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Influence Of Heat Treathment On Caracteristics Of Inkjet Prints On Textile Material

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Abstract
This paper presents research regarding influence of heat treatment on changes of prints on textile material which are obtained by inkjet printing technique. Research was done on three characteristic materials (100 % polyester) on which ware printed test chart. Test chart consisted of four colour fields each 100% of one of process colours (CMYK). Printing machine used was Mimaki JV22-160 with J-eco Subly nano inks. Variable factor was number of ink layers, textile materials ware printed with one, two, three, four and five layers of ink. The analysis of heat treatment influence on prints was done according to SRPS F.S3.311 standard (temperature 110 0C). Total of 60 samples were analyzed, 20 for each material used in this experiment. Resistance of colour to heat treatment and transfer to cotton cloth was determined for characteristic temperatures by using the gray scale. The surface changes of textile material before and after heat treatment ware monitored by SEM analysis.

Key words: ink jet, polyester, heat treatment , ironing colour resistance , SEM

Introduction

Usage of Ink jet printing technique for printing on textile materials is growing in popularity because of its flexibility.

It is important to emphasize reduced preparation time and its cost effectives in smaller runs compared to screen printing (Novaković et al., 2010). The ink jet printing process can achieve better visual effects in comparison to the screen printing and it‘s not limited in format size while it is easier to repeat same printing (Hue et al., 2006, Owen, 2003). One of important characteristics of textile ink jet printing process is that it can be used for wide range of materials. Textile materials during the exploitation can be under the influence of various treatments such as Ironing, washing, aging etc. Heat treatment during ironing is very important factor because the heat influences both the ink applied on surface of material and textile material itself. As a consequence of that changes in colour range and structural changes in textile material and ink happen (Novaković et al., 2010). Heat can be transferred thu textile material in three ways: conduction, convection and by electromagnetic radiation (Mao et al., 2007, Bankvall, 1973, Bomberg et al., 1983). heat transfer can lead to changes in structure of materials (Michalak et al., 2009).

Several standards can be used to examine influence of heat treatment on changes in printed material. One of such standards is SRPS F.S3.311, this standard evolves treatment of printed materials by ironing them using temperatures 110 °C, 150 °C and 200 °C. After heat treatment the colour resistance and transfer to cotton cloth is judged, gray scales are taken as a reference (Figure 1 i 2, Stankovič Elesini, 2007). Judgment on the scale from 1 to 5 is taken as characteristics of materials examined, 1 being worst and 5 best.

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Figure 1. Gray scale for colour changes judgment

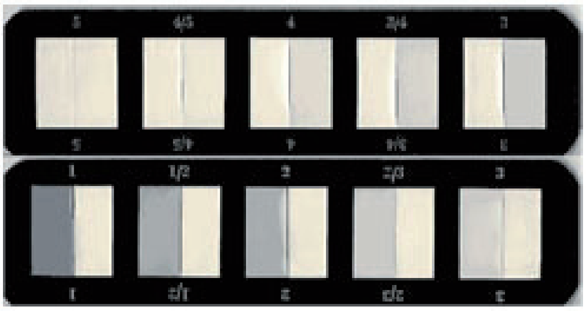

Figure 2. Gray scale for judgment of ink transfer to other materials

Experimental part

Research is examining influence of heat treatment on changes of prints on textile material which are obtained by inkjet printing technique. Polyester is chosen as a substrate material for this experiment because it's often used as the substrate for printing in textile industry for its specific characteristic such as superior strength and resistance (Zhang et al., 2009). Three tipes of 100% polyester material ware chosen. Samples were printed and after that heat treated by ironing acording ot SRPS F.S3.311 standard (temperature 110 ^{0}C). Resistance of colour to heat treatment and transfer to cotton cloth was determined by using the gray scale. The surface changes of textile material before and after heat treatment were monitored by SEM analysis.

Methods and materials

During experiment the measurements were taken and relevant data was gathered in order to examine influence of heat treatment on printed samples. Printing machine used was Mimaki JV22-160 with J-eco Subly nano inks. Variable factor was number of ink layers, textile materials were printed with one, two, three, four and five layers of ink.
Three materials (100 % polyester) were used and characteristics of each of them was demined: weight according to standard (SRPS F. S2.016), knitting density (SRPS F. S2.013) according to standard (SRPS F. S2.013) and composition according to standard (SRPS F. S3.112).

Characteristics of used materials:
Sample 1: *Grammature* 110.6 g/m^2; Knitting density - Rows across length: 260 p/10cm, Knitting density - Number of loops across length: 120 p/10cm; Composition: 100 % polyester.
Sample 2: *Grammature* 101.5 g/m^2; Knitting density - Rows across length: 160 p/10cm, Knitting density - Number of loops across length: 100 p/10cm; Composition: 100 % polyester.
Sample 3: *Grammature* 141.3 g/m^2; Knitting density - Rows across length: 260 p/10cm, Knitting density - Number of loops across length: 120 p/10cm; Composition: 100 % polyester.
Test chart was printed on each of sample materials, dimensions of the chart were 150 x 10 cm (Figure 3). *Test chart consisted of four colour fields,* dimensions of one colour field were 35 x 10 cm. The colour value of fields were: first field – 100 % cyan, second field – 100 % magenta, third field – 100 %, fourth field – 100 % black.

Figure 3: Test chart

Printing system Mimaki JV 22 – 160 offers the possibility of printing in more than one layer of ink by multiple passing's of print head. Test chart was printed with one, two, three, four and five layers of ink. The influence of number of ink layers was taken in to consideration also alongside the analysis of heat treatment influence.

Total of 60 samples were analyzed, 20 for each material used in this experiment. All of the samples were heat treated according to SRPS F.S3.311 standard. Recommended heat according to material composition was 110 °C.
Gray scales shown in Figures 1 and 2, visual judgment of colour changes and ink transfer on cotton cloth was conducted. Results for each of process colours ware grouped and the trend function was made.
Alongside these measurements, SEM analysis on JEOL 646O LV electronic microscope was conducted. Special attention was given to changes on textile material caused by ink and heat treatment. Samples ware classified, tagged and prepared according to specifications for laboratory measurements. Samples were steamed with gold in vacuum to achieve electric conductivity.

Results

Heat treatment influences the material, changes the colour of the prints and as a final result changes the visual perception of the prints.

Visual judgment

Visual judgment according to SRPS F.S3.311 standard showed good resistance to heat treatment by ironing for all colours printed on sample material 1 as it can be seen in Figure 4. All 20 samples received grade 4 regarding the resistance to heat treatment. The transfer to cotton cloth grades are not so uniform and it can be noticed that cyan, yellow and black samples printed with one layer of ink and yellow sample printed with three layers of ink received slightly higher grades 4-5.

Based on gathered results for each of process colours trend function was made. In case of cyan colour change is linear function with y = 4 being constant, while the transfer to cotton cloth is presented with second degree polynomial function with determination factor of 0.857 as shown in Figure 4a. In case of magenta both the colour change and the transfer to cotton cloth can be presented with linear functions with y = 4 being constant shown in Figure 4b. Results for yellow colour (Figure 4c) shows linear function for colour changes with y = 4 being constant, while the transfer to cotton cloth is presented by fourth degree polynomial function with determination factor of 1. Black colour showed similar results as the cyan colour change is linear function, while the transfer to cotton cloth is presented with second degree polynomial function with determination factor of 0.857 as shown in Figure 4d.

Results for second material (sample 2) presented in Figure 5 shows that this material has slightly lower grades regarding transfer to cotton cloth, especially in case of cyan colour prints with greater number of ink layer (four and five). Other than that lover grades are noticeable for magenta prints with five ink layer and black prints with three and five ink layer, although with grades 3-4 still higher than cyan. Yellow colour showed best results with grade 4 regarding the transfer to cotton cloth. Grade for colour change is constant value, 4 for all colours.

Same as for sample 1 based on gathered results for each of process colours trend function was made for material sample 2. In case of cyan colour change is linear function with y = 4 being constant, while the transfer to cotton cloth is presented with second degree polynomial function with determination factor of 0.809 as shown in Figure 5a. In case of magenta the colour change can be presented with linear function with y = 4 being constant and transfer to cotton cloth is presented with polynomial function with determination factor R^2 = 0.857(Figure 5b). In case of yellow both the colour change and the transfer to cotton cloth can be presented with linear functions with y = 4 being constant shown

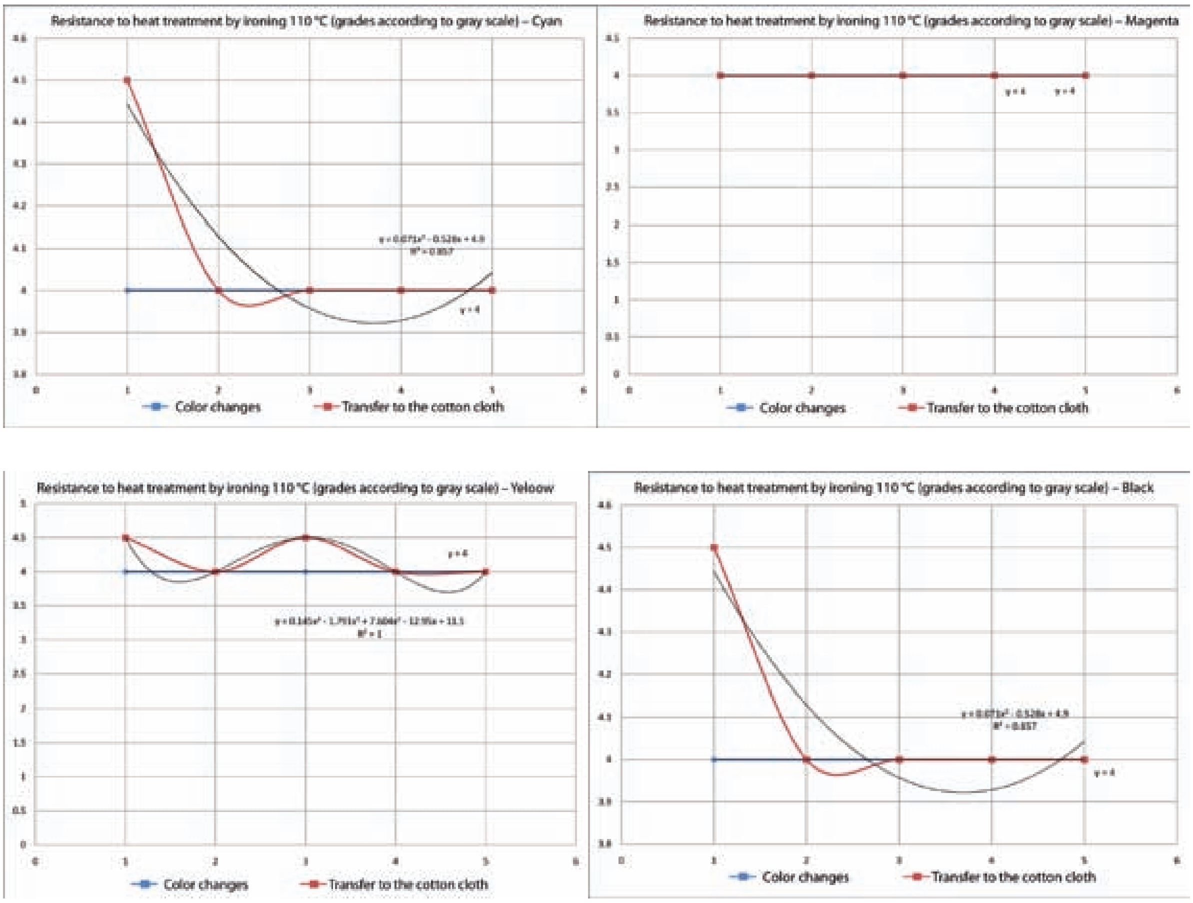

Figure 4: Resistance to heat treatment by ironing 110 °C (grades according to gray scale) – sample 1, represented by functions: a) cyan, b) magenta, c) yellow, d) black

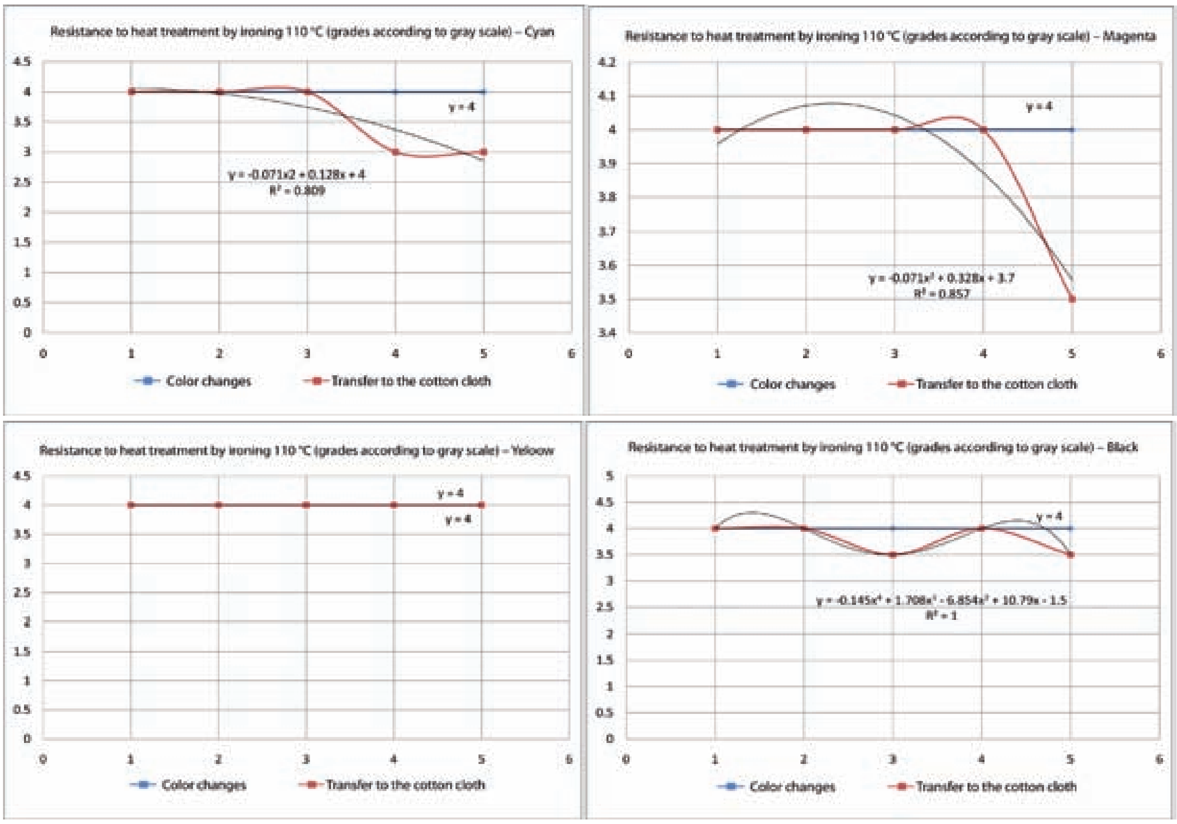

Figure 5: Resistance to heat treatment by ironing 110 °C (grades according to gray scale) – sample 2, represented by functions: a) cyan, b) magenta, c) yellow, d) black

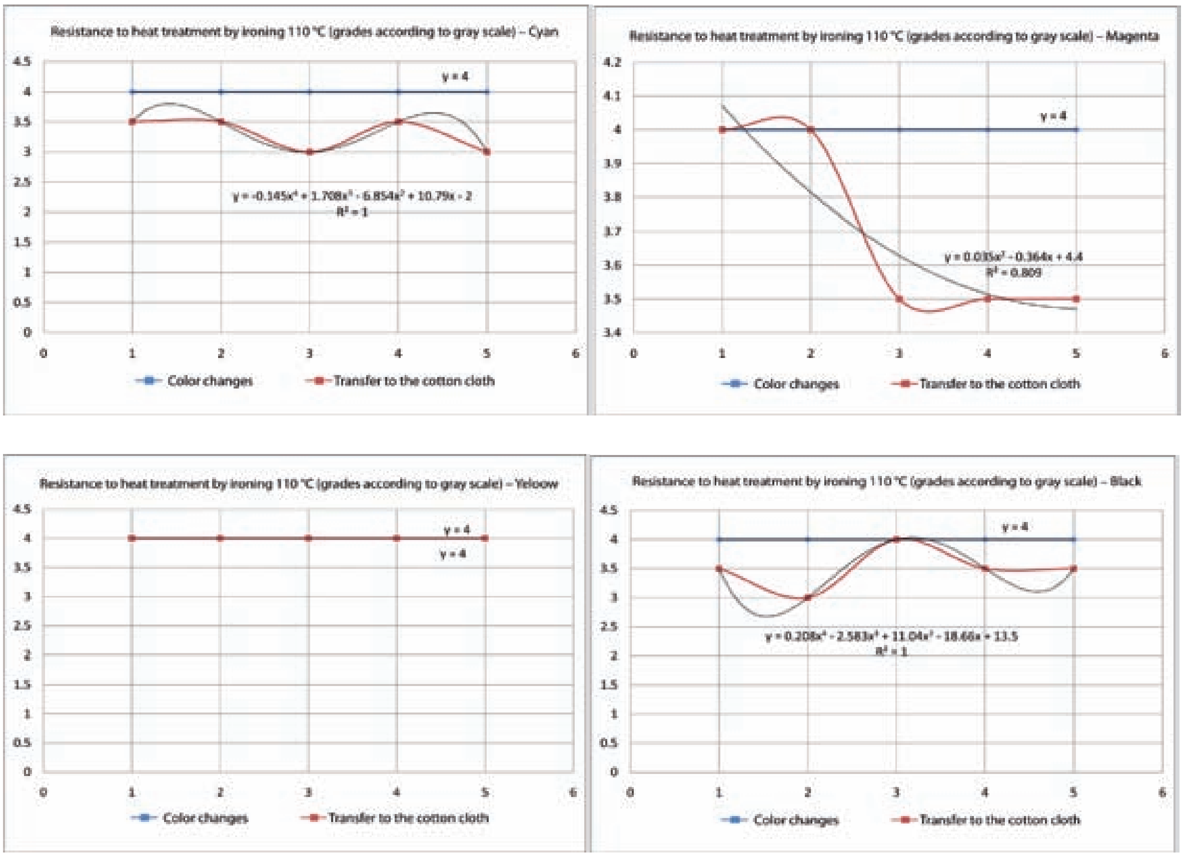

Figure 6: Resistance to heat treatment by ironing 110 °C (grades according to gray scale) – sample 3, represented by functions: a) cyan, b) magenta, c) yellow, d) black

in Figure 5c. Black colour showed that colour change is linear function, while the transfer to cotton cloth is presented with fourth degree polynomial function with determination factor of 1 as shown in Figure 5d.

Analysis of material sample 3 is shown in Figure 6. Colour change is graded with grade 4 in case of all the colours and printed with different number if ink layers. The transfer to the cotton cloth grades are lower in comparison with two previous material samples, cyan received lowest grades raging from 3 to 3-4. Magenta was graded better than cyan in case of one and two ink layers while the higher number of ink layers caused lower grade 3-4. Yellow colour proved to be most resistant in this case to with constant grade 4. Black colour received lower grades ranging from 3 to 4, the prints with two layers of ink received grade 3, while prints with three ink layers received grade 4 in other cases grade was 3-4.

Analysis of material sample 3 showed that linear functions can describe colour change for all colours, with constant value y= 4. The function for the transfer to the cotton cloth of yellow colour is linear as shown in Figure 6a, while other colours can be described by polynomial functions. The function for the transfer to the cotton cloth of cyan and black is fourth degree polynomial function with determination factor R^2= 1 (Figure 6a, 6d). Magenta has the second degree polynomial function with determination factor R^2= 0.809 (Figure 6b).

SEM microscopic analysis

The surface changes of textile material before and after heat treatment ware monitored by SEM analysis. Figures 7, 8, 9 show images of samples used in analysis. Figures show first the textile fibers before printing (a), second image shows the textile materials after printing, five ink layers (b) and third image shows printed textile materials after heat treatment (c).

Figure 7a, 7b, 7c show material sample 1 before printing, after printing of five ink layers and printed textile materials after heat treatment respectively.

Figure 8a, 8b, 8c show material sample 2 before printing, after printing of five ink layers and printed textile materials after heat treatment respectively.

Figure 9a, 9b, 9c show material sample 3 before printing, after printing of five ink layers and printed textile materials after heat treatment respectively.

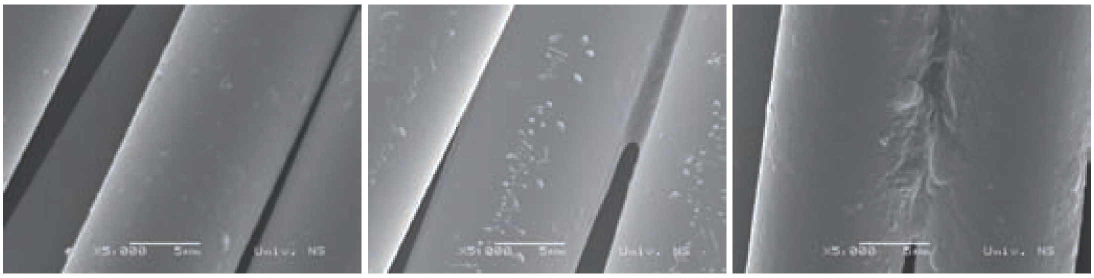

Figure 7: SEM images samples 1, a) before printing, b) after printing, c) after heat treatment (110 °C)

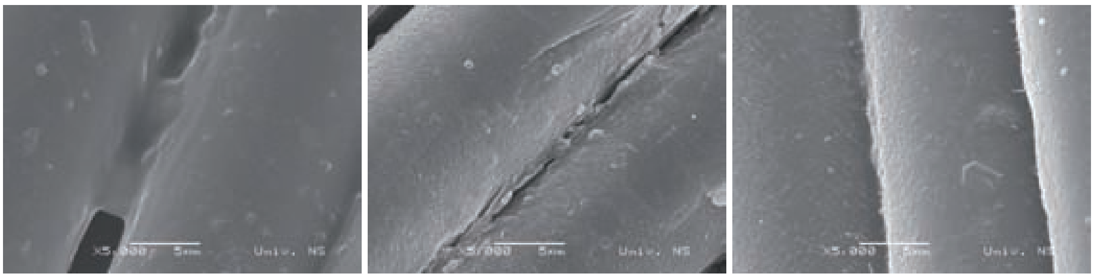

Figure 8: SEM images samples 2, a) before printing, b) after printing, c) after heat treatment (110 °C)

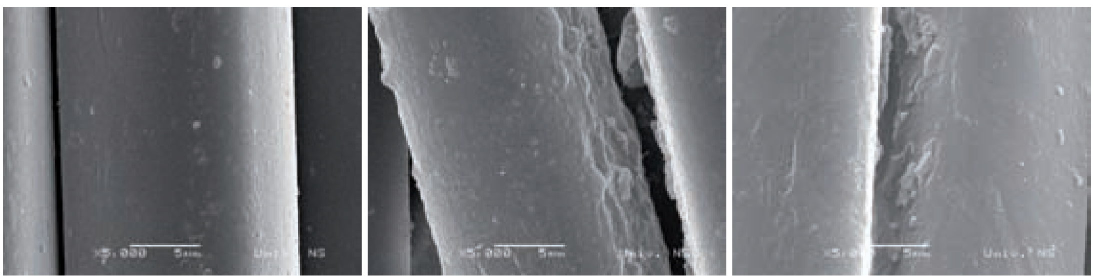

Figure 9: SEM images samples 3, a) before printing, b) after printing, c) after heat treatment (110 °C)

Discussion

Each textile material have specific characteristics, textile materials with same composition but different knitting density and weight beehive differently during exploitation.
Analysis of three textile material samples with same composition (100 % polyester) and different knitting density and weight showed to resistance to heat treatment 110 °C showed that materials have grade 4 for colour changes after heat treatment same for all materials but results for the transfer on the cotton cloth were different amongst materials.
Material sample 1 showed highest resistance to transfer on the cotton cloth with highest grades 4-5 for cyan (1 ink layer), yellow (1 ink layer), yellow (3 ink layer), black (1 ink layer) while other the samples were graded 4.
Material sample 2 showed lower resistance to transfer on the cotton cloth with lowest grades 3 for cyan (4 ink layer) and cyan (5 ink layer). Magenta was graded with a slightly higher grade 3-4 for magenta (5 ink layer) and black (3 and 5 ink layer) while other the samples were graded 4.
Material sample 3 was graded worst of all material samples, allot of samples of this material were graded under 4. Samples of cyan (3 and 5 ink layers) and black (2 ink layers) were graded 3, while cyan (1, 2 and 4 ink layers), magenta (3, 4 and 5 ink layers) and black (1, 4 and 5 ink layers were graded 3-4. Other samples of this material were graded 4.
All of this grades were given by visual judgment according to gray scales shown in Figure 1 and 2. Subjectivity of this method can cause some problems, so in some cases it is better to use spectrofotometric colour measuring device. Table 1 (Stankovič, 2007) determines roughly colour difference ΔE if it were obtained by spectrofotometric measurement, so we can say that all the material samples have colour difference ΔE before and after heat treatment in range from 1,25 to 2,10. On the other hand, values for colour differences ΔE in case of transfer to cotton cloth were in range from 0,40 to 2,95.

Table 1: Relation between colour difference ΔE and visual judgment according to gray scale

Colour difference – ΔE	Visual judgment
< 0,40	5
0,40 ≤ ΔE <1,25	4–5
1,25 ≤ ΔE < 2,10	4
2,10 ≤ ΔE < 2,95	3–4
2,95 ≤ ΔE < 4,10	3
4,10 ≤ ΔE < 5,80	2–3
5,80 ≤ ΔE < 8,20	2
8,20 ≤ ΔE < 11,60	1–2
≥ 11,60	1

SEM analysis of material samples showed joining of textile fibers by ink making bridges and remaining on the material surface as it can be seen in Figures 7b, 8b and 9b. Heat treatment causes penetration of certain amount of ink deeper between material fibers, thus making bridges between fibers wider as shown in Figure 7c, 8c and 9c.

Conclusion

Conclusion reached by experiment is that there are changes of textile material caused by printing and by ironing heat treatment. Changes in surface structure of printed material are noticed, penetration of ink between material fibers is noticed after heat treatment. By changing surface structure of the printed material there are some changes in reflective properties of ink, which further causes changes in colour perception. This was proven using gray scales based visual judgment according to SRPS F.S3.311 standard. Analysis of images obtained by SEM showed that ink isn't just binding to the surface of the fibers but it binds material fibers together. Heat treatment caused further binding of material fibers. Fact that changes in structure of textile material induced by heat treatment causes colour changes. Interesting thing to emphasize is that all textile materials used had received high grades regarding colour changes witch mean that they are all resistant to heat treatment regardless of material, ink or number of ink layers used. The transfer to cotton cloth showed significant differences when different materials and different amount of ink layers is used, this could be subject of further studies.

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