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CUTTING WITH LASER IN POSTPRESS

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Abstract: *Laser technology in post-press is used for various products to get a unique shape. It has been used in producing packaging prototypes, finishing and marking the surface of both paper and other materials, thus making the graphic industry more flexible and diverse. Whether in the coming years, the production of graphic products, especially packaging, will be able to rely on the advantages offered by laser technology depends on the extent of degradation of materials that are cut by the laser. In addition to the visual analysis, it is necessary to carry out experiments examining whether material degradation occurs during laser treatment or whether the structure, homogeneity, and mechanical characteristics are kept. Perhaps the most effective method to show if the packaging obtained by laser cutting can be used in the industrial production of packaging is a comparison with the characteristics of packaging materials obtained by traditional cutting methods with the cutting and die-cut machines. The work examines which parameters need to be examined and compared so that laser cutting can be applied in packaging production.*

Keywords: CO_2 laser, die-cutting, packaging, paper, post-press

1. INTRODUCTION

Use of laser technology in processing and cutting material has shown many advantages over conventional techniques. Speed of operation, accuracy, precision, suitability for the environment, and good hygienic conditions distinguish laser technology. Laser cutting technology has opened up new opportunities in the packaging market compared to conventional packaging manufacturing techniques. The advantages are reflected in the diversity of packaging shapes, sizes and complexity, with fewer design limitations, as well as opportunities to improve the quality of packaging production. The quality of laser-cut products is reflected in the cut edges that are clean, glued, and do not contain material fibers that come out of the cutting edge. The profitability of this technology for small runs has contributed to the growth of smaller crafts and special workshops. Laser cutting is computer controlled, fast direct method, easy to use, and the line drawing representing the path of the cut can be changed one after the other by software, which is an advantage. Also, the speed of the process is largely influenced by the fact that this technology does not require tool replacement - a laser beam is a universal tool that moves along a software-defined path. Laser devices must be equipped with systems for vacuuming fumes that arise in the evaporation material process. Depending on the material being processed, different fumes can be expected in the immediate nearby during the cutting process, so it is necessary to ensure good ventilation.

2. PAPER AS LASER CUTTING MATERIAL

Paper and cardboard are materials that appear to have a smooth, uniform and flat surface, while at the micro level, one can see their structure - they are composed of interlaced cellulose fibers (Kirwan, 2005; Riley, 2012; Piili, 2013). As such, papers can be printed and have physical properties that allow the initial paper shape to be changed so that flexible, semi-rigid and rigid packaging can be made (Kirwan, 2005).
There are many different types of paper and cardboard. The properties that paper has, such as strength, appearance and many others, vary depending on the following influential parameters (Bajpai, 2018):

- type and quantity of fibers;
- how the fibers were processed in the separation process;
- treatment of fibers, as well as in producing paper and cardboard.

Paper and cardboard can be characterized by weight per unit area (paper grammage) and thickness (Bajpai, 2018).
Regarding paper thickness, papers that fall over 200 g/m^2 are defined as cardboard according to the ISO standard (English: International Organization for Standardization) (Kirwan, 2005). Therefore, specific papers are classified as cardboard even though they weigh less than 200 g/m^2. On the other hand, the

organization CEPI (Confederation of European Paper Industries) counts cardboard as those papers that weigh more than 220 g/m^2 (Bajpai, 2018). All papers and cardboard can be processed by laser for cutting, die-cutting, or engraving.
Paper materials are characterized by properties that allow them to be folded into flexible, semi-rigid, and rigid packaging by cutting, folding, shaping, corrugation, and gluing operations (Kirwan, 2005). Paper materials can be used in a wide range of temperatures, from packaging for frozen food to boiling temperature, for example, when heating in a microwave oven (Kirwan, 2005).
The properties of paper and cardboard depend on the ingredients used for their production and the type and amount of fibers used. These properties of paper are related to its appearance and technical packaging performance (Kirwan, 2005):

- The appearance of paper and cardboard related to colour and visual impression e.g., printing, has a significant influence on the appearance of the packaging.
- The performance related to strength, consumer protection and efficiency of packaging.

Paper materials have a smooth, flat and uniform surface, however microscopic images show that paper materials have a complex structure consisting of a network formed by interwoven fibers originating from wood. The paper contains filler particles (clay/kaolin, calcium carbonate or other minerals) (Piili, 2013). Also, paper is a composite material consisting of cellulose, hemicellulose and lignin (Hosoya, Kawamoto & Saka, 2007). Some paper materials are coated with a thin layer of mineral pigments (usually clay/kaolin, calcium carbonate or other minerals or a mixture of the pigments mentioned above) or a thin layer of plastic (Piili, 2013). Some paper materials contain layers of different paper materials, for example, a middle layer of mechanical pulp and a bottom layer of chemical pulp (Piili, 2013).
Fibers are usually much longer (the average fiber length is 1 mm) than thick (average fiber thickness is 100-200 microns). Due to these dimensions, the wood fiber network looks like a 2D network. When the air between the fibers is considered, the fibers form a 3D network. Such a 3D structure of wood fibers strongly affects the optical properties of paper materials. Paper materials contain different optical barriers: pores of different shapes and sizes, mineral pigments, long fibers, etc. (Piili, 2013). Light can perform transmission, scattering, reflection, diffraction, and absorption when it interacts with paper materials and their components (Pauler, 2002).
All these characteristics of paper change the way it reacts to the laser. Increased moisture in paper will increase the laser strength needed to cut through the paper (Malmberg, Immonen & Kujanpää, 2006). One of the requirements for paper substrates is that they have the sufficient tensile strength to pass through the processing process and usage without tearing (Riley, 2012). In addition to the breaking point, an important characteristic is the elongation at which the breaking occurs, and the tests are performed on dry and wet papers (Riley, 2012). The tensile strength test is standardised according to the ISO (International Organization of Standardization) ISO 2758:2003 (ISO 2758 2003).
By definition, tensile strength represents the force required to break a material (Kirwan, 2005). Under the action of this force, the material exhibits elastic properties up to a certain level. Force applied to the paper strip is proportional to the deformation or elongation caused by the applied force (Kirwan, 2005).

3. POSSIBILITIES OF LASERS IN PAPER CUTTING

Finishing, post-press is a segment of the printing production flow in which the printed product is given the appropriate form or function (Kipphan, 2001). When it comes to packaging material, it can be open or closed, cut to a final format and formed into a hollow body in the process of forming the packaging.
Cutting is usually done conventionally with paper-cutting knives (guillotine). Depending on the application, the knives can be integrated into the printing machines or be separate devices. As an alternative to knives, innovations have brought the possibility of cutting paper with a water jet and cutting paper with a laser (Stepanov et al., 2015).
When cutting paper materials, the quality of the cut is reflected in the variations in dimensions, which can occur in the process of final graphic processing during cutting, folding, and binding (Kipphan, 2001). However, even minimal deviations from the desired paper dimensions can seriously damage the final product's quality when cutting. Therefore, a high level of cutting accuracy is necessary, and it depends on the properties of the material of the product being cut (Kipphan, 2001).

Cutting quality includes the following parameters (Kipphan, 2001):

- deviations concerning the defined cutting edge
- format deviations in the cutting direction
- cutting edge accuracy - deviation from a straight line
- uniformity of the cutting surface

In the conventional way of paper cutting with a guillotine, the quality of cutting also depends on the tool itself (Kipphan, 2001):

- life of the cutting knife
- the angle of the knife
- pressure force
- the sharpness of the knife

The use of laser cutting is limited to individual sheets because the focus of the laser beam is relatively narrow and is not suitable for cutting thicker layers of paper or thicker materials (Pinćjer et al., 2020). By changing the lenses used to focus the laser beam on the material, the focal length can be increased, but it is limited to sizes of about 1cm. The use of the guillotine is necessary for the preparation of materials when it is necessary to cut paper stacks to the appropriate format for printing. However, laser cutting can successfully replace the cutting of different packaging shapes achieved by die-cut.
The conventional way of cutting paper and cardboard, which implies the use of a mechanical way of cutting by the action of the blade on the material, can lead to various problems during cutting, such as the poor quality of the cut material or the destruction of the material itself (Piili, 2013). When cutting material with knives, one can single out a cutting method of crucial importance for obtaining the shape of the packaging, which is die-cutting. The die-cutting operation involves cutting the printed product into another shape or adding perforation to the product (Johansson, Lundberg & Ryberg, 2011). A die is a wooden board on which there are holders for knives that are bent to take the shape that needs to be obtained after cutting (Johansson, Lundberg & Ryberg, 2011).
Since the die-cut operation is performed with knives (tools), depending on the job, the tools are changed. The most used tools are (Wyrzykowski, 2020):

- Cutting knives - used to cut the packaging material.
- Slitting knives - enable partial cutting of material.
- Creasing knives - similar to partial cutting, only, in this case, the knife creates a fold line on the packaging material. The crease allows the material to bend on both sides, thus giving greater flexibility to the material.
- Perforation - perforation implies the creation of a line formed by holes in the material. This operation does not separate the material however, it facilitates the separation of the material if necessary.

It is impossible to achieve creasing with a laser, so preparing a paper to fold can be achieved with a laser by perforation or partial by cutting (slitting).
One problem that occurs during the mechanical cutting of materials is dust, which consists of particles of fibers and pigments that are torn from the material by the blade of the guillotine (Piili, 2013). This kind of dust can cause problems in production. In addition, the cutting edge of the material contains fibers that protrude beyond the edge itself, which can cause many problems in further production (Malmberg, Immonen & Kujanpää, 2006). For example, Figure 1a shows an SEM microscopic image of the cutting edge's appearance under a mechanical blade's action. In contrast, in Figure 1b, the appearance of the edge after laser cutting can be seen.

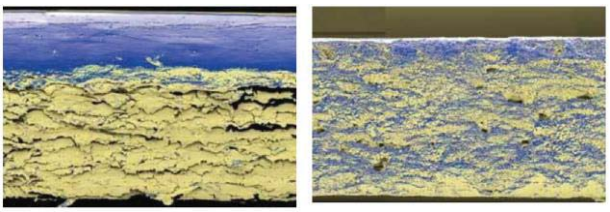

Figure 1: a) SEM micrograph of an edge that was cut by a mechanical blade and b) an edge that was cut by a laser (Malmberg, Immonen & Kujanpää, 2006)

4. COMPARISON BETWEEN LASER AND MECHANICAL CUTTING

Below is a comparison of conventional material cutting (mechanical cutting) and laser cutting by Rämö (Rämö, 2004):

- Laser cutting is a flexible way of cutting. If the shape of the cut is changed, there is no need to change the cutting tool. It is only necessary to change the drawing on which the cutting is done in the software.
- Laser cutting is a non-contact technique. Therefore, no tool can be worn off or damaged in contact with the material.
- A large amount of dust appears as a by-product of mechanical cutting. Laser cutting does not create a large amount of dust. Also, if by-products in the form of dust appear during laser cutting, they can be removed during cutting with the help of suction systems that collect fumes and dust.
- When cutting with a laser, the loss of material is less.
- Laser cutting provides the ability to cut complex geometric shapes at high speed.

Laser cutting of materials can provide a unique solution to manufacturing requirements. The use of lasers is ideal for applications that require cutting complex profiles and edges with high accuracy. Laser can cut materials of different thicknesses, cutting the same part in large quantities (mass production) or cutting very soft and hard materials (Eltawahni, Benyounis & Olabi, 2016). Laser processing of paper materials opens up new possibilities for improving the appearance of graphic products. Laser technology made it possible to make the appearance of these products unique and original.
Figure 2 shows examples of products with more complex geometry. This type of geometry can be made with higher quality with laser cutters (Trotec, 2020).

Figure 2: Examples of products with more complex geometry that are made by laser (Trotec, 2020)

5. THE INFLUENCE OF CUTTING ON PAPER

We can expect the paper to suffer a specific degree of degradation using laser or conventional cutting. Paper material is subject to degradation if it is exposed to external influences. The result of degradation can be a decrease in paper strength and a change in structure (Stepanov et al., 2015). A question arises about which type of cutting degrades the paper and which experimental method can answer that question. Indeed, changes in aesthetics and performance after cutting are essential for the further use of paper.
It has been observed that paper materials change colour during or after laser treatment, primarily newsprint, copy paper, and some cardboard. These materials contain high levels of different types of cellulose with a significant amount of lignin, such as SGW cellulose, thermo-mechanical cellulose (TMP), or chemical-thermo-mechanical cellulose (CTMP), as well as impurities. These types of cellulose are increasingly present in paper production due to the reduced price of paper products. Therefore, paper colouring is a problem that needs to be solved so that lasers can be applied to producing paper materials (Stepanov et al., 2015).
SEM analysis showed the difference in cutting edges between conventional and laser cutting. However, new research is needed to show how these edges affect the material's tensile strength. For example, will edges obtained mechanically result in lower tensile strength, or will the laser adversely affect the tensile strength due to the way the beam changes the chemical composition at the point of interaction with the material?

6. CONCLUSION

Cutting paper materials with a laser beam can be combined with digital printing machines. The advantage of digital printing is the ability to produce small runs with a quick change of the printed image. The advantage of this way of cutting is that there is no change of tools when changing jobs, while the image that needs to be cut is changed in the program (Boyle, 1999).
Authors Malmberg and others (Malmberg, Immonen & Kujanpää, 2006) list situations in which it is recommended to use a laser for cutting paper materials:

- when the cutting process is done by hand,
- when working with small editions below 1000 pieces,
- always with products that are printed using the digital printing technique,
- when it is necessary to achieve a high degree of cutting accuracy, as well as cutting of complex geometric shapes,
- when making samples or series of samples,
- if expensive material is used for the processing of which a high degree of manufacturing accuracy is necessary,
- in production where different types of products are made and when a high speed of delivery is required.

According to the author John Powell, the following advantages of cutting materials with a laser stand out:

- Laser processing of materials is a non-contact process requiring the material to be lightly attached or positioned under the laser beam. Flexible materials or light can be cut with great precision without warping or distortion during cutting that can occur if the material is mechanically cut;
- The width of the cut is minimal (typically about 0.1 to 1 mm). Therefore, excellent details can be made without the limitations of the machine tool radius of tooling devices;
- A laser is a computer-controlled device. The job changes on the computer;
- Laser cutting is a thermal process, but the heated surface is small and most of the heated material is removed during cutting. Therefore, the influence of temperature is minimal if a layer of material is placed;
- High cutting speed compared to other cutting methods;
- In most cases, laser-cut components will be ready for use immediately after cutting without the need for a cleaning operation;
- Thanks to the very narrow cutting edge, the components to be cut can be placed very close to each other, which contributes to less material waste. Therefore, the components being cut may share a cut line. However, this may not apply to all jobs;
- The laser as a device has a high price, while the costs of its use are low. Therefore, it is possible within specific industries to pay off the purchased device in less than a year;
- The process is quiet compared to other cutting devices, which contributes to the improvement of the working environment, as well as more efficient work of the operator;
- A laser as a device is very safe and reliable to use compared to mechanical cutting devices;
- One tool for all shapes – the laser beam is a universal tool for all geometric shapes and material thicknesses;
- High-quality processing of paper materials - the laser enables paper engraving without soiling;
- Creating fine details – small font sizes and delicate patterns can be engraved. Easy workflow – the design created in the graphics software is sent with the Print command to the laser software;
- Absence of a die - therefore, there are no tools, parts, or costs to replace knives on a die.

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