A comparison of superficies and reductive superficies is given in Table 4.

Table 1: Superficies of elements in segments for small letters a, b and c

Character	Superficies of elements in segments							
	Left part of character				Right part of character			
	$P_1$	$P_2$	$P_3$	$P_4$	$P_5$	$P_6$	$P_7$	$P_9$
a	0	3.46	4.84	0	0	6.54	5.79	0
b	4.67	5.83	5.89	0.17	0	4.36	4.31	0
c	0.25	5.02	5.02	0.25	0.25	3.60	3.60	0.25

Table 2: Portions of superficies according to left or right half of character and predominant geometric element in each segment for small letters a, b and c

Character	Portions of superficies according to half of character								Predominant geometric element in each segment							
	Left part of character				Right part of character				Left part of character				Right part of character			
	$d_1$	$d_2$	$d_3$	$d_4$	$d_5$	$d_6$	$d_7$	$d_8$	$S_1$	$S_2$	$S_3$	$S_4$	$S_5$	$S_6$	$S_7$	$S_8$
a	0	0.42	0.58	0	0	0.53	0.47	0	brez	okr	okr	brez	brez	rav	rav	brez
b	0.28	0.35	0.36	0.01	0	0.50	0.50	0	rav	rav	rav	okr	brez	okr	okr	brez
c	0.02	0.48	0.48	0.02	0.03	0.47	0.47	0.03	okr	okr	okr	okr	okr	okr	okr	okr

Table 3: Values of reductive factors and reductive superficies for small letters a, b and c

Character	Values of reductive factors								Reductive superficies							
	Left part of character				Right part of character				Left part of character				Right part of character			
	$f_1$	$f_2$	$f_3$	$f_4$	$f_5$	$f_6$	$f_7$	$f_8$	$R_1$	$R_2$	$R_3$	$R_4$	$R_5$	$R_6$	$R_7$	$R_8$
a	0	0.9	0.9	0	0	1	1	0	0	1.30	2.54	0	0	3.47	2.72	0
b	1	1	1	0.9	0	0.9	0.9	0	1.32	2.05	2.09	0	0	1.98	1.93	0
c	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.01	2.15	2.15	0.01	0.01	1.51	1.51	0.01

Table 4: Comparison of superficies and reductive superficies for small letters a, b and c

Character	Comparison of superficies and reductive superficies							
	Original left and right part of character				Reductive left and right part of character			
	Superficies of left part of character	Superficies of right part of character	Portion of left part of character (%)	Portion of right part of character (%)	Reductive superficies of left part of character	Reductive superficies of right part of character	Portion of left part of character (%)	Portion of right part of character (%)
a	8.30	12.33	40	60	3.84	6.19	40	60
b	16.56	8.68	66	34	5.46	3.91	58	42
c	10.55	7.70	58	42	4.32	3.04	59	41

Table 5 demonstrates the final values of side bearings for small letters. In the experiment, we started defining the metrics between two characters, trying to find appropriate variable factors. When satisfied with the space between two letters or characters, we added a third character. If the spaces were not satisfying, we started defining the appropriate value of variable factors once again. The whole procedure was repeated a few times until the side bearings at characters were satisfying. However, when the letters were combined into words, the poorness of using merely the mathematical calculation came into expression (cf. Figure 4). We realized that 56% of side bearings had minimum or maximum values, which was not acceptable. For our typeface to be useful, we had to move away from the empirical theory.

Table 5: Mathematically based final values of side bearings for small letters a, b and c

Character	Final values of side bearings							
	Letter width	Factor for transformation of superficies into side bearings (k)	Left-side bearing ( $r'_L$ )	Right-side bearing ( $r'_R$ )	Minimum allowed side bearing	Maximum allowed side bearing	Final left-side bearing ( $r_L$ )	Final right-side bearing ( $r_R$ )
a	5.12	0.35	1.34	2.17	1.10	1.65	1.34	1.65
b	5.37		1.91	1.37			1.65	1.37
c	5.37		1.51	1.07			1.51	1.10

čaj babica dah familija

Figure 4: Letters in words and side bearings based on empirical equations

In the end, the side bearings of characters were defined optically. Then the side bearings of letters, numbers, punctuation signs etc were tested in a text. The final values of side bearings attained optically are given in Table 6. In spite of the side bearings being done optically, kerning was required. The typeface Harmonia has 653 kerning pairs. Some letters and their final optically defined side bearings are shown in Figure 5.

Table 6: Optically defined final values of side bearings for small letters a, b and c

Char acter	Left-side bearing	Right-side bearing
a	0.70	1.23
b	1.23	0.79
c	1.05	0.74

ključni, vrednotimo, izkušnje, Vzporedno,  
njim, oblikujemo, izboljšujemo, moremo,  
ustaviti, prav, stagniranja, strani, ravno,

*Figure 5: Characters in words and optically defined side bearings*

#### 4. Conclusion

The typeface Harmonia was designed with the help of two basic mathematical elements, i.e. straight and circular line. Each character of a typeface should have a side bearing, otherwise the reading of a text is made impossible. Often, the left- and the right-side bearings are different. To give side bearings the parameters for each small and capital letters, numbers, punctuation signs etc, we tried to follow the same – mathematically based – experiment. For body typefaces, the latter has not been done yet. Therefore, the side bearings were determined with empirical equations. For the experiment purpose, it was necessary to define individual segments and superficies of each character parts, calculate portions, define predominating geometric character elements in each segment, initiate reductive factors, define reductive superficies of each character elements, transform the sum of reductive superficies of elements into side bearings, and define their minimum and maximum values. Unfortunately, the result was not satisfying and the legibility of the typeface was limited. For our typeface to be useful, we had to move away from the empirical theory. Therefore, we went back to the conventional defining of side bearings. In the experiment, it was demonstrated what the realistic possibilities in the typeface design are when using non-conventional methods.

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## COLOUR GAMUT OF FM SCREENING

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**Abstract:** *Designers who are familiar with technical possibilities of graphic equipment they use are more likely to get expected finish results for every design they produce. Enlargement of the color gamut provides a more realistic picture. The influence of color, sharpness and contrast to the overall design is large. Larger color gamut can provide that one step ahead, from all others products, in the battle for customers.*

**Key words:** *color gamut, dot gain, design.*

### 1. Introduction

This research is based on an experimental method. The purpose of this paper is to make an assessment of differences between various methods of halftoning. The FM and AM screening is going to be used. Focus of this research is color gamut of these two halftone methods. Color gamut affects the quality and final appearance of printed material. Experiment goal is to give closer and detailed view of advantages and disadvantages which can appear during usage of different screening technique. Every technique has advantages and disadvantages that can emerge, depending on type of job that is going to be printed. Recognition of these advantages and disadvantages of each screening technique enables defining a optimal method of screening for every individual printed material. As a result, it will be determined the possibility of reaching standard color gamut for offset printing according to ISO 12647-2:2006.

Unconventional techniques of screening are not yet covered with printing standards such as ISO 12647-2:2006. This standard is solely dedicated to graphic industry and defines the parameters for conventional AM screen. On the basis of these approaches, certain assumptions can be made, hypothesis which could define values for frequency modulated screening. These values will be analyzed during the experiment, and achieved results will be compared with existing norms.

Recent developments in computer hardware, CTP systems, Raster imaging processors (RIP), as well as software development, enable higher flexibility in reproduction of digital image, including color correction, grey component replacement and digital imaging on films and plates. Nowadays, digital halftone screening has become the standard for output on films or printing plates. Introduction of digital electronic screening for halftone reproductions has begun in the early 1970's /3/. It procured to usage of electronically generated dots through high-tech electronic scanners in color as an alternative to traditional photomechanical screening principle. Today, many prepress operating environments have implemented digital screening technology in their system. Digital screen is a binary image  $[h(x, y)]$ , where every dot is either totally black or totally white, resulting with impression of image with continuous grey tones. In AM screening, frequency of screen dot is constant while its size is variable. AM screening disassembles image in dots of different size which are cluster together under certain fixed screen angle. For every printed color, angle of screening is shifted for certain value, thereby avoiding moiré effect. Screen dot is produced by laser, divided in dot matrix. The dependence can be clearly seen between the number of grey tones, resolution of output device and line of screen. The number of halftone dots inside halftone cell depends on following parameters: frequency of screen/angle of screening, resolution of imaging device/grey tones, size of dot, shape of dot/allocation of dot /2/. The end result of screening is continuous tone – darker or lighter tones.

### 2. Colour gamut

The gamut is the set of possible colors within a color system. No one system can reproduce all possible colors in the spectrum. Extent of color gamut and its shape depends on several factors considering physical characteristics of color. Color gamut of a certain device is determined by physical characteristics of substrate and ink. In this test we will determine the gamut of FM and AM screen while maintaining exactly the same factors that influence the color gamut. It means, that the eventual differences are going to depend exclusively on method of screening/1/.

This work will not be analyzed conditions under which one can increase the color gamut. The paper will be focus on the analysis of the differences between AM and FM screening techniques.

There are two initial indications that the FM CMYK color gamut is larger than the AM CMYK color gamut:

1. The first indication is that FM color range includes more details in the saturated parts of the picture than AM halftone screen. The majority of press operators and photographers will see the material printed with FM technology more richer in color and more approximate to the original.

2. Two projects presented on the 1996 IS&T Fourth Color Science Conference described FM color space largen than one obtained with AM halftone screen /6/.

In this experiment we used FM screen resulting from the analog conversion of grayscale. With this type of halftoning was observed increased staining. Color range is described according to CIEL\*a\*b\* color space. Color range FM screen is larger and different shape than conventional halftone dots.

FM gray balance with CMY colors is closer to lightness axis (luminous) which is spanning from white to black spot in comparison with AM screen. On test printed material CMY gray balance marks are closer to lightness axis than its possible with AM halftone screen. FM screening increases aesthetic quality of printed image and fidelity of reproduction. FM technique also increases sharpness of details due to smaller size FM dots.

### 3. Prepress

Imposition is made on B2 printing sheet. Test form is made out of following elements: Altona Test Suite 1.1a (measure and visual), GRID control measuring strip, ECI/Bvdm Gray Control Strip – Fogra 43 recommended by ECI (European Color Initiative), BvDM, Fogra and Ugra institutions. Test form contains certain control elements which are used to determine print quality during printrun. These elements, better said, control fields are used for subjective as well as objective evaluation method. ECI 2002 characterization target serves for creating ICC profiles for proofing devices and non-standard printing conditions.

HDS (Harlequin Dispersed Screening) stochastic screen was used in process of platemaking. HDS ensures reproduction of fine details, raises sharpness of image and avoids the possibility of moiré effect. Despite that elements of HDS screen contain stochastic calculation, they are set in an grid, laid out in an certain configuration. Screen ensures sharp printed image even with somewhat lower input resolution. HDS is ideal for reproductions prone to appearance of moiré effect and reproductions with very fine details. HDS screens are distinguished by fineness of structure i.e. size of dot that is formed. This division of HDS is introduced for using in different graphic processes, different substrates and printjobs.

Chosen option of screen in this experimental research is HDS Coarse which is closest by its characteristics to mostly used conventional 150 lpi AM screen.

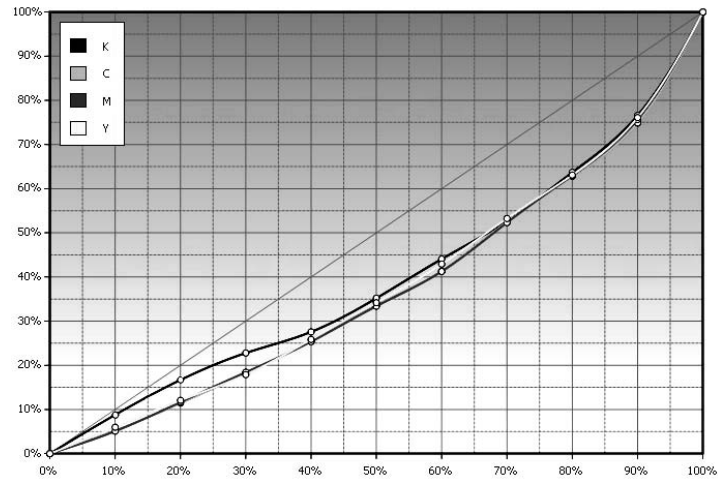
### 4. Printrun

After the measurement and checking of printing plates, printing test followed. Printing process was carried out on machine KBA Performa 74. This offset machine is constructed for printing sizes to 520x740 mm. Thanks to its universal construction KBA Performa 74 finds wide use in small, middle and large printhouses in printing of wide range of printed products including most demanding reproductions of artistic character.

Good parameter of precision in registry on this machine guarantees high quality multicolor reproduction on wide range of substrates. Quality of print is conforming to regulations of Federal association of printers in Germany (BvDM) and FOGRA graphic institute.

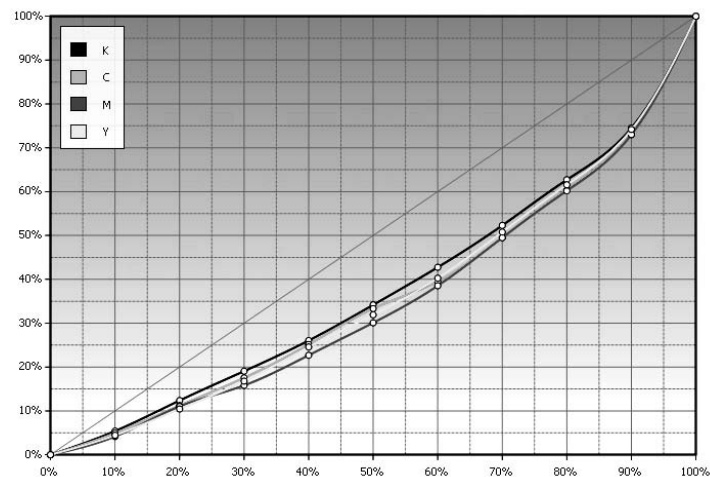
### 5. Measuring

The SpectroPlate - Techkon was used for the measurement of the plates. After the process of making test printing plates, measurements of raster values were performed. The measurement results for each extract are shown on Figure 1.



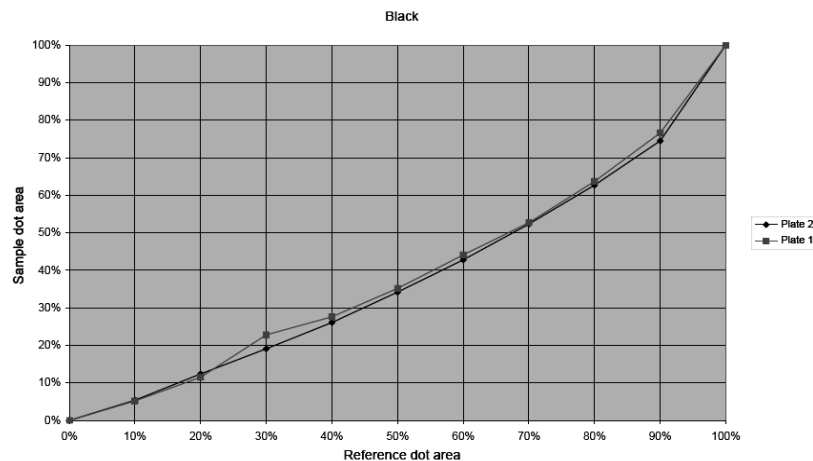
*Fig 1. The measurement results of transfer curve*

The obtained data from analysis was used to make the correction of transfer curve, so that it can adapt to the conditions of the press in the GRID laboratory. After making those corrections again the measurement was performed with SpectroPlate, as in the first case, and then were obtained following results shown on Figure 2.



*Fig 2. The measurement results after calibration*

It is also interesting to present the relations between the values of the transfer curve before and after a correction (Fig 3.)



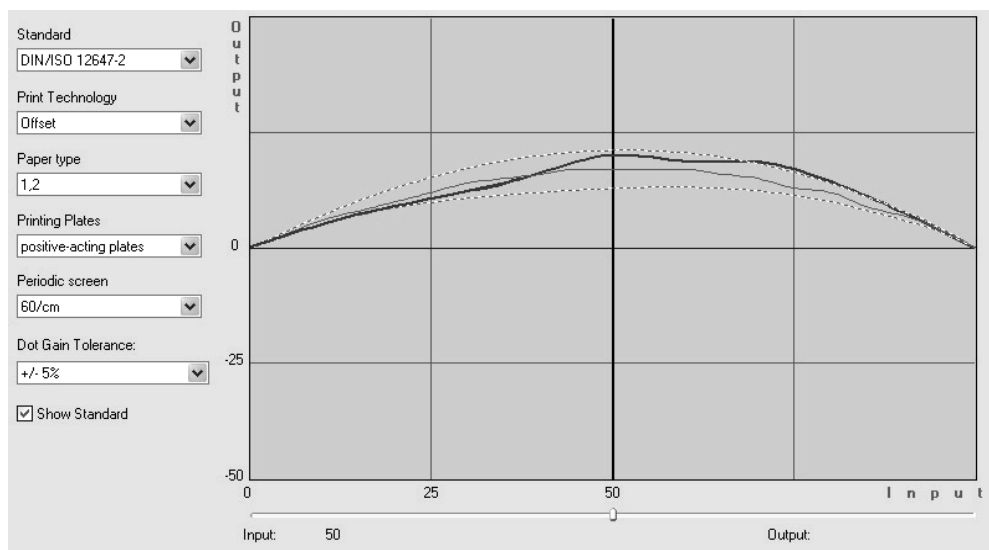
*Fig 3. Transfer curve before correction (Plate 1) and after (Plate 2)*



For fast, automatic and precise measuring of color chart Spectrolino is attached to SpectroScan x / y plate (panel). Color chart is set to SpectroScan board and attaches to it by electromagnetic fields, fixing in this way with the base. Strengthening the foundation of the chart provided accurate and smooth automatic measurement without the possibility of any errors due to shifting base. Then the measurement is done automatically without the possibility of erroneous measurements, i.e. inaccurate placement of measuring devices on the field that is measured.

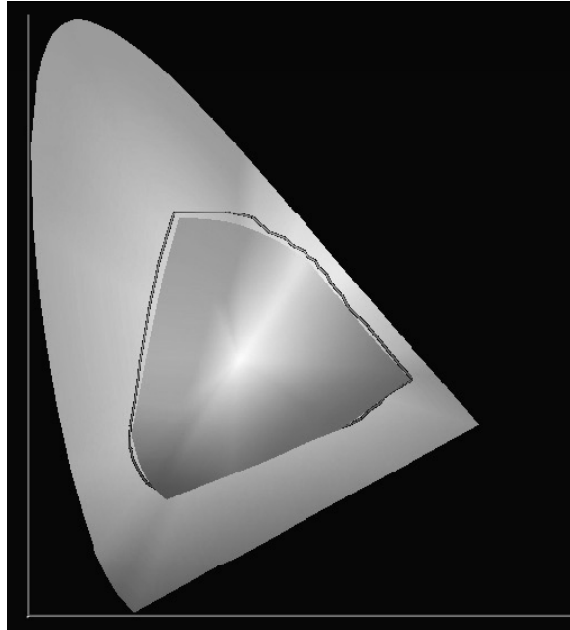
The printed form of test was measured at Spectrolino device. Each of the randomly selected samples was measured. The results of measurements that are performed for each sample were then entered into a chart and double the mean value of measurements. During the sample sheets that have found their results on the threshold, were not taken into account, thus exclude errors due to uncontrolled environmental factors. Such errors are called random errors. They are the difference between an infinite number of results in the measurement and the average results of the endless series of measurements performed in conditions of repeatability. Random measurement error can not be determined precisely, it can be determined only by the interval at which it is, with the given value ranges. Also, the random error can not be taken into account as a correction to the uncorrected result of measurement, i.e. these random errors, if they rarely appear, should not affect the evaluation of print quality, but it certainly must determine their cause and to access their elimination.

The average value of all measured samples was obtained using software GreteMacbeth ProfileMaker Pro 5.0.1 with the option Calculating - Averaging. The one test map with average values for each field is obtained in this way. The results prepared in this way were then compared with standard DIN / ISO 12647-2 for offset printing techniques, paper type 1 and 2, positive offset plate.



*Fig 4. Achieved reduced dot gain*

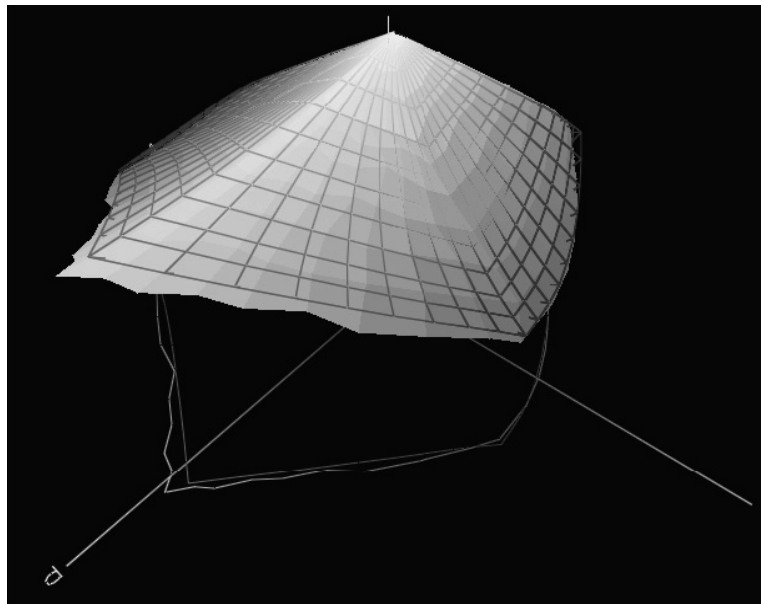
Reduced dot gain enabled the increase of color shades. Compared to the FOGRA profile for FM screen, Fogra 43, can be seen extending range. This increase is exactly the place where, after analysis, the first test chart shown a loss in the range reproduced. Both ranges (FOGRA 43 and GRID FM) are shown in CIELab color space on *Figure 5*.



*Fig 5. Comparison of the range of experimental test chart and Fogra 43 range within the spectrum of CIE Lab*

In the figure 1, inside the Lab spectrum, it can be seen two areas. The first area which is shown with line represents the color gamut of experimental test print. The filled area represents Fogra 43 color gamut. It can be seen that the Fogra 43 gamut is within the gamut of colors obtained in the experiment. This is confirmed by the 3D model view of the relationship between these two gamuts

In 3D projection, it is clearly shown, that the area of yellow color, obtained in the experiment, is beyond the standard FOGRA 43 gamut.



*Fig. 6. 3D projection relations between Fogra 43 and test print*

The Figure 6 shows the wireframe Fogra 43 model gamut of colors and the gamut of color test print, which is filled with color. The figure shows part of the gamut from green through yellow to red, that goes beyond the scope of Fogra 43. Greater reflection of the substrate will give a wider spectrum of light that are deducted from it. Considering that the standard is same for the glossy and the matte papers it can be assumed that the glossy paper will give a larger gamut comparing to matte.

## 6. Discussion

Analysis of measurement results is showing improvement in reproduction quality and improvements in the colors gamut. Each of these improvements can be seen through the prism of an impact on product design as well as their reflection on the graphic design. Often the smallest changes in the appearance of certain colors, the contrast reduction due to increased dot gain, which leads to loss of detail in the picture, make an impression that the picture is not well printed, or that was not enough color in the printing process. Each of these side effects can be reduced with appropriate adjustment of process. The influence of color, sharpness and contrast to the overall design is large. By improving all these parameters in prepress allows the designer greater freedom in design as well as better results, unfettered with unforeseen negative impacts.

Enlargement of the color gamut provides a more realistic picture. As the reproduction is based on the faithful reproduction to the original, larger gamut will give a picture most similar to the original. If this is not the case, the observers will be less able to identify with the image and the image will not leave a lasting impression on them.

## 7. Conclusions

The results showed that when printing with FM raster image gets sharper. During printing was not observed larger variance compared to printing with AM raster. Time for machine adjustment and machine paper are within the limits as in the AM offset printing. Setting the print parameters to match the ISO 12647-2:2006 standard is performed without problems. Parameters did not change during the entire circulation, although there was no operator intervention at the printing machine during print run. Therefore, it can be concluded that the print process is stable and that is not plagued by changes caused by outside influences. Analysis showed that color density is inside ISO 12647-2:2006 values. The dot gain is also in the standard values. Spectrophotometer analysis revealed that the color gamut which can be delivered using Harequin FM screens, is in certain parties even beyond the standard color gamut PSO Coated NPscreen ISO12647.

## 8. Directions of further research

Unexpected variations occurred in the control elements of the gray balance. Yellow color is shown as a dominant inside the gray balance. How the human eye is least sensitive to yellow color, this error could not be seen by visual observation. The reason why they occurred should be further explored.

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## A SOFT - PROFING METHOD OF PRINTED TEXTILES WITH A SIMULATION OF TEXTURE

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**Abstract:** A method of simulation of printed textile materials has been proposed. An idea is that perception of a colour would be influenced by a texture of a surface. The method has been following standard procedure and utilizes ICC profiles with addition of texture simulation on a profiled image. Two input devices, scanner and digital camera, were used as imaging systems whose outputs, in terms of images, have been compared with simulated images, on a computer monitor. Results show that if all parameters of the process are carefully controlled, method could give acceptable match for most of the application. Additional parameters that should have been involved are discussed as well as purposed improvements and further work.

**Key words:** Soft-proofing, texture simulation, colour management

### 1. Introduction

Textile digital print industry developing rapidly and there is ever growing need to keep up with it. Conventional colour management system does not provide full description of a colour for this type of prints. Rather, it is concerned more on a colour, and does not include information about texture of a printed surface.

The aim of this project is to simulate appearance of printed textiles on a computer display. As appearance of the colour is highly influenced by spatial luminance or texture of a surface, it has to be accounted for when reproducing or simulating a colour on such surfaces (Montag, Berns, 2000). This means colour shifts are inevitable when it comes to the textile prints.

To communicate colour across variety of media, accurate profiles has to be present, and these would be sufficient elements for soft - proofing of uniformly coloured substrate. However, most of the textile materials do not exhibit uniform nature and when it comes to these surfaces, predicting a print appearance becomes rather complicated.

Soft - proofing is a process that provides a view on computer monitor of what your print will look on specific surface. Surface and ink combination (medium) is defined by the profile that has been created for particular printer. Also, used display has to be properly profiled and calibrated to a known state. Problem that might occur is primarily directed to the colour gamut of a display, which in most of the spectrum exhibits higher colour selection (colour space) then most of the printers, but there are some regions where this is not a case. This has to be evaluated prior to the soft - proofing process.

An input instrument for a colour management system today is usually colorimeter or spectrophotometer, which basis its output on a summation of an input light. This method has proven to be very successful for most applications and for devices that exhibit uniform coloration over a measured surface. However, this is not the case with textiles where additional variable in terms of surface texture information needs to be included in order to provide a full characterization of the process. For this purpose, very useful devices are scanner and a camera. Only problem with these is that there are not colorimetric devices and therefore are not real representative of the real world colour.

### 2. Method

In order to import texture information, five surfaces were imaged with both scanner and camera. Performance of both of these devices will be evaluated for the purpose of simulation. Profile has been constructed for a Linotype - Hell scanner using standard Kodak IT8-7 target. Chosen backing for scanning was black. Camera systems (in this case Canon 300D with macro lens) are highly dependable on a imaging illumination source. For each of light conditions a separate profile should be constructed. As this might be rather time consuming process and would require not readily available test target, the raw sensor information has been used to obtain surface texture information and custom white balancing was preformed prior to imaging. Materials that have been used are cotton, wool - acryl combination, banner, and two types of polyester material.

Workflow in this project follows the standard procedure for soft - proofing with the addition of surface texture simulation (Figure 1). So, profiles has been made for viewing display, scanner and for printed surfaces, where raw format was used with a camera system which extract an information directly from the imaging sensor (Slavuj, 2010).

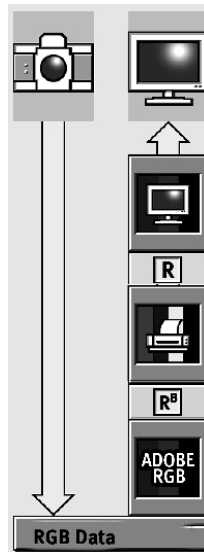


Figure 1: Scheme of the soft – proofing (Homann, 2009). Conversion from a RGB file (scanner or camera) first to the printer profile using relative colorimetric rendering intent with black point compensation and then from printer profile to a monitor profile

The Adobe Photoshop has served as a soft - proofing application. The test samples were in a form of 100 % CMYK colour patches measured with Gretag Macbeth I1 spectrophotometer whose output were Lab values. These values then have been applied in colour space of the printed sample prior of being corrected for a texture. Later, whole image is converted into a colour profile of the monitor using relative colorimetric rendering intent in order to map a surface white and right appearance of a print when compared with an image. Images for comparison have come from a scanner (with applied scanner profile) or form the camera.

Other approach is to import an image, apply texture correction and then to apply print profile. These approaches will yield similar appearance at the end.

Most of computer displays corresponds to the standard sRGB space in which the comparison was performed. In order to avoid colour shifts, it is important to establish that print media gamut is within sRGB gamut (Figure 2).

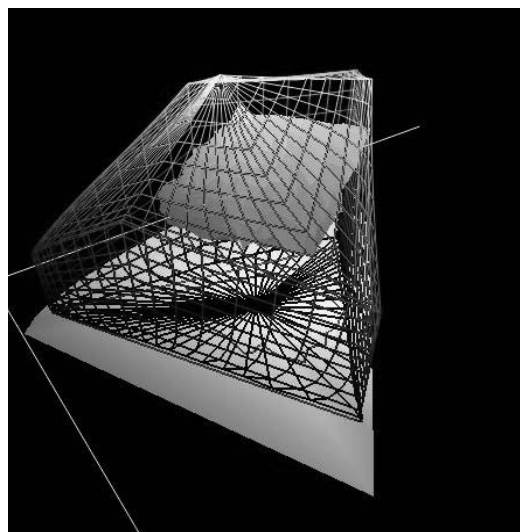


Figure 2. Comparison of a monitor (wire- frame) and textile print (solid) gamut

Surface textures have been obtained as luminance information expressed as  $L^*$  channel in CIE Lab colour space. A RGB image was imported in Matlab and subsequently converted to Lab coordinates. Luminance profile has been created for each type of evaluated surface (Figure 3). An input RGB image is therefore normalized for the luminance texture information to provide a full colour textured image.

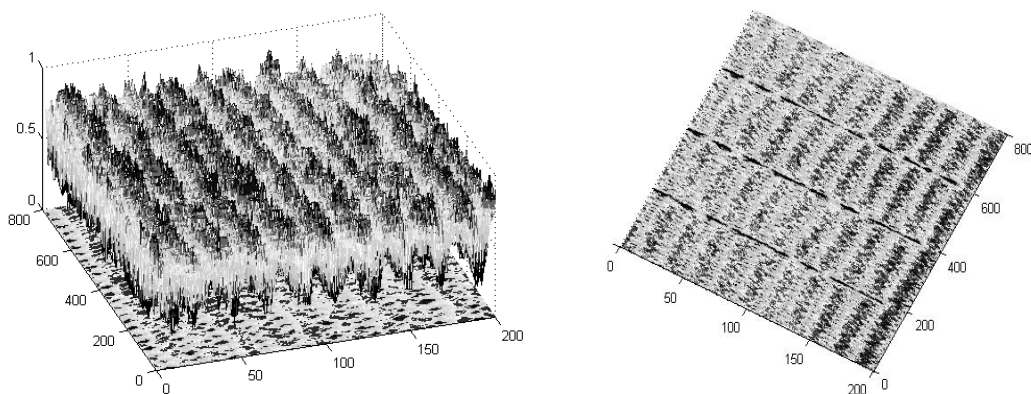


Figure 3. Textile material surface texture (luminance profile), for wool (left) and polyester (right)

Textile surfaces exhibit quite uniform pattern nature, but depending on a material and woven pattern there will be more or less open spaces in the material. This means that kind of materials like these are highly dependent on a backing used for measuring, imaging and observing. Measured colour difference could go up to from 4 to 14 in average  $\Delta E_{2000}$  units, depending on the surface. This might be slightly misleading as neither camera nor an observer would read the difference of that magnitude. Spectrophotometers are contact instruments and therefore they collect more light from the bottom end of a sample.

However, to avoid this problem, one type of backing should be used throughout whole process. Within this project, black backing was used, although as long as it is constant, white would be appropriate too.

### 3. Results and Discussion

A method has been evaluated for its goodness of simulation (Figure 4 and Figure 5) by taking simulated image (texture and colour) and comparing it with original (taken by camera or scanner). To avoid any resolution or other disagreements, scanned samples are compared with simulated image whose texture has also come from the scanner. Same stands for camera. All comparisons are preformed in sRGB space (profile) of the monitor.

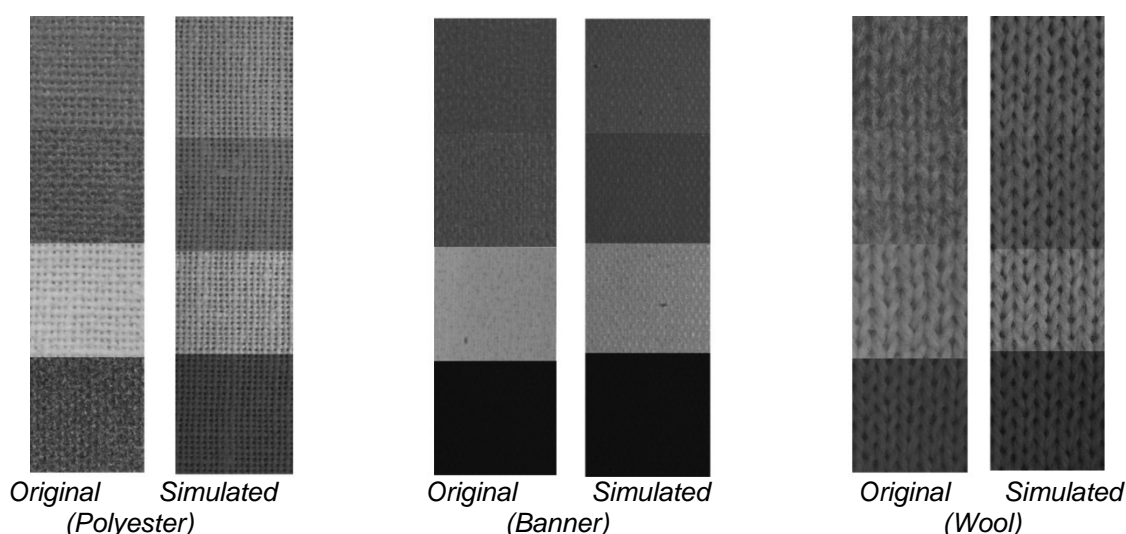


Figure 4. Comparison of a simulated and imaged textile prints using digital camera

It can be seen from the comparison above, that simulation could satisfy needs for most of the applications. However, the exact match is difficult to achieve as there are radical difference in the nature of coloration. Namely, for simulation process, a RGB image has been corrected for L\* channel of CIE Lab space and this is essentially an additive processes, where coloration of the textile samples is performed primarily by subtractive CMYK process. Also it can be noticed that dye or ink coverage is not ideal and printed areas are not uniformly covered (especially in a case of wool based material). This has for result, a number of open areas of non printed substrate, which increases luminance of the selected colour patch or area and therefore changes its appearance. There is noticeable change in brightness and also some change in hue and saturation direction.

Additional note here is that soft – proofing is highly dependable on the accuracy of the profiles, and control of the conditions. As noted before, backing will influence measurement and imaging and therefore would yield different profile if not carefully controlled.

In case of camera, the colour will be influenced by spectral power distribution of an incoming light as well as its uniformity all over imaging surface. Moreover, noise (especially dark current noise), flare and the angle dependence have not been considered in this project.

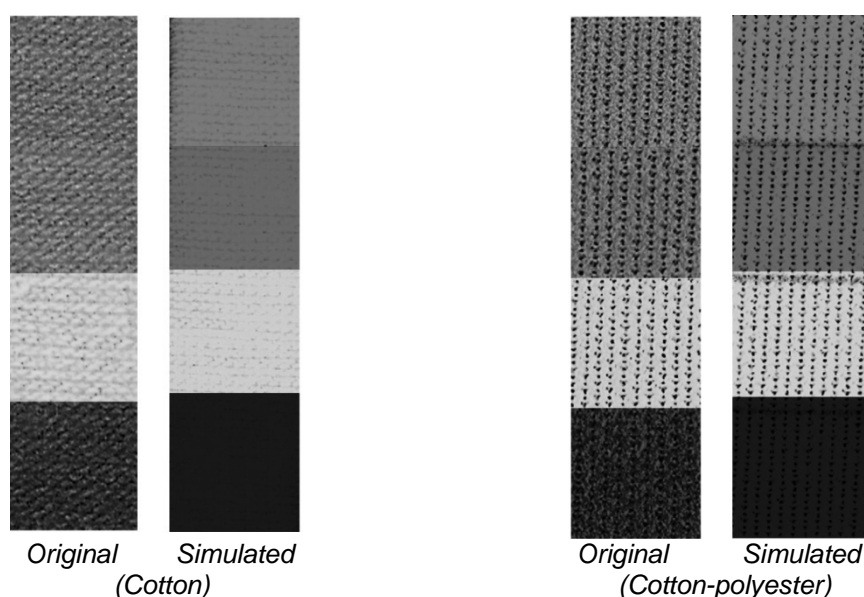


Figure 5. Simulation of the textured prints using scanner to record texture and image

First problem when using a scanner for this purpose is that, insufficient information have been conveyed, especially in mid-tones, and it does not cover satisfying dynamic range. Reason for this is a form of white balancing, where adopted white is the white of the substrate and images look rather over exposed and colours washed out. Therefore it fails to deliver information about real colour of the substrate and therefore tends to give colour shifts in almost all regions. Second problem is related to the colour noise, especially in dark regions.

Property that has occurred with camera based simulation is repeating in scanner case as well, even more amplified. Areas of low ink coverage are not simulated properly using this method and additional correction must be applied to count for this problem. Some solutions for a selective coloration have been offered (Shen, Xin, 2006), as well as those that utilize statistical property of printed surfaces or objects (Montag, Berns 1999) to simulate a colour of a texture.

## 5. Conclusions and Further work

This work has considered evaluation of images matching in their colour appearance. One set of images have been generated from base of imaged texture and combined with profiled set of colours, while other set came directly by imaging with camera and scanner.

The match is highly influenced by properties of used devices, degree of colour coverage of a substrate, and spatial luminance of a sample. Probably different match would result if someone changes input devices. As input devices are not real representative of real world, the great effort must be taken to transform these into colorimetric devices.

According to this, the best way for evaluation of goodness of a soft – proofing system would be visual. As printed samples are reflective materials and displays are emissive devices, it might be a problem to actually match overall luminance and contrast of colour. However, simultaneous observation of these two would solve the problem as the degree of adaptation and white point adaptation would be balanced. Parameters like surround and background effect, simultaneous contrast, overall luminance level and the degree of adaptation (chromatic and luminance), must be taken into account in visual observation and colour judgment. The purposed model would be CIECAM02 colour appearance model, which accounts for all mentioned parameters. Subsequently, this could be used as a reference space for evaluation of colour differences and could provide a means for correction of the used colour profiles.



## 6. Literature

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## ZAHARIUS GOTOANTIKVA

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**Abstract:** The first printers were completely dedicated to Gothic writing. Gutenberg used Textura and Rotunda while Peter Schöffer devoted himself to a transitional form of writing between Gothic and Antiqua or Roman with the prominent inclination to Antiqua. Schöffer's fonts had a more gentle fraction on the stress than any other previous typographic forms. The craftsmen of Gutenberg's workshop Arnold Pannartz and Conrad Schweinheim copied the Peter Schöffer's writing pretty unskillfully at Subiaco Monastery in 1465. Nevertheless, the final outcome of the aspiration to adapt Roman capital and Carolingian minuscule to the distinctiveness of printing was achieved by Nicolas Jenson in Venice five years later. Jenson's Venetian Antiqua is the first form of Antiqua writing to be known and recognized today in many different reflections and interpretations.

**Key words:** Gothic and Antiqua, typography, font

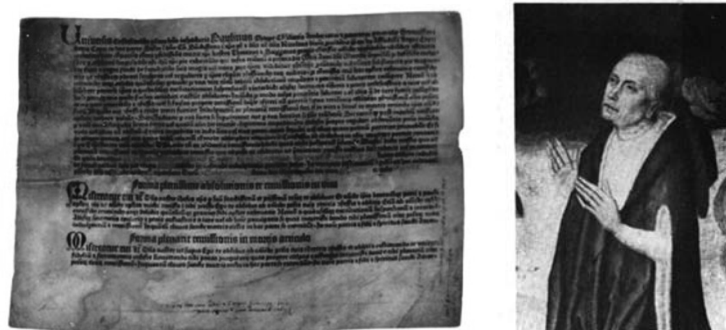


Figure 1,2: Gutenberg's Letter of Indulgence is the first known printed securities of the incredibly non-fixed price! Cardinal Nikolaus von Kues was the reputed initiator of the printing of the Letter of Indulgence, multiplied repeatedly in 1453 and 1454.

### 1. Introduction

As the work on Gutenberg's Bible was coming to an end, Johann Fust's confidence of investing the money in the thing was growing. The second ranking craftsman in Gutenberg's printing workshop was Peter Schöffer, a skillful engraver, typographer and printmaker, who attracted the attention of Fust as well as his daughter Christina, who liked him very much. It sped up Fust's decision to claim the return of the money given to Gutenberg disregarding the work on the Bible was completing slowly but surely. Gutenberg's delay and "the needless waste of time on illumination" firmed Fust's decision that the old master was unnecessary for him in the business.

In their studies typography historians often connected the pre-orientation of typographer ( in the spirit of the Renaissance idea) to Anthiqua with the transfer of printing skills across France and Switzerland to the Apennines. However, the real truth is that the very first fonts of Gotoantiqua emerged in Fust- Schöffer's printing workshop. "De Officiis" by Marcus Tullius Cicero printed in Mainz in 1465 is the most historically significant book in printing and its creation (from the font to the realization of the complete printing) was in charge of Peter Schöffer himself. (106)



Figure 3: "De Officiis" by Marcus Tullius Cicero was printed on parchment in Mainz in 1465. The excessive "ornaments of the book painting" hid Schöffer's attempt to present the writing of the book as "Early Renaissance writing" from which derived the font called Gotoantiqua.

This expert practitioner was said to have worked as an engraver before starting printing career. He paid great attention to the fonts presented in the book edition. Even though we know for sure that Nicolas Jenson, a French coin engraver from Thiers, stayed in the printing workshop at the request of Charles VI starting from 1458, it was undoubtedly certain that Schöffer was responsible for the creation of the writing. It has never been proved how much Jenson himself was involved in the process but there was a record that this type artist used his stay in the first European printing workshop for devising optimal Anthiqua fonts then resulting in his Venetian Antiqua in 1467. That is also an explanation of partial competence of this kind of writing of the typographers Pannartz and Schweinheim.



Figure 4: The example of IMPRESUM of Peter Schöffer and Johann Fust from Incunabula with the use of Antiqua.

In addition to this, the Catholic Church became extremely busy collecting donations for the construction of St. Peter's Church in Vatican. New ways of raising money began to be invented. The good Catholic Johannes Gutenberg adhered to the habitual frequent need for confession

so as to get down to duties at work readily and without previous sins. As his aristocratic background again became significant and drew public attention in Mainz, his confessions to high priests, probably to the bishop of Mainz himself resulted in the incredible story of multiplication of the books, which sounds insane but possible.

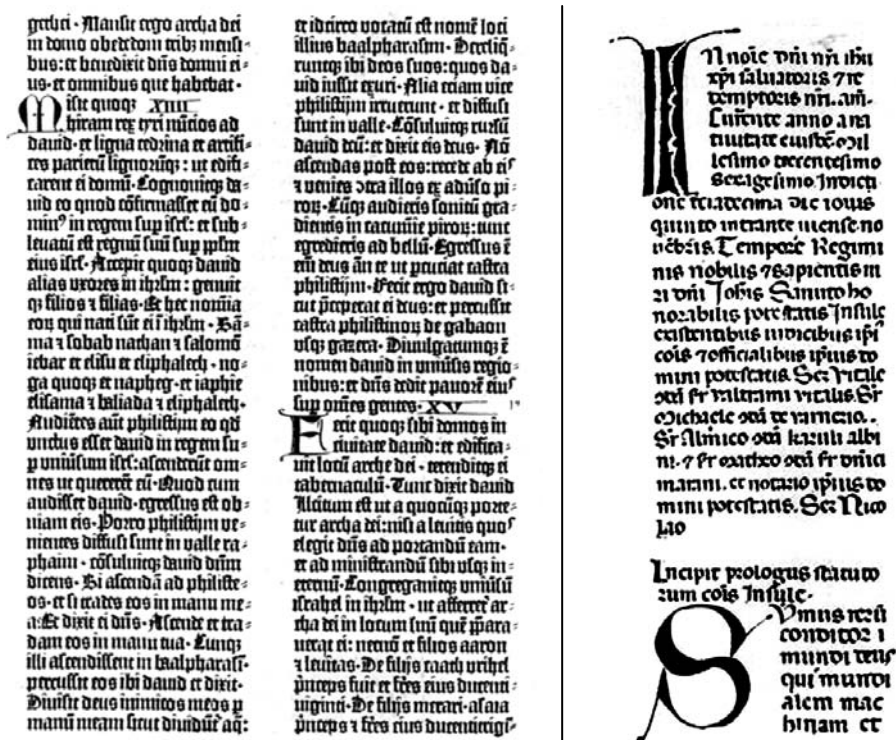


Figure 5,.- The 36-line Bible in Textura which Gutenberg printed helping his former assistant Albrecht Pfister in Bamberg in 1460 (16) On the left, Rotunda manuscript from 1360, the first page of the Statute of Isola ( The Historical Archives of Rijeka)

During the following, this time informative and businesslike conversation the bishop asked Gutenberg if he had understood the parts of his confession and Gutenberg gave the positive answer not having anything to hide from the God. This oral confirmation resulted in losing his printing workshop. As the bishop could not hide his interest and against the rule of the secrecy of confession, he inquired him about the possibility of the multiplication of letters of indulgence in the way Gutenberg had mentioned. Being a good Catholic and in full swing of the final work on the Bible, the master offered the Church and the Bishop that he would print a few hundreds of letters as a present. In the enclosure above we can see a letter of indulgence

and the archbishop who elicited from Gutenberg this extra task which took him a half of the year of the preparation, casting, typesetting and printing. In such a manner this paper/parchment turned out to be the most expensive piece of paper of the Early Renaissance. The donations for obtaining the indulgence depended on the severity of the sin and the assets of the sinner.

The authors of these lines tend to speculate that using this paper/parchment Vatican found out about the secret of the black art ten years before the printmakers from Mainz arrived at Subiaco monastery. The 42-line Bible was made in Textura, the basic writing of Gutenberg's Bible, but the letter of indulgence, printed a year before the official publication of the Bible, was in Rotunda, so we can conclude that the area of indulgence selling was expanded to the Mediterranean part of Europe.

ΑΒΒΓΔΕΖΗΘ  
 ΙΚΛΛΜΝΝΟΠΡ  
 ΣΤΥΦΧΨΥΩ  
 0123456789!"(). ?.

ΑΒCDEFG  
 HIJKLLJMNNO  
 PQRSTU  
 VWXYZ  
 0123456789!"(). ?

αδβγδεζηζυ  
 ικλμνξοπρ  
 στυφχψυω

abcc̃cd̃defg  
 hijklmnopq  
 rstyvwxyz̃z̃

Figure 7: Mega Zaharius Gotoantikva (Antikva Nedeljkić) u ćirilici i latinici, verzal i kurent

Gutenberg's letter of indulgence, the first known printed securities of the incredibly non-fixed price! Cardinal Nikolaus von Kues was the reputed initiator of the printing of the letter of indulgence, multiplied repeatedly in 1453 and 1454.

In such a manner in Subiaco monastery, 70 km far from Rome, competent German printmakers from all over Europe started the experiment resulting in Gotoantiqua. They struggled to please high clerical dignities who always had in mind the powerful Roman Empire whose monuments they walked by every day. (www.26)

## 2. Forum of the ancient capital

Arnold Pannartz and Conrad Schweinheim, the competent practitioners of casting and printing, made their best effort to create the writing according to the wishes of Benedictine cardinal. As it has been mentioned above, Gutenberg confided to the friend from Mainz, the local cardinal Nikolaus von Kues (who was also Benedictine), the invention of printing which led to letters of indulgence. It is possible that the whole idea of bringing the craftsmen from Gutenberg's printing workshop to Subiaco monastery was of Vatican's highest authorities because they believed that they are the best capable of multiplying the letters as well as printing the more serious religious literature.

**N**on igitur nascitur, quod fieri non potest  
 ex portis ante factorem omnium  
 id: ac fructes iocunditate innumerabil  
 omne deleueris: quod eos ad regnum ita  
 philosophi quoque dicit aliquid conat  
 ras transire aias in noua corpora disput  
 ex pecudibus in homines. et se ipsum ex  
 quē Cicero ait fulcitur porticus stoicorum  
 inuentione mundi loqueretur: hęc inuoluit  
 διανομῶς οὐδὲμ ἀδύνατο

Type of the Subiaco Lactantius (exact size).

Ouidius metamorphoseos.  
**H**ec tamē ex aliis generis primordia ducit.  
 Vna ē: que reparat: sequi ipsa refertur alaf  
 Afflym phœnice uocat: nō fruge. nec herbis:  
 Sed lacrimis thursi: et succo uiuit amomi.  
 Hec ubi quinq; sue cōpleuit secula uite:  
 Illic in ramis: tremuleq; cacumine palme:  
 Vnguib; ac puro nictu sibi construit ore.  
 Quo simul ac castas: et nardi leuif. aristali  
 Quasq; cū fulua subtrauit cynama mirra  
 Se super imponit: fimeq; in odoribus eum.  
 Inde ferunt totidē: que uiuere debeat: annos  
 Corpore de primo uolucrum phœnice renasci.  
 Dante:  
**P**ossi per li gram saui se confessar:  
 Chella phœnice muore e poi renasce  
 Che al anq; centeno ano se apressa.  
 Herbe ne buado in sua uita non pascē.  
 Malol de inconfō: lacrimē: et amomo:  
 E nardo: e mirra: sun le ultime phasce.

Figure 8: Indeed, two craftsmen were from Gutenberg's printing workshop, but apart from diligence and printing skills they did not possess any creativity. In 1467 three works were printed: "De oratore" by Cicero, "De diuini institutionibus" by Lactantius and "De ciuitate dei" by Augustinus. The segment of Lactantius's text (above left) with the last line set in Greek writing showed unskilful font making of Pannartz and Schweinheim. The font was far beyond the expected and therefore the worried Spanish cardinal Giovanni of Turrecremata sent for the brothers Pietro and Francesco de' Massimi to help them. The brothers contributed to more quality typography instructed by German printmakers. Their contribution to the creation of the writing can be evaluated on two verses of Dante's work in 1469. As it can be seen, the typography is just a step away from Venetian Antiqua of Nicolas Jenson.

It should not be concluded that Gotoantiqua is the creation of the printmakers invited to Subiaco in 1465 because in the same year Fust-Schöffer's printing workshop published "De Officiis", the collection of letters by Marcus Tullius Cicero, which was arranged as well as set typographically by Peter Schöffer himself. According to the historians of Early Typography, Nicolas Jenson worked on a version of Humanistic writing-the future Antiqua during his four-year stay at Schöffer's starting from 1458.

After the Schöffer's printing workshop was burnt down, the French engraver Nicolas Jensen left Mainz and headed to his homeland to place himself at the disposal of King Louis XI. It has not been known whether the ruler was interested in Jenson's work but he ended up in Venice in 1465. Along with his compatriots Johann and Wendelin von Speyer, who worked on Gotoantiqua as well, Jensen printed the first books in Venetian Antiqua itself. More precisely, Johann von Speyer obtained the permission of Venetian authority for printing business in the Venetian Republic area.



Figure 9: A detail from the book from Ulm in the German version of Gotoantiqua. A part of the page with the illustration of "The Prayer of Heaven". This form of Gotoantiqua was among the first to appear in German states with the letter characteristic between Rotunda and Humanistic writing.

The skilful coin engraver from the French town Thiers, who joined the adventure of printing thanks to King Charles VI of France and Johann Fust, the new owner of the printing workshop, found the perfect solution for the fraction of the stress, which his colleagues could not get rid of and was at the same time the final goal of Vatican. Thereby the masters of Gothic Textura and Rotunda from Mainz achieved the goal-the writing which the only true yet enough powerful people commissioned and strove for Antiqua. We do not have to talk about the confusion of Humanists who were unpurposely tricked by the copyists of Aachen Academy so they mistook Carolingian minuscule as the authentic writing style of the ancients and gave it wrong but later useful term – Antiqua (that is littera antiqua)

### 3. Conclusion

Gotoantiqua Zaharius was an exceptional challenge for two completely different reasons. The first one which makes it challenging is the approach to the problem solution by the fusion of two highly diverse writing, Gotica and Antiqua, presented in this "transitional" form of writing.

The second one, which makes this challenge really dramatic is the formation of the letters in Cyrillic alphabet as well. The result represents a new form of Cyrillic which is the link between

Cyrillic forms of writings with their own regularity and in so doing it associates with both Medieval Cyrillic and Rotunda, the Mediterranean form of Gothic writings. Gotoantiqua was simultaneously the pastiche of all the transitional Early Renaissance typographic fonts and the Cyrillic hybrid transitional form which had never existed before. To conclude, GOTOANTIQUA is the writing which is supposed to bridge two alphabets.

Gotoantikva je izuzetan izazov za kreatore iz dva sasvim različita razloga. Prvi koji je trebao da predstavi sponu između dva bitno različita pismovna oblika, gotike i antikva, koja svoje sjedinjenje treba da predstave kroz „ovu prelaznu“ formu pisma, jer u tabeli Klasi kacije treba da poveže dva različito koncipirana oblika pisma i... одлук ћупуиуе коју шреда га прегцшавља спону између ћупуиуиуи форми писана која имају своје законитости а га подсећају на Средњовековну ћупуиуу и како сам у шекету набео Ротунде (Rotunde), медиштеранског облика готичких писана ! Готтоантикба је била изузетан изазов из гђа сасвим различита разлога.

*Figure 10: Text typeset in Zaharius Antiqua and Zaharius Antiqua Cyrillic*

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## EDUCATION: GRAPHIC DESIGNER AND REPRODUCTION KNOWLEDGE

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**Abstract:** *In this paper the differences in education of graphic designer who is involved in reproduction workflow, on one side, and a graphic designer as an artist on the other side, has been defined and compared. From the technological point of view graphic design has been diversified and the differences between art and design were clearly identified. The stress was on technological stages and points which should be relevant in graphic designers' education in relation to the classical, artist education.*

**Key words:** *education, graphic design, art*

### 1. Introduction

The difference between the design and art is convoluted and has been debated for a long time. Designers and artists both create visual compositions using a shared knowledge base, but their reasons for doing it are entirely different. Many designers are artists and many artists are designers but the line between the two is complex and intriguing. So what exactly is the difference between design and art? Should we limit or increase the number of subjects in graphic designer education to create steady-ready professionals and prepare them for the real world? In this paper, it will be diversified and defined areas which are relevant in graphic design education and compared with the education principles of artistic education.

### 2. Background

Design is all around us: explaining, decorating, identifying. It communicates with the audience in order to send them and present a message, to get the important statements forward. It could be seen in everything what is readable, in road signs, magazines, advertisements, different package forms, textiles, logos. It could be seen daily on printed textiles for fashion and interiors, different accessories, ceramic and glass-ware, wallpapers and wrappings, decorative laminate and floor coverings, etc. Communication strategy, the essence of graphic designer, can be jeopardized by poor choice of colour [1], text, type, image or illustration, layout or even reproduction technology.

Education of graphic designer today is quite different than twenty years ago. Computers and digital technologies have changed our practice in many ways, but the basic educational issues have been the same. The increasing complexity of the usage of creative communication in graphic design industry, the specialties in digital, multimedia, and web-based areas that have developed recently, and the increased number of graphic design tools and programs, lead to a highly competitive field. But, the need for clear, creative, effective communication is still the same as it was in the past.

### 3. Graphic designer: advertising agencies-printing companies vs. art studio

Graphic design performs a number of functions. It sorts and distinguishes, informs, acts on the cultural and socio-psychological emotions of the audience. The main purpose is to motivate the audience to do something: buy a product, use a service, visit a location, and learn certain information. The most successful designs are those that most effectively communicate their message and motivate their consumers, audience, to carry out a task [2-3].

On the other hand, the main purpose of the graphic designer, as an artist, is to create a work, to share their feelings and impressions with others, to allow the viewers to relate to it, learn from it or to be inspired by it. The most renowned works of art today are those that establish the strongest emotional bond between the artist and their audience. But who is the audience? There is no specific audience in art, no one to diffuse, set an objective or define it as successful or not, to call the purpose of the work. In his work, the artist is creating his own rules. It should express an emotion and it does not have to adhere to any specific rules. He can express a single thought or feeling such as frailty or power, love or pain and the composition simply by his hand. The artist is free to express themselves in any medium and colour scheme, using a number of methods to express their emotion. No artist ever has to explain why they did



something on a certain way, as their work expresses what they felt in the certain moment by using the best portrayal of their feeling, emotion or message.

One can say that the fundamental difference between art and design is obviously on their purposes. It can be said that good design will motivate the audience and that good art will inspire its audience [4].

#### 4. Reproduction specifications for graphic designers

Commercialism, trends and growing technology have been dictating the course of design and made a clear line between the designer and the artist.

In today scenario, technology is present in every sector and it could be present in every artistic work. The artists could, if they are willing to, use the advantages of reproduction technologies to enhance the value of their work, or to swiftly carry out his work. Even somebody's passion and emotion can be dragged to a higher level with the help of advanced reproduction technology. On the other hand, do the artists really need this kind of preceding their work?

Nowadays, the understanding of graphic design has to be involved with its commercial sense and it has to be defined as a strictly calculated and defined process. It is discussed among a specially educated team and implemented taking careful steps to make sure the objectives of the project are to be presented in the specific way. In this surrounding, designer is similar to an engineer in that respect and must not only have an eye for colour and style but must adhere to very intricate functional details that will meet the objectives of his work.

The development in the computer and technology areas has rapidly changed the content of subjects in graphic design education over the last decades. For example, subjects related to type reproduction were from the hot type supplanted by phototypesetting, which was, in turn, replaced by desktop publishing. It is not hard to imagine that the desktop publishing will soon be replaced by some new technology. According to the Waite (Waite, 2006) printing companies have been downsizing their prepress department as a result of technological development [5]. Printing companies that may have once employed a number of persons who operated cameras, retouched film, duplicated films, operated scanners, assembled film onto printing forms, and made proofs and plates in today scenario may give the same function to five or six prepress personnel. One can say, there are fewer people employed to correct errors in jobs prepared for the reproduction process by graphic designers. Therefore, it is more important for designers to prepare completed files for reproduction as accurately as possible. And, further more, they has to be given the adequate education in order to know and prepare their creative work for the reproduction process.

When graphic designer create a digital file using his own workstations, printers, most frequently, assumed that those files would be defective in one way or another. Thus, elaborate preflighting (checking) and file intervention (if needed) processes have to be put into the place. Prepress personnel often repair designer's files and make specific changes to optimize jobs for the company's presses. Although printers still do not assume that incoming files are completely accurate, nowadays, the job for preparing accurate files for reproduction has been pushed out of the prepress department to the graphic designer. As a result, the prepress departments of many printing companies are specialized in just a few activities: preflighting, imposition, trapping, RIPing, proofing, and platemaking processes. Most importantly, price quotations often include only these prepress functions. File intervention activities are often treated as customer alterations and charged separately.

To minimize faulty files, printing companies, for example, gravure, flexography, and offset printing houses, banded together and formulated documents that define the specifications for both, designer and printer. In theory, if the designer and printer follow the specifications, the final product should be as desired by the customer. These specifications are gradually introduced and, in many cases, are now demanded by printing companies. Incoming files that do not meet the specifications may be, in some cases, rejected by the printers.

Because of those specifications and guidelines, it is vital that educational subjects for graphic designer contain and implement them into their matter. It is no longer financially feasible for designers to simply assume that the printing companies' personnel will check and correct the files. In this situation, frequently, printing operators, do not understand what the designer's idea was. They can decide about, and have the knowledge about the interaction between the used printed materials, used inks and reproduction stages which will affect the final product. They will be the executors of designers work and idea with the possibility to adjust the reproduction processes to their ideas, which could be (and in most cases is) in disproportion and do not

mach to the designer's project. In this situation designer cannot possibly know all the interactions and transformations between the printed material (paper, paperboard, plastics, etc.), ink, processes in prepress, press and finishing stages. In fact, he may not even know which printing company is going to reproduce their work.

Finally, no matter how motivating, trendy, strait and inspiring designers work will be, reproduction process could result in a product that does not meet the customer needs.

In addition, it is important for students to know that each set of guidelines is different. Thus, if the same idea has to be printed in a different reproduction processes (i.e. flexography, web-offset or a sheet-fed-offset) three different files must be prepared.

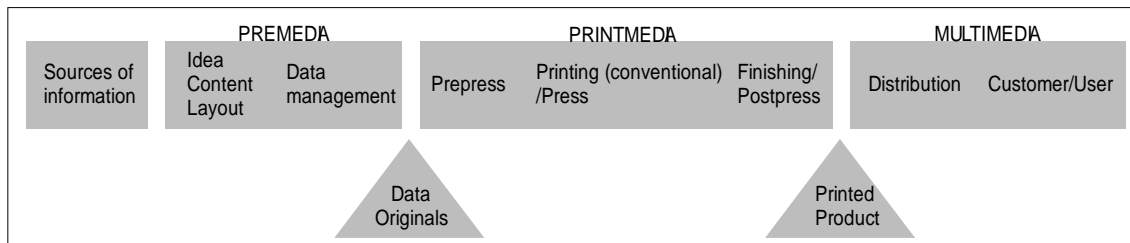


Figure 1: Reproduction workflow

Specifications for everyone involved in graphic arts workflow (Figure 1) [6], which includes all forms of reproduction, whether analog or digital are selected by IDEAlliance (International Digital Enterprise Alliance), a not-for-profit membership organization that has been a leader in information technology and publishing since 1966 [7]. IDEAlliance advances core technology to develop standards and best practices to enhance efficiency and speed information across the end-to-end digital media supply chain: creation, production, management, and delivery of knowledge-based multimedia content, digitally and in print. Specifications needed for graphic designers are defined in Branding, Media & Color specifications related to technologies that enable colour and process control across media types and end-to-end in the digital media supply chain. There are defined printing industry guidelines important to graphic designers' education which corresponds to the industry segment in which the designers are likely to be employed. Nevertheless, whether it is going to be offset printing company, gravure or flexography, following paragraphs should be involved in their education [5]:

- File format (TIFF/IT-P1, PDF/X1a, /X2a, or /X3a)
- Colour specification settings (CMYK, RGB, monitor calibrating, work areas)
- Image resolution
- Font and typefaces (technologies, sizes, embedding fonts)
- Bar Codes and trapping.

According to these specifications it is clearly identified the differences between art and design and a clear line could be drawn between them. Most of the graphic design projects have a detailed set of instructions for its reproduction and most design works are based on current cultural trends and influences in the society. On the other hand, an artist could never be given any specific instructions in creating its work because his emotions and impressions are defined by the movement of his hands and the impulses for the usage of the medium. No art director is going to yell at an artist for producing something completely unique because that is what makes an artist an artist and not a designer.

Those are the reasons why education of graphic designers should be, apart from basic education, directed and expand by the subjects related to reproduction technologies. Considering the fact that graphic designer, opposite from an artist, is confronted to many technological boundaries, their free expression cannot exist in isolation from the reproduction process. With this awareness, graphic designer's creativity will be able to come shining through. An understanding of all stages in graphic reproduction process will enable them to express their ideas in most amazing way and to completely express their creativity. On the other hand, understanding of the reproduction process will prevent graphic designer's work from failing for technological reasons [8].

They should be aware that their creative work, the idea, will undergo through several transformations before ending up in a printed and finished publication. Not so long ago, graphic designers used to just sketch rough layouts covered with key lines and instruction to the print

houses, and hoped for the best. Nowadays, it is expected from designer to do more, to create its ideas in a computer generated form with a good idea and overview of how the printed result is going to look.

Designers' style should be of overall excellence and their identifying symbol based on the specific usage of the combination of all the particular choices of typefaces, usage of materials, colours, illustrations, photos and so on. They should be aware of all the advantages and disadvantages of different technologies in order to know how to use them and produce a product of their creativity. Even the knowledge of different reproduction possibilities could form their direction and lead them from their creative thought and brainstorming to the finalised product.

## 5. Conclusion

This paper stresses some main differences in education between the graphic designer who worked in the reproduction areas, and a graphic designer as an artist. From the technological point of view graphic design has been diversified and the differences between art and design were clearly identified. The stress was on technological stages and points which should be relevant in graphic designers' education in relation to the classical, artist education.

Designers and artists both create visual compositions using a shared knowledge base, but the reasons for doing it have been entirely different. According to the paper overview of this paper one can conclude that the basis education of the graphic designers should be in certain relation to the reproduction technologies. Education of future graphic designers' should be based on this methodology. By learning to think and be aware of the designer's idea and the creative process on the one side and reproduction options on the other side, producing a final product will result with effectiveness and efficiencies in wide variety of circumstances.

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## INFLUENCE OF INK VISCOSITY ON PRINT QUALITY AND GLOSS IN GRAVURE PRINTING

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**Abstract:** Rotogravure printing is based on ink transfer from gravured cells on surface of cooper cylinder to printing substrate. Therefore, ink viscosity has a major role in printing process and has a great influence on the quality of printed substrate.

Namely, the rheological properties of ink, influence the print quality and smoothness. Ink and its viscosity cause dot sharpness, ton value increase, variations in ink thickness, smoothness and mottling. Lower viscosity causes tone value increase, and consequently results in low sharpness and dirty prints, inconsistent ink thickness and smoothness. Higher viscosity may also cause problems in inconsistent ink transfer on the substrate, causing mottling.

The influence of ink viscosity on imprint quality through two parameters of control - colorimetric values of the colours and tone value increase have been presented in this paper. One printing substrate and four different inks (CMYK) have been used for printing.

**Keywords:** Gravure, viscosity, colour difference, gloss

### 1. Introduction

Rotary gravure printing differs in a way that it has advantages over other printing techniques in the production of medium and high circulation, which requires the uniform application of ink. Viscosity is a measure of ink fluidity or measure of the degree of fluidity. Viscosity is the most important characteristic of ink, which should be monitored during printing process in gravure printing. It should be controlled to ensure the uniformity of printing process and consistency of ink during the printing process. It also has an influence on ability to print, the speed of drying, ink absorption, gloss, adhesion and penetration of ink in the substrate. (G.A.A. 1991),(Kipphan, 2000)

Besides the viscosity, the important role of visual experience of colour also has gloss of printed ink. Gloss is reflected light from the surface of the observed object.

Gloss measurement determines the amount of light that is reflected at an angle from the object of measurements. Output and the angle of incidence of light are equal only in opposite directions. The amount of reflected light is essential for seeing the reflection from the surface of objects, so that the measurement of gloss determines how an object is glossy (Bright).

This paper analyzes the influence of viscosity on the quality of the printed patterns by monitoring the colour difference compared to the ISO standard (CMYK). We also analyzed how different values of viscosity affect on gloss. This allows you to determine the optimum viscosity for obtaining high quality prints.

### 2. Experimental Setup (Materials and Methods)

The samples were printed on printing machine ATN Atena, on paper Niklakett Classic Forte 70g/m<sup>2</sup>.

The sample was printed in four colors (C, M, Y, K) without coating, from roll to roll. Viscosity of printed samples was measured automatically within the machine, which provides a constant viscosity during printing process.

However, due to the inability of determining the type of viscometer within the machine, the value of viscosity was expressed as the time needed ink to pass through a special device in the machine and is expressed in seconds.

For the purposes of this study three different samples from the printed rolls were taken for each value of viscosity (flow time) of 16, 17 and 18 seconds.

Measurement of the samples was done with densitometry Vipdens 2000

This device complies with the DIN / ISI 13655 standard, where as light source is used D50 (5000 K), and the standard observer (reading) is performed at an angle of 2°. For the purposes of this study, measuring device was used to measure the full tone field for the four process colours (CMYK) in three different places on one sample.

For the amount of gloss with a full tone field for the four process colours (CMYK) we used the device Master Gloss / Gloss Mate with three angles for measurements, angle of  $20^\circ$ ,  $60^\circ$  and  $85^\circ$  which compiles to ISO 2814 standard. Angle of  $60^\circ$  is used for most materials, while the angle of  $20^\circ$  is used in cases where the value of gloss at an angle of  $60^\circ$  is greater than 70, which is a substrate with high reflectivity. Also angle of  $85^\circ$  is recommended when the value of gloss at an angle of  $60^\circ$  is less than 100, which is a matte surface. (KBA Process, 2006)

The colour difference for the four process colours (CMYK) is calculated based on the value in ISO 12647-4:2005 standard and value of measuring samples. Each sample was measured three times for each colour and all three values of viscosity, and the final result is taken from the  $\Delta E$  mean value of three samples. (Joshi, 2007)

The value of ink gloss in the fields of full tone for the four processes colour was achieved on the basis of five measurements for each colour and each ink flow time respectively. As the final result the mean value of gloss obtained from five measurements was taken.

### 3. Results and Discussion

#### 3.1 Results and discussion for four process colours (CMYK)

Figure 1 graphically presents the obtained mean value of colour difference for the  $\Delta E_{76}$  and  $\Delta E_{94}$  measured on prints obtained by printing at three different values of flow time balance: 16s, 17s and 18s. ISO standard for gravure printing 12647-4:2005 provides that if the value of colour difference does not exceed 5, reproduction is subjected to the standard. (Fairchild, 2005), (Ebner, 2007)

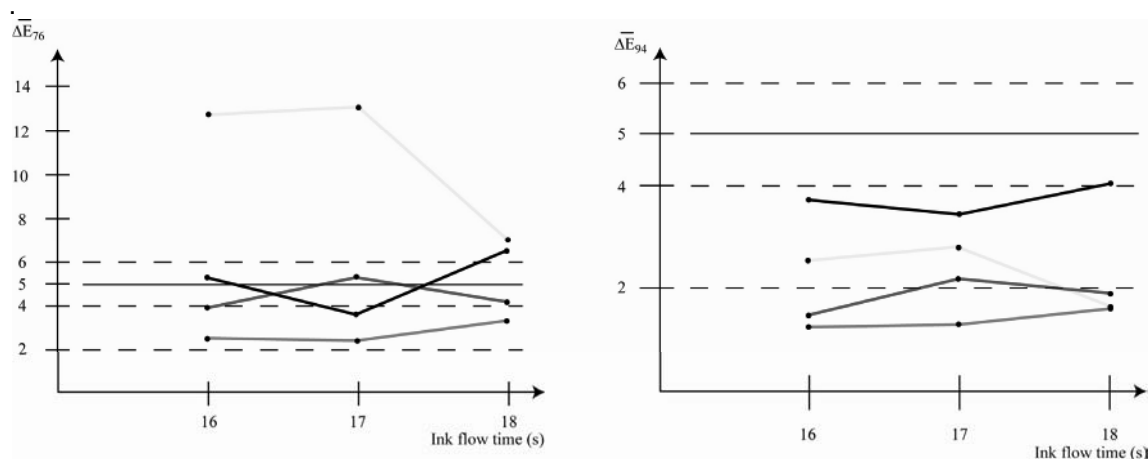


Figure 1: Graphic representation of colour difference colour depending on the flow time value of the process colours (CMYK) expressed by two standards to display colour difference  $\Delta E_{76}$  and  $\Delta E_{94}$ .

By observing the graphs for the mean colour difference for both the  $\Delta E_{76}$  and  $\Delta E_{94}$  for process colour Cyan, it can be concluded that the data values for all three values of ink flow time located within the tolerance prescribed standard. The graphics are clearly showing that the smallest colour difference printing is achieved when the value of ink time flow was 17 seconds, while the highest colour difference value obtained when the flow time was 18 seconds.

In process colour Magenta, from graphics for the mean colour difference for the  $\Delta E_{76}$  and  $\Delta E_{94}$ , we can see that the colour difference value for the  $\Delta E_{76}$  out slightly from the prescribed standard values when ink flow is 17 seconds, while if  $\Delta E_{94}$  all values obtained are subject to the standard. From graphics can be seen that the smallest colour difference reproduced  $\Delta E_{76}$  and  $\Delta E_{94}$  achieved at the time of ink flow of 16 seconds, while the largest colour difference strength achieved at the time of 17 seconds.

For process colour Yellow, looking at graphics for the mean colour difference was observed that all the values calculated by the colour difference for the  $\Delta E_{76}$  is not very in line with standards. In contrast to the  $\Delta E_{76}$ ,  $\Delta E_{94}$  graphic shows that all measured values are subject to the standard, with the smallest value of colour differences obtained by ink flow time of 18 seconds, and the highest yield at the time of 17 seconds.

In process colour Black, based on the graphic for the mean colour difference  $\Delta E_{76}$  we can see that only the value obtained by ink flow time of 17 seconds is subject to the standard, which

is backwards in comparison to the measured values of process colour Magenta. Furthermore, colour difference values during the ink flow of 16 and 18 seconds were significantly higher than the ink flow time of 17 seconds. Unlike the graphic for the  $\Delta E_{76}$ , the graphic mean value of colour difference  $\Delta E_{96}$  recognizes that all measured values are subject to the standard. In the case of  $\Delta E_{76}$  and  $\Delta E_{94}$  minimum value of the colour difference is achieved at the time of ink flow of 17 seconds, and the highest yield at the time of 18 seconds.

### 3.2 Results and Discussion for gloss

Table 1 shows the mean values of gloss for the four process colours (CMYK) obtained from five measurements for each colour separately and each value of ink time flow. Values were obtained by measuring angle of  $60^\circ$ .

*Table 1: Mean value of ink time flow for four process colours*

Ink time flow	16 seconds	17 seconds	18 seconds
C	23.1	24.88	19.4
M	23.54	23.38	20.9
Y	28	25.92	26.14
K	24.5	26.46	21.66

From the results, we see that the minimum value of gloss is achieved when the value of ink flow time was 18 seconds apart in the case of process color yellow.

In process colors, Cyan lowest gloss value occurs during ink flow of 18 seconds while the highest value measured when ink flow was 17 seconds. The process colors Magenta and Cyan measurement with the smallest value of gloss occurs during ink flow of 18 seconds while the highest gloss value obtained by ink flow of 16 seconds.

In process color Yellow, lowest gloss value was obtained when the value of ink flow was 17 seconds, while the highest gloss value obtained by the ink time flow of 16 seconds. As for the process colors of Black, the results are the same as the process colors Cyan, i.e. Minimum value of gloss is obtained when the value of ink flow was 18 seconds, while the highest value obtained at the ink time flow of 17 seconds.

Overall gloss values obtained for all four processes colours in the case of time flow of ink from approximately 16 seconds are the same except for the process colours of yellow, which deviates the most. Unlike during the flow of ink from 16 seconds in the ink time flow from the 17 seconds the difference is much greater, and this may be the time to see the flow of ink from 18 seconds where the difference is most pronounced in relation to the previous two times, yielding colour.

## 4. Conclusions and Summary

Results and their analysis led to the following conclusions:

In process colour cyan, obtained values for the colour differences for the value of ink flow time are the lowest at 17 seconds, while in the case of the smallest gloss value is obtained at the ink time of flow ink of 18 seconds. Therefore, it can be concluded that the optimal flow time value for printing cyan is 17 seconds but in that case, we derive the most gloss value of paint. But in case that we want to get middle gloss value on our print while they do not have large discrepancies in his sight colour differences, the most optimal value of ink flow would be 16 seconds.

For process colour magenta, it is evident that optimal print quality achieved by printing the value of ink flow of 16 seconds, as indicated by the values calculated for the colour difference, but then we get the greatest gloss value. However, due to small differences in values obtained for the gloss paint from the value of flow 16 and 17 seconds we adopt that the optimal value for the magenta printing is, the value of 16 seconds.

In the case of colour yellow process, lowest value of the colour difference is achieved by the time flow of ink from 18 seconds, while the lowest gloss value achieved at the time of 17 seconds. However, as with process colour magenta and yellow with the slight difference in the values of gloss during the flow of ink from 17 and 18 seconds can be inferred that the value of ink time flow from the 18 seconds is optimal for printing yellow.

In process colour black, the lowest value of the colour difference is obtained by printing ink flow time of 17 seconds, but then gloss value is the greatest. In the case of process colour black we can see that all three gloss measured values are very different from each other for each

value of time flow of ink. Minimum gloss value is obtained with ink glow time from 18 seconds and at that value, there is the biggest colour difference compared to the standard. in order to get quality print, we have to decide either to release the value of ink time flow from 17 seconds, where the value of colour difference is the smallest or in 16 seconds where we get some middle ground with regard to the value of colour difference that is not much different from standard, and the gloss value is considerably smaller than the ink flow time of 17 seconds.

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# THE INFLUENCE OF SUBSTRATE ON PRINT QUALITY AND ELECTRICAL PROPERTIES OF PRINTED ELECTRONIC COMPONENTS

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**Abstract:** This Paper deals with the printing of conductive layers based on conductive ink by using screen printing technique. Experimental part of the paper is focused on the monitoring interaction between the Ag particles based conductive ink and different types of printing substrates. The evaluation of the print quality was realized by using printed testcharts and by measuring the electrical properties of selected patterns. For the evaluation were prepared sets of prints, which were then printed under same conditions on following substrates: APCO, Melinex, Pretex, Synaps. Prints were investigated by means of image analysis methods and by measuring of electrical properties of selected patterns. The results confirmed that the print quality and electrical properties of prints depend on choice of printing substrate.

**Key words:** conductive ink, electrical properties, screen printing

## 1. Introduction

During last years, electronic components are produced by using different printing technologies. These electronic components are usually called "Printed Electronics"; for example electronic circuits, thin flexible battery, RFID tags [1,2], thin film transistors and others. Screen printing is the most frequently used printing technology in this area. The main advantage of screen printing is the possibility of conductive inks deposition with different thickness of layers in dependence on printing conditions. Print samples were made with semiautomatic screen printing machines with vacuum table for fixing of the substrate. The influence of substrate properties on the print quality and electrical properties of printed layers were examined.

## 2. Methods

Four printing substrates were used to print (2 synthetic papers – Pretex, Synaps, coated paper – APCO, PET film – Melinex). Selected properties of printing substrates were measured (Table 1). Roughness was provided by Parker test method with using instrument – Parker Print Surf M590, the surface tension of printing substrates was measured on instrument – CAM 100 (sessile drop method). Grammage was specified by quadrantal weigher. Thickness of the used printing substrates was measured by instrument Micro-TRI-gloss m 4435.

*Table 1: Properties of printing substrates*

Printing substrate	Roughness [μm]	Surface tension [mN/m]	Grammage [g/m <sup>2</sup> ]	Thickness [μm]
APCO	1.14	52.48	140	107
Melinex	0.93	48.50	250	175
Pretex	3.95	35.79	155	143
Synaps	1.43	40.86	110	100

Composite conductive printing ink based on Ag particles (CI-1001, ECM) was used for printing of patterns. The properties of conductive ink are shown in Table 2.



Table 2: Properties of conductive ink CI-1001

Viscosity [Pa·s at 30°C]	17
Total solids content [%]	61
Flash point [°C]	100
Specific resistance [ $\Omega/\text{sq}$ at 25.4 $\mu\text{m}$ ]	<0.015

Print samples were made by using semiautomatic screen printing machine Ever Bright S-200 HF. Printing settings, printing conditions, curing temperature and curing time were the same for all substrates. Screen printing frame including polyester mesh with the mesh density of 140 fibers/cm was used for printing of samples.

### 3. Results

Test chart (Figure 1) contained patterns for an evaluation of the print quality and electrical properties of printed layers. Pattern R1 was used for an evaluation of printing resolution perpendicularly and toward to print direction by using Image analysis method. Patterns HF1, V1 and V2 were designed for electrical properties evaluation of printed layers. Pattern HF1 served to relative comparison of the resistance of printed layers on different substrates. These patterns simulated typical design of HF RFID antennas. Patterns V1 and V2 indicated a tendency of determination for electrical materials characteristics of printed layers – specific resistance (resistivity) or specific conductivity.

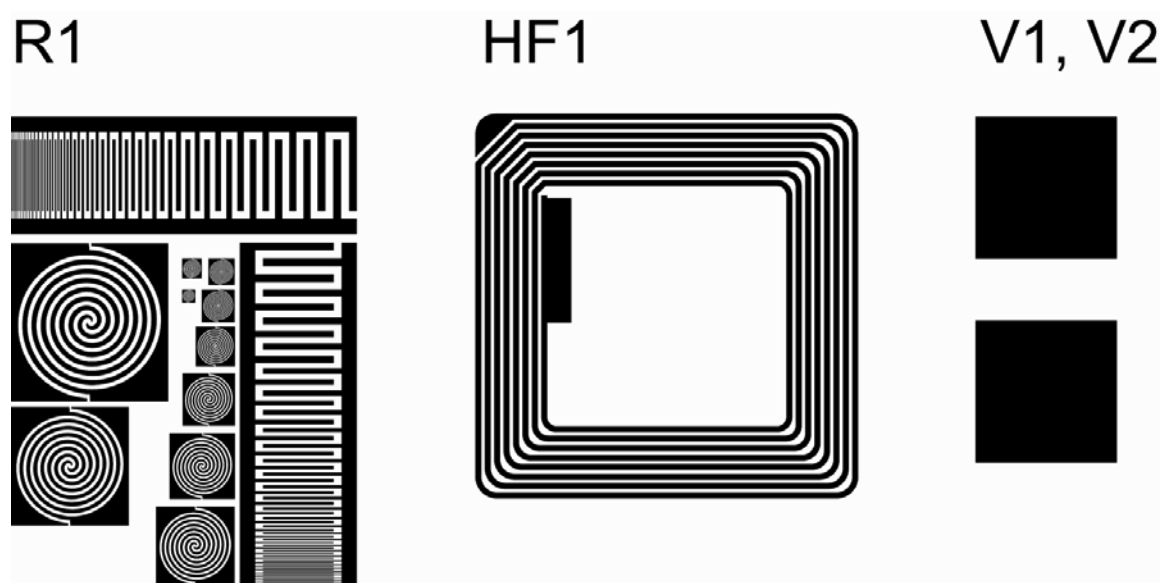


Figure 1: Test chart

#### 3.1 Image analysis

The image analysis was used for print quality determination. Pattern R1, printed on different kind of printing substrates, was microscoped at 40 multiple magnification with optical microscope Bresser Erudit and CMOS camera MicroOcular 3 Mpx. Thinnest printed lines, which were without defects and were not connected with neighbouring lines, were evaluated from microscopy images (Figure 2). Otherwise told by, the last one unbroken line and space between this and next wider line was chosen as the thinnest printable line and space. This thinnest line and space were segmented in software Adobe Photoshop CS4 and their characteristics were calculated by using software MATLAB (Table 3). Print resolution was determined dependably on printing substrate and line orientation to print direction. The value of lpi was estimated from sum of width of the thinnest printable line and width of the space between thinnest printable lines. Parameter, standard deviation, was used for comparison of homogeneity of line width.

Table 3: Printing resolution depending on printing substrate

Printing substrate	Print direction	Line width		Space width		Resolution [lpi]
		Average [ $\mu\text{m}$ ]	Standard deviation [ $\mu\text{m}$ ]	Average [ $\mu\text{m}$ ]	Standard deviation [ $\mu\text{m}$ ]	
APCO	perpendicularly	117	15	54	15	149
	towards	102	11	57	10	160
Melinex	perpendicularly	194	13	74	14	95
	towards	127	10	75	9	126
Pretex	perpendicularly	124	14	80	12	125
	towards	143	18	129	22	93
Synaps	perpendicularly	117	14	55	15	148
	towards	97	12	51	14	172

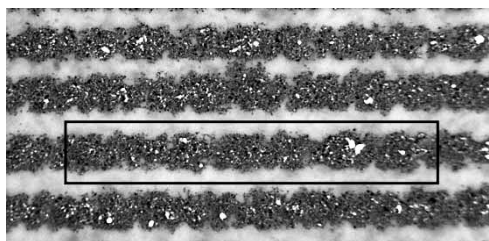


Figure 2: Evaluation of thinnest printable line on substrate APCO

### 3.2 Electrical properties of printed layers

RLC Bridge Motech MT 4090 LCR Meter with devices, which contain contact points for two-point and four-point method of measurement, was used for measurements of electrical properties of printed layers [3,4]. Relative electrical properties comparison of the printed pattern HF1 in dependence on printing substrate was performed with the aid of two-point method (Table 4). Resistivity of square elements V1 a V2 in dependence on printing substrate was performed with the aid of four-point Van der Pauw's method (Table 5).

Table 4: Resistance of HF1 pattern depending on printing substrate

Printing substrate	APCO	Melinex	Pretex	Synaps
Resistance [ $\Omega$ ]	223.5	239.8	235.1	169.1

Table 5: Resistivity of V1, V2 patterns depending on printing substrate

Printing substrate	APCO	Melinex	Pretex	Synaps
Resistivity [ $\Omega/\text{sq}$ at 25,4 $\mu\text{m}$ ]	0.010	0.007	0.025	0.012

## 4. Discussion

The characteristic properties of substrate (roughness, surface tension, porosity, e.g.) exert an influence on variation of the thickness, quality of the printed ink layers and electrical properties of printed layers [5]. Estimated properties of used substrates are shown in Table 1.

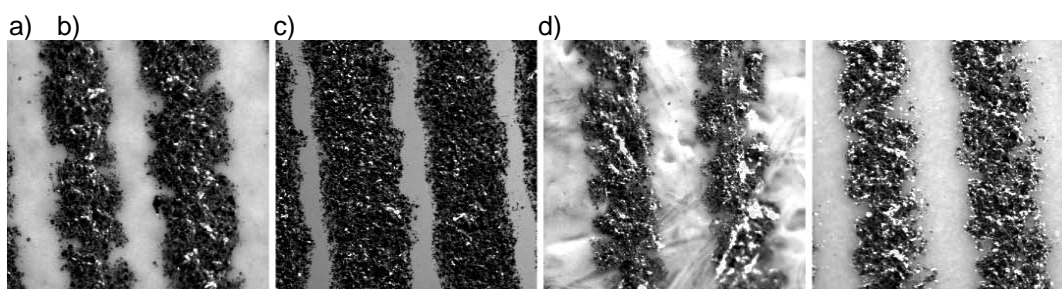
#### 4.1 Image analysis

The porosity and roughness of substrate typically increase the absorption of the ink inside the structure of substrates, which make differences in the thickness, roughness and quality of the ink layers. The quality of printed layers (e.g. rate by homogeneity of ink layers, homogeneity of line width, edge quality) is affected by the surface tension as well. Table 1 shows that the substrate Melinex had smoother surface compared to other substrates, together with relatively high surface tension caused very good spreading of conductive ink on the surface of substrate as shown Figure 3. For these reasons, prints by the substrate Melinex had very smooth edges with small variation of line width that is apparent from the standard deviation of line width (Table 3). On the other side, smooth surface of substrate Melinex and relatively high surface tension resulted in low desirable print resolution; especially width of the thinnest printable line perpendicularly to print direction were wider than for other substrates (Table 3).

The most consistent results for both print directions were obtained for substrate APCO. The substrate APCO as a smooth coated paper has very low value of roughness and also relatively high surface tension. These properties allowed to print lines with resolution 160 lpi towards to print direction and 149 lpi for lines oriented perpendicularly to print direction. The high surface tension of the substrate led to good surface wetting of conductive ink.

The worse quality of printed patterns was found for prints on substrate Pretex. This synthetic paper is characterized by high roughness, high porosity and relative low surface tension. High roughness of substrates (visible fibers of substrate on microscopy images) caused bad spreading ink on the surface of substrate and conductive ink could penetrate to structure of substrate. Therefore, the defective lines with non-uniform edges formed on this substrate. From these reasons, prints on this substrate had lower print resolution. Mainly, prints printed towards to print direction on substrate Pretex had worse print resolution compared to other substrates. Usually, prints printed towards to print direction had better resolution. This fact is practicable from the principle of screen printing. Ink is transferred on printing substrate squeezing through screen by scraper. When the printed line is in parallel orientation to print direction (direction of squeegee motion), the line edges are smoother than in the perpendicular direction. The pattern is better connected and contains fewer defects. Hence, it is possible to print thinner lines oriented in print direction and printed pattern orientated in print direction that has higher print resolution. By the substrate Pretex, the higher printing resolution in print direction was not achieved, as in case of the other substrates. This could be caused by the orientation of substrate fibers which were oriented perpendicularly to print direction. These fibers made barrier for ink spreading in print direction and therefore, the lines oriented in the same direction as a substrate fibers, had fewer defects.

Substrate Synaps has closed structure and surface coating with low surface tension. Therefore the conductive ink did not penetrate to the structure of substrate. Due to a low surface tension, the ink did not spread well on the surface of substrate.



*Figure 3: Prints of lines with composite ink on different substrates –  
a) APCO, b) Melinex, c) Pretex, d) Synaps*

#### 4.2 Electrical properties of printed layers

The electrical properties of printed patterns were characterized by resistance measurement as a function of printing substrate. Electrical resistance for pattern HF1 was lower for substrate APCO than for substrates Melinex and Pretex. Even lower resistance exhibited pattern HF1 printed on substrate Synaps (probably due to the surface properties of the substrate). The worse electrical properties of ink layers were found for prints on substrate Pretex. This synthetic paper is characterized by the high roughness, high porosity and relative low surface tension.

These properties caused that conductive ink penetrated to the structure of substrate. From this reason, the lack of the conductive material on the surface of the substrate causes the higher amount of defects of patterns, resulting in higher resistivity. The lowest resistance was measured by the substrate Synaps and lowest resistivity for the substrate Melinex.

## 5. Conclusions

Experimentally, it was verified that the print quality and electrical properties of printed conductive layers are dependent on properties of printing substrates.

## 6. Acknowledgement

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## 7. Literature

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## INTERNET SURVEYS AS A TOOL FOR DATA GATHERING IN SCIENTIFIC RESEARCH

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**Abstract:** Development of internet technologies and wide range of users offers new possibilities for reaching participants in scientific research. While commercial sector is using internet as a medium for conducting all kinds of researches and data gathering government and scientific institutions are not using all its potential. That potential being ability to access big number of people in a short time, data gathered is already in electronic form so it's easier to process it further statistically etc. This paper has a goal to research the possibilities for using internet as a medium for conducting scientific research and data gathering. This is accomplished by short overlook of available technologies and research in to a practical usage of those technologies. As a result of a research practical flash based web application was made and used for researches concerning color perception. Research conducted by the internet showed a possibility of quick access to large number of research subjects and possibilities for access the people during whole day, which is not possible without considerable trouble if conventional survey is used. This kind of data gathering could be used for wide variety of researches especially in graphical engineering, design and other human oriented fields.

**Key words:** Internet, survey, research, data gathering.

### 1. Introduction

With development of internet technologies in the last ten years great number of people became available for marketing surveys and data gathering for scientific research in easier way. Person who uses computer became available for data gathering during work hours. Majority of people who use computer for work also use computers at home as a communication and entertainment center. Computer became standard part of a household thus making people available whole day. Internet survey applications are making possible data gathering involving large number of participants, studies can be conducted during greater periods of time and subjects are available during whole day. As a result studies can be carried in more precise manner and it's possible to create wide variety of surveys during work hours or to contact participant at home without disturbing them much.

First decade of 21. century considerably changed the way that data is gathered for marketing surveys. According to ESOMAR in 2001. 20% of all marketing researches conducted in USA were internet surveys. In 2007. the percentage of internet surveys grow to 40% and since then growth is not that rapid but it is constant (Couper, 2008). Government and scientific research did not adopt internet surveys in that percentage, but there is a considerable growth specially as the supplement to conventional data gathering methods. Usage of internet survey in USA is a good representation of things to come in rest of the world where internet surveys are not used as much.

Advantages of internet surveys are speed, lower cost of conducting surveys, easier data processing, availability of subjects (place and time), etc. Beside these advantages there are some constraints. Availability of internet varies for different demographic groups and there are differences amongst people who use internet and those who don't inside one demographic group. Internet survey typically have problems with low response rate.

Having in mind potentials of internet applications for data gathering and problems that follow there is obvious need for careful design of such applications. Designing an internet survey is complex task of combining web technologies, graphic design data processing, etc. The design of internet survey should take in consideration the target group, purpose of the survey, topic of the survey, quality of gathered data, whether the internet survey is only means of data gathering or is it a supplement to other methods is the sole medium of data collection, etc.

### 2. Internet survey

Internet surveys have much in common with other methods of survey data gathering, but the design challenges are unique. There is much that can be applied from other methods of survey data gathering there are still some unique features of internet surveys. Web surveys are self-

administered, Web surveys are computerized, Web surveys are interactive, Web surveys are distributed, Web surveys are rich visual (graphical and multimedia) tools.

Internet surveys can be divided in two groups on terms where are they executed, so there are the surveys that execute on a respondent's machine (client-side) and those that execute on the survey organization's Web server (server-side). (Couper, 2008)

Client-side survey are mainly e-mail surveys. The survey form is sent to survey participant as an e-mail attachment. Survey participant answer the survey questions entering responses using a word processor and sends reply by the e-mail, the answers are transmitted back to the survey organization. E-mail surveys are popular and simple way of conducting internet surveys, but there are some technical limitations and security concerns. This way of conducting survey can provide two way communication between the survey participant and the survey organization, but the transmission of information back and forth is not happening in real time (Couper, Blair, and Triplett, 1999; Schaefer and Dillman, 1998).

Server-side applications run on a web server, survey participant are completing the survey while connected to the Internet through a browser, with the answers being transmitted to the server by pressing the button (submit, next...) on a HTML page. Server application has a possibility to choose next question according to last given answer in real time. Main distinction between these two approaches is whether the Internet connection is active while the respondent is completing the survey and if the flow of information is happening in real time. Server-side applications are dominant form of Internet surveys today. Special case of server-side application are Flash and Java (client-side scripts) based applications, this kind of applications are running on survey participants computer but data is transferred to server in a real time.

When conducting the internet survey participants are no longer restricted to computer users. Internet is now available on other devices also, such as mobile phones, palmtops, WebTV, etc. Wireless networks are also contributing to availability of participants. Number of potential survey participants is greater if survey is adapted to technical abilities of these devices and protocols they use.

## 2.1 Internet survey principles and technology

Typical process of conducting internet survey starts with sending an invitation to potential participant asking him or her to take part in the survey, usually invitation is sent by e-mail and now often in other form of electronic messages such as SMS, MMS, etc. E-mail message with an textual invitation contains the link that leads to web page that contains survey. Participant by clicking on the link opens web browser and sends a request via the Internet using hypertext transfer protocol (HTTP) to the web server to deliver an HTML page. This is usual way of communication via hypertext transfer protocol but web surveys are more complex for two reasons: data needs to be sent from the client to the server, and the data needs to be stored or processed on the server, this is shown in Figure 1.

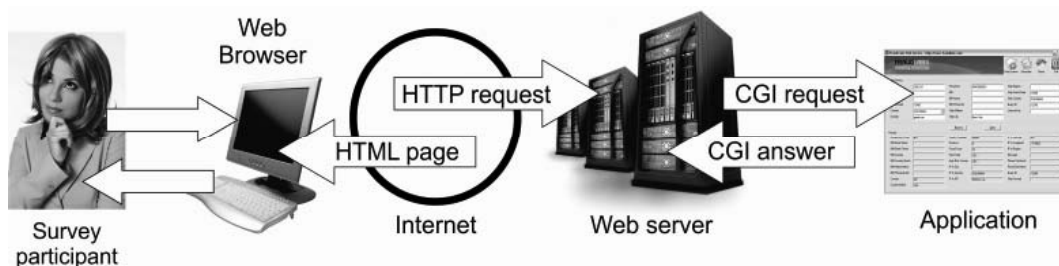


Figure 1: Usual data transfer in internet surveys

HTML forms are rather used than regular web pages to send data. Forms are special types of Web pages that permit the input of information using form elements or widgets available in HTML forms, like radio buttons, check boxes, drop boxes or select lists, text fields and text areas.

To deal with the data storage and data processing on the server, Common Gateway Interface (CGI) scripts are used. CGI is a standard for interfacing external applications with information servers. CGI program is executed in real time, so it can output dynamic information. When the Web server receives the data from a form, it transfers this information to another application – for example, a database, a program, or a survey application – which acts on that

information and sends a message back to the Web server regarding the next action to take. CGI program can do different actions, from simply storing the submitted information in a database, to processing complex algorithms to determine the completeness and consistency of responses, to generating new HTML forms dynamically based on the answers submitted, verifying that the survey has not already been completed by that respondent, permitting respondents to resume where they left off, generating automatic e-mail invitations and reminders. CGI scripts can be written in several different programming languages – Perl, ColdFusion, ASP, PHP, etc.

HTML is a markup language designed initially for the presentation of information, *not* as an interactive data collection or entry tool. An alternative is to build the dynamic elements directly into the Web form, using client-side scripts. Client-side scripts are known as dynamic HTML, or DHTML. The most common client-side scripting language in use is JavaScript, which is supported on most browsers. The use of client-side scripts permits interactive enhancements to internet surveys. Scripts can be of two kinds. First, those that load automatically when the Web page is loaded can do a variety of tasks in the background, some very useful to the survey researcher. For example to detect the capabilities of the participant's browser, to collect a variety of metadata such as timing data, the order of clicks, etc. (Couper, 2005; Heerwegh, 2003). The second kind of script loads or executes in response to a user action such as onclick, onmouseover, onkeypress, onsubmit, etc. Both types of scripts produce a set of actions – which may or may not be visible to the respondent – without sending any information to the server. In browsers that do not have JavaScript activated, the script simply is not executed, and the rest of the HTML form is unaffected. Scripts are not the only way one can add interactivity to a Web form. Application Adobe Flash is increasingly being used for graphical interactivity.

## 2.2 Expanding potential participants base

Computer platform, operating system and web browser used by the potential survey participant can limit interpretation of certain scripts and as a result of diminish number of survey participants. A number of different Web sites report browser statistics, still, they can serve as a rough guide. For example, Schwarz and Reips conducted a Web-based experiment in Germany in which half the subjects were assigned to a JavaScript version and half to a standard CGI (server-based) version. The completion rates (completes among starts) were significantly different: 49.8% for the JavaScript version and 63.2% for the CGI version (Schwarz and Reips, 2001). According to research conducted by Millward Brown survey company in December 2009, 99% of web browsers is able to play flash files and 77% of web browsers are able to interpret java scripts as shown in Figure 1. ([http://www.adobe.com/products/player\\_census/flashplayer/](http://www.adobe.com/products/player_census/flashplayer/)). Beside the question is the flash player installed on participants web browser survey organizer should have in mind which version of flash player is best suited for region that the survey is going to be conducted in. Research on a usage of flash player version conducted in December 2009. ([http://www.adobe.com/products/player\\_census/flashplayer/version\\_penetration.html](http://www.adobe.com/products/player_census/flashplayer/version_penetration.html)) shows that in Europe 99,1 computer users have flash player version 8 and lower version, while 98,8 have flash player version 9 and 95.6 have flash player version 10 installed, as shown in table 1.

*Table 1: Usage of Flash player versions 8 and older, 9 and 10*

	Flash Player 8 and older	Flash Player 9	Flash Player 10
USA/Canada	99.0%	99.0%	94.2%
Europe	99.1%	98.8%	95.6%
Japan	98.0%	97.7%	93.4%
Australia	98.9%	98.6%	94.3%
New markets	98.2%	98.0%	92.7%

It is particularly important to ensure that the scripts work the same way across multiple platforms and browsers. Despite the intention of being platform independent, there are variants of JavaScript that necessitate testing on different machines. Flash based surveys are executable on most platforms, although there are some problems with apple operating systems and mobile devices due to marketing wars.



### 3. Practical application of internet survey in scientific research

Internet survey is used to collect data for research on changes in inclination towards the color during the period of one day. The purpose of research is to determine changes in inclination towards the color during the period of one day which means the survey participant must be available for questioning three times during the day. By using standard survey methods survey participant and survey organizer would have to meet three times in order to fill survey. Time and resource saving is obvious and there is added benefit of participant choosing the time for survey at his own convenience thus paying more attention to questions.

Data gathering and storage is done completely by the web application, processing is later done by Microsoft excel application using collected data. Flash with addition of Action Script programming language offers wide variety of possibilities for multimedia communication with survey participants. Flash application is used to present survey questions and gather data while PHP script is used to storage collected data for further processing as shown in Figure 2. Ideally XML language should be used to storage the collected data but that is not mail goal of this paper.

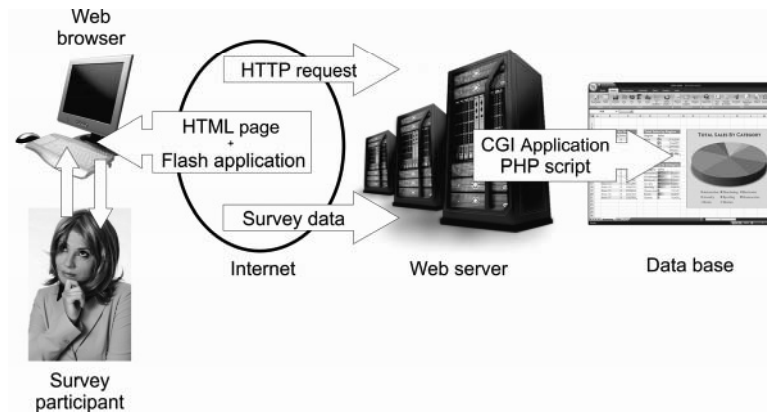


Figure 2: Data transfer in Flash based internet survey

Collecting data for research on changes in inclination towards the color during the period of one day requires from participant in first step to fill out information's about himself, than to chose one of primary and secondary colors offered and then one of color variations according to HSB parameters (Hue, Saturation, Brightness) as shown in algorithm, Figure 3.

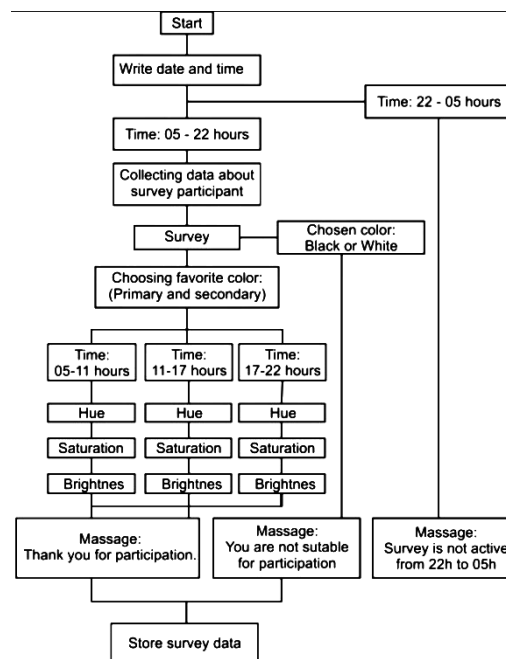


Figure 3: Flash based internet survey algorithm

### 3.1 Survey design

First application has to be able to determine what time it is because for this research one day is divided in to four intervals. it is possible to do the survey in three of those four intervals from 05.00 until 11.00 o'clock, from 11.00 until 17.00 o'clock and from 17.00 until 22.00 o'clock. From 22.00 until 05.00 survey is not in operation, because the research in question is not interested in data collection for that period. Participant is asked to answer the survey three times during the day in different part of the day. For each interval different layout of the color variations is made so the participant is not able to remember position of previously chosen color or variation of color.

First screen that survey participant is interacting with is questioner about participant name, occupation, origin etc. These information's are divided in two pars mandatory information's important for research and information's that are not important for research and aren't mandatory, Figure 4.

After collecting data about participant application is directing participant to first question of the survey. The participant is asked to choose most pleasant color from bunch of primary and secondary colors Figure 5.

A screenshot of a web browser displaying a questionnaire form. The form is titled 'DEPARTMAN ZA GRAFIČKO INŽENJERSTVO I DIZAJN' and 'Fakultet tehniških nauk / Univerzitet Novi Sad'. It contains fields for 'Ime' (Name), 'Prezime' (Surname), 'e-mail', 'Ad', 'Kod pošte' (Postal code), 'Opština' (Municipality), 'Zemlja' (Country), 'Radno vreme' (Working hours), 'Pol' (Gender), and 'Urad' (Official). There are also checkboxes for 'Molimo Vas, popunite molimo podatke' and 'Pobliže se sa svojim odgovorima na pitanja u ovom i sledećem pitanju'. The form is branded with 'GRID' and 'AVB' logos.

Figure 4: Questioner about participant



Figure 5: Survey interface

Participants who chose black or white color are excluded from further questioning as unsuitable for this research with "thank you for participation" message. Other participants are directed on to next stage of survey, the participant chooses one of eleven hue color variation as most pleasant, Figure 6.



Figure 6: Color variation of Hue property

In the next step of survey participants can chose one of eleven saturation color variation as most pleasant, Figure 7.



Figure 7: Color variation of saturation property

Last survey question offers the participants choice of eleven color variations of brightness property, Figure 8.



Figure 8: Color variation of brightness property

At the end of survey participants are thanked for taking the survey and reminded that they need to fill the survey in other intervals until all of them are filled and data is complete, Figure 8. Data is automatically stored when last page loads. PHP script is used to transfer data to storage file.



Figure 8: Final screen of survey

#### 4. Conclusions

Internet surveys can be powerful tool for scientific data gathering in human oriented scientific fields. They can be used for scientific data gathering by them self or as a supplement to usual data gathering techniques. Providing pleasant experience while participating in survey is of greatest importance and can significantly affect number of participants. Interface design is very important element of internet survey creation process. Choosing adequate technologies for the task and assuring wide availability of survey is crucial for success of survey. Adobe flash based application are suitable for the task of creating rich multimedia content adequate for conducting surveys in the scientific field of graphical engineering and design, as shown in practical example.

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# READABILITY WEAKENING OF PASSIVE RFID UHF TAGS

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**Abstract:** Readability of passive RFID fundamentally depends on the tag empowering. The minimum required power, usually referred to as sensitivity, depends on the chip and antenna manufacturing. The sensitivity affects the readability but it is not the sole determinant of readability. The readability of RFID comprises a number of factors, particularly in the UHF band. This paper proposes a classification of tag readability weakening factors and measurement methods to quantify the factors. It is shown that tag performance change at the attachment may affect the readability. A tag probe, a power measurement antenna at the position of tag attachment, can monitor essential data to comprehend the situation and establish a countermeasure to improve the tag readability. The operating environment, involving reader antenna positions and standing waves result from the multipath fading, is another important factor for the readability. The characteristics of the environment could be also grasped by using the tag probe.

**Keywords:** UHF RFID, readability, power measurement

## 1. Introduction

UHF band RFID has been gathering significant industrial and technical interest. Technical standardization and local radio regulations have been developed in a rapid manner [1, 2]. The fundamental feature of UHF RFID resides in the long range and simultaneous multi-read of the target tags. This enables an automatic inspection or inventory at, for example, a gate of warehouse without unpacking. For the industrial adoption of UHF RFID a sufficient readability from remote, like 3m, reader is indispensable. In a practical reading environment, however, the readability could be easily deteriorated. Author has been extensively investigated on such readability weakening [3]. This paper outlines the experiments and obtained results with the classification of major factors that influence the tag readability. In previous researches, author had revealed that the fundamental factor that dictates the tag readability is empowering of tags from reader [4]. This is particularly true where can be neglected the interference from other readers. The experiment, therefore, is basically a reader power measurement at the position of tags using a small antenna that is referred to as a tag probe.

In Section 2, the validity examination of power measurement to assess the readability is presented. In Section 3, the measurement of fundamental characteristics of tag probe and the readability performance of tagged objects measured in the anechoic chamber are presented. The measured objects are medical ampoules contained in cardboard boxes. Measurements in a typical warehouse environment are also reported.

## 2. Preparation

### 2.1 Tag probe

The actual measurement of the received power at a tag position is done by a small folded dipole antenna, referred to as tag probe hereafter, shown in Fig.1. The antenna gain Figure 1. Tag probe of the tag probe in and near the Japan UHF RFID frequency band, 952-954MHz, is approximately -3.5dBi. The antenna pattern of tag probe is of the typical dipole antenna i.e.; nulls in the end-fire directions.

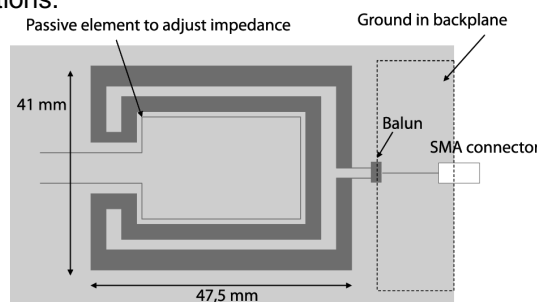


Figure 1. Tag probe

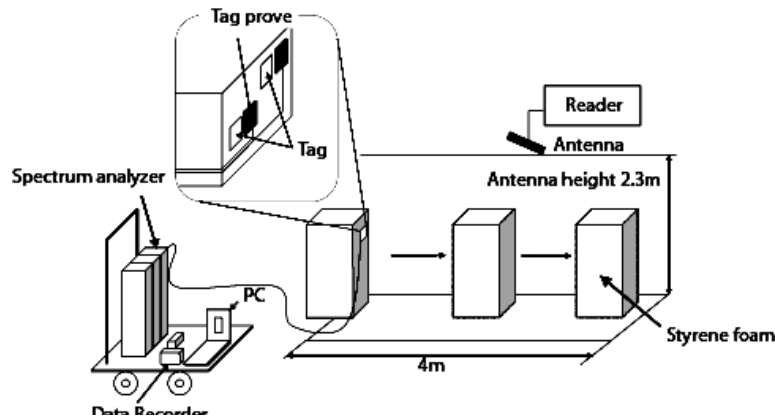


Figure 2. Calibration experiment

It should be noted that the antenna impedance and the frequency characteristics of the tag probe and the existing tags are different, naturally. Also, the absolute power required by the tag chip could not be identified with tag probe. The measurements provided by tag probe could provide the relative readability rather than absolute so that the calibration between the readability and the measured power, in the following subsection, is needed.

## 2.2 Tag readability and tag powering

The readability and the measured power are calibrated by an experiment in an anechoic chamber. The experimental setup is shown in Fig.2. The ground of the anechoic chamber was covered with a RF absorbing material, which is also required to provide a smooth surface for the cart to move. The RF absorbing performance of the floor, therefore, is not sufficient. In the experiment, tag probes and tags are attached to styrene foam side by side with in two different heights, 50cm and 120cm. The reader emission is measured by tag probes while recording the readability of tag in accordance with the position of styrene foam. The results are shown in Fig.3. It is shown that there is clear fading because of the imperfect absorbance of the ground floor. The measured power exhibits field nulls at 40cm and 150cm, regardless the position of the measurement. The lower tag receives smaller power since the path loss from the reader to the lower tag is larger than that of higher tag. In the figure, circles denote the tag at the distance can be read by reader. It is shown that the tag could be read if the received power measured by tag probe is larger approximately than above -8dBm, with an exception at the field null at about 40cm.

## 3. Experiments

Experiments were performed in an anechoic chamber to understand the fundamental performance of tags when they are attached to target objects and a warehouse to measure principally the influence of setup and environments.

### 3.1 Fundamental performance of tags attached to objects

The readability of a cardboard case containing 25 small boxes each for 10 medical ampoules (filled with pure water if not empty) is investigated by measuring the radiation power by the tag probe. The tag probe is attached to the outside of the case. Also measured was the case where tags are attached also to inner small boxes to measure the influence of the cascaded tagging. Figure 4 shows the case and the inner boxes. In the experiment, it was measured the antenna pattern of the tag probe at the attachment to understand the antenna gain weakening and pattern changes. The tag probe antenna pattern when the ampoules are filled and empty are shown in Fig.5 with the original tag probe alone pattern as the reference. The radar chart represents the received signal level in decibel. Only the relative values are our interest here. It is shown that when the tag probe is attached to the case, the tag antenna gain decreases as much as 2dB (shown in the 0 degree direction) and the highest directivity emerge in the direction of 180 degree. Since 0 degree represents the orientation where the tag probe is directly facing the transmitting antenna, the result can be interpreted such that the tag probe antenna has the highest directivity in the direction where the radio wave penetrates the case. This characteristics is somewhat enhanced when the ampoule is filled with water. In the case,

the tag probe directivity in the 180 degree direction exceeds the original tag gain by 2dB. As the reverse effect of the tag probe directivity, two nulls appear in the directions of approximately  $\pm 130$  degree. It is revealed that tag attachment may entail not only the tag antenna gain weakening but also the antenna pattern change. The fundamental mechanism of the pattern change is the interaction between the tag (or tag probe) and the attached object, which has dielectric characteristics to some extent.

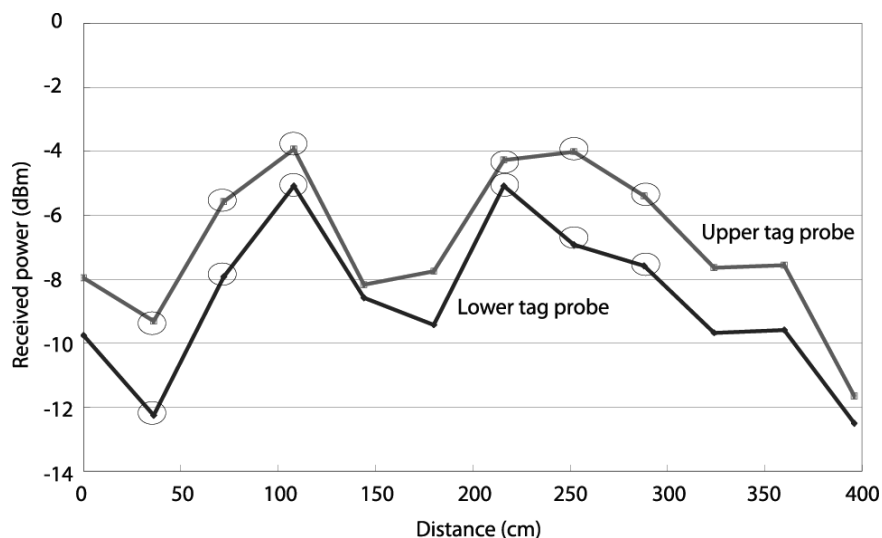


Figure 3. Calibration result



Figure 4. Package of medical ampoules and tag probe attachment

When tags are attached to inner boxes containing filled ampoules, the antenna pattern of the tag probe is shown in Fig.6. The tag probe is attached at the same location, i.e. outside the case. It is interesting to observe that the antenna directivity is reverse to what has been observed in the case where there are no inner tags. The highest antenna gain is observed in the direction of 0 degree while the antenna gain in the direction of 180 degree significantly is degraded by 10dB. This is an interaction or mutual impedance between tag probe and tag antenna. The tag antennas act as passive elements to tag probe.

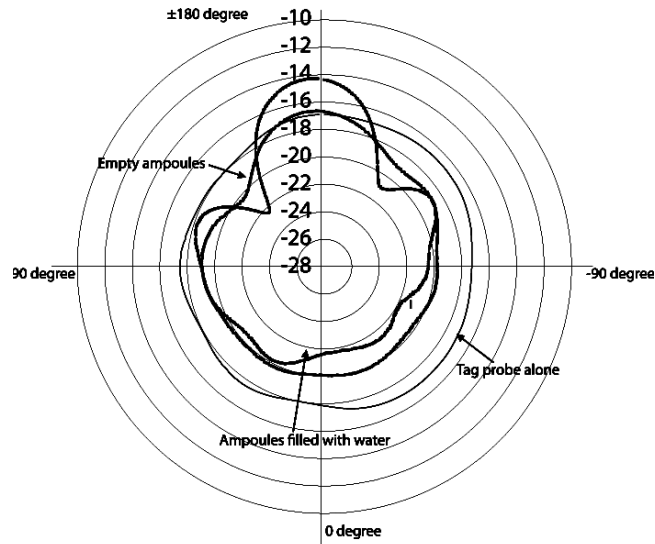


Figure 5. Tag probe antenna pattern

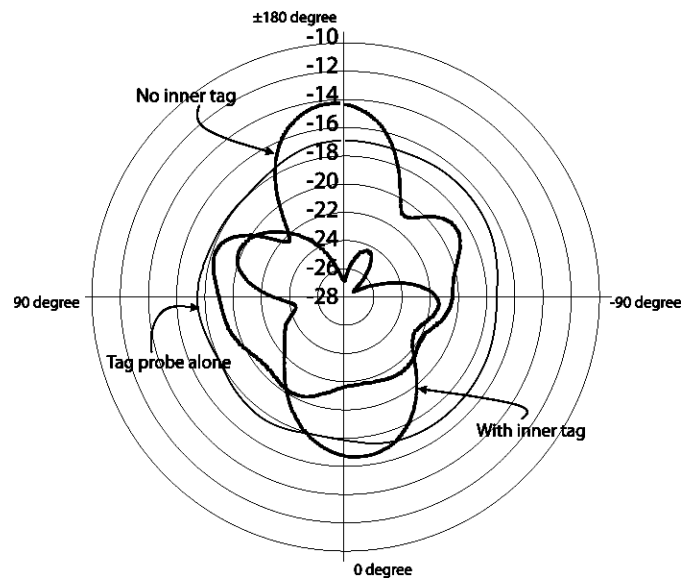


Figure 6. Antenna pattern when tags are attached inner boxes

### 3.2 Performance of tags attached to objects in warehouse environment

Forty cases containing filled ampoules are piled up on a hand pallet truck as shown in Fig.7 and are inventoried in a gate in a warehouse (Fig.8). The reader radiates from the upper antenna with EIRP 36dBm. Tags are attached to each of 40 cases. Tags attached to the cases are the same tags that are used in the calibration described in Subsection 3.1. The calibration revealed that a tag attached to the case can be read if the power measured with tag probe is above -8dBm. The attachment position of tags was determined a priori by the owner in this case. Most of the 40 tags can be successfully read while several tags suffer poor readability. The objective in this experiment is identifying the determinant of the poor readability in a particular position, tag 866. The power level of the position of tag 866, which could not be read once, out of two trials, and the below and above tags, 85E7 and 7EA respectively, are measured by using tag probe. The 85E7 and 7EA tags, below and above of 866 tag, are stably read. The measured power with an analytical power deduced from the reader EIRP, tag antenna gain and gain weakening due to attachment, which is explained in Subsection 3.1, and cable loss are shown in Fig.9. A two path model is established considering the gate geometry, reader antenna pattern, polarization and the cable loss. The analytical power presumes Rice fading with one reflection from the floor. The measurement data above 4m involves the influence of the person who pushed the cart. It is shown that the tag sensitivity -8dBm is reached when and only when the distance is approximately 2.5m. The measured power agrees

fairly with the analytical power while the measured values indicate fading due to multipaths [3]. This explains the low readability of tag 866. It should be the effect of reflection, essentially from the floor. It is also shown that stable power supply is available for tag 85E7, which is placed below tag 866, although the peak power is slightly smaller than that of tag 866. This short interval of the power fluctuation at tag 866 stems from the geometry of the reflection. This may provide a basic understanding on the readability, yet, the satisfactory agreement with the measured power and simulation definitely need further investigation.



Figure 7. Multiple cases implementation



Figure 8. Warehouse environment

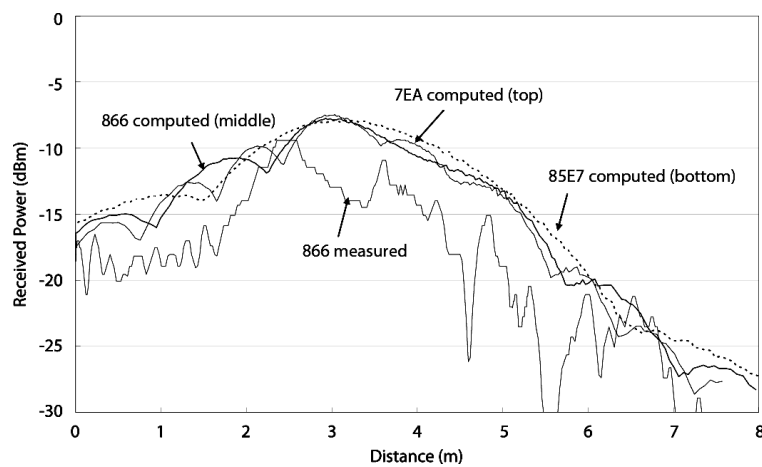


Figure 9. Available power at tag positions



#### 4. Conclusion and further study

Tag readability, particularly in UHF RFID, relates to a number of factors. It is essential to classify the tag readability deterioration factors and establish methods to quantify them. Analytical and experimental investigation reveals that the factors could be classified as tag performance, tag attachment and reader setup and environment and shows that power measurement using a tag probe could provide quantified indexes to the factors. Since this study only focus on the static inventory, further study will be needed to illuminate the dynamic inventory question, involving a moving object and multiple readings. Interference between RFID readers and with other wireless equipment is another important factor that may dictate the readability.

#### 5. Acknowledgement

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## CORRELATION OF QUALITY OF HI FI DIGITAL PHOTO PRINTING TECHNOLOGIES

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**Abstract:** Digital photography is realized through various printing techniques today. Among the dominant printing techniques today are actual techniques realized with halftone printing and those that achieve print through continuous tones transition. Among the halftone techniques prevalent are inkjet Hi Fi high-resolution techniques in which the print is realized on RC substrates with special reception layer. In this paper photo prints generated through bubble jet printing with different Hi Fi solutions on the same, appropriate, substrates are colorimetric and visually estimated. For testing motif, which consists of the standard color checker and black and white and color portrait photographs, was defined.

**Key words:** Bubble jet, photo printing, Hi Fi printing

### 1. Introduction

Hardcopies of digital photographs are one of the main interests in the professional photography. Today, there is a number of different technologies that can be used to realize photographs taken in digital photo system. Dominant photo printing techniques today realize the image with halftone printing or through continuous tones transition. Among the halftone techniques prevalent are ink jet Hi Fi high-resolution techniques in which the print is realized on RC substrates with the special reception layer. Ink jet technology is typical representative of digital printing technique in which digital data come to printer, which creates final printing direct on the substrate without previous forming of master image, which is then transferred on the substrate [1]. Generally, two principles of ink jet are known - continuous and "drop on demand" (DOD) ink jet. Principle of continuous ink jet is following: liquid toner - "ink" is, by means of piezoelectric signal, pressed out through the nozzle and, due to high frequency tightening and spreading of piezoelectric element, transforms in a series of drops. Drops of ink are then electrically charging depending on digital signal and come to deflector, which, in the dependence of the charge, directs them on the substrate or in gutter, which excess of ink returns in the container. As it is matter of complicate system in which amount of ink is lost, today this system is practically not used for digital photography printing, but it is interesting in the area of high format poster printing in which, for those needs, quality reproduction in the resolution of 300 dpi and higher can be attained [2]. "Drop on demand" (DOD) ink jet printing technology is based on press out of ink drops on the substrate on places where ink should be placed to form image (photograph). Today, as the dominant digital photographs printing technique two principle of DOD ink jet printing are used - thermal - "bubble jet" and piezoelectric. DOD ink jet printers are printing photographs in continuous ink deposit, meaning that they can't create real tonal image, but an image is printed as halftone one. Modern ink jet photo printers in the combination with adequate the algorithm of screening produce the hardcopies that are visually expressed as prints with the continuous tonal transit.

### 2. Theoretical

#### 2.1 Hi Fi Ink Jet Photo Printing

Printing of color photographs with ink jet printers is in the idea based on subtractive color synthesis and printing with cyan, magenta and yellow ink. As in other halftone printing of digital color photographs, in ink jet printers besides these, primer colors have to print key black. Possibility of printing with black ink only could be pointed even as a potential advantage of these printers in printing of black and white photographs due to possibility of achieving neutral tones in all optical coverage of area [3]. As in digital photo printing exist the problems of printing bright tones and tones of human skin, photo ink jet printers use extra printing inks - most often it results in six color CCMMYK printing (besides standard four (CMYK - cyan, magenta, yellow, key black), also light cyan and light magenta are printed), but today there is a number of another

solutions such as printing CMYKK (CMYK + "deep black"), CMYKRGB (CMYK + red, green, blue) etc. Those solutions are called Hi Fi (High Fidelity) photo printing.

## 2.2 Bubble jet photo printing

Bubble jet (thermal ink jet) is the oldest DOD ink jet technology and is present on market since 1980s – and now it is one of the most used techniques of digital photo printing. Bubble jet technology is based on following principle: ink is in the container from which is led to chamber in printer "head". There is a heater in the chamber, which gets electrical impulse leading to warming (boiling) of ink. It results in creation of steam bubble that spreads and by the pressure through the nozzle presses out ink on the substrate. After that, cooling of the heater follows which results in disappearing of steam bubbles and creation of sub pressure that make possible coming of new amount of ink in the chamber. Beside standard requires, for ink jet ink, bubble jet ink has to be resistant on high temperature. [2]

## 2.3 Materials for ink jet photo printing

Photo ink jet techniques are techniques in which choice of substrate essentially influences on the quality and characteristics of printed photographs. Although, as in other printing techniques, choice of materials is strictly limited with possible (allowed) combination defined by producer [4], in the difference of concurrent sublimation printing technique, photographer-author has at disposal a wide range of substrates that can be used in the combination with ink of concrete printer. Ink jet ink can contain as substance that gives color one kind of dye or pigment or more of them, and they make 5-20% of ink structure. Size of the colorant essentially influence on color saturation of prints, transparency and lightfastness, and preservation of printer head so the typical particle size is about 1/20 of ink jet printer nozzle diameter. Molecules of dyes are generally smaller than molecules of pigments and ink jet inks based on dye solution in binder are more transparent in the relation with those based on dispersion of pigments in binder.

For quality photo printing, in consideration can come only defined combination of ink and substrate. [5, 6]

As the most often base of substrate for photo ink jet printing RC (resin coated) papers are used. RC paper basis is on both sides coated with polyetilen ("plastificated" - "plastificated papers") with what absorption of humidity is prevented. That ensure flat printouts (substrate doesn't became undulated), but, in the first place, gives ink jet printouts that visually and on touch relates to "classic" ("chemical") photography. The main printing characteristics of RC ink jet photo paper are defined with so-called receptor layer (Figure 1). Receptor layer ensures increased contrast of hardcopies, higher optical densities, larger gamut, increases resistance of hardcopy on water and lightfastness. Active part of receptor layer consists of binding medium and absorbent of humidity. Medium for colorant binding has to be of such manner to accept, and not to reject, colorant and depends on character of colorant. (11)

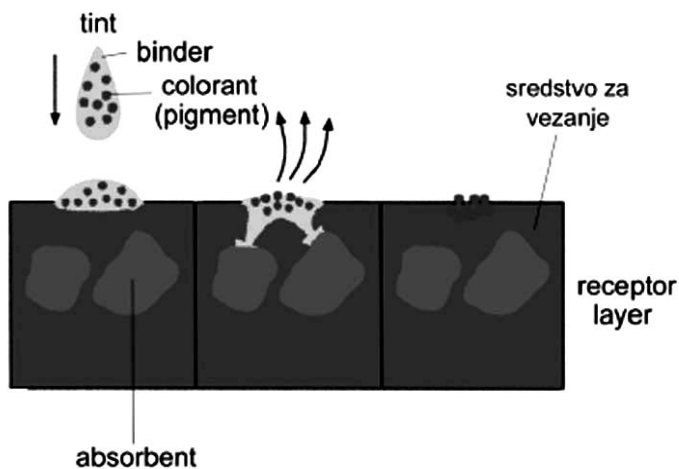


Figure 1 Receptor layer and ink jet ink

### 3. Experimental

Test motif consisting of standard Munsell Color X-rite Color Checker and black and white and color portrait photographs is created and printed on two bubble jet photo printers. One printer uses CMYKK (CMYK + deep black) and another CCMMYRGBKKKK (CMYK + light cyan and magenta, red, green, blue and additional 3 blacks/grays) technology. Printing substrate was RC photo paper with receptor layer suitable for both printers.

L, a, b values of the printed Color Checker were measured with X-rite digital Swatchbook spectrophotometer, color differences ( $\Delta E_{00}$ ) were calculated and CIE ab diagrams were defined. Printed portrait photographs were estimated by 10 professional photographers and evaluated with marks 1 – 5.

### 4. Results

CIE ab diagram for standard and printed Munsell Color X-rite Color Checker are shown in Figure 2.

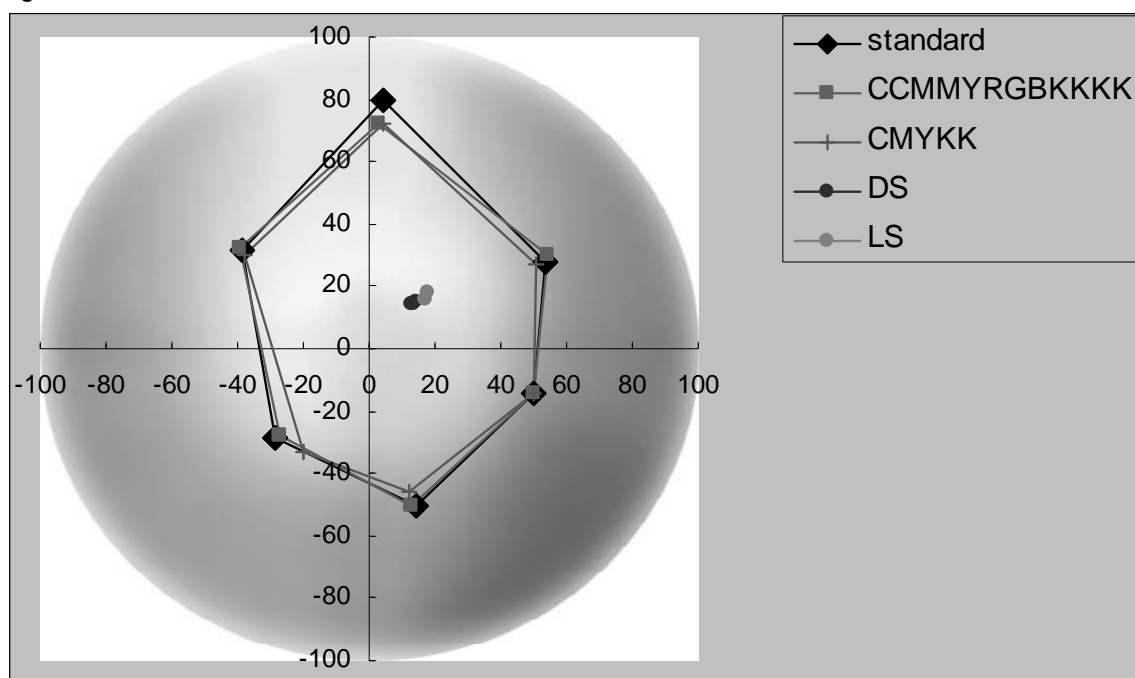


Figure 2 CIE ab diagrams for standard and printed Munsell Color X-rite Color Checker

Color differences and L values for standard and printed Munsell Color X-rite Color Checker are shown in Table 1.

Table 1: Color differences and L values

	R	G	B	C	M	Y	LS	DS
L(standard)	48,67	61,34	27,48	55,50	56,51	83,25	68,07	42,39
L(CCMMYRGBKKKK)	46,11	62,02	56,58	56,98	58,01	81,07	69,00	43,97
L(CMYKK)	44,12	60,01	26,10	57,02	58,00	81,06	67,02	39,99
$\Delta E$ (standard-CCMMYRGBKKKK)	2,76	0,69	1,34	1,56	1,39	2,38	1,30	1,55
$\Delta E$ (standard-CMYKK)	4,55	1,23	1,48	5,21	1,39	2,34	1,38	2,22

Table 2 shows the results of visual estimations of printed portrait photographs.

*Table 2 Results o visual estimations*

	B&W	COLOR
CCMMYRGBKKKK	4,6	4,7
CMYKK	4,6	4,8

## 5. Discussion and conclusion

The results indicate that the Hi Fi bubble jet technology largely satisfy the demands of high-quality photo printing. Obtained from the ab CIE diagram (Figure 2), it is obvious that both observed Hi Fi printing result with photographs with gamut that can be compared with the standard input gamut. CMYKK printing at this point shows somewhat larger deviations in the cyan-blue area, which is confirmed by the color differences as well (Table 1). The color difference for CMYKK print is larger for cyan and red (Table 1), but for both prints for the observed colors color differences are acceptable for an open (photo) system.

High visual estimations for color portrait photograph in both prints (Table 2) can be confirmed by measuring - good skin colors reproductions, especially negligible changes of lumination, which can be considered as crucial for colors near achromatic point, are achieved on both prints (Table 1).

Visual estimation of black and white portrait photographs is somewhat lower, but also still very high (Table 2) and the observed Hi Fi bubble jet photo printing solutions can be considered as appropriate in the field of black and white photography.

Generally, based on the results and theoretical considerations it can be concluded that Hi Fi bubble jet photo printing is a good solution for printing digital photo records. Moreover, as it was expected, 12 color printing results with slightly better results, but also increases the price of printing and it can be recommended for large format gallery printing while for smaller format photographs printing with fewer colors can recommend.

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## USE OF ADDITIVES TO IMPROVE MECHANICAL PROPERTIES OF PACKAGING PAPER

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**Abstract:** Production of packaging paper is a very complex technical process that consumes huge quantity of various raw materials, energy-generating products, industrial water, additional tools, and spare parts for plants involved in the production process. It also comprises to have devices for cleaning polluted water and gases as well as tip sites for disposal of solid waste. Strategic raw materials for production of packaging paper is waste paper which is irreplaceable, as well as a range of new technical and technological solutions that have come up recently, thus enabling the use of all kinds of waste paper enriched with polymers, tar, bitumen and different kinds of printing.

It is a technical fact that the quality of cellulose mass derived from processed waste paper is changeable in regard to a repeated recycling process and it is calculated that the same treatment repeated 2 or 3 times does not significantly affect the decrease of physical and mechanical properties of fiber. However, every further treatment leads to a rapid decrease of its mechanical properties. In order to preserve mechanical properties of paper derived from the waste paper, natural and synthetic additives are being used. The research that was conducted in the Natron-Hayat Company in Maglaj offered new answers to the questions such as: what is the share of waste paper regarding the mass composition of larch cellulose improved by starch (within mass and paper surface)?; what is the alteration of mechanical properties within the given standard values of packaging paper. In order to achieve technological and economic effects of production the share of paper could be successfully increased in the mass of normal cellulose if enriched with starch up to 50 %, without decreasing the quality of packaging paper.

**Key words:** packaging paper, waste paper, starch, mechanical properties.

### 1. History of paper and its development

Paper (Greek pápyros; *plant papyrus*) is the material used for writing, drawing, printing, packaging, etc. It is produced mainly from wood or cellulose. Paper as a basis for writing, in its present form, appeared in China around 105. Until then, in China people wrote on silk. Paper was made manually from bamboo, rice straw, bass, hemp, old fishing nets, in general, from raw materials that basically have fibrous structure. The mentioned materials were fragmented by crushing in stone vessels or grinded in order to obtain mixed up small fibers. Mixed up fibers were placed in a pot and poured over with the lime water (lime - *lime*, *clack*, *slack lime* is a construction bonding material). It is obtained from limestone by baking in cylindrical rotary stoves at temperatures of about 100 - 120 °C.). Obtained mushy mass was poured on a sieve with a net made of silk fibers or thin sticks cut from bamboo. Shaking of the sieve would produce merging of fibers and the excess water would filter through the sieve into an underlying bowl with mushy mass. This procedure would result in a sheet of "paper". The sheet formed on the sieve was carefully separated from the sieve and placed on drying. Separation of water from the sheet was conducted by putting of the wet sheet on a flat surface (lumber, stone, and clay table) and with evaporation of water in the sun. Then the dried sheet of paper was plunged into a sticky mass obtained by cooking of rice and re-dried. After pasting and drying phases, the dried sheets were put in cups, pressed in wooden presses and then the individual sheets were ironed on a marble tablet with ivory or a smooth stone. This paper could be used quite well for writing with ink made from plants or minerals. The Chinese cut paper in a certain format. Initially, paper was produced mainly from flax, hemp, straw, cotton and cloth. The increase in consumption of paper resulted in increasing shortages of raw materials, so by the mid of 19<sup>th</sup> century the development of paper production process with wood processing, and with use of wood fiber. These methods of paper manufacture quickly prevailed, with gradual cessation of the use of wood fiber and the transition to the use of cellulose fibers. Wood fibers are coarse and short, and give the paper its small strength. Cellulose fibers are fine, long and hard, and they provide for manufacture of very fine and solid paper.

Paper is made from a network of very thin fibers that are found in plants. Trees are a major source of fiber, but they can be obtained from straw, bamboo and sugar cane. Since then, more

and more different paper products have appeared. Only some of these products include: office paper, tissues, newspapers, magazines, books, phone books, products for packaging and carton boxes.

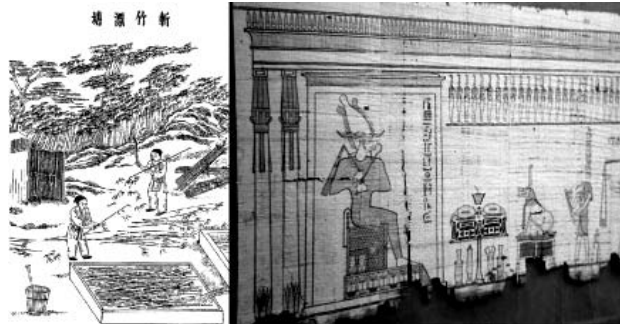


Figure 1: Paper manufacture in the past in China and Egyptian papyrus

## 2. Basic raw materials for production of paper

Wood is the most important raw material for production of cellulose, with 90% of total world production of cellulose is obtained from wood. For the production of paper from wood fibers, it is necessary to obtain small fibers with separation of fibers from wood mass.

To obtain a favorable fiber structure, the deciding factors are the following:

- morphological structure of fibrous raw materials
- possibility of industrial separation of raw materials
- possibility of half-product obtained from certain raw material for the process of further processing.

The paper industry is now largely processing perennials and deciduous conifers. Structure of these plants is extremely fibrous, which is actually the result of fibrous structure of cellulose molecules.

Wood is used for paper and paperboard and cellulose and pulp, as follows: Conifers: spruce, pine, fir

- Cellulose 50 %
- Chemicellulose 16 %
- Lignin 30 %
- Resins and greases 3.3 %
- Ash 0.7 %

## 3. Production of recycled paper

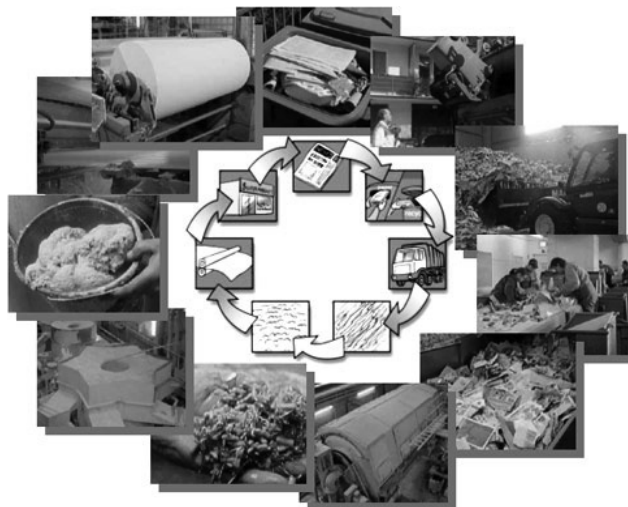


Figure 2: Production of recycled paper

The factories produce original environmental paper, recycled paper and cardboard. *The original environment-friendly paper* is produced from 100% from waste paper without bleaching and coloring with minimum spending of energy and water. *Recycled paper* is produced 80-100% from old and new cellulose with the addition of chemical additive raw materials. In average, cardboard is 90% made of waste paper. The main raw material for paper manufacturing is pulp (for the less quality kinds of paper) and wood cellulose (for finer papers). Recycled paper is used for all copying machines, is opaque, 4-5 times less strains the environment and its life is over 100 years. It is used in the paper industry, construction (as insulation material) and furniture industry (a substitute for plywood). However, we should know that the waste paper cannot be recycled an infinite number of times!

Waste paper cannot be recycled indefinitely, because it contains fiber breaks and cannot maintain the stable mass that connects it. Before it falls apart, a single sheet of paper can be recycled seven times. To maintain the quality of paper, there must be added fresh, new fibers obtained by processing of wood. Every time when paper is recycled, its fibers become weaker and shorter, so that the new cellulose must be mixed with used paper to obtain the strength. Because of weakening the paper can be recycled 4 to 6 times. There is no universal standard for the maximum amount of new fiber in recycled paper (paper is valid if it contains 10-100 percent of used paper).

There are three categories of paper that can be used as raw material for the production of recycled paper: the remains from factories, waste before the use and waste after the use. The remains from factories are parts of paper from paper mills. Waste before use are those materials that were discarded before they were ready for use by the user. Waste after use are the materials that were discarded after use by the user.

According to EIA (Energy Information Administration) paper mills save up to 40 percent of energy when producing paper from recycled paper, not from trees. The bleaching process requires much less chemicals for recycled cellulose fibers than for new fibers.



Figure 3: Paper mill

### 3.1 Waste paper for manufacture of new paper

Test liners are papers manufactured from 100% waste paper that guarantee the tested quality. Today, the test liners are the most important raw materials in corrugated cardboard industry. The term "test liner" comes originally from English language. "Liner" is the English name for the covering paper. The word "test" indicates that test liners must meet certain requirements and testing ("test") for stability. The title test liner emphasizes the tried and tested quality. At the same time it points out that in certain cases the test liner produced 100% from waste paper can be good, but above all an economical alternative to craft liners produced from new wood fiber. There are three types of test liners (T1, T2, T3). The highest quality of waste paper is used for type T1, while for other two types the lower quality waste paper is used. If a test liner consists of two layers, usually the thicker wearing layer is taken and its surface is coated with a surface layer of higher quality.

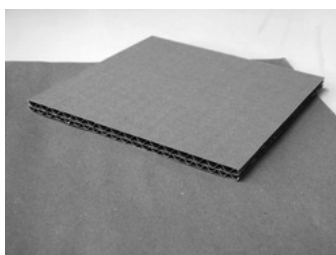


Figure 4: Testliners



The processing of waste paper and cardboard in paper mills for manufacture of new paper products consists of the following processes:

- Classification and sorting
- Fiber separation
- Cleaning done through:
  - *sorting on sieves*
  - *washing*
  - *centrifugal classifiers*
  - *flotation*
- Thermal Process
- Grinding
- Paper, cardboard and corrugated cardboard is made by:
  - *forming of paper tape*
  - *filtering*
  - *densification*
  - *drying*

### 3.2. Classification and sorting

In the first phase of collecting of waste paper, sorting is done according to the type of waste paper (newspapers, magazines, boxes, paperboard and other paper and cardboard packaging, books ...). This initial sorting is relatively coarse, and at the entry into a paper mill, materials must be inspected and sorted according to their origin and processing.

### 3.3 Fiber separation

Fiber separation of waste paper and cardboard is made in a Pulper, containing a larger quantity of water, where the pulp is added (the suspension of waste paper or cardboard and water). Pulper has the form of a simple container with a device for mixing. The content of solid substance in Pulper ranges from 2 to 15% which means that fiber separation of 1 kg of waste paper or cardboard needs 4.9 to 5.7 liters of water. Pulp in Pulper remains up to 20 minutes, but certain kinds of waste paper and cardboard need even longer retention until complete Fiber separation.

The purpose of Fiber separation is to separate the fibers from the mesh isprepletene structure of the paper into separate fibers. In the process, a partial separation of ink from the fiber occurs in the form of fine particles of pigment. The Pulper pumps in hot water, a weighed quantity of waste paper and chemicals. The main part of Pulper is a rotating element with paddles, which make the mass move and realizes micro turbulation. During the procedure the following is continuously controlled: pH, temperature, concentration and time of Fiber separation.

### 3.4 Cleaning

In the process of cleaning, the removal of hazardous materials from the pulp is made, which negatively affects the quality of new paper and cardboard products, such as:

- Multi-layered materials of the packaging waste (tetra pack)
- Plastic and aluminum foil
- Fillers and pigments from printing paper
- Staples and similar metal parts
- Styrofoam from packaging material
- Paint, etc.

The cleaning process includes the separation of pure pulp with fibers and residues that may be further processed eventually (so it still contains fibers), or disposed of as waste.

#### 3.4.1 Sorting on the sieve

Impurities, which retain on the sieve because of their coarseness and shape, are removed from the suspension as over-sieve fractions. The form of the openings of sieving surfaces on these sieves is circular with a diameter of 1.5 to 5.0 mm or gaps with a width from 0.258 to 1.0 mm.

### 3.4.2 Washing

The smallest, as well as emulsion-, dispersed or soluble substances are extracted from the pulp by washing. Pulp washing is done on sieves, on which impure substances are extracted as sub-sieve fractions, and over-sieve fraction is the pulp with fiber content from 4-15%.

### 3.4.3 Cleaning in centrifugal classifier

Impure particles of material, floating or falling down (sinking) in the pulp, are separated in the centrifugal classifier. Contents of dry substance in pulp separation process in this classifier are approximately 4%.

### 3.4.4 Flotation

The process of flotation is used, if the pulp contains impurities that are didrifobe. This procedure is usually performed to extract pigments, printing ink and similar from the pulp blowing the air into the flotation cells, which forms air bubbles which bind these impurities, and together with the bubbles they swim to the surface, forming a layer of foam that is removed. This pulp cleaning process is called DE-Inking procedure.

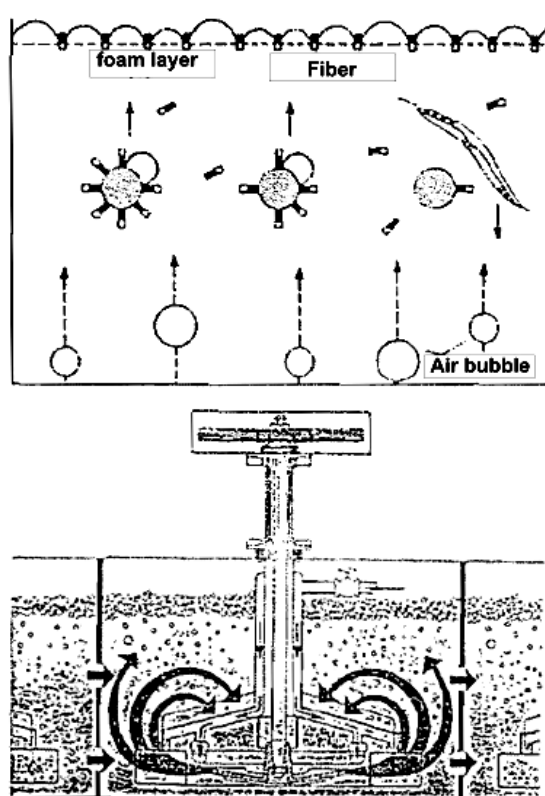


Figure 5: Model of a flotation cell

### 3.5 Deinking process

Flotation is a key part of the processing of waste paper. This procedure removes the printing color from the fiber suspension. Deinking flotation is a process of selective separation, which uses air bubbles to remove paint particles from defragmented paper pulp. In the flotation cell the paint particles link to air bubbles, which carry them to the surface. Adding chemicals into the mass increases the hydrophobicity of paint particles and improves the performance of flotation. On the surface the foam concentrates, which is removed as a flotation waste. The success of the flotation depends on three conditions:

- Collision of paint and bubbles
- Linking of paint particles to a bubble
- Removal of bubbles with a paint particle from pulp

The performance of flotation is affected by various factors, which can be divided into four groups:

- *Particle properties*: size, color, shape, chemical properties of surfaces, etc.
- *bubbles properties*: their size, number, chemical properties of surface and dispersion
- *degree of mixing*: time and intensity of flotation
- *Process conditions*: type of waste paper in the procedure, amount of filler, properties of fibers, pH suspension, temperature of process.

The success of the flotation is determined by image analysis. This method can determine the number and size of present paint particles, and the size of surface covered by these particles.

### 3.6 Thermal process

In spite of all mentioned processes, certain impurities remain in the pulp, mostly thermoplastic because of their minor characteristic strength. Separating of these materials from the pulp is made by thermal processes, or by heating of the pulp, whereby these materials are melted and mixing leads to their separation in the pulp.

Paper components which retain a certain degree of strength in water in addition to natural fibers contain some synthetic links. Fiber separation of these papers requires their further fragmentation.

With increasing of the pulp temperature, the fiber quality, which is required for the manufacture of certain paper products decreases. Therefore, the thermal treatment of the pulp is made in a temperature zone of 60-140 degrees, whereby the content of dry substances in the pulp is about 25 %.

Apparatus in which heat treatment of pulp is carried out are called dispergers. Increase of dry substance in the pulp is carried out through appropriate filters, which are tied into the pulp cleaning system by washing process.

## 4. Change of the properties of recycled paper

### 4.1 Fine particles

The recycled paper also contains a certain amount of fine particles (Engl. fines) which due to their presence can significantly affect the properties of a sheet. These fine particles are defined by dimension (Patel, M., Trivedi, R, 1993), the name includes all the particles in the pulp which can pass through a sieve of 200 wires per inch.

Only after the dimensional classification the fine particles are classified by type, or origins. They may be single short fibers after grinding, then may be the debris of fibers and bits of fiber walls, so called fiber "fines" with dimensions of 100-100 µm; fine particles include the fillers because the filler particles are typically smaller than 0.1 micrometer; and, finally, to a lesser extent fine particles may get into the recycled paper with process water used for Fiber separation of paper with the pulp, and it consists particles of ink.

### 4.2 Optical properties

Effect of ink to the properties of the secondary sheet is extremely present in the optical properties of recycled paper. Brightness of paper is reduced, while opacity increases due to the presence of particles of non-removed ink on one side and an increase in ash content, i.e. recycled filler paper, on the other side. Increased presence of the filler that comes with entering of the coated paper into the pulp may affect the increase of brightness of recycled paper, but also with fillers in the pulp the amount of ink increases due to which brightness decreases. The negative impact of remaining ink particles overcomes the filler brightness despite the increase in the amount of the filler in the sheet. Effect of color on the reduction of brightness dominates over the influence of filler on its increase. After deinking flotation, increased laboratory sheets brightness occurs as a result of removing of paint by flotation..

### 4.3 The particles of ink

The particles of ink in the pulp are usually sorted according to their largest diameter. The efficiency of removing of paint particles from the fiber in the pulp is different in each stage of the procedure, so that the flushing ispiranjem removes the particles up to 10 micrometer the best, the flotation those from 50-150 micrometer, and cleaning the larger particles of more than 1000 micrometer.

#### 4.4 Intensity rate Jakost lista

Testing the strength of fibers extracted from the sheets of paper that have been subjected to repeated recycling has shown that such individual fibers with each further cycle are slightly less stretched and simultaneously become firmer, stronger. These results are consistent with the fact that recycled fibers experience damage such as micro compression and corneation. At the same time, laboratory sheets made from the same fibers show a decrease in the strength with each next recycling cycle. Such studies confirm the crucial importance of the fiber - fiber connection to the overall strength of the paper. The strength of the fiber is insufficient for the strength of paper if the fibers in the paper are not sufficiently linked to each other and intertwined.

#### 4.5 Changes in fiber

Paper made of recycled fibers differs from the papers of primary fibers inter alia, in that they have weaker mechanical properties. Drying of fibers in the primary paper production is just the one phase of the process which bears the greatest responsibility for that. McKee (1971) demonstrated the influence of consecutive drying of fiber to the tensile strength of paper made of recycled fibers and found that successive drying of fibers, with each recycling affect the progressive weakening of the tensile strength of recycled paper. To study the strength of paper made of recycled fibers, properties of fibers are very important, namely:

- A - fiber strength,
- B - fiber length,
- C - swelling of the fibers or their plasticity,
- D - potential for bonding of fibers.

So papers manufactured from recycled fibers differ from the papers made from primary fibers in optical and physical characteristics. The cause of these differences is changes in the fibers, and the possible presence of various impurities, which in recycling were not sufficiently removed from the mass. The presence of contaminants in the paper produced from secondary fiber can also affect the strength of paper. Particles of impurities can affect with its presence the fiber-to-fiber bonding. Fibers in the vicinity of such particles cannot be interconnected well, and cracks in the structure of sheet occur. During loading of the paper in the press, especially the press from roll, such crack could affect the splitting of the whole strip of paper. Changes in printing properties of recycled paper in relation to the papers from primary fibers are related primarily to physical changes in the paper. A safe, quick and clean printing process depends on the physical properties of paper.

#### 4.6 Optical properties of recycled paper

Recycled papers are usually grayish in color. Depending on the amount of recycled fiber supplement, the whiteness of the paper does not exceed 80% ISO whiteness.

#### 4.7 Mechanical properties of recycled paper

Multiple recycled fibers experience damage such as micro-compression and corneation. Paper made from these fibers shows a decrease in firmness following each cycle of recycling. The strength of the fibers is insufficient for a favorable strength of paper, if the fibers in each sheet are not sufficiently interlinked and intertwined. When it comes to recycled fibers, the term "paper" literally refers only to paper, not cardboard and paperboard. This is because the way of intertwining of fibers in the cardboard and paperboard is somewhat different from that in the paper. In the case of cardboard and paperboard, due to their thickness the intertwining of fibers takes place in the third dimension. In preparation of cardboard and paperboard from recycled fibers whiteness is not the primary as for the printing paper, so for its manufacture we can use fibers that were not subjected to deinking process (cheaper process).

But despite all the "shortcomings" of recycled paper, it still has a "high price", because the recycling provides for:

- Preservation of nature and natural resources.
- Reduction of air, water and soil pollution.
- Savings in expensive and precious energy.
- Reduction of landfill space.

#### 4.8 Cardboard-types and forms

Paper product with a surface weight of more than 150 g/m is called cardboard, and over 600 g/m paperboard. Cardboard is widely used in making of cardboard packaging for the food and confectionery industry, pharmaceutical, chemical, tobacco, textile, automotive industry and spare parts industry for machinery industry. It is also used for laminating in the production of transport packaging. Cardboard is produced and delivered in sheets or rolls, depending on the demands of customers. Production of cardboard is made on a cardboard machine, whose width varies.

#### 5. Overview of used paper consumption

The development of science and technology, as well as rapid population growth, especially in 20<sup>th</sup> century, had ordered the influence on the growth of consumption and production of paper and cardboard. The average annual consumption of paper and cardboard in the world is around 55 kg per capita, and today the total production of paper and cardboard in the world is about 340 million tons. About 70% of total world consumption of used paper is in Western Europe, USA and Japan, with less than 15% of world population. Consumption of paper and cardboard in BiH over the past 15 years or so has a declining trend, so that the average consumption of paper and cardboard in BiH is as follows:

*Table 1: The share of used paper and paperboard in the manufacture of new paper and cardboard products in 1999*

Type od products	Waste paper, %	Primary fibre,%
Cardboard and cardboard boxes	95.6	4.4
Tissue paper	83.4	16.6
Newspaper printing paper	67.3	32.7
Corrugated cardboard and packing paper	62.9	37.1
Writing paper	13.6	82.4
AVERAGE	43.1	56.9

In 1991, it totaled approximately as the average consumption in the world, or about 52 kg per capita, while the average consumption in 2004 amounted to about 8.0 kg per capita. According to forecasts, the consumption of paper in the world in 2010 will reach the extent of about 420 million tons, which is an increase in consumption by about 35%. compared to 1999.

So intensive production and consumption of paper and cardboard is possible, inter alia, due to their recycling characteristics, which can be repeatedly used for the production of new paper and cardboard products.

Recycling of paper, cardboard and corrugated cardboard in Western Europe has a steady upward trend, especially in the last 15 years or so. (Table 2). Paper recycling industry pollutes the air by 74% less and pollutes water by 35% less than the industries that use raw wood!

*Table 2: The scope of recycling of used paper and cardboard in Western Europe*

Year	Realization, %	Forecast, %
1991	38.5	-
1993	42.1	-
1995	45.7	-
1997	47.8	-
1999	48.6	-
2001	50.7	-
2003	52.5	-
2005	-	55,8

The term used paper and cardboard includes the whole paper and cardboard, which becomes unusable after its use, where we differ:

- Waste paper and cardboard
- Used paper and cardboard

The waste paper and cardboard include paper and cardboard emerged in the process of production and processing of packaging, printed and unprinted formatted paper and cardboard foil etc. Scrap paper also appears in the printing industry in the production and processing of printed products (newspapers, books, notebooks, advertising materials, etc.).

In the U.S., paper accounts for the largest part of municipal waste, and accounts for about 40% of the landfills. In 2006, 53.4% of paper was recycled. This means that about 51 million tons of paper and its products is recycled annually, accounting for 76% increase compared to 1990 (the goal is to achieve 55% of paper recycled by 2012).

Paper recycling in Europe has a long history, and European producers and processors of paper work together to meet the standards of the European Commission. Their goal is to reduce the impact of waste on the environment during production, processing, printing, collecting, sorting and recycling in order to get an optimal and environmentally friendly recycling. In 2004, the percentage of paper recycling was 54.6% or 45.5 million tons per year.

In Austria there are 27 factories of paper which in 2008 achieved a record production of 5.2 million tons of paper, cardboard and cellulose. There is great demand for high-quality paper, manufactured in Austria. Feature of the Austrian paper industry is not only innovations in the production process, but also efforts for ecological and social progress.

Austropapier is the Association of the Austrian paper industry, which in addition to Paper industry association represents companies including in the field of foreign trade. The export quota of paper-processing industry is around 65%.

The quantity of paper, cellulose and cardboard produced in 2006 was increased compared with the previous year by 250,000 tons, which is over five percent. Turnover of the industry was increased by 7% to EUR 3.6 billion. In the field of paper industry, Austria has a lot to offer and it exports all kinds of paper of the highest quality. Austrian standards are supplement to international and European regulations aimed at ensuring of high-quality products for different purposes.

*Table 3: Percentage of recycled paper in 1998*

Country	% of recycles paper
Austria	65
Belgium	48
Denmark	52
Finland	63
France	41
Germany	70
Greece	21
Ireland	21
Italy	33
Netherlands	58
Portugal	42
Spain	43
Sweden	63
England	40
EU	49

## 6. Technological procedure of treatment of used paper and cardboard

Used paper is collected in dedicated containers that are painted and visibly marked. Such containers are suitable for disposal of: cardboard packaging, magazines, booklets, cardboard folders, newspapers, office notebooks, paper bags, books and similar paper products. The collected used paper and cardboard in paper mills is processed by complex procedures, whereby the recycled fibers are obtained, which are better than those made from wood, and less quality than those made of cellulose.

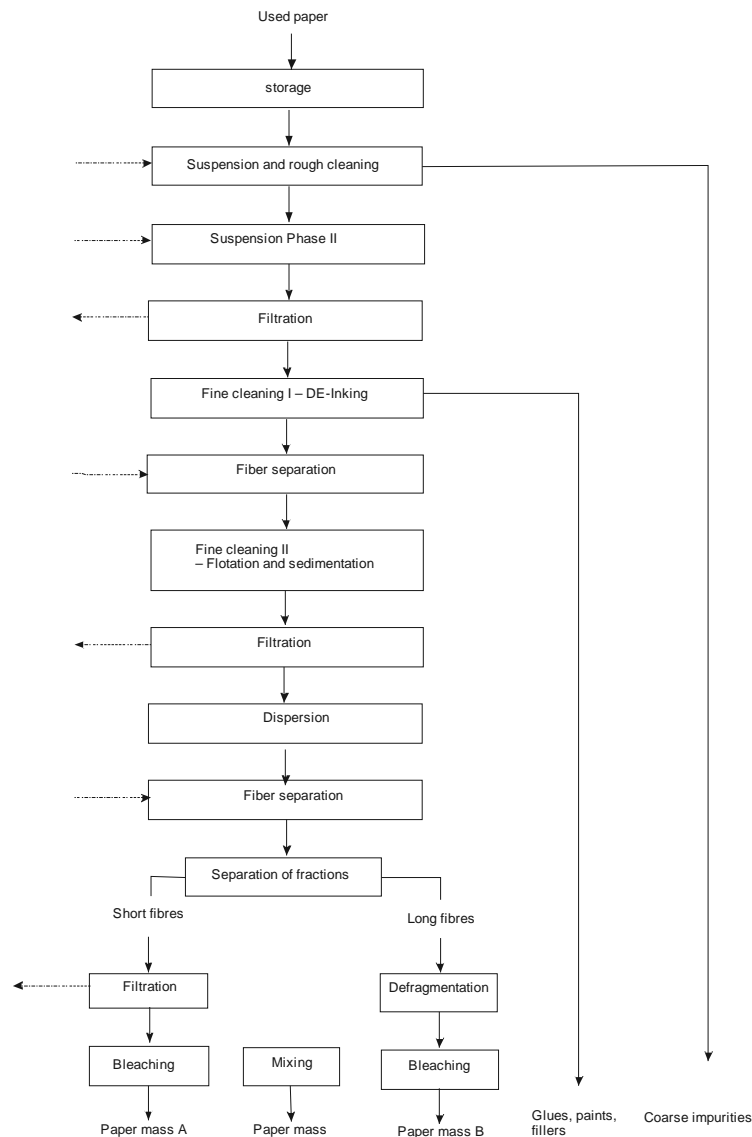


Figure 6: Principle scheme of processing of used paper and cardboard ..... ➡

## 7. Investigations carried out in company "Natron - Hayat Maglaj

The aim of the research was to establish the relationship between the mass of the original coniferous cellulose and mass prepared of used paper in the composition of the mass that will be used for the production of packaging paper. The truth from the very beginning of operation of the factory of sulfite pulp and natron craft paper, used its own waste paper from the process, and during the production line extension the waste paper was introduced as base raw material in addition to its own sources of printing, trading houses, construction, etc. With respect to constant lack of biomass, the business commitment of the company has been to find alternative sources of raw materials such as fast-growing conifers and broadleaves, annual plants, wood waste and waste paper is primary. While preparing for the exploration and use of polymer materials, a long-term program of research in the area of use of old paper is innovated because of very rapid changes in production line and quality of used paper with the addition of synthetic and natural polymer materials. The share of the mass of waste paper in composition with a mass of coniferous cellulose, has a crucial impact on the reduction of physical and mechanical characteristics that are significantly improved by adding starch (surface layer, the entry into the mass). Already applied results of the process economically justify the use of starch not only for traditional wrapping paper, but also for natron craft paper.

*Table 4* Overview of mechanical celluloses made from the risk composition and with the treatment of starch

PROPERTIES	USED PAPER	CELLULOSE	50:50 Cellulose: used paper	50:50 (finale starch) Cellulose : used paper	50:50 (starch in mass) Cellulose: used paper
Degree of starch gringing	30	20	-	-	-
Grammage g/m <sup>2</sup>	68.47	68.15	68.46	69.10	68.15
Thickness mm	0.133	0.096	0.115	0.120	0.121
Capacity gm/m <sup>3</sup>	0.49	0.70	0.59	0.57	0.56
Length breakout m	3710	11570	5690	7600	7620
Elongation percentage	1.44	2.47	1.7	2.54	2.25
Resistance to cutting Mn	533.6	596.4	627.8	596.4	565.0
Resistance to pressure Mullen KPa	112.6	462.2	211.4	287.3	301.0
Resistance to air according to Garli S	9.69	23.18	12.49	11.02	12.20
Resistance to breaking KN/n	2.49 KAPPA BR	7.69 42.6	3.82	5.15	5.09

## 8.Final considerations

Cellulose and paper industry must seek new sources of raw materials, due to the costly and inhumane society relation towards forests, environment, and consequently there are modifications and innovations of technological processes and accelerated exploration of new additives for use in the whole technological process. Research in the field of use of starch will continue in collaboration with other scientific and research institutions



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# OPTICAL DENSITY AND OPTICAL TONE VALUE INCREASE OF UV INK JET PRINTS MADE ON FILM SYNTHETIC PAPER

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**Abstract:** Ultraviolet (UV) cured printing is a fast growing area of printing which has many diverse applications. The present study deals with the influence of different types of UV ink jet printers on densitometric properties of CMYK prints. Prints of CMYK color fields with different intensity were made by two UV ink jet printers; Océ Arizona 250 GT and DursRho205. As a printing substrate a film synthetic paper Yupo FEB 130 was used. The research was focused on the investigation of the differences in the optical density and tone value increase of UV ink jet prints. The analysis revealed some differences; optical density and also tone value increase were lower at prints made by printer Océ Arizona 250 GT.

**Key words:** UV ink jet print, film synthetic paper, optical density, optical tone value increase.

## 1. Introduction

Ultraviolet light (UV) reactive ink jet printing has become well known as a reliable printing method for graphic printed products. Areas of interest for UV ink jet are also packaging materials. Advancement in ultraviolet (UV) curing technology, i.e. the processes of transforming a liquid into a solid by using UV light, is responsible for some of the recent changes in the printing industry. Some advantages are: inks do not dry in the nozzles, they have good adhesion to non-porous substrates and they do not have high volatile organic solvent emissions. After printing there is a cure stage, where photoinitiators interact with the UV light to form free-radicals, which then attack double bonds in the acrylate monomers creating a coloured image polymeric coating (Hartley, 2009). Once the UV light comes in the contact with the ink, polymerization occurs instantaneously, unlike polymerization with oxidation inks which takes several hours to cure (Hoff, 1997). Cured UV inks offer vibrant, high opacity, high gloss color, and superior print definition on a variety of substrates, including packaging materials (Kipphan, 2001). UV printing has become pervasive in the label printing market and is a good choice for applications like luxury cosmetics and wine labels (Hershey, 2007).

Synthetic papers are being used as multi-layer bags of high strength, outdoor tags, labels and flexible packaging materials for many applications. Their usage in the pharmaceutical field is expected to increase, especially with the products that are known to have a high and expensive pilferage rate (Polischuk, 2008).

## 2. Methods

### 2.1 Printing material

As a printing material, a biaxially-oriented film synthetic paper Yupo FEB 130 was used (Mitsubishi-Yuka, Paper, Oji-Paper, Yupo Corporation, Japan). It consists of extruded polypropylene polymer and doesn't contain wood pulp or other bio materials and has a penetration layer on both sides. It can be used as a high value-added packaging such as shopping bags, pharmaceutical bags, wrapping paper, in-mold labels. Material is highly resistant to pulling, bending and impacts. While maintaining a high-degree of flexibility, Yupo FEB 130 also supports package by offering printing ability (Yupo, website).

### 2.2 UV ink jet printing

Film synthetic paper was printed with two different UV ink jet printers; printer Durst Rho205 hereinafter referred as a *UV printer 1* (resolution: 300 dpi, CMYK inks, piezo ink jet technology: drop-on-demand) and printer Océ Arizona 250 GT as a *UV printer 2* (resolution: 1.440 dpi, piezoelectric ink jet using Océ VariaDot imaging technology). A printing test form was prepared with color patches of 20%, 40%, 60%, 80%, and 100% raster tone values.

## 2.3 Measurements

For the color measurement reflection densitometer D19C (Gretag-Macbeth, Canada) was used under following conditions:  $\varnothing < \text{deg} > : 45 < \text{deg} >$  a measurement geometry, 0.00 – 2.50 D measurement range, 3.6 mm measurement aperture, and 2x linear polarization filter, calibrated on the unprinted paper. The optical density (D) and tone value increase (TVI) for each of the colors C, M, Y and K were determined.

## 3. Results

### 3.1 Optical density of UV ink jet prints

Optical density D is defined in the form of logarithmic ratio:

$$D = \log \frac{1}{\beta} = \log \frac{I_0}{I} \quad (1)$$

Reflectance factor  $\beta$  is the ratio of the light intensity  $I$  of the light remitted by the ink film in relation to the intensity of light  $I_0$  remitted by the blank paper. Reflectance factor  $\beta$  decreases as the film thickness increases (Kipphan, 2001).

The optical density (D) of the CMYK prints was measured on the fields of 20%, 40%, 60%, 80% and 100% ink coverage. Figure 1 presents the optical density (D) of CMYK prints made with two different UV printers.

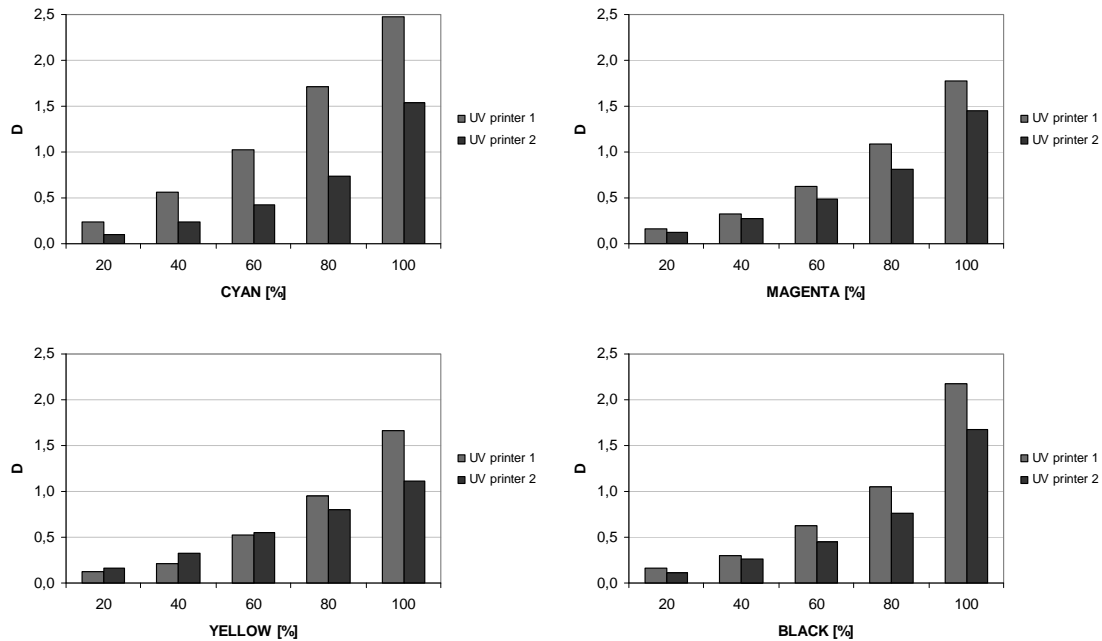


Figure 1: Optical density (D) of CMYK prints made with two different UV ink jet printers

The results indicate that the UV printers have a significant impact on the optical density of CMYK prints. The cyan print made with the *UV printer 1* obtained the highest optical density for all ink coverage values compared to others prints. With increasing the percent of ink coverage, the difference between the prints made by two printers becomes greater, with the largest difference occurring at 100% ink coverage. At 100% ink coverage the optical density of the cyan print ( $D_{C,100\%}$ ) made with the *UV printer 1* was 2.48, made with the *UV printer 2* only 1.54. In the case of the cyan prints made with the *UV printer 1* a linear increase of optical density ( $r_{xy} = 0.9727$ ) and at prints made with the *UV printer 2* a power increase ( $r_{xy} = 0.964$ ) was observed. The optical density of the magenta print made with the *UV printer 1* for all ink coverage values was also higher ( $D_{M,20\%} = 0.16$ ,  $D_{M,40\%} = 0.33$ ,  $D_{M,60\%} = 0.63$ ,  $D_{M,80\%} = 1.09$ ,  $D_{M,100\%} = 1.78$ ). Only at the yellow print the optical density was not at all percents of ink coverage higher at prints made with the *UV printer 1*. At lower values of ink coverage (20%, 40% and 60%) the optical

density was higher at prints made with the *UV printer 2*. For the optical density of the black print made with the *UV printer 2*, similar values as those for the magenta and cyan prints in the lower ink coverage ranges were obtained. The black print made with the *UV printer 1* obtained similar value as the magenta print at all ink coverage percents, except on the solid color.

### 3.2 Tone value increase of UV ink jet prints

Based on the theory of densitometry, there are a number of process attributes that can be assessed. The most important is tonal value, or “dot gain”. It is a phenomenon in printing and graphic arts whereby printed dots are perceived and actually printed bigger than intended. It causes a darkening of the screened images or textures, especially in the mid tones and shadows, due to the viscosity of ink and its ability to spread through the paper as it is soaked in. The ink, being at liquid state, makes contact with the substrate, spreads (or gains) and covers a larger percentage of the screen cell. This additional percentage is defined as dot gain or Tone Value Increase (TVI). The first measurement of dot gain was provided in the 1930s by Murray, who related the three quantities: dot area, density of the ink and solid density (Density&Dot Gain, website).

The results of the calculated TVI values are given in the Figure 2.

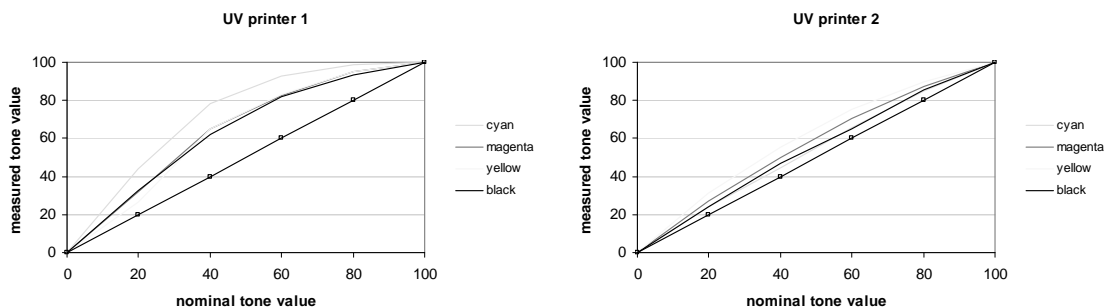


Figure 2: Optical tone value increase of CMYK prints made with different UV ink jet printers.

From the Figure 2 it can be seen that some differences between the gradation curves of individual CMYK prints made with the different UV ink jet printers occurred. CMYK prints made with the *UV printer 1* obtained higher tone value increase (TVI) compared to the prints made with the *UV printer 2*. Tone value increase for the cyan print made with the *UV printer 1* was very high even at the lowest ink coverage ( $TVI_{C,20\%} = 24\%$ ,  $TVI_{C,40\%} = 38\%$ ,  $TVI_{C,60\%} = 33\%$ ,  $TVI_{C,80\%} = 19\%$ ). The cyan print reached its maximum TVI value already at 80% ink coverage. The yellow, magenta and black behaved similarly, they also reached high values of TVI, especially at 40% ink coverage. On the other hand, the cyan print made with the *UV printer 2* obtained the lowest tone value increase ( $TVI_{C,20\%} = 3.80\%$ ,  $TVI_{C,40\%} = 4.60\%$ ,  $TVI_{C,60\%} = 5.50\%$ ,  $TVI_{C,80\%} = 5.20\%$ ), while the yellow print the highest ( $TVI_{Y,20\%} = 11.60\%$ ,  $TVI_{Y,40\%} = 15.60\%$ ,  $TVI_{Y,60\%} = 15.20\%$ ,  $TVI_{Y,80\%} = 9.60\%$ ).

## 4. Conclusions

In this study the different UV ink jet prints using the piezo ink jet technique, made on the film synthetic paper are presented. The results have shown that the UV printers (DurstRho205, Océ Arizona 250 GT) have a significant impact on the densitometric properties of CMYK prints. Based on the results of the optical density measurements, it was established, that CMYK prints made with the printer DurstRho205 obtained higher values. The cyan print deviates the most. On the other hand, the yellow print made with the printer Océ Arizona 250 GT resulted in the smaller optical density values. The differences between TVI values of CMYK prints were also noticed. The cyan print made with the printer DurstRho205 reached the highest peak values at all percents of ink coverage. CMYK prints made with the printer DurstRho205 reached a much higher tone value increase than the prints made with the printer Océ Arizona 250 GT.

It can be concluded that the print quality depends on the type of the UV ink jet printer used and that the gradation curve should be adjusted before printing, especially at the printer DustRho205 for lower TVI values. In our experiment the printer Océ Arizona 250 GT gave better results.

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# INVESTIGATION OF FLEXOGRAPHIC PRINTING ON PE AND BOPP FOILS

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**Abstract:** Flexographic printing is one of the fields of print industry that experiences rapid development. With this technology it is possible to print on coated and uncoated paper, paperboard, and non-absorptive substrates such as plastic foils, typically used in packaging. About 40% of all packaging products are printed using flexographic printing. Surface properties of the substrates varies, inks with different components and printing properties are needed; development is essential for the improvement of print quality.

In our research work we investigated two inks for printing PE and BOPP foils. The targets of visual investigation were errors, small distortions, colour deviances. Optical measurements were used to determine density, tone value increase (TVI), colour evenness and abrasion resistance of the prints.

**Key words:** flexo printing, PE, BOPP, TVI, abrasion resistance.

## 1. Introduction

Flexographic printing is one of the most dynamically developing field of the printing industry. However, fast development represents a burden to printing houses. Printing should be performed on substrates with different surface properties, using inks having different composition, and constant development is a must in order to produce better quality prints. The main scope of application is packaging material manufacturing. In packaging material manufacturing plastic foils are mostly used. Most frequently used plastic foil print carriers: polyethylene, oriented polypropylene (OPP), polyester (PET), polyvinyl-chloride (PVC), polyamide (PA) [1]. Polyethylene is the mostly widely used plastic on earth with an annual production of approximately 80 million tons. Its major application area is packaging industry. Polyethylene is created by polymerising ethylene. Types: HDPE high density, MDPE medium density, LDPE low density polyethylene. Oriented polypropylenes are versatile materials both regarding processing and utilisation. They are light, durable, excellently printable, and the graphic representation is more cost efficient than with other flexible print carriers. They are easy to laminate with paper, metal foils or other plastic foils. The main application area is the food industry. Polyester foils provide an excellent combination of optical, physical, mechanical, thermal and chemical properties. Their good oxygen sealing ability is utilised in flexible packagings and laminates. They can be printed, metal vapoured, and welded excellently and have outstanding abrasion resistance and processability. The application area is food industry, in particular dairy products. Main properties of PVC foils: can be thermoformed in an excellent way, have good resistance to chemicals and an optimal protection function. Main application fields: pharmaceutical industry, food industry [2] [3].

## 2. Methods

Test prints prepared on Soma Flex MIDI 105-8 EG flexographic press with central impression cylinder have been tested. The test prints were printed on polyethylene (PE) and polypropylene (BOPP) foils (Table 1) (Figure 1). The inks of two manufacturers (Sun Chemical, Flint) were used.

Table 1: Characteristics of print carriers

Name	Type	Thickness, mm
Polyethylene (PE)	plastic foil	0,02
Biaxially-oriented polypropylene (BOPP)	plastic	0,05

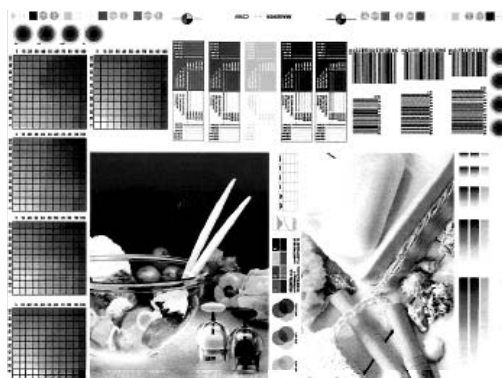


Figure 1: Test figure

The printing press was operating continuously and the test figures were printed during switch-over. Printing of test figures was made under normal operating circumstances in the following way:

- printing press: Soma Flex MIDI 105-8 EG
- temperature: 20 °C
- printing ink temperature: 20 °C
- printing ink viscosity: 20 Pas
- thickness of printing forme: 1.14 mm
- number of prints: 500-500 per each
- sampels tested: 10-10 per each

We did not change the colour sequence, the type of the anilox roller applied and the position of the given colour during printing (Table 2).

Table 2: Colour sequence of test figure and the properties of the anilox rollers

Colours	Serial number of the printing unit	Anilox roll	
		screen frequency l/cm	exhaustion $x^3/m^2$
Yellow	2.	320	5,2
Magenta	4.	320	5,2
Cyan	5.	340	5,0
Black	7.	320	5,2

Screen frequency (l/cm) and exhaustion ( $cm^3/m^2$ ) are properties related to the anilox rollers. Printing was performed on the two substrates in succession using the following ink types: Sun Chemical (CMYK) and FLINT (CMYK). Care has been taken during the tests to influence the productivity of the printing press to the slightest degree only. Tone test prints for investigation of abrasion resistance were prepared in the second step the properties of which are presented in Table 3.

Table 3: Colour sequence of tone test print and the properties of the anilox rollers

Colours	Serial number of the printing unit	Anilox roll	
		screen frequency l/cm	exhaustion $x^3/m^2$
Yellow	2.	180	8
Magenta	4.	180	8
Cyan	5.	180	8
Black	7.	180	8

### 3. Results and discussion

The purpose of the test were the proper operation of the Soma Flex MIDI 105-8 EG type flexographic printing press as well as the examination of inks and foil substrates for a better quality and more economical printing. Print quality was examined visually and using instruments [4].

### 3.1 Visual investigation of test prints

During visual investigation deviations that can be observed with the naked eye were examined on the test prints primarily.

The CMYK scale (Figure 2) decreases from 100% tone value field to the 1% field. It includes 27 pcs squares to enable the examination of the number of tones that can be distinguished with the naked eye.

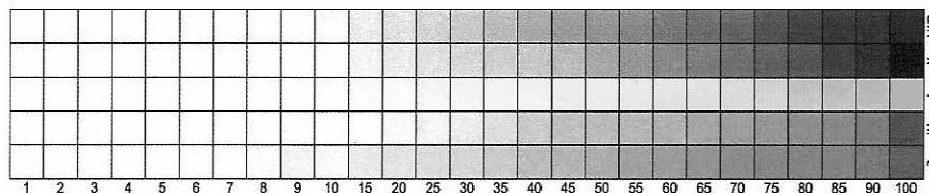


Figure 2: CMYK tone scale

On Figure 3 positive and negative text and line elements printed with the CMYK process colours can be seen; their purpose is to examine the line thickness and font size that can be reproduced by the printing press. Line thickness was from 0,02 mm to 0,5 mm, font size from 3 to 6 points with four transitions.

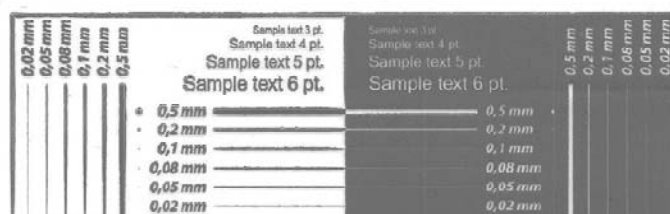


Figure 3: Positive and negative line and text elements

#### Examination of text elements

No difference was observed with the inks of Sun Chemical, 3-point texts printed on PE and BOPP foils are excellently legible to the naked eye. In case of FLINT ink positive and negative texts are easily legible in cyan and black coloured prints on PE and BOPP foils. On PE and BOPP foils yellow coloured 4-point and 3-point texts can only be read using manual eyeglass. In case of magenta colour text elements are easy to read on BOPP print carrier with naked eye, the edges of the letters are sharp. The text on the PE foil is easily legible but a quench ring (protrusion) can be observed at the edge of the letters.

#### Examination of line elements

Positive line elements printed with the Sun Chemical ink are fully visible to the naked eye on both print carriers; however on the negative sections the 0,02 mm wide lines close. The exception is black print on BOPP foil where 0,02 mm rules are fully visible. The edges of positive lines are notched that is only visible with manual eyeglass; however the edges of negative lines are sharp. On samples printed with FLINT ink the closing of 0,02 wide negative lines can similarly be observed. When examining with eyeglass the black colour is the exception as the 0,02 mm line is visible on the print. The mostly closed is the yellow print as the 0,05 mm lines are only visible through eyeglass.

#### Examination of points

Point sizes equal line thickness values. On the PE foil at Sun Chemical cyan and black colours the 0,2 mm points are visible, but smaller points are not visible even with eyeglass. With magenta and yellow colours the 0,05 mm points are just visible, but 0,02 mm points are not visible even with eyeglass. In negative print the points diminishing from 0,1 mm are not visible. On BOPP foil in black colour points are visible to the naked eye to 0,05 mm, but 0,02 mm only with eyeglass. In case of FLINT ink on PE foil points are visible to the naked eye from 0,5 – 0,05 mm, the 0,02 mm point with eyeglass; in negative 0,5 – 0,2 mm with naked eye, the 0,1 mm with eyeglass.



### Examination of tone scale

Examinations were performed on a scale divided to 27 tone steps by examining the four process colours. Examinations were started from the field with 1% tone value and proceeded to the 100% ratio. Tones could be distinguished with the naked eye on prints printed on PE foils with both inks, on the cyan scale to the 60% square. On PE foil and magenta print the difference between the inks was two squares. Yellow and black colours did not show a difference on the PE foil. On BOPP foil the tonal range of cyan, magenta and black colours was identical for the two inks but yellow showed a significant deviation. It could be distinguished by square 65 with FLINT ink, and by square 50 with the Sun Chemical ink. By examining print carriers we drew the conclusion that more tonal steps can be distinguished with the naked eye on BOPP foils i.e. the tonal range of the tones is larger.

### Examination of photos

Test figure contains two photos. No difference was observed during the examinations regarding print carriers and inks, neither on the darker nor on the lighter photo. On the photo with darker tone colours we observed printing defects in the colour of the background and in the cauliflower on the left of the photo.

## 3.2 Examination of tone value increase

The tone value increase (TVI, %) was examined on the CMYK tone scale with X-rite SpectroEye colorimeter/spectrophotometer (Table 4-5).

- Measurement parameters:
- CIE D50 (5000K) radiation distribution illumination,
- 2° normal detector,
- without polar filter,
- density compared to the print carrier
- the white underlay was PE/EVOH/PE White 0.05 mm thick mounting foil.

Table 4: Tone value increase with Flint ink on 40% raster prints

Colour	Foil		ISO standard
	PE	BOPP	
	Tone value increase (TVI), %		
Cyan	44,5	39,9	36
Magenta	42,5	39,1	36
Yellow	46,2	43,5	36
Black	41,2	79,9	36

Table 5: Tone value increase with Sun Chemical ink on 40% raster prints

Colour	Foil		ISO standard
	PE	BOPP	
	Tone value increase (TVI), %		
Cyan	40,5	41,0	36
Magenta	39,4	39,5	36
Yellow	46,7	45,2	36
Black	39,8	39,7	36

Standard ISO 12647-6 was used for the evaluation of the tests/examinations. Based on the calculated results we established that for both foil substrates and inks the tone value increase measured on the 40% tone value prints was greater than the values obtained on the 80% tone value prints. It can be stated that the tone value increase exceeds the values of the standard on the 40% tone value prints, and that the tone value increase were extremely high on yellow colour prints on all sample series.

## 3.3 Examination of colour coordinates

During the examination we were looking for the most suitable ink for the printing house, by testing prints made on PE and BOPP plastic foil (film) substrates. The CIE L\*a\*b\* values were measured with an X-rite SpectroEye colorimeter/spectrophotometer (Table (6-7)). Parameters of

the colour measurement with spectrophotometer: CIE D50 (5000K) radiation distribution illumination, 2° normal detector, polar filter was not used.

*Table 6: Colour coordinates on prints printed with Flint ink*

Foil	Colour	L*	a*	b*
PE	C	63,11	-41,99	-36,86
	M	46,16	63,70	-17,06
	Y	83,13	-6,31	-91,25
	K	27,46	1,77	5,61
BOPP	C	59,92	-45,24	-44,06
	M	47,64	70,04	-16,04
	Y	85,27	-8,76	86,37
	K	26,22	1,30	3,23

*Table 7: Colour coordinates on prints printed with Sun Chemical ink*

Foil	Colour	L*	a*	b*
PE	C	65,67	-40,40	-33,58
	M	52,06	53,74	-17,30
	Y	82,00	-6,17	86,54
	K	31,08	1,80	7,74
BOPP	C	62,85	-44,28	-40,89
	M	52,16	61,30	-18,96
	Y	83,76	-8,32	82,39
	K	32,65	1,74	6,25

Based on the data compared it can be stated that the FLINT ink has shown smaller deviations in the L\* values laid down in the ISO standard, except for the yellow print. No significant deviation can be observed for the a\* and b\* values.

### 3.4 Density measurement

We have measured the density of the fields with 100% tone value of the tone scale of test prints. Tables 8-9 include the arithmetic mean values of the measured densities.

*Table 8: Density values on prints printed with the Flint ink*

Foil	C	M	Y	K
Density, D				
PE	1,32	1,27	1,39	1,14
BOPP	1,26	1,21	1,31	1,18

*Table 9: Density values on prints printed with the Sun Chemical ink*

Foil	C	M	Y	K
Density, D				
PE	1,15	0,92	1,30	1,03
BOPP	1,12	0,92	1,25	1,00

When comparing the density values the higher values were observed with the Flint ink. A thinner ink layer is applied on BOPP foils every time. In case of CIEL\*a\*b\* colour coordinates there is no significant difference in case of inks and substrates, respectively.

### 3.5 Examination of abrasion resistance

The products of flexo printing are generally packaging materials. They are deep frozen products and collective packagings in many cases. Consequently, the surface of the dried ink should have a high resistance to different mechanical impacts. Therefore from the resistance properties the abrasion resistance plays an important role. Abrasion resistance is equally influenced by the surface properties of substrates as well as the properties of the ink. Abrasion resistance tests were performed with a Prüfbau Quartant tester. For the purposes of the tests tone strips were printed on PE and BOPP foils with the four process colour inks distributed by

Sun Chemical and FLINT ink manufacturers. The density of the ink stuck to the counter-plates was measured with X-rite SpectroEye colorimeter/spectrophotometer.

Based on the results of the tests it can be stated that both inks can be removed from the PE foil easier and in bigger quantities. The exception is the yellow colour in case of the ink distributed by Sun Chemical. A lower density value was measured here on the counter-plate of the PE foil. Comparing the two inks the values of the yellow colour are outstanding. The yellow print made by FLINT greatly differs from the yellow print made by Sun Chemical, and a high density value is obtained even compared to the results of the other measurements.

#### 4. Conclusions

By summarising the results of the visual tests it can be stated that good quality prints can be printed on PE and BOPP substrates with the Soma Flex MIDI 105-8 flexo printing machine. During the examination of the text elements the 3 and 4-point texts printed with the yellow Flint ink were not legible with the naked eye on either print carrier. In case of line elements positive lines were fully visible every time and the negative 0,02 mm lines have closed. When examining points the negative elements are not visible with the naked eye from 0,2 mm. During a tonal range examination no sharp differences can be observed on any of the test prints from the 50% tone value prints.

During the instrumental examination of the prints the tone value increase on 40% tone value prints did not comply with the values of standard ISO 12647-6 and the permitted value was exceeded every time. On 80% tone value prints the values measured on the yellow print printed on BOPP substrates exceeded the parameters laid down in the standard on two occasions. When comparing colour coordinates during colour measurement no significant difference was observed between the prints made on the two different print carriers using the two different types of ink. We examined the correlation between the ink load and the CIEL\*a\*b\* values of the prints. We have established that a thinner ink layer is applied on BOPP foils at similar colour properties on every occasion.

According to the results of the abrasion resistance tests both inks have adequate resistance to rubbing on both print carriers, and there is no significant difference between the density values measured on the counter-plate.

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## EXAMINATION OF ANTI SET-OFF SPRAY POWDERS USED FOR SHEET OFFSET PRINTING

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**Abstract:** In case of sheet offset printing inks that dry by oxidation polymerization are normally used. A specific time is required for the ink to dry on the print. In order to minimise of sticky surfaces' ink transfer anti set-off powders are used. During the research work we have examined the rubbing effect exerted by different types of powders on prints printed on print carriers having different surface properties. Our goal was to determine the spray powder that best suits the properties of the given print carrier and ink. During our examinations the rub fastness of the prints was measured following printing tests after a specified drying time had elapsed. In addition, electron microscopic images were taken from the prints by which we could reach conclusions related to the properties of the paper, the prints and the powder.

**Key words:** anti set-off powder, abrasion resistance

### 1. Introduction

In case of sheet offset printing inks that dry by oxidation polymerization are normally used. A specific time is required for the ink to dry on the print. Directly after printing the fresh ink layer on the print carrier is not thoroughly dry, and because of its sticky surface the risk of ink transfer subsist during unloading and too early processing. In jobs where the printing forme requires more inking than usual (e.g. if the total fill ratio is high) the unloaded sheets may even stick together.



Figure1: The phenomenon of ink transfer

In order to minimise risk factors anti offset powders are used. The quantity of the powder applied depends mainly on the ink uptake of the printing forme and serves the purpose on the print to keep a distance between the sheets lying on top of each other on the front table. This distance prevents that a direct contact is formed on the front table between the surfaces of the freshly printed sheets. A further advantage of applying powders is that the air cushion created due to the distance between the unloaded sheets facilitates drying procedures in case of oxidative drying offset inks.

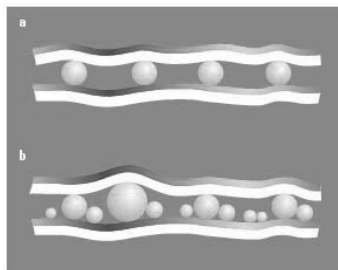


Figure1: The function of spray powders (a: properly sorted powder b: improperly sorted powder)

The proper distance between freshly unloaded sheets and proper drying conditions can only be achieved by using spray powders that have been properly sorted according to grain size.

## 2. Methods

### 2.1. Rub fastness in the printing industry

Rub fastness is the ability of the ink film freshly applied on the print carrier to resist mechanical impacts. When rubbing a rubbing effect arises in case of two contacting surfaces. This effect can influence and thereby change the surface.

Factors influencing resistance to rubbing:

- ink
- print carrier
- ink layer thickness
- composition of the dampening material
- quantity of the dampening liquid
- spray powder applied on the print
- current status of ink drying
- surface smoothness of the ink layer

During rub fastness tests it must be taken into consideration that the resistance against the attainable rubbing effect cannot be determined by the quality parameters of the ink or the print carrier. The properties of a given ink-print carrier combination must always be examined.

### 2.2. Properties of anti set-off spray powders

The function of anti set-off spray powders is to create an air cushion between the sheets in the front table of the printing machine which prevents that freshly printed sheets stick together on the one hand, and on the other hand the oxygen content of the air cushion facilitates the drying through of the ink layer that dries by oxidation polymerization.

The proper distance between freshly unloaded sheets and proper drying conditions can be achieved only by spray powder properly sorted according to grain size. A spray powder is considered to be of good quality if the grain size within a product is almost uniform.

It has several disadvantages if the spray powder contains small size grains in a quantity bigger than specified. Therefore the printer has to increase the quantity of the powder applied which leads to higher contamination of the machine parts and the air. Powder-clods (agglomerates) may form which cause visible stains and surface cloudiness on the print carrier.

Main criteria of spray powders:

- economical application,
- many grains of identical size in the desired location, as far as possible,
- distribution in a uniform layer thickness on the print,
- utilisation should not hinder further processing,
- utilisation should only be accompanied with minimum „dusting”,
- should not contain fine grains in large quantity.

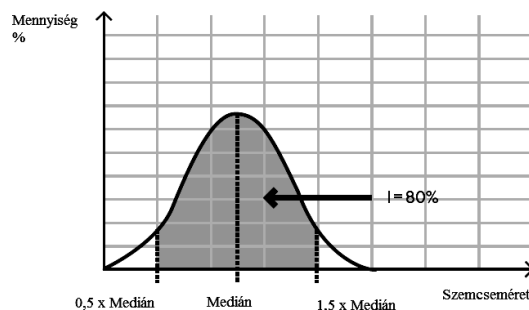


Figure 3: Classification of spray powders according to grain size (On the vertical axis the quantity of the spray powder is shown in %. The horizontal axis represents the grain size in micrometer. The area underneath the curve shows the uniform grain distribution. 80% of the average grain size of a good quality spray powder should fall in the area under the curve in order to meet the requirements).

It depends also on the size and mass of the grains where the given substance is practical to apply. The coarser the surface of the print carrier and the higher the surface of the ink load the bigger the grain size of the spray powder applied should be.

Several spray powders are commercially available that differ from each other in grain size, purity, origin and the surface properties of the grains. According to grain origin the powders can be mineral and vegetable spray powders.

The manufacturers provide the volume of the spray powder to be used during printing with the help of curves.

### 2.3. Test printing

Test printing was performed on a KBA RAPIDA 105 sheet offset printing press (5 printing units + lacquer unit) equipped with a WEKO AP 130 print powder spraying device. Several different spray powders have been tested.

During printing SunLit EXACT PSO printing ink series distributed by Sun Chemical were used. The ink series is a top quality four-colour offset ink ideal to meet the requirements of ISO 12647 standard („Process Standard Offset“). The SunLit EXACT PSO printing inks can be lacquered with inline/offline water based lacquers and inline/offline oil based lacquers. The SunLit EXACT PSO process inks dry by oxidation and soaking in.

The surface properties of the print carrier greatly influence the rub fastness of the prints therefore six print carriers with different surfaces were applied.

Table 1: Tested print carriers

Type	g/m <sup>2</sup>	Surface
LUMILABEL STANDARD	80	glossy coated (on one side)
UPM FINESSE	100	matt coated
SOLOFSET	100	uncoated
BVS GLOSS	100	glossy coated
LUXO ART SAMT	135	matt coated
PROFIBULK	200	matt coated

Glossy art papers should have a good resistance to rubbing than that of the mat coated or uncoated print carriers as their smoothness is better due to the surface gloss and the manufacturing technology. From the point of rub fastness the surface properties of uncoated offset paper are the most unfavourable. However, their advantageous property from the point of ink drying is that their absorption ability is good because they are not coated and therefore the ink film dries quicker.

Four type of spray powders were used for the tests. They were tested and is recommended by the German printing industry trade association, BG.

*HARTMANN H 666 PUDER* / grob, which is a vegetable (starch) spray powder. The average grain size is 20 µm. It is suitable for print carriers coated on both sides above 250 g/m<sup>2</sup> or – in case of uncoated print carriers – above 200 g/m<sup>2</sup>. In case of moderate application the use of the spray powder influences the rub fastness only to a small extent.

*KSL K4* type (calcium carbonate) spray powder was used for mineral based spray powder. Due to the unique production technology the grains are not angular but rather round shaped. Thus the manufacturer ensures a lower rub fastness of the prints and more reliable use. The average grain size is 20 µm. The spray powder is not hygroscopic and the grains are not able to static charge. Due to the relatively large mass of the spray powder grains the velocity of fall of the grains is high which means good aiming and less „dusting out“ when used during printing.

*KSL L3* type was used for an sugar based spray powder. The product is a dry water-soluble substance with special properties. The mass of the grains is smaller, their surface is smoother than that of the mineral and starch powders. It is a system that operates smoothly and influences the rub fastness of the print only to a small degree. Because of the properties of the grain the manufacturer recommends the substance for all printed products that are further processed and surface refined. The grains are not hygroscopic, however, contact with moisture and water must be avoided. The grains are sensitive and become water soluble on high temperatures or in the vehicle of the ink, therefore contact with concentrated heat must be avoided. It is not recommended for printing machines equipped with UV and/or hot air drier unit. Because of the lower mass of the grains less dust is generated during its application. It is

susceptible to clotting therefore its application requires careful attention. The average grain size tested by us was 20 µm.

*DS POWDER 2020* spray powder was a vegetable spray powder and the average grain size of 20 µm was used. Currently this is the general spray powder used for the majority of the jobs. The product is insoluble in water and in the ink vehicle, and is recommended for in-line dispersion lacquering for print carriers with a square meter weight less than 150 g/m<sup>2</sup>.

### 3. Results and discussion

#### 3.1 The rub fastness (abrasion) test procedure

Rub fastness was tested with the Prüfbau Quartant rub fastness and surface strength meter (abrasion tester).

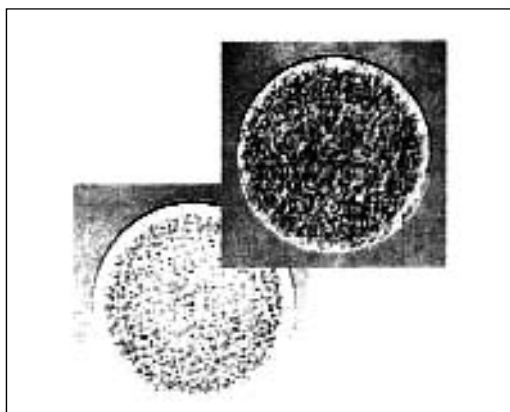
Technical data of the equipment:

- rubbing pressure:  $5 \times 10^{-1}$  N/cm<sup>2</sup>
- stroke number: 1-1999 double strokes (the cycle of the counter specimen making one forward and backward movement)
- specimen format: max. 50×250 mm, min. 45×100 mm
- format of the counter-specimen: diameter 45 mm
- total specimen thickness: 3 mm

After the rub fastness test the density of the ink layer transferred to the counter-specimen was measured with a GretagMacbeth D19C type densitometer with polar filter, at 2856 K illumination and 0:45° meter geometry.

The substances having different grain size and composition were tested on different print carriers and the resistance to rubbing, a factor influenced also by the substances themselves was determined on the individual prints. The surfaces rub against themselves and – depending on the test – against other surfaces at clearly defined conditions (given pressure, rubbing speed, rubbing movement and dynamics). The so-called rubbing image, produced after the stress ceases is evaluated and then the rate of resistance to rubbing is given for the surface. During the operation of the device a specimen and a counter-specimen move towards each other on all occasions while the counter-specimen moves horizontally there and back and performs rubbing simultaneously. The goal of the movements is to achieve the most uniform and optimal rubbing image possible.

The first measurements took place after the 12-hour drying period. The second series of measurements were taken after a 33-hour drying period.



*Figure 4: Image of the counter-specimen showing mild resistance to rubbing*

#### 3.2. Evaluation of the measurement results

The measurement results were evaluated with a graphical method. The average density values measured on the counter-specimens were represented by colours, as a function of the different spray powders. Value deviations were caused by the rubbing effect of the spray powder substance applied.

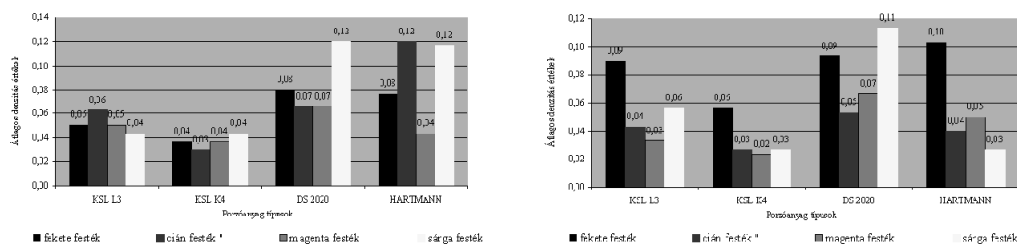


Figure 5: Density values measured on the counter side in case of LUMI LABEL STANDARD (left) and UPM FINESS (right) papers in the second series of measurement

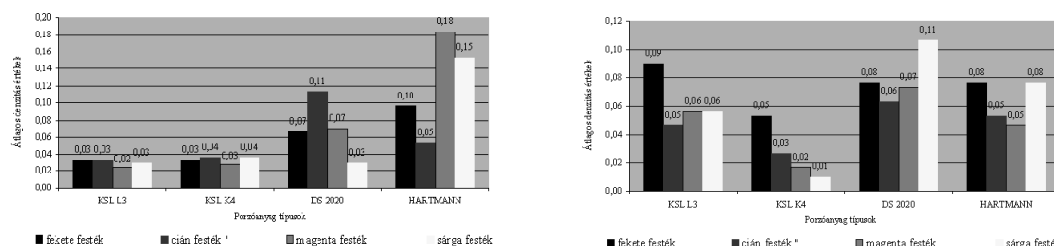


Figure 6: Density values measured on the counter side in case of SOLOFSET (left) and BVS GLOSS (right) papers in the second series of measurement

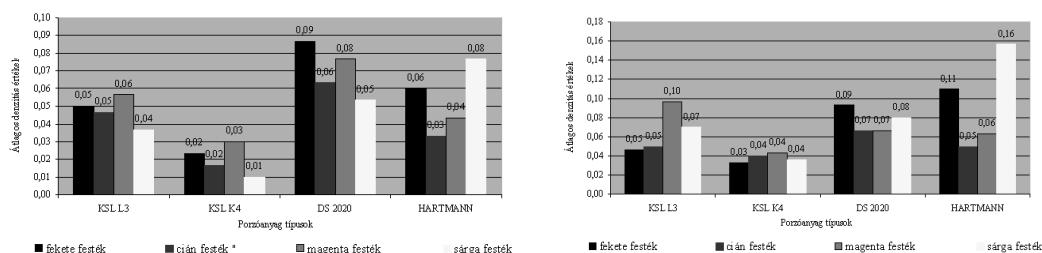


Figure 7: Density values measured on the counter side in case of LUXO ART STAMT (left) and PROFIBULK (right) papers in the second series of measurement

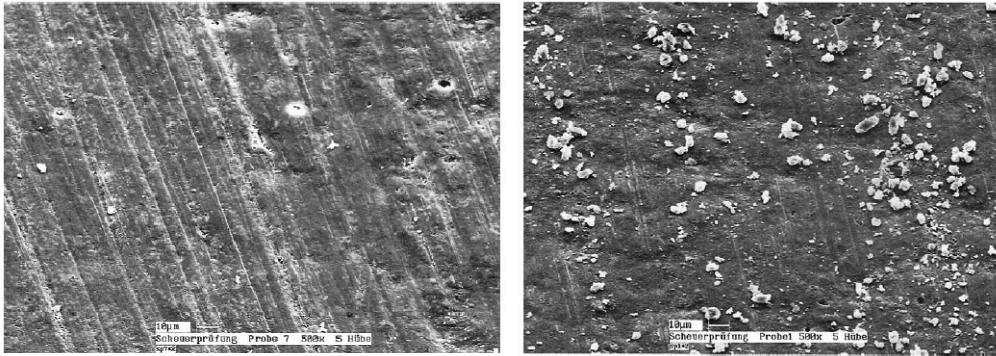
It can be read from the diagram how the tested powder matches the given print carrier and its suitability can be assessed.

Table 2: Evaluation categories of rub fastness tests (The values are in relative density to the print carrier)

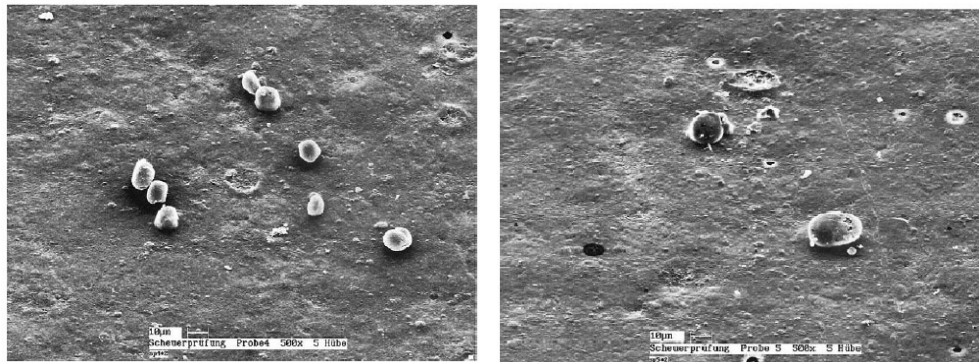
Density of counter specimen	Category
$D > 0.03$	outstanding
$D \ 0.03 \leq D < 0.06$	good
$0.06 - 0.12 <$	suitable
$0.12 < D$	unsuitable

The interference of the print carrier, the ink and the spray powder was studied on a digital image recorded by a video microscope. Images of 20x, 50x, and 500x magnification were prepared. The structure differences of anti set-off spray powders at 500x magnification were visible properly.





*Figure 8: KSL L3 sugar based powder and KSL K4 calcium-carbonate grains at 500x magnification*



*Figure 9: DS P2020 and HARTMANN H666 types vegetable (starch) based powder grains at 500x magnification*

#### 4. Conclusions

As a conclusion we established that all spray powders taking part in the tests fulfilled their function. However, KSL types (mineral and sugar based) show a much better resistance to rubbing as the DS and Hartmann anti set-off spray powders. The last two types have proved rub fastness only according to the „just suitable” category for all print carriers based on the density values measured on the counter-specimen. However, the KSL 3 spray powder achieved „outstanding” value in case of 2 print carriers and „good” on 4 occasions.

We have also established that if because of the surface refining method – for example because of varnishing - these properly usable sugar or mineral based substances cannot be chosen, starch based spray powders may also provide satisfactory result when used to speed up drying, as in this case the protection of the surface against rubbing is performed by the varnish or foil applied for surface refining purposes.

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## THE EVALUATION OF EFFECTS OF THE DIFFERENT MULTIMEDIA COMBINATIONS ON E-LEARNING OUTCOMES

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**Abstract:** Besides the quality of the learning content, the crucial influence on the efficiency and effectiveness of e-learning systems has the choice of appropriate multimedia combination for presenting the given content. This work evaluates how various multimedia improve e-learning unit from a specific graphic engineering course. The six experimental groups have been comparatively investigated in order to gauge the effects of six different versions of learning unit, each supplied with different multimedia combination: text with (version 1A) or without (version 1B) emphasized words; pictures (still graphics) and text with (version 2A) or without (version 2B) the control over the presentation rate; animation and text with (version 3A) or without (version 3B) the control over the presentation rate. The collected data consist of retention test scores and subjective evaluations from two usability satisfaction questionnaires. On retention test, the best mean score had the group that was learning the unit with interface versions 2A and 2B, while the worst learning performance gave the group tested with version 1B. The versions 2A and 2B are, also, subjectively evaluated as the versions with the highest usability satisfaction level and the most adequate for learning. Inside the each group, subgroup A proved to be more successful solution in terms of learning outcomes. The obtained research results are consistent with a cognitive theory of multimedia learning (Mayer, 2001) and can be used in leveraging multimedia combination for the unit content in order to align with human learning processes.

**Keywords:** e-learning, multimedia, cognitive theory.

### 1. Introduction

The computer-based and web-based e-learning systems and the technologies, on which they are based, are advancing rapidly and growing exponentially, with tendency of supplementing or even replacing traditional learning systems (face-to-face classrooms) (Horton, 2000).

The multimedia features supplemented in e-learning systems has huge potential for improving learning. However, that potential is often unused due to a lag in exploration of multimedia capabilities in supporting learning, so that multimedia features are either too little (no visuals, no audio, and no interactive elements to engage the learner) or too much employed (too much stimulus at once).

Bernard et al. (2004) conducted a meta-analysis which integrated the results (the effect size value) from 318 individual research studies comparing learning from various forms of distance learning systems to learning in traditional classroom environment using different content, different learners, different lengths etc. Figure 1 shows a histogram of the effect sizes from these individual studies.

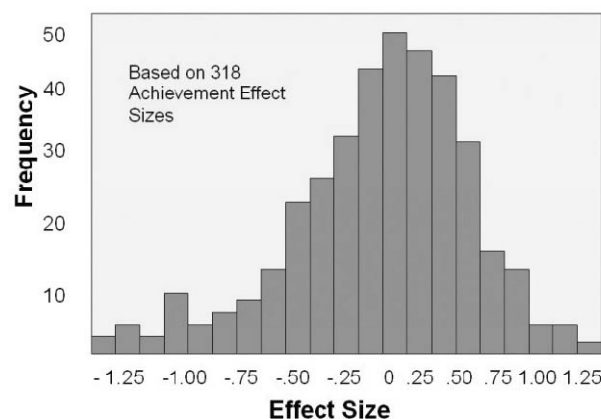


Figure 1: The histogram of effect sizes of e-learning systems compared to traditional systems (Bernard, 2004) Effect size interpretation: 0.2 or below - too small to matter much; 0.5-moderate; 0.8 and higher - large

The reason for the inconsistency in learning outcomes is that the quality of a learning environment is not in the technology, but in how the used technology supports human learning processes. If two units include all of the elements needed for learning, learning will occur whether the unit is delivered in an e-learning version or in a classroom (Mayer, 2002).

Najjar's (1995) technical report (GIT-GVU-95-29) gathered 45 research studies in order to explain the learning value of different multimedia features. The general guidelines from included study results are that learning is better when related information is presented simultaneously via verbal (text, audio) and pictorial (still pictures, animations, video) media than when the information is presented via verbal and pictorial media sequentially, via verbal media alone or via pictorial media alone.

In order to understand how multimedia combinations affect learning, the human learning process should be firstly analyzed. In the field of educational psychology, widely accepted theory is Mayer's cognitive theory of multimedia learning (2001), illustrated in Figure 2.

Mayer's cognitive theory gives three theory-based assumptions about how people learn from multimedia instructional messages as presentations involving words (spoken or printed text) and pictures (illustrations, photographs, animation or video):

- the dual channel assumption (based on dual coding theory);

The human cognitive system consists of two distinct channels for representing and manipulating knowledge: a visual-pictorial channel and an auditory-verbal channel (Baddeley, 1999; Paivio, 1986).

- the limited capacity assumption (based on cognitive load theory);

Each channel in the human cognitive system has a limited capacity for holding and manipulating knowledge (Baddeley, 1999; Sweller, 1999). The visual-pictorial (auditory-verbal) channel can become overloaded due to too much pictures (words) presented at one time.

- the active processing assumption (derived from constructivist learning theory);

Visuo-spatial (auditory-verbal) thinking is involved in process of knowledge construction through the processes of selecting images (words), organizing images (words) into a coherent mental representation in working memory called a pictorial (verbal) model, and integrating that model with prior knowledge from long-term memory. These active learning processes are more likely to occur when corresponding verbal and pictorial representations are in working memory at the same time (Mayer, 2002).

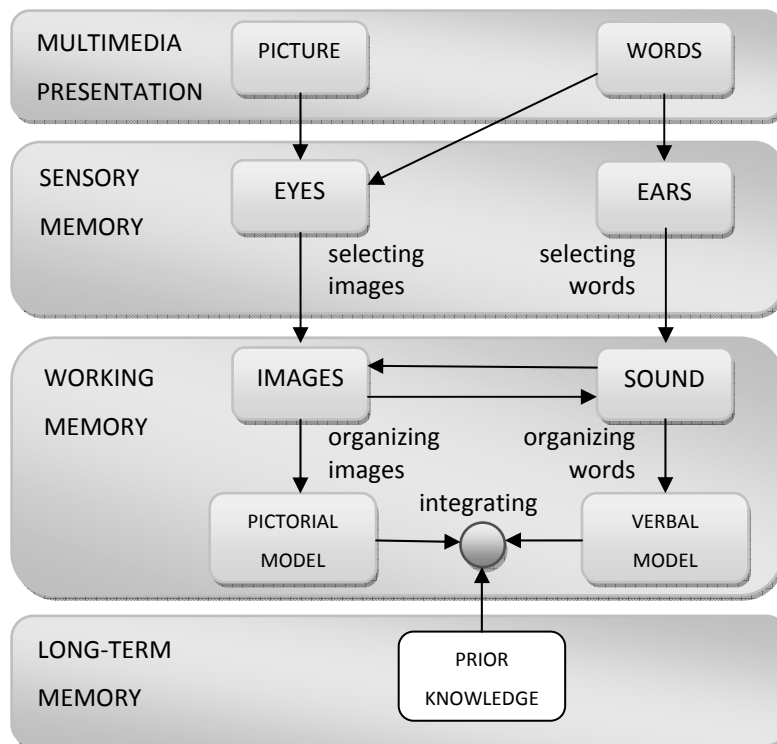


Figure 2: The cognitive theory of multimedia learning (Mayer, 2001)

Based on the cognitive theory of multimedia learning, following principles of instructional design for supporting multimedia learning are derived and tested:

- **multiple representation principle** recommends that it is better to present an explanation in words and pictures than solely in words;
- **contiguity principle** states that deeper learning occurs from presenting words and pictures simultaneously rather than successively;
- **coherence principle** states that multimedia explanations are better understood when they exclude extraneous words and sounds that are not related to the learning material;
- **modality principle** recommends that it is better to present words as auditory narration rather than as on-screen text;
- **redundancy principle** states that deeper learning happens when words are presented as narration rather than as both narration and on-screen text; and
- **interactivity principle** recommends the presentations where learners are allowed to control the presentation rate.

In order to become universal guidelines for designing e-learning systems, these principles must be confirmed with statistically significant number of independent research studies that will include various educational levels and fields.

Every new empirical study concerning a new field and supplied with a new multimedia features gives results that support decision what certain multimedia combinations appear to be better than others in terms of helping people learn different kinds of information.

The purpose of this research has been comparing the influence of different multimedia combinations (text; text and illustrations; text and animations) employed in different versions of e-learning unit on learning outcomes and subjective evaluation of version in terms of adequacy for learning the content. Methods, as well as presentation and discussion of results, are defined below.

## 2. Method

### 2.1 Versions of learning unit and experimental groups

The learning unit used in the study is about conventional production process of photopolymer printing plates for flexographic printing technique. For the purpose of investigation, the six e-version of the same learning unit has been designed. The time of exposure to e-learning material is 5 minutes for all the versions and all the versions have the same information content.

The participants of this investigation were 90 undergraduate students (the 3<sup>rd</sup> year of studies) from the Department of Graphic Engineering and Design, the Faculty of Technical Science. The sample can be considered satisfyingly homogeneous since the subjects had no prior knowledge about the learning material used in the experimental learning unit (production of photopolymer printing plates for flexographic printing), but they had similar level of prior knowledge needed for comprehension of e-learning unit (basic knowledge about the flexographic printing technique).

These 90 participants were randomly assigned to one of the following three groups, each containing two subgroups:

- text group (version 1): the unit content was presented in the form of plain text (approximately 400 words);

In the case of the first subgroup, unit version was text with emphasized headings and keywords (version 1A), while in the version for the second subgroup text didn't have emphasized words (version 1B).

- text and illustration group (version 2): the unit content was presented in the integrated combination of text and illustrations (approximately 300 words and 7 illustrations);

In the case of the first subgroup, unit version was with the facility to navigate between 7 illustration with integrated text so the presentation rate could be controlled (version 2A), while for the second subgroup, illustration was sequentially replacing the previous illustration after certain time interval, where the time of illustration sequence is approximately 5 minutes (version 2B).

- text and animation group (version 3): the unit content was presented in the integrated combination of text and animations (approximately 300 words and 7 short animations);

In the case of the first subgroup, unit version was with the facility to navigate between 7 animated short movies with integrated text so the presentation rate could be controlled (version 3A), while for the second subgroup, animation was sequentially replacing the previous

animation after certain time interval, where the time of animation sequence is approximately 5 minutes (version 3B).

The six learning unit versions were design in Adobe Flash CS3 software and reproduced with Flash Player 9.0. The versions 1A, 2A and 3A were grouped in module A, and the versions 1B, 2B and 3B were grouped in module B.

A screenshot of different version designs is shown in Figure 3.

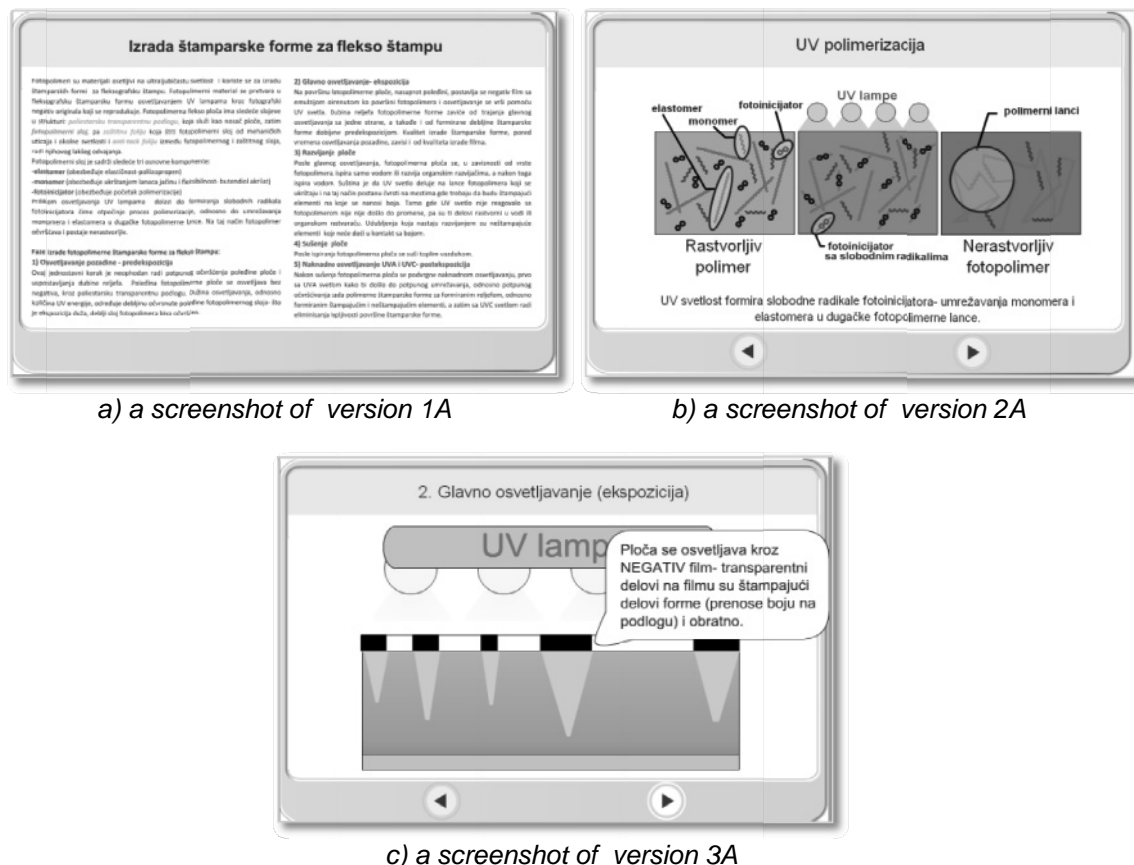


Figure 3: Design of e-versions from module A

Module B looks almost the same like versions from module A (Figure 3) with difference that version 1B doesn't have emphasized words and versions 2B and 3B don't have navigation buttons.

## 2.2 Retention test and post-usability questionnaires

The subjects completed test for measuring the retention of the obtained knowledge. The retention test had fourteen questions with ABC answers (for example, Photopolymer used in flexographic plate making process is sensitive on: a) IR light, b) UV light, c) visible light).

Besides performance measures, the collected data included two usability questionnaires: the first questionnaire represents adapted IBM Computer System Usability Questionnaire (Lewis, 1995) for subjective evaluating of assigned version's content and interface quality and the second questionnaire for comparative evaluation of module versions (for example, 2A version is compared with 1A and 3A; 1B is compared with 2B and 3B etc.).

## 2.3 Experimental procedure

The determination of experiment length was based on recommendations for limiting eLearning lessons to 2–5 minutes (Mayer, 2007), due to working memory's restrictions on how much information can be held at one time.

The experimental procedure had the following steps:

- students were randomly assigned the one of six subgroups and explained what is expected from them to do;
- each of the participants viewed the version corresponding to his/her treatment group on the separate computer in duration of 5 minutes;

- students were given 5 minutes for completing the retention test;
- students completed the first usability satisfaction questionnaire;
- students watched the other two versions in module and completed the second questionnaire.

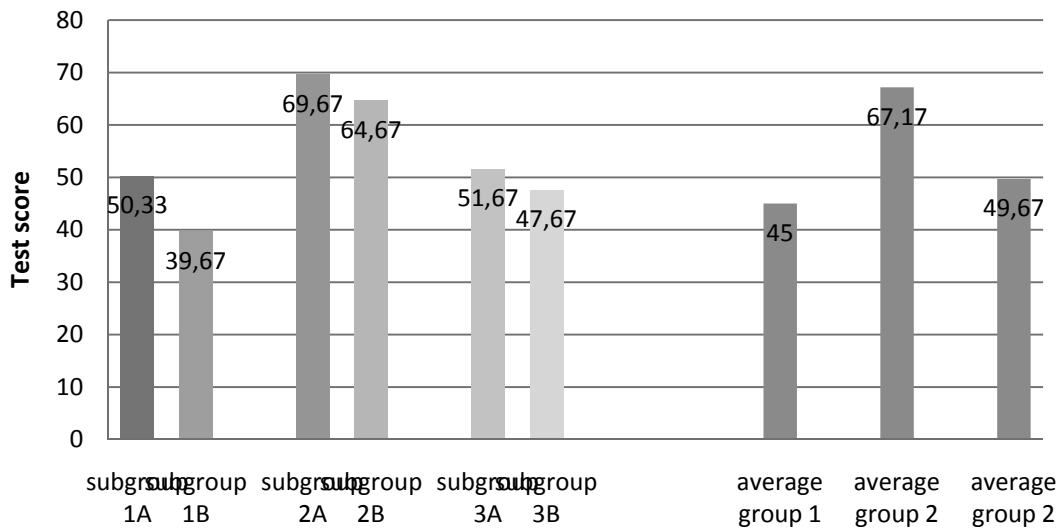
### 3. Results and discussions

#### 3.1 Performance test scores

The obtained results of participants' performance on written test are presented in Table 1 and, also, graphically on Figure 4.

*Table 1: Mean performance score and standard deviation for the each experimental subgroup and each average group*

Subgroup	Mean performance score	Standard Deviation	Average Group	Mean performance score	Standard Deviation
1A	50.33	11.94	1	45.000	13.66
1B	39.67	16.63			
2A	69.67	14.31	2	67.17	11.86
2B	64.67	11.81			
3A	51.67	20.02	3	49.67	18.90
3B	47.67	20.12			



*Figure 4: Mean achieved scores on the retention test (maximum score is 100)*

From Figure 4 can be noticed that the best performance gave the subgroups tested with versions that integrate text and illustration in presenting learning content (2A and 2B) and the lowest mean test scores were achieved in the subgroups tested with plain text (1A and 1B). Within each average group, subgroup A had better mean test scores.

Even a very small difference in mean performance scores can be statistically significant, but not practically significant. In order to determine practical significance, value of the effect size is calculated using following equations:

$$d = \frac{M_{TG} - M_{CG}}{\sqrt{(S_{TG}^2 + S_{CG}^2)/2}}, \quad (1)$$

$$r_Y = \frac{d}{\sqrt{d^2 + 4}}, \quad (2)$$

where:

d is Cohen's d,  $M_{TG}$  and  $M_{CG}$  are mean values of tested and controlled group, respectively,  $S_{TG}$  and  $S_{CG}$  are standard deviations of tested and controlled group, respectively, and  $r_Y$  is the effect size correlation.

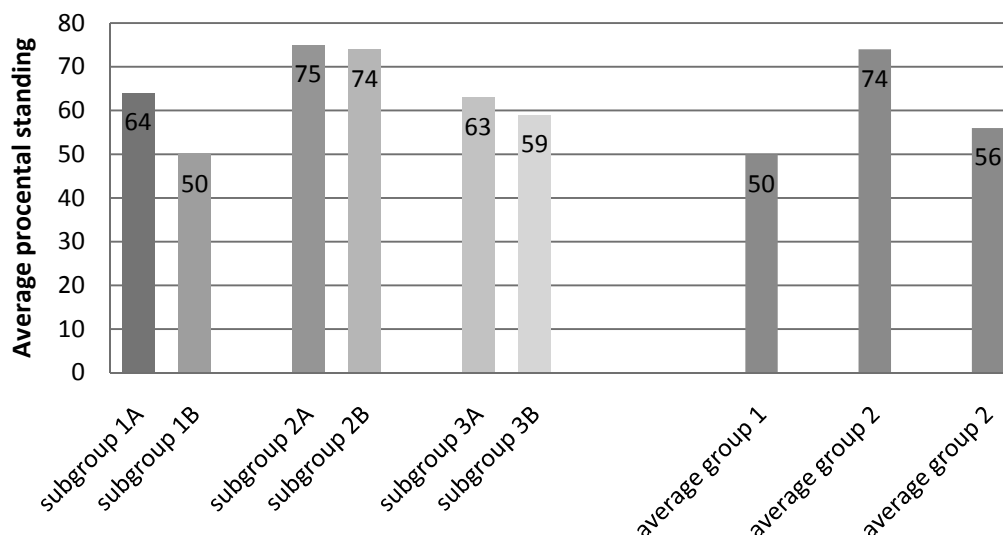
An effect size is the degree of standard deviation difference in the test group compared to the control group. For the test group is chosen the simplest version 1B, in which the learning unit is represented only in plain text without emphasized words. The effect size values of all subgroups and mean effect sizes of average groups are shown in Table 2 and graphically presented on Figure 5.

Effect sizes can also be thought of as the average percentile standing of the average experimental participant relative to the average control participant. The effect size of 0.0 indicates that the mean of the experimental group is at the 50<sup>th</sup> percentile of the control group. For explanation, in Table 2, an effect size of 0.35 indicates that the mean of the group 1A is at the 64<sup>th</sup> percentile of the control group 1B etc.

*Table 2: The effect sizes of subgroups (control group is 1B) and mean effect sizes of groups (control group is group 1 representing mean from versions 1A and 1B)*

Version	Effect Size	Percentile Standing	Version	Effect Size	Percentile Standing
1A	0.35	64	1	0.00	50
1B	0.00	50			
2A	0.69	75	2	0.65	74
2B	0.65	74			
3A	0.31	63	3	0.14	56
3B	0.21	59			

*Effect size interpretation: 0.2 or below - small; 0.5- moderate; 0.8 and higher - large*



*Figure 5: Average percentile standing of the average experimental participant relative to the average control participant (1B for subgroups and 1 for groups)*

From the effect size values of 0.69 and 0.65 for the groups 2A and 2B, respectively, can be concluded that enhancement in learner's performance is large enough to have considerable practical significance (Bernard, 2004). Including standard deviations, performance improvement of the subgroup 1A is higher than in the case of 3A and 3B subgroups.

### 3.2 Subjective evaluating of assigned version's content and interfaces

Subjective usability satisfaction measurements, obtained from usability satisfaction questionnaire (adapted from the IBM Computer System Usability Questionnaire) are presented in Table 3.

*Table 3: Mean evaluation values for each statement in the usability satisfaction questionnaire (adapted from IBM questionnaires, 1995)*

OVERALL QUALITY	INFO QUALITY	Question	Version 1	Version 2	Version 3
		1. The amount of presented information is adequate.	5.200	5.167	5.067
		2. The content of learning unit is easy to understand.	5.300	5.267	5.333
		3. The presentation and selection of information enable easy memorizing.	4.233	5.067	5.100
		4. Sequence and organization of information is adequate.	5.300	5.333	5.100
	INTERFACE QUALITY	5. Interface of learning unit is pleasant.	4.100	5.100	4.967
		6. Interface of learning unit is easy to use.	5.467	5.333	5.067
		7. Interface of learning unit enables efficient memorizing.	3.933	5.167	5.000
		8. Interface of learning unit makes learning easier.	4.133	5.367	4.900
		9. Generally, I am satisfies with e-version of learning unit.	4.700	5.267	5.000

*Response scale: 1- very strongly disagree, 7- very strong agree*

According to Table 3, there are no significant differences between subjective evaluations of content and interface quality for all three groups.

### 3.3 Subjective comparative evaluations of tested versions

After completing the usability satisfaction questionnaire for evaluating of assigned version's content and interface, the participants watched the other two versions in given module. Table 4 summarizes the responses from the second questionnaire for subjective compaction of versions.

*Table 4: Subjective comparing evaluation*

Unfinished statement:	Version 1 [%]	Version 2 [%]	Version 3 [%]
1. The easiest understanding of the is with version:	14.44	51.11	34.44
2. The most suitable for efficient memorizing version:	6.67	54.44	38.89
3. The best keeps attention version:	7.78	48.89	43.33
4. The most motivates for learning version:	10.00	54.44	35.56
5. The easiest way to learn the unit is with version:	11.11	54.44	34.44

From Table 4 can be concluded that participants prefer versions that integrates text and illustrations or animation compared to textual version in terms of comprehension, easy memorizing, keeping attention and motivation. The dual coded versions (with both verbal and pictorial elements) are evaluated (54.44 % and 34.44%) as more adequate solutions for learning this kind of e-lessons.

## 4. Conclusion

There is a rapidly growing demand for multimedia e-learning systems, which offer great potential for learner's performance improvement. However, for learners to achieve the optimal results, it is of crucial significance that implemented multimedia features support the human learning processes.

The obtained results suggest that learning outcomes are enhancing when the learning content is dual coded (both with words and images).

The superiority of version 2 provides substantial evidence for the multiple representations principle, derived from the dual-coding theory, which states that adding visual modes of instruction to verbal ones results in deeper understanding.

However, the group 3 tested with also dual coded versions with integrated animations and text (3A and 3B) poorly performed compared to group 2, although this multimedia combination seemed like a good solution for providing better comprehension of unit content. The possible



explanation for this poor result can be found in postulates of the cognitive load theory in the way that multimedia combination that integrates animation and text can cause the cognitive overload of visual-pictorial channel. Guidelines for preventing the channel overload can be found in modality principle, derived from the cognitive load theory, which recommends that deeper learning will occur when words are presented as auditory narration rather than as visual on-screen text.

Inside the each group, subgroup A proved to be more successful solution in terms of learning outcomes. In the case of versions 2A and 3A, obtained performance results are confirming interactivity principle, according to which deeper learning occurs when learners are allowed to control the presentation rate; and, in the case of version 1A, the reason for enhancement of learning outcomes is in perception of emphasized words as pictorial elements.

This pattern of retention test and questionnaires results provides strong confirmation of the three cognitive theory-based assumptions about how people learn from multimedia instructional messages.

Overall, the findings of this empirical research have both a theoretical goal of contributing to a cognitive theory of multimedia learning and a practical goal of recommending the design guidelines for effective multimedia e-learning units for different levels of technical education.

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## NEW STUDENTS HANDBOOK: DIGITAL IMAGE PROCESSING – APPLICATIONS IN GRAPHIC ARTS

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**Abstract:** *The authors, professors at the Faculty of Natural Sciences and Engineering, University of Ljubljana, decided to write a students-oriented handbook on fundamentals of digital image processing and, to some extent, image analysis that would be of interest primarily to the students, engineers and technicians working in the graphic arts, papermaking and related industries. A large number of high-quality books about image processing and -analysis currently exist, but only few of them are written in Slovene language and virtually none that would be focused towards the specific problems found in the field of graphic technology.*

*Image processing and -analysis algorithms can be implemented in prepress, press and postpress operations. In quality control, for instance, they can be seen as a useful tool for precise assessment of different substrate-printing ink interactions and negative phenomena and nowadays increasingly replace conventional e.g. densitometric measurements.*

*The handbook comprises two parts: first one is an introduction to the field of image processing featuring chapters on digital image basics, point operations, spatial filtering, morphological operations and color image processing. Second part – applications in graphic arts – will be finished in the following months containing a number of practical examples where tools described in the first part have been successfully implemented.*

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