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ANALYSIS OF BLACK ELECTROINK SCREENING ELEMENTS AFTER PRETREATMENT THE FINE ART PAPER SUBSTRATE

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Abstract: *Coating the substrate as a method of surface finishing is very common in the printing industry. It is used to improve the properties of the final printed paper substrate and also as a pre-treatment method before applying the printing ink. Such pre-treatment is primarily used to modify the surface tension of a substrate, which primarily aims to achieve higher print quality and better ink adhesion. In this paper, the effect of the HP Indigo WS 6800 print press on the paper substrate was tested with a variation of corona power (0 W, 450 W, and 950 W) and the application of the different thicknesses of primer intended for working with ElectroInk inks (0 g/m^2, 0,5 g/m^2 and 1 g/m^2). To determine their influence on achromatic reproduction, an image analysis is carried out to determine the diameter of the black halftone elements (Personal PIAS), which could also diagnose the halftone shapes (deformation of the circle of black print dots). Black separation without corona treatment produces the smallest, but also the most deformed halftone elements, while the optimum (highest print dot) is achieved by a corona voltage of 450 W. The most effective black print is achieved by applying a primer of 0,5 g/m^2.*

Key words: paper pretreatment, HP Indigo, print quality, screen element analysis

1. THEORETICAL PART

In order to realize the basic process colors during the printing process, it is necessary to apply 2/3 of the transparent inks to the white reference printing substrates. In other words, CMY prints reflect 2/3 of the visible spectrum while absorbing 1/3 of it. These colours are cyan, magenta, and yellow, and are also known as process colors with addition to achromatic black. Their halftones can be achieved by screening mixing, which is performed in the prepress process, where multi-tone images are converted into 4 halftones color separations (CMYK). Such an image will be composed of a series of small halftones that, depending on the position and size, will cause different tonal perception (due to the sluggishness of the human eye, which cannot register halftones). (Heidelberg, n.d.)
Screening methods have been modified over time. i.e., the application of mathematical methods (RIPs for image processing). Depending on the applied mathematical algorithm, it is possible to form the following screening methods: amplitude modulated screening (AM), frequency modulated screening (FM) and hybrid screening. In Figure 1, examples of commonly used screenings applied in the printing industry are shown. Amplitude screening is the oldest halftone image generation principle used in the printing industry. It is characterized by the exact positions of the smallest halftones (dots) whose size varies depending on the tonal value. Thus, light tonal values on picture will have small dimensions of halftones (area coverage), while darker tonal values will have larger dimensions that will be gradually closed. Amplitude screening is recommended for reproduction of mid-tones (with light and dark tones, halftones are lost, and with it many details). The screen elements of each colour separation are placed at different angles in CMYK colour prints. A colour rosette made of halftones can be seen when the angles of halftones are well defined. (Rousu, Gane & Eklund, 2003)
Frequency-modulated screening is a modern process of generating a color image that cannot be performed without a computer. At the beginning of its application, a random distribution of screen elements whose dimensions are always the same is characteristic. Sizes in the range of 40 µm to 10 µm are typically generated. Thus, light tonal areas will be realized with a lower concentration of halftones, while dark tonal areas will be realized with a higher concentration. Some of the advantages of stochastic screening are good reproduction of details, lines, and small typography elements, many colors can be achieved on the print, less consumption of ink (it dries faster), and no problems with halftones corners and the appearance of moiré. Higher quality reproduction is achieved by using the smallest possible raster elements that create a very sharp image with a lot of details. Disadvantages are high technical requirements (when making and imaging printing plates), higher quality printing material is required, and

there is a problem with the increase of screening values (mostly in the area of mid-tones), which causes worse reproduction of tonal values in mid-tones. For the needs of electrophotographic digital printing, a special principle of frequency-modulated screening is applied. That means that each halftone is generated within an 8-bit matrix. Thus, all halftones (dots) will have the same dimension, but their tonal value will vary by the tonal value (coverage of image). With these screening methods, the Moiré effect is eliminated. However, color images are characterized by a specific graininess that is visually noticeable in the mid-tone areas. (Kipphan, 2001)

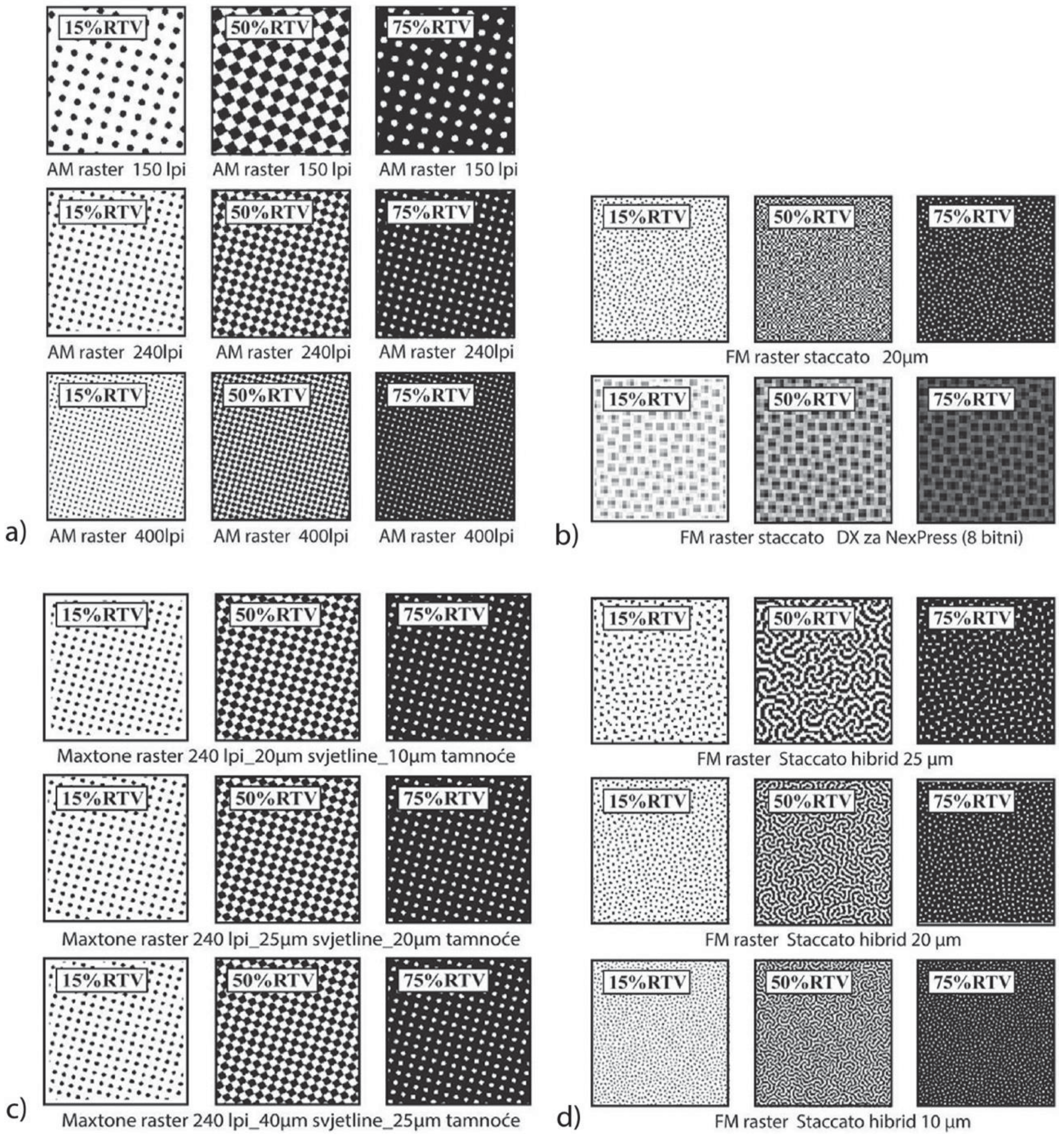

Figure 1: Enlarged image of printed typical screens: a) AM screen of 150 lpi, 240 lpi, and 400 lpi; b) FM rasters with an element of 20 µm and 8-bit staccato raster; c) hybrid Maxtone screening of 240 lpi 40 µm, 25 µm; d) FM raster Stacato hybrid 10 µm, 20 µm, and 25 µm

Since amplitude and frequency modulated screening has certain disadvantages, to achieve optimal color results, there is a need for their corrections (combining their positive properties). This is the reason for the generation hybrid screening process. In prepress, a common screening method is Maxtone. It is an amplitude-modulated screening in which the light and dark tonal values are additionally corrected (the smallest halftones are only in the low tonal values and are slightly increased, while the smallest halftones in the high tonal values are slightly reduced). This allows the reproduction of a wider range of grayscale, which is problematic with poorer printing substrates (flexographic printing). (Bartolić et al., 2013)

With the development of faster and stronger computers, the possibility of combining different frequency-modulated screenings has been realized. A representative of such screening methods is Staccato, wherein a color image, in addition to the stochastic distribution of halftones, different dimensions (from 25 to 10 µm) are found.

This reduces the traditional image graininess (better sharpness) while reproducing a larger range of gray colors. To apply this screening, the printing units of the offset machines must be ideally adjusted. This refers to the printing unit system (exactly defined diameter of cylinder and hardness of the offset rubber cover), the wetting units (applying a minimum amount of damping solution with the use of IPA alcohol), and the inking units (temperature-controlled cooling). One such printing unit is Heidelberg's Anicolor printing unit. (Zjakić, 2007; Majnarić, 2015)

Screening in flexo printing

The screening method is especially important in flexo printing. In flexo printing, the halftones are small, and they are made on a relatively soft polymer printing form. Under the influence of pressure, the deformed halftones bend and create deformations that result in a bad quality of imprints. This problem is especially visible when printing large format width OPP films that require more pressure or when printing uneven printing substrates such as cardboard. For this reason, the minimum size of the halftones is defined in the prepress. The white point is defined in percentages and serves as orientation when creating printing forms so that the halftones are not too small. Of course, the definition of this minimum point depends on the type of printing machine, the printing conditions, and the printing substrates. Precisely by defining the minimum size of the raster element, the performance quality of more demanding designs is directly affected. This problem is particularly emphasized when printing soft transitions or shadows that should start at zero. In this case, the transitions end with sharp edges in the values of the minimum halftones. (Bolanča, 1997)

Hybrid raster has also found application in flexo printing. It solved the problem in flexo printing known for bad blending from one color to another, colloquially called the "flexo break effect". By using XM screening technology, the mentioned problem is reduced to a minimum. Manufacturers of CtP equipment currently offer different solutions for these transitions, known under the factory names Artwork System Quantum Hybrid and Heidelberg Prinect Hybrid. However, each of the mentioned screening technologies still has its advantages and disadvantages. FM technology, for example, is recommended for printing sharp images, whereas grainines may occur when printing medium tonal values. AM raster is suitable for printing mid-tones, but it has issues when printing lighter transitions; lighter tones typically look cut off. As for XM technology, it will reduce the visibility of moiré, and provides the possibility of reproducing high dot line frequency without losing details and transitional tones.

HD screening is also a more advanced raster technology known as HD technology (HighDefinitionScreen). It is based on the application of CtP devices with high-resolution optics, which enables a finer recording on the printing plate and the reproduction of more advanced types of halftones. HD technology works on the principle of reducing the size of the white point and making the size of the halftone as small as possible. By using this technology to achieve lighter tones, the classic reduction of raster elements is not used as with AM technology, but a combination of larger and smaller dot elements is created. Thus, larger dot elements serve as a support and carry the pressure load, thus preventing the deformation and damage of smaller dot elements. This way, a smaller amount of ink is transferred and creates the impression of a lighter imprint. With this technique, a finer record of higher resolution is possible (in the size of 4000ppi) and a regular (round) shape of the printed halftone is obtained.

Kodak's Flexcel NX system eliminates all possible disadvantages characteristic of flexo printing. It is a system with many innovations and advantages compared to existing solutions for making photopolymer printing plates. The technical advantages of the Kodak Flexcel NX CtP device are manifested in: a speed of 9,5 m^2/h, a printing resolution of 10,000 dpi, and the possibility of making a printing plate for all printing techniques (except gravure printing). In this way, the prerequisite to produce printing plates was realized, the characteristics of which are: the halftones are completely flat and of the same height over the entire surface of the printing plate, regardless of the tone values, the durability of the printing plates is seven times greater, and the lowest tone value that can be produced and printed is 0,4%. (miraclon, 2021)

2. EXPERIMENTAL PART

In experiment, we use an HP Indigo WS 6800 7-colour printing machine with an integrated in-line priming device and corona unit to generate prints. For colour separation, an ESCO HPE ProLiant ML350 RIP model was used, with standard LUT 0,5 calibration curves and 180lpi. The standard print form "FOGRA Image Quality" of SRA3 was used as a test form and only black separation was studied (Kraushaar, 2018).

The printing substrate used is 90 g/m^2 Condat digital gloss RL (gloss-coated fine art paper). The paper is made out 50% virgin cellulose, 40% calcium carbonate, 4,5% water, and 5,5% latex and adhesive (Lecta, 2018). During the printing, process paper was treated through two different primer depositions (Michem® In-Line Primer 030 manufactured by Michelman) in an amount of 0,5 g/m^2 and 1 g/m^2. The corona treatment impact test on the reproductions was also performed. The Vetaphone model VE1A-A (C4) 410 corona unit was used with 450 W and 950 W charging power settings. (Vetafone Corona & Plasma, 2020)

Experimental prints were obtained with a variety of predefined corona voltages (0 W, 450 W, and 950 W) and a different amount of primer applied: a) untreated surface (without primer); b) surface treated with primer deposit of 0,5 g/m^2 (46 rpm) and c) surface treated with primer deposit of 1 g/m^2 (96 rpm). As a result of combining all the setups, nine distinct monochromatic samples were obtained. (Fig. 2). To determine the quality of monochromatic reproduction, the QEA PIAS II digital microscope (QEA, 2006). The obtained CIE L*a*b* and CIE LAB ΔE results were compared to the existing graphics industry standard ISO 12647-8 (Morić, Majnarić & Modrić, 2020; International Organization for Standardization, 2012).

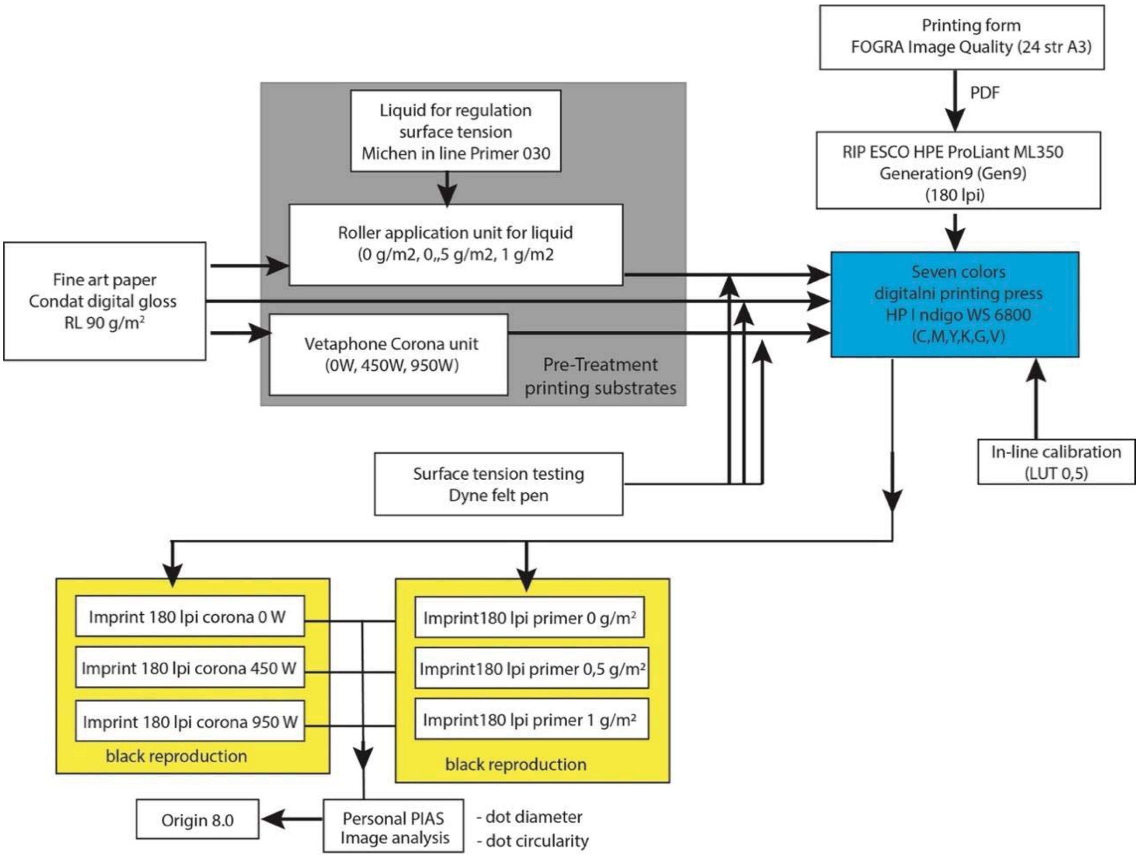

Figure 2: Schematic representation of a chronologically executed experiment

3. RESULTS AND DISCUSSION

As a result of printing, a double transfer of inks is achieved from the virtual printing form to the offset rubber and from the offset rubber to the printing substrate. As a result of these transfers, tone value increments (TVI) are realized, and thus deformations of the smallest print elements. Figures 3 and figures 4 show deviation curves in diameters and circularity of black ElectroInk halftones printed on a measured surface of 2,54 x 2,54 mm.

Figure 3a shows that the size distribution of the diameters of the black halftone is non-linear. Deviations in the sizes of halftones are visible on all tone values, but the most significant is the deviation of halftones on imprints without treatment. In the area of 30% TV, it amounts to $\Delta d_{30\%\ (0W\ -\ 450W)}$ = 19µm. The largest raster elements were formed on a printing substrate treated with a 450 W corona ($d_{\text{avr\_450}W}$ = 61,77 µm), while the smallest were on prints without corona treatment ($d_{\text{avr\_0}W}$ =50,43 µm).

The curves in Figure 3b show the diameters of black halftones with minimal primer application. They have a regular, linear shape. All resulting deviations in all measured fields of TV are minimal, regardless of the application of corona power. This is also evident from the sizes of the diameters of the halftones, which range from $d_{\text{avr (950}W)}$ = 58,43 μm to $d_{\text{avr (450W)}}$ = 60,6 µm.

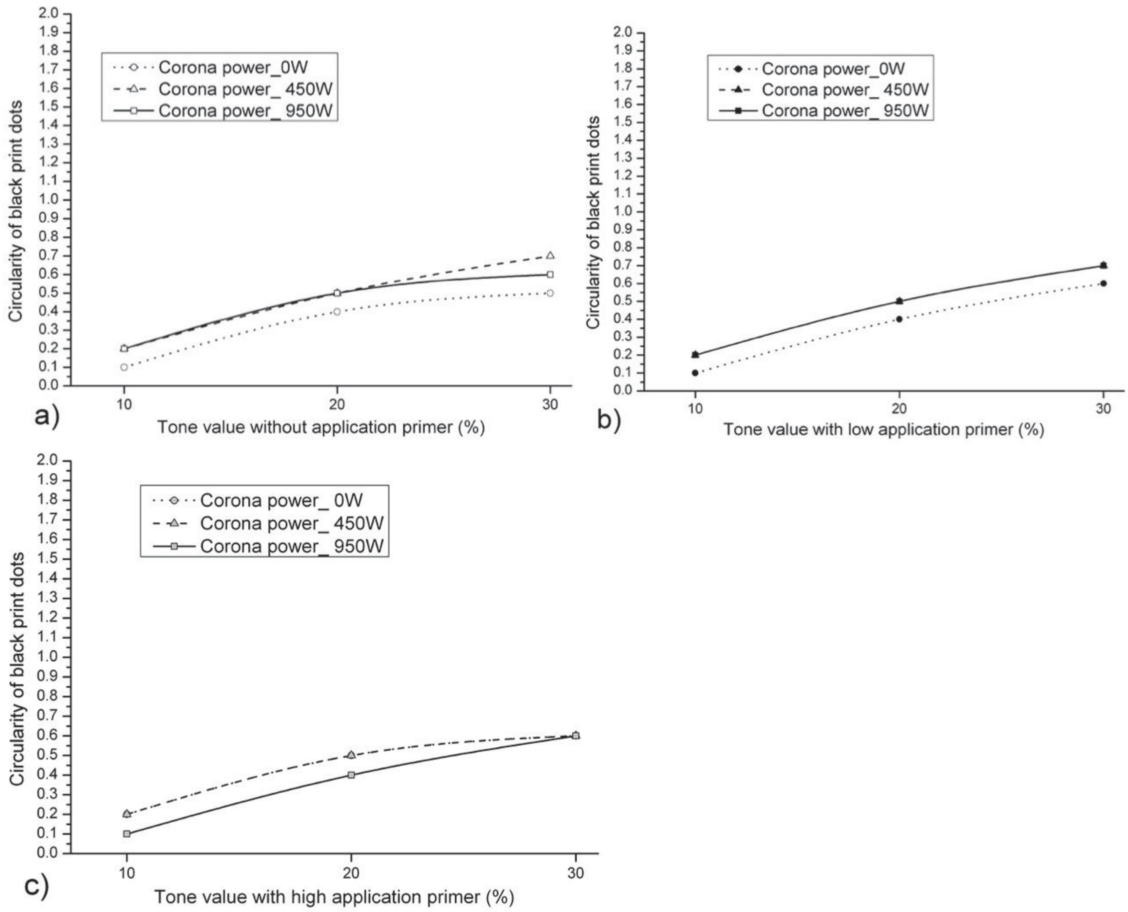

Figure 3: Curves of the dependence of the diameter of the halftones on the imprints are obtained by varying the corona power of 0 W; 450 W and 950 W, and application of the primer in a surface mass of a) 0 g/m^2; b) 0,5 g/m^2; c) 1 g/m^2

Figure 3c shows that a visible change in the dot diameter can be achieved with the maximum application of the primer. Simultaneously, the imprint without the corona power effect varies out from the other two curves. This is especially emphasized on the surfaces of 30% TV ($\Delta d_{30\%(0W-450W)}$ = 17,5 µm). The resulting dot deviations are very small, but still, the 450W corona treatment will achieve somewhat larger diameters of halftones in darker fields ($d_{\text{avr}(450W)}$ = 61,6 µm). The smallest diameters of black halftones were thus obtained on prints without the effect of the corona device ($_{(0W)}$=50,3 µm).

The deviation of the circularity obtained on the printing substrate without corona treatment is negligible ($\Delta C_{10\%(0W\text{-}450W)}$ = 0,1). In the darkest areas (30% of TV), the circularity of the elements is best on the substrate treated with a 450 W corona ($C_{30\%}$ = 0,7), while on the other two types of the substrate it is slightly worse, but not so much as to be significant ($C_{30\%\ (0W)}$= 0,5 and C30% (950W) = 0,6). By analyzing all reproduced black prints, a small average deviation of the circularity of the dot elements was observed, which amounts to $C_{\text{avr}(0W)}$ = 0,33 µm, $C_{\text{avr (450}W)}$ = 0,47 µm and $C_{\text{avr } K\ (950W)}$ = 0,43 µm. The similarity of the circularity of the halftones is also visible in Figure 5.

In the case of black imprints (Figure 4b), the circularity of the dot elements is the same on the printing substrate without treatment and the substrate treated with a 450 W corona. This applies to the analyzed values of TV. The deviations of the circularity of dot elements on the printing substrate treated with

950W corona are $\Delta C_{10\%\ (450W\text{-}950W)}$ = 0,1 and $\Delta C_{20\%\ (450W\text{-}950W)}$ = 0.1. In the area of 30% TV, the circularity obtained on all three processed printing substrates is the same and amounts to $C_{(0W,\ 450W,\ \text{and}\ 950W)}$ = 0,6. By calculating the average circularity of the dot elements, it was noticed that on the substrates without corona treatment and with corona treatment of power 450 W, the identical circularity of the dot elements is formed ($C_{\text{avr}\ (0W\ i\ 450W)}$ = 0,43). With the 950 W corona treatment, slightly more irregular dot elements were created ($C_{\text{avr}\ (950W)}$ = 0,37). This is also visible on the enlarged segments of the HP Indigo imprints in Figure 5.

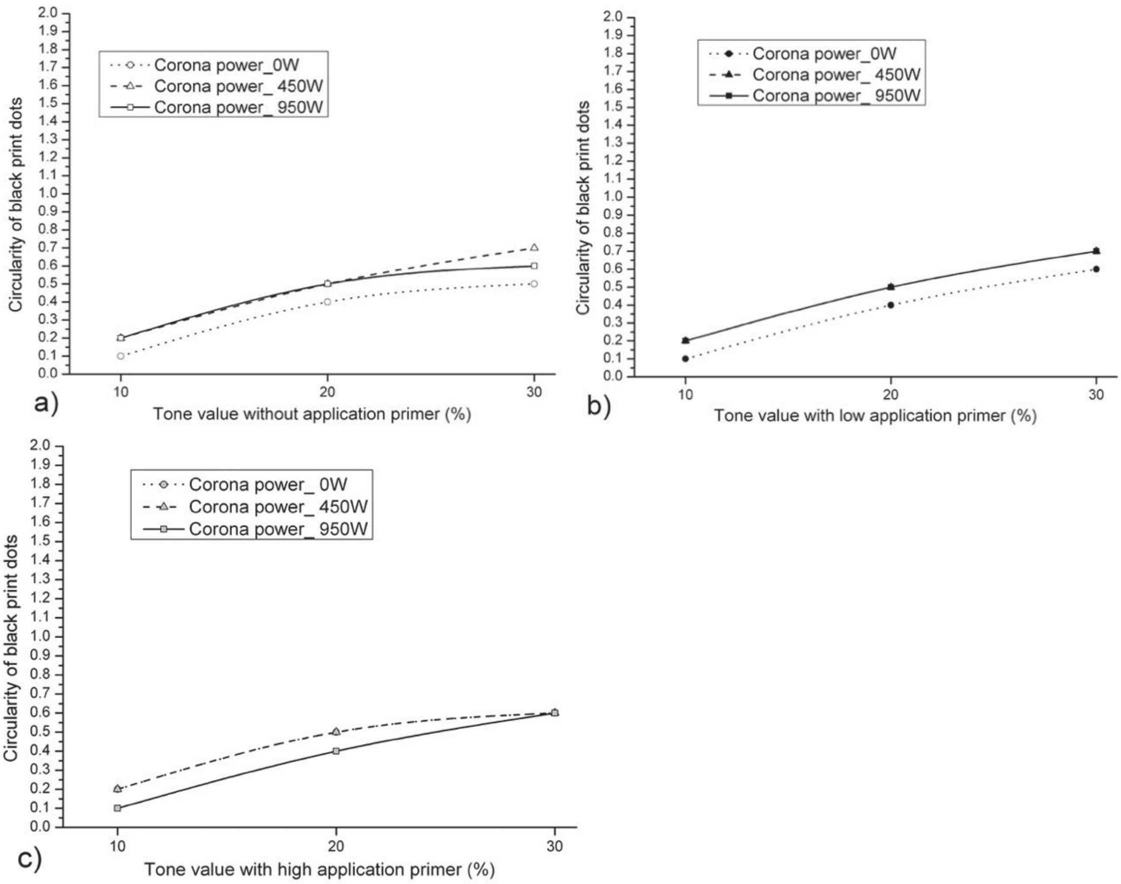

Figure 4: Curves of the dependence of the circularity of the halftones on the imprints are obtained by varying the corona power of 0 W; 450 W and 950 W, and application of the primer in a surface mass of a) 0 g/m^2; b) 0,5 g/m^2; c) 1 g/m^2

On the substrates treated with 450W and 950W corona treatment (Figure 4c), it is visible that in all areas of the TV dot elements of identical circularity were formed ($C_{10\%\ (450W\ i\ 950W)}$ = 0,2, $C_{20\%\ (450W\ i\ 950W)}$ = 0,5 and $C_{30\%\ (450W\ i\ 950W)}$ = 0,7), and the values of the circularity of halftone elements formed on the substrate without corona treatment are lower on all TVs by ΔC = 0,1. For elements formed on the substrate without treatment, the average dot circularity is thus $C_{\text{avr}\ (0W)}$ = 0,37. For halftones formed on substrates treated with 450 W and 950 W coronas, the average circularity is the same, $C_{\text{avr}\ (450\ i\ 950W)}$ = 0,47 µm (Figure 5)

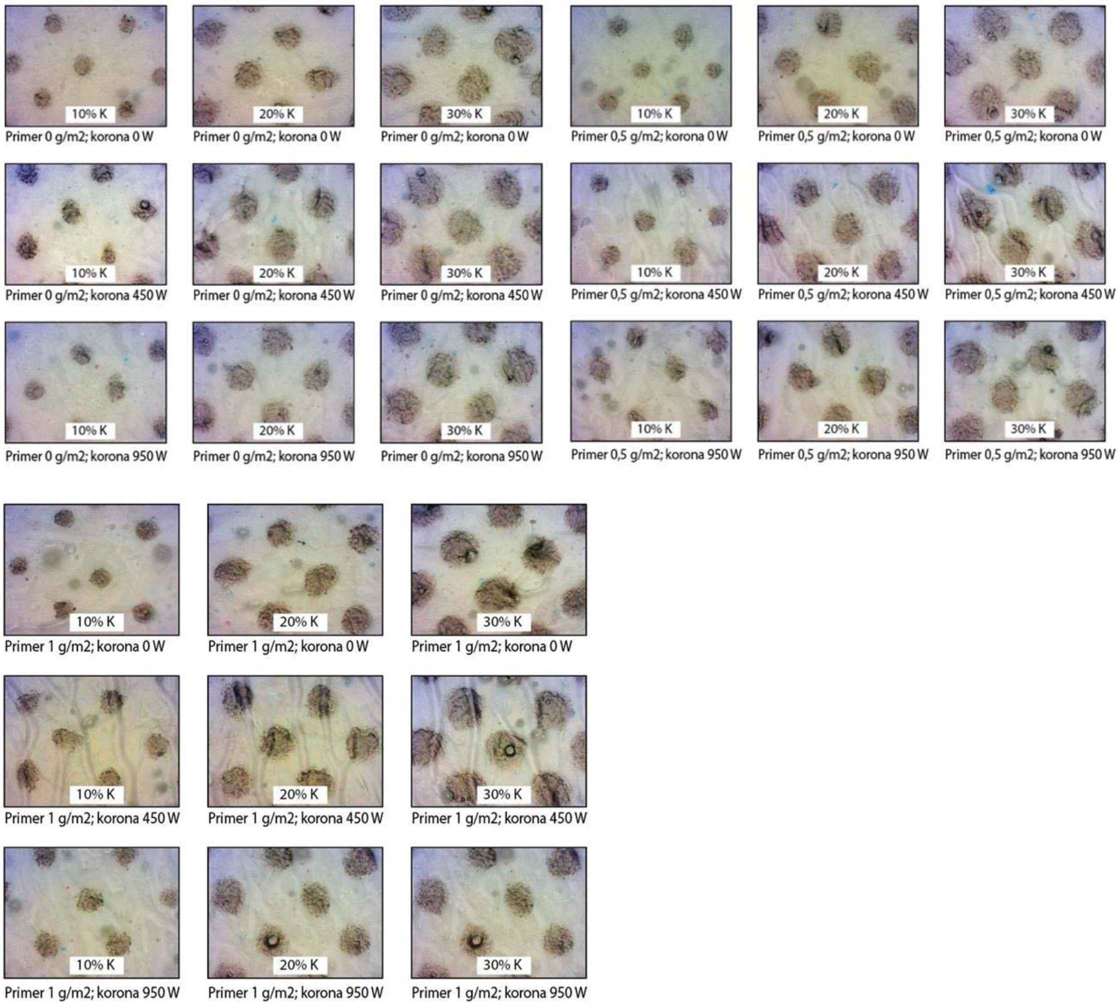

Figure 5: Magnified view of halftones of ElectroInk black ink realized with thicknesses of primers of 0 g/m^2, 0.5 g/m^2; 1 g/m^2, and corona power 0 W, 450 W, 950 W

4. CONCLUSIONS

The smallest halftones were found in the prints created without use of corona treatment and primer (standard prints). On a standard HP Indigo print, the corona treatment increases the diameter of the halftones. When the corona treatment is activated at 450W, larger halftones are realized in comparison with prints where the corona treatment was activated at 950 W, resulting in more articulated halftone dots.

Applying primer in the amount of 0,5 g/m^2 will not cause significant changes in the realized black halftones, and corona treatment will also produce microscopically visible (larger in diameter) halftone deformations. A larger application of primer (1 g/m^2) eliminates the action of the corona device.

If the corona device is not activated, black imprints without a primer will achieve the higher regularity of halftone elements (circularity). Using a primer to fine art paper makes halftones more rounded, which is more noticeable in higher tonal values (30% < TV). The optimal shape of the HP Indigo halftones will be obtained with an application of 1 g/m^2 primer and activation of the corona power of 950 W.

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