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Digital printing in wood industry

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Abstract: *Digital printing in wood industry*. The article presents modern techniques for surface finishing of wood-based panels, including the dynamically developing digital printing technology. The basic technological factors affecting the result of the digital printing process are discussed, and advantages and disadvantages of different types of this technology are presented.

Keywords: digital printing, wood-based panels, wood, industry

INTRODUCTION

Decorative aspects of furniture today are the base for effective marketing and sales of these products. Today, the most important factors affecting purchasing decisions are the functionality and durability of the furniture. However, in the future, following trends and fashion may become more and more important. The average furniture usage time is also reducing (Grochownia and Krzemińska, 2017) Personalization of products is a worldwide trend seen in many markets. Research has shown that up to 30% of today's customers want a personalized offer of products. Walcher, a German researcher on the subject of personalization, states that tailoring products to client's needs (Piller and Walcher, 2017) and mass customization are key elements of about 50% of all business models included in business plan's competitions. The report Expenses on furniture in Poland (B+R STUDIO, 2015) has shown that the industry is significantly divided in segments, among which the product customization is the one of the strongest. These factors force producers to have flexibility in the offer and quickly adapt to the market demand and customer expectations.

Manufacturers of furniture and wood based panels must look for innovative solutions, that will meet the growing expectations of customers. Digital printing technology can be one of the solutions to these challenges.

TECHNOLOGY AND TRENDS IN FINISHING FURNITURE SURFACES

Finished wood-based materials are today the basic raw material for the furniture production, in particular for ready to assembly furniture (RTA) (Utkina, 2017). Particle board (PB) and medium density fibreboard (MDF), the basic material for furniture production, usually require prior finishing to be used as decorative surfaces (Proszyk, 1999). There are many methods of finishing surface of wood-based panels. The main of methods applied to the wood-based panels are veneering with natural or polymer materials (e.g. finish foil) and laminating by the application of one or more paper layers, impregnated with synthetic resins, as well as covering surface of panels with varnishing products. The obtained coatings are characterized by high aesthetic-decorative qualities and high resistance to mechanical and chemical factors (Maloney 1977, Deppe and Ernst 2000). In Poland, similarly to other EU countries, the two main lamination technologies include:

a) direct lamination, i.e. surface treatment using melamine films, which are pressed in short-stroke or "conti-roll" presses;
b) indirect, i.e. covering of flat surfaces in wood-based panels with HPL or CPL laminate, followed by so called post-forming technique.

c) For non-flat, 3D surfaces, it is usually used to apply polymer foils in vacuum presses or to use varnish coatings with spray application (Krzoska-Adamczak, 2007).

The technologies of finishing wood-based panels are under constant development. Motivation for this are primarily: growing environmental awareness (Hemmilä, 2018), new regulations and legal restrictions [SGS, 2019], design trends including mass personalization (Suzic et al, 2014) and mainly the need to increase the competitiveness of wood industry companies (Oniśko, 2011) . Strong emphasis is placed on reducing emissions of volatile organic compounds (VOC), including formaldehyde from furniture surfaces (Hemmilä, 2018; SGS, 2019). The methods of reducing the emission of harmful chemical compounds from wood materials and their coatings include, among others : using formaldehyde free resins based on plant protein, lignin and tanin [Solt et al, 2019] and the use of low-VOC coatings, such as water-based coatings (Zhu et al. 2016).

The use of nanoparticles is another trend in wood finishing technology. Zhu et al. (2016) used nano TiO_2 and nano montmorillonite (MMT) to reduce VOCs emissions from coating panels. Vardanyan et al. 2014 use cellulose nanocrystals to reinforced UV-waterborne varnishes. Sow et al. (2011) use alumina and silica nanoparticles to improve properties of polyurethane-acrylate coatings.

Reducing the environmental impact and reducing production costs is also associated with reduction electricity consumption. A visible trend in this area are pro-environmental and cost-saving measures - primarily in the curing processes of varnish products. An example here are UV LED radiators which, in addition to lower energy consumption, are also characterized by spectral homogeneity and no heat generation (Leonhardt, 2013; Dake et al, 2004).

The next trend in wood finishing technology is increasing production flexibility and the possibility of personalization, including mass personalization (Suzic et al, 2014; LIGNA press release, 2019).

At the same time, there is also continuous improvement of currently used technologies. Burkle company has developed a new roller coating process. This technology delivers reduced paint consumption and increased performance and enables it to be used on formed, non-flat furniture parts with four paintable sides and tapered ends. The paint rollers are repositioned by means of servo-motors, and the system enables continuous coating without paint tearing. An example of 4.0 industry solutions in the furniture industry can be new solutions from Makor company. Together with Tapio company, they showed smart work-pieces with Radio-frequency identification (RFID) chips that automatically configure the coating plant, automated, robotic paint application systems that enable rapid color changes with reduced paint wastage (LIGNA press release, 2019).

Digital printing technology is the latest trend in the technology of surface finishing of wood-based materials and can become a breakthrough technology for many companies. The next section will discuss the details of this technology and its advantages and disadvantages.

DIGITAL PRINTING TECHNOLOGIES USED IN WOOD INDUSTRY

Definition

Digital printing is based on the conversion of printed graphics into binary code, which is stored and reproduced by electronic devices. Currently, there are two main types of digital printing technology - the ink jet and the electrophotography (Pira International, 2006).

The inkjet printing process involves spraying small drops of liquid ink on the substrate. The drops are applied with high precision to produce high-quality images. The inkjet printing is used to print non-standard substrates such as textiles, metals, ceramics and also wood-based materials. The first printing heads, using piezoelectric materials, which printed the drops, only when the drops were required on the substrate, were developed in 1940

at Radio Corporation of America (RCA) in New York (USA) by Clarence Hansell. Later this technology later came to be known as drop-on-demand, in brief DoD. Hansell's idea used a disc of a piezoelectric material to convert electrical energy into mechanical energy, but device was never developed into a product (Svanholm, 2007).

The electrophotography is used in photocopiers, new-generation digital printers and laser printers. It is based on the principle of image production using light that influences the distribution of electrostatic charge on the surface of the photosensitive drum. The electrostatic charge attracts the toner and then transfers it to the printed substrate [Pira International, 2006]. The most important difference compared to common traditional, analogy methods (lithography, flexography, screen and offset printing) is that, there is no need to replace any printing plates in digital printing, whereas in analogy printing it is necessary, when we would to change graphic. Thanks to that we get very high flexibility of created printouts, without printing plate production and machine retooling (Klumpp a).

Types of printing technologies

Nowadays digital printing technology is used in the wood industry in various ways. The basic ones will be discussed below.

Single-pass digital printing

High performance technology used in large production plants. In this technology, the number of printheads cover the entire working width of the machine. It allows printing on rigid substrates such as PB and MDF boards, doors, glass, flooring panels and others. Printheads remain stationary in the machine body, while the printing substrate is transported by conveyors. The advantages are very high machine efficiency (feed speed up to 55 m / min), low unit cost, the possibility of combining into an automatic technological line with systems for preparing the substrate before printing and finishing after printing, as well as high flexibility. The disadvantage are the high initial investment costs, as well as the limited maximum of the printed substrate. This technology also includes roll to roll digital printing, which allows printing on flexible pre-impregnated paper substrate. In the next step, in order to achieve high mechanical and chemical resistance, the printed paper is top coating, for example with varnish curing by ultraviolet (UV) irradiation. Thanks to digital printing technology, we can achieve great flexibility of produced designs, as well as achieve previously unattainable, creative design (Cefla; Barberan).

Multi-pass digital printing

Low-performance technology for use in small and medium-sized production plants. Similar to single-pass technology, it allows printing on rigid substrates such as PB, MDF boards, doors, flooring panels and others.

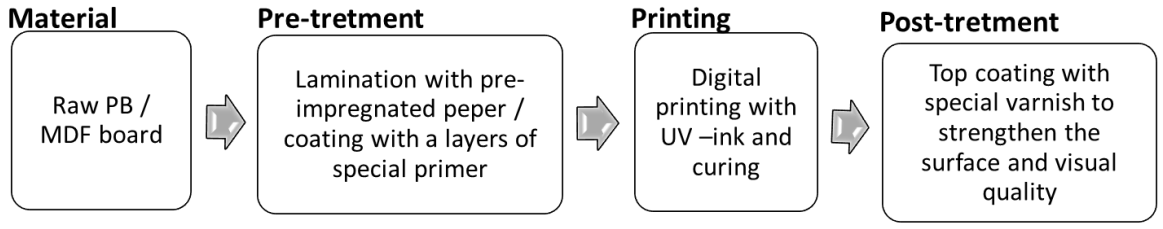

Figure 1. An example diagram of the digital printing process (Source: own study based on available materials from printing devices manufacturers)

In this technology, due to the smaller number of printheads, both the substrate and the printhead are moving , printing subsequent part of graphic on the substrate. The advantages of

this technology, compare to single-pass printing, are lower cost of purchasing, and also usually the ability to print very wide elements (the maximum width of the print is not limited by the number of printheads, because the whole printing heads support are moving). The disadvantages are low efficiency and difficulty to connect this device into one, continuous, technological line with pre- and post- treatment (Cefla; Agfa)

Key technological factors related to digital printing in the wood industry

Print resolution

The amount of drops applied to the unit area has a direct influence on the aesthetics of the manufactured components and on the consumption of the ink used in the production process. To describe resolution usually is used number of dots per inch (DPI). According to Kumar et al. (2012) the highest possible resolution for printed color images is determined by the diffraction limit of visible light. In case of popular ink-jet printing resolution is limited by printing head and drop size. For furniture and flooring industry for high quality printing, usually is used resolution from 360 to 1200 DPI (Agfa, Barberan).

Drop size

Drop size mainly depend from printing head and is connected with printing resolution. The popular trend is to reduce the volume of sprayed drops, even to a few pico-litters (e.g. 7 pl) (Agfa) Smaller drops reduce the dots on the printed substrate and allow for a more precise reproduction of the printed image. This gives the ability to receive many shades of color and their varied saturation. In the piezo ink-jet printing the droplet sizes, and thus the printed dot sizes, are differentiated. Creating an image from smaller dots allows to receive sharp edges in texts and graphics. Decreasing the volume of ejected droplets and simultaneously increasing their quantity has also negative effects - it increases the processing time of the input data and decreases printing speed.

Number of primary colors

By default, 4 basic pigment colors are used: Cyan, Magenta, Yellow, and Black (CMYK). For special, demanding uses, it is also possible to use additional primary colors: Light Cyan (LC) and Light Magenta (LM) and White (Agfa; Barberan; Cefla).

Type of ink

There are many types of inks on the market: aqueous, solvent-based, oil-based, hot-melt and UV-curable. (Svanholm, 2007). UV curable inkjet inks were introduced in the 1990's. Today, the most popular technology of digital printing directly on wood and wood-based substrates incorporates the use of UV-curable inks (Cefla, Barberan). The UV curing process is based on a photochemical reaction. Liquid monomers and oligomers with a small addition of photo initiators, that are components of the ink, are crosslinked and cured under the UV light (Carroll et al, 2011). With the development of UV inks, digital printing technology has become more widely used. These inks can be used for many types of substrates, including those with flexible, irregular shapes, such as textiles.

Surface preparation before printing

Thanks to use of UV-ink, it is possible to print of many kind of different surface. Despite this, the adhesion of the ink to the substrate is a very important issue affecting the quality and durability of printed surfaces.

Depending on the type of substrate, pre-treatment may be required. For this purpose, a special primer is used, usually applied as a thin layer of coating, before printing. Primers

enhance adhesion and neutralize the variability in the surface characteristics of wood with various surface qualities (Balentine, 2018).

Surface reinforcement after printing

Post-treatments are mostly used to increase mechanical and chemical resistant of printed surface. Investigation Altun and Köse (2012) showed that UV curable inks, on most of the tested surfaces is not resistant to selected chemical and mechanical factors. This is important especially for flooring materials to protect the printed surface against mechanical factors. For treatment after printing , among others UV transparent water-based varnish can be used.

Maximum size of printed substrate

In case of printing way based on printing directly on ready elements, (e.g. particleboard after pre-treatment) it is important to be able to use different sizes of substrates. The maximum print width depends on the technological details of the printer. In case of single-pass printers, the maximum print width is connected with number of installed printheads (Agfa; Barberan; Cefla).

Printing speed

Print speed and, consequently, machine performance is a very important technological factor. Working width of the machine, the number of printheads, required print quality, and print resolution have effect on printing performance. Maximum productivity depends on the type of machine and ranges from 350 m^2 per shift for multi-pass technologies, up to 3500 m^2 per shift for single-pass lines (Agfa; Barberan; Cefla).

New trends in digital printing technology in the wood industry

Like most modern technologies, digital printing is also constantly developing. An area of interest is to improve the quality of prints by increasing the resolution, reducing the minimum droplet size, and thus more precise image reproduction. To improve the strength and adhesion of prints to the substrate, work is continuing on adjusting inks to the material. Moreover, there are also a number of design improvements in the spraying mechanisms (e.g. the change in design of spray - US Patents: 6 902 262, 6 502 929).

A flat printed surface today seems insufficient to surprise and capture the customer's attention. Therefore, very intensive development occurs in the technology of surface treatment after printing. There are various technologies to give the surface a three-dimensional structure. The example is technology "myTEXTURE". It is the inkjet texturing technology developed for the demanding flooring, furniture and panel markets application. In this technology special fluid is jetted by special digital printing head on the liquid, uncured coating. In next step UV coating is gelled to fix the generated texture. After drying the special fluid is evaporated, and an embossing effect is achieved. Because it is digital technology, it is possible to create various types of textures, such as similar to wood or stone (ZEETREE).]

Progressing automation in industry, including the upcoming 4.0 industrial revolution, also forces the implementation of autonomous quality control tools. There are also solutions in this area in the demanding process, like digital printing. An example of such a solution is It is special real time inspection system to surface control at Single-Pass digital printing lines. It is working in extremely high resolution to detect every missing or interrupted nozzle. After noticing the problem, this device can do classification, automatic color match, evaluation of visibility or automatic calibration [Baumer].

CONCLUSION

Digital printing in wood industry is still a new, but dynamically developing technology. Today it is mainly used in flooring industry. The main advantages of digital printing technology include: high flexibility of design produced, the possibility of mass personalization, and an unlimited kind of graphics produced. The disadvantages include high investment costs, the need to maintain high process hygiene, need to install special pre-and post-surface preparation devices, as well as often higher unit costs of the finished surface, compared to conventional finishing methods.

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Streszczenie: *Druk cyfrowy w przemyśle drzewnym.* W artykule zebrano i przedstawiono nowoczesne techniki uszlachetniania powierzchni tworzyw drzewnych, w tym dynamicznie rozwijającej się techniki druku cyfrowego. Omówiono podstawowe czynniki technologiczne wpływające na rezultat procesu druku cyfrowego, przestawiono także wady i zalety poszczególnych rodzajów tej technologii.

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