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Effect of Ink Layers on Inkjet Printing Quality

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Abstract: **This paper will discuss research concerning the influence of the number of ink layers deposited by ink jet for textile printing. With the aim to establish the optimal number of layers as to achieve good quality prints, it discusses the good colorfastness during longer time period and exposure to different environmental factors including temperature, light etc. Three typical materials with the same raw material compositions, but different fabric weight and thread count were chosen and printed with digital ink jet technology. Materials were printed with variations in the ink layers number and the correlation between K/S factor and number of applied ink layers was determined after the printing process. Upon finished printing process, the samples were treated with heat, light and other simulated environmental influences in line with the appropriate international standards. The changes were detected by common visual ranking methods (gray scale and blue wool reference scale) as well the spectrophotometric measurements for obtaining spectral data of the colorfastness and staining, what was followed by additional testing of the heating element with thermo vision camera. Microscopic view of the changes on the printed surfaces upon exposing them to different simulated factors was obtained by SEM microscope. It can be concluded that increase of printed ink layers will lead to a better quality of final product in terms of resistance to various environment influences. This research offers insight in the influence of one parameter in textile materials printing process on longevity of flag products, which can also be applied to any other product printed on polyester material.**

***Keywords*— Polyester, Ink jet printing, Color fastness, Heat, Light fastness**

I. Introduction

Many innovations in digital textile printing techniques have been introduced in recent years.

The efficiency of ink-of inkjet printing as a flexible ink transfer method is based mainly on cost and time savings for small runs. Moreover, this printing technique allows achieving better visual effects, much more flexible formats, moreover, with the repeated printing process better reproducibility and consistent quality is achieved. The ink is also one of the influential factors in the print behavior. It is debatable which type of ink is most stable to light and heat.

Different authors give different opinions on dye- and pigment-based inks. Hence, one group claims that dye-based inks have poor lightfastness and insufficient thermal stability, while pigment-based inks have lower gloss quality, the others maintain higher optical density, a wider range of prints, and better durability of service conditions for pigment inks.

Nano dyes, such as those used in this experiment, are a combination of two previously mentioned types of inks commonly used in ink-jet printing. The additional advantage of digital printing techniques, is the ability to print on a large number of different substrates. One of the materials used in digital textile printing is polyester and due to its properties its use is continuously increasing.

Therefore, it is widely used in flag printing. The materials used in flag printing are often exposed to the effects of environmental factors such as heat, ultraviolet light, moisture, rain and etc. One of the most influential processes applied in daily use on flags is the heat treatment or ironing process. Heat treatment by ironing transfers heat through textile materials in three ways: conduction, convection and electromagnetic radiation all of which can lead to structural changes of the fibres. Changing the amount and color of ink can reduce the impact of this negative effect on the quality of the printed material. The effect of ironing heat on changes in material properties can be tested by several different standards such as ISO 105-X11, where the effect of ironing heat is measured at temperatures of 110°C, 150°C and 200°C. After heat treatment, the color fastness and color fastness tests are applied to the cotton using the standard grey scale test with a score of 1 to 5, where a score of 5 represents the best ironing color fastness as well as stain transmission quality. Another very important factor in the quality and long-term usability of a product is light fastness or light stability. Exposure to light and other environmental factors can cause color changes, which is a problem primarily because it is difficult to predict the final appearance of the product. . Previously, it was found that the influence of light and time can cause color changes between impressions, as well as changes in the structure of the tested material. This study aims to demonstrate the enhancement of the properties of digitally printed textiles by applying multiple layers of ink, with a focus on
on heat, light and atmospheric conditions.

II. Material And Methods

Three types of textile materials were used in this study, all printed with a Reggiani Hyper digital inkjet printer and J-Eco Subly nano inks. Polyester textiles were chosen as they are well known for their strong resistance and durability and due to their properties are widely used in flag production. All materials are characterised by the following parameters: fabric weight using ISO 3801, thread count (ISO 7211-2) and material composition (ISO 1833). These properties are presented in Table 1.

To analyse the effect of ironing (heat treatment) and light fastness, a test mould was prepared with dimensions 150 x 10 cm (The test mould consisted of four patches of 35 x 10 cm with 100% tone value of all four process colors (cyan, magenta, yellow, black).

For applying different amounts of ink the ability of the Reggiani Hyper Inkjet Printer to print multiple layers (ink application quantities) was used. and variations of 1 to 5 layers of ink were printed. The samples were tested for color

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fastness of the ink amount applied and color difference caused by accelerated aging and heat. Based on printing system it is assumed that the larger amount of ink (more printing steps) will improve the durability or color fastness of the samples for longer use and exposure to environmental factors. For colorimetric measurements of reflectance properties of prints is Datacolor Spectraflash SF 600® PL Spherical Spectrophotometer was used Using these parameters, color strength was determined by Kubelka Munk analysis. The color strength (K/S value) of dyed or printed fabrics is a measure of the concentration of dye or pigment in the tissue. It is calculated by measuring the K/S values of the dyed or printed fabrics with a spectrophotometer in reflection mode. This method is defined by Vickerstaff as "Direct colorimetric evaluation". The principle is based on Kubelka-Munk theory, which gives the relationship between K/S and R (reflectance). In the present study, the color strength of the printed samples was calculated according to the Kubelka-Munk equation:

$$K/S = (1 - R)2 /2R \quad (1)$$

where R - the reflection coefficient of incident light from the material; K - the absorption coefficient; S - the scattering coefficient.

All K/S values in the presented study were determined at the maximum absorption wavelength at which the reflection value is lowest. All materials were heat treated by ironing in accordance with ISO 105-X11. In accordance with the raw material composition, the recommended temperature is 110 °C To ensure the accurate temperature during ironing, a FLIR thermal imaging camera was used to obtain images and temperature distribution in the heating element.

The camera works on the basis of IR (Infra Red), where the measurement procedure does not interfere with the surface temperature and has a high degree of accuracy. Due to the mentioned qualities, it is often used in research, with the following measurement procedure:

-Temperature of the measurement area shall be recorded.

- A thermal picture of the object can be obtained by a suitable application for further processing,

- The measured value temperature can be expressed as a function of 5 parameters.

Tob =f (ε ob , Tatm , T0 , ω, d), (K), where: εob - is the surface emission; Tatm - is the atmospheric temperature; To - is the measured surface temperature, ω - is the relative humidity; d - is the thermal IR chamber distance.

An ironing experiment was conducted and the results were evaluated by a visual grayscale test for color fastness and staining when testing the surface of the heated element.

The second part of the testing was carried out with to assess the environmental factors on the flags during their exposure to outdoors. They were assessed visually using a blue wool reference tape with ratings from 1 to 8;

Grade 1 indicates poor resistance, while 8 indicates very good color resistance to the artificial ageing process. The printed samples were placed in a Xeno Test Alpha chamber from Atlas, which simulates environmental factors so that results for the effect of light and environmental factors on resistance to simulated accelerated ageing are obtained, held constant and programmed according to standard values for these types of tests.

Accelerated aging and weathering tests were followed by visual and instrumental evaluations to determining color fastness. While the visual part was conducted with a blue wool scale. Spectral curves were established using a spectrophotometer before and after ironing as well as before and after wear and ageing, on both the original and reference materials used for color control. The scanning electron microscope (SEM) provides qualitative microscopic views of the fibers and further investigation of the possible causes of stability changes on colors. SEM images were performed on a JEOL 646O LV electron microscope, where the colored surfaces were treated separately after the ironing and aging process.

III. Results and discussion

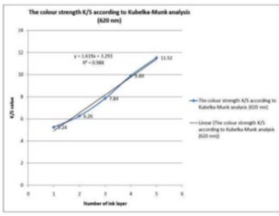
Determination of color Strength (K/S value) Using Kubelka Munk Analysis.

The Kubelka Munk analysis was used to assess the color strength (K/S value) prior to conducting the ironing and ageing tests. 10 replicate measurements were performed on all samples and their average value was used for further calculation. K/S was correlated between ink quantity and K/S value, with a high R2 determination factor , ranging from 0.974 for magenta, to 0.997 for yellow ink (Figure 2).

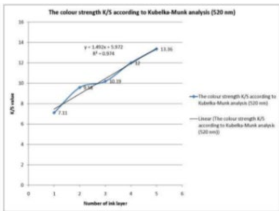
Similar to material 1, material 2 shows a linear correlation between the ink layers and the measured K/S value. The coefficients of R2 determination are also high for these samples and are above 0.9 except for the magenta colored samples where an R2 value of =0.891 was calculated.

Samples with black color have R2 = 0.974. The measured values are presented on Figure 3.

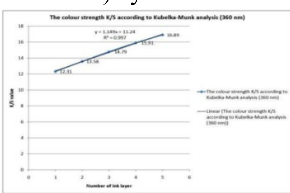
Fig. 1. Test form



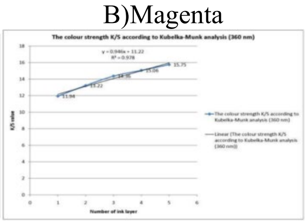
A) cyan



B)Magenta

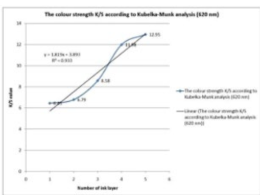


C) Yellow

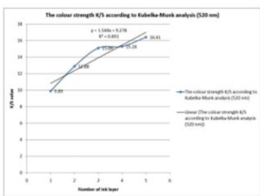


D) Black

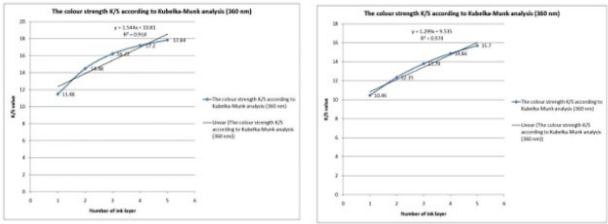
Fig. 2. Color strength K/S according to the Kubelka-Munk analysis (material 1) a) cyan, b) magenta, c) yellow, d) black - with a high R2 factor - from 0.974 for magenta, to 0.997 for yellow ink



A) Cyan

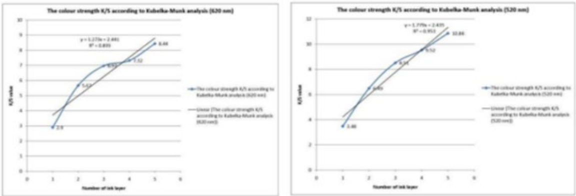


B)Magenta

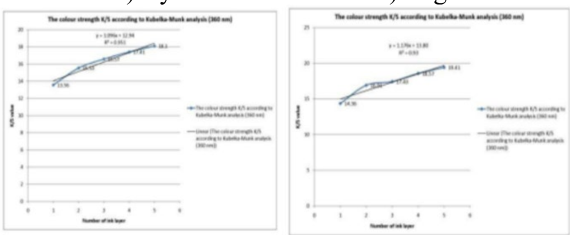


C) Yellow D) Black

Figure 3. Color strength K/S according to Kubelka-Munk analysis (material 2) a) cyan, b) magenta, c) yellow, d) black - with a high R2 factor of 0.974 for black, and a low of 0.891 for magenta.



A) Cyan B)Magenta



C) Yellow D) Black

Fig. 4. Color strength K/S according to Kubelka-Munk analysis (material 3) a) cyan, b) magenta, c) yellow, d) black - with a high R2-factor of 0.953 for magenta, and a low of 0.899 for cyan

Apart from the fact that the materials were different thread counts and fabric weight, it is also interesting that the highest K/S values for the cyan and magenta samples were measured on material 2 (lowest fabric weight and thread count), while for material 3 - with the highest fabric weight and thread count – the these values were measured on yellow and black samples. In addition, material 1 proved to be better than material 3 in terms of seal of cyan and magenta; material 2 for printing the black ink, meaning that the quality and reproducibility of the preprint material can be improved by selecting the appropriate substrate.

IV. Analysis of thermal influence

All samples were processed with a process of ironing in accordance with ISO 105-X11 at 110°C. The exact temperature was determined using a thermal IC chamber of the iron surface.

Figure 5 shows a thermal image of the heat distribution of sample patches with minimum and maximum temperature values. As can be seen, the minimum offset implies that the heat applied to the printed surface is uniformly distributed and of the correct temperature.

Table 2. shows that all colors printed on material 1 were found to have good color fastness after ironing. The highest values were obtained for cyan and black color samples with only one layer of ink applied.

In addition, the highest values for yellow samples were obtained for prints with one and two layers of ink. Table 2 presents the analysis of material 2, which shows that there was a slightly lower degree of staining measured on this material, which is highlighted in the samples with a higher number of cyan ink layers (four and five), where the samples were rated 3. With the exception of this color, lower color values were also recorded for magenta colors(five layers) and black (five layers), which were nevertheless higher than the values for cyan, estimated at 3-4.

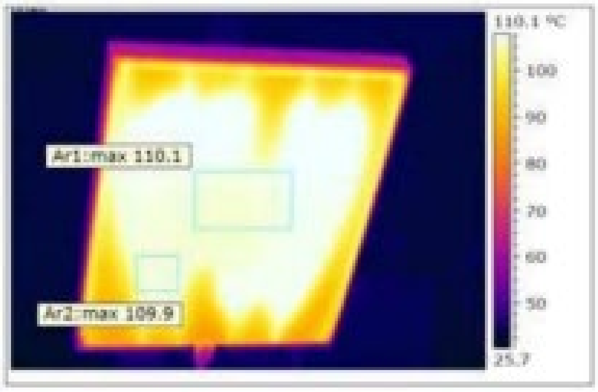


Fig. 5 Thermal imaging analysis of a heat element at 110°C

Samples with yellow color had the smallest offsets and its recorded value for the cotton stain was 4. It should be noted that the color fastness to ironing for all colors is rated 4.

Table 2 presents the results of the last series of analyses performed on material 3, showing the same value for the gray scale change of all ink quantities, while for the coloration ranking the values vary. Compared to the other two, this material has a greater number of lower scores, with cyan being the least durable and its values ranging from 3 to 4. Values of 4 for the magenta samples were higher for samples with two printed layers of ink, while values for additional printed layers decreased to 3-4. While yellow proved to be the most colorfast with the constant value of 4, black and cyan had lower values ranging from 3 to 4

A value of 4 was recorded in the black sample with a single layer of ink. In all other cases the values were around 3-4.

TABLE 2
COLORFASTNESS TO IRONING AT 110 °C

проба	Материал 1		Материал 2		Материал 3	
	Устойчивост на гладене	Степен на оцветяване	Устойчивост на гладене	Степен на оцветяване	Устойчивост на гладене	Степен на оцветяване
циан 1	4	4-5	4	4	4	3-4
циан 2	4	4	4	4	4	3-4
циан 3	4	4	4	4	4	3-4
циан 4	4	4	4	3	4	3
циан 5	4	4	4	3	4	3
Магента 1	4	4	4	4	4	4
Магента 2	4	4	4	4	4	4
Магента 3	4	4	4	4	4	3-4
Магента 4	4	4	4	4	4	3-4
Магента 5	4	4	4	3-4	4	3-4
Жълто 1	4	4-5	4	4	4	4
Жълто 2	4	4-5	4	4	4	4
Жълто 3	4	4	4	4	4	4
Жълто 4	4	4	4	4	4	4
Жълто 5	4	4	4	4	4	4
Черно 1	4	4-5	4	4	4	4
Черно 2	4	4	4	4	4	3-4
Черно 3	4	4	4	4	4	3-4
Черно 4	4	4	4	4	4	3-4
Черно 5	4	4	4	3-4	4	3-4
Забележка: Числото след името на цвета показва броя на слоевете мастило, отпечатани върху субстрата						

The previous analysis showed that after heat treatment (ironing) the color changes were ranked with a value of 4. Therefore, increasing the amount of ink applied does not increase the resistance to changes during ironing.

Although the coloration of the cotton varied from material to material, the best results were recorded in material 1, with the fabric weight being higher than in material 2, and the number of threads as in material 3 the lowest value was recorded with the material with the highest fabric weight (material 3).

Finally, the application of additional ink layers reduces the stain transfer.

V. CONCLUSION

Textile materials used for flag printing are often exposed to various influences during use. All materials tested have different characteristics as well as colors and applied amounts of color. The results lead to the conclusion that increasing the number of ink layers causes a linear increase in the K/S value, which was confirmed by high coefficients of determination. The analysis also shows that the K/S value is influenced by the material characteristics, in particular the fabric weight and the number of filaments, but also depending on the ink color. This was also observed for samples printed with black and yellow ink, where the K/S value increases with higher fabric weight and filament count, while in the case of magenta and cyan the ink effect remains.

Increasing layers of printed ink will result in a better end product in terms of resistance to different environments influences. In the production and reproduction process, it is important to anticipate and properly simulate the behavior of the final product during the service period.

This study offers an insight into the influence of one parameter in the textile printing process on the durability of flag products, but can also be applied to any product produced by inkjet printing on polyester material.

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