Applied Thermal Engineering 90 (2015) 215–220

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research paper

# The influence of heat treatment on print mottle of screen printed textile knitted fabrics

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## HIGHLIGHTS

- Textile can be printed with screen and digital (Inkjet) print technologies.
- Heat can not only change the reproduced colour, but also affects the print mottle.
- Results induce the use of 130 °C temperature for ironing.

## ARTICLE INFO

*Article history:*
Received 5 May 2015
Accepted 4 July 2015
Available online 14 July 2015

*Keywords:*
Textile material
Screen printing
Heat treatment
Image quality analysis

## ABSTRACT

Printed fabric is widely used, and it is exposed to various influences. One unavoidable impact is heat treatment during subsequent maintenance – ironing. Hence, many printed textile materials are exposed to different temperatures. Textile can be printed with conventional (screen) and digital (Inkjet) print technologies. In this paper, we analyzed screen printed textile and its sustainability after heat treatment. Heat can not only change the reproduced colour, but also affects the print uniformity (print mottle). The goal of this paper was to find what could be controlled and changed in order to get long-lasting printed textile. We used one natural textile material – cotton that was printed with screen print technology. Constant parameter during the experiment was a time of heat treatment. Ironing temperature and screen mesh count were varied. Results showed that samples printed with smaller screen mesh count maintain print uniformity after heat treatment.



## 1. Introduction

Nowadays, print on substrate such as textile is widely applied. These materials can be printed using various techniques, but the most common in use are conventional screen and digital Inkjet printing. Screen printing is the most important conventional printing technology in the textile world [1–3]. The advantages of this technique are less cost and higher productivity for large print runs [4,5]. It is developed to carry out mass production [6]. On the other side, due to the physical and chemical nature of the substrate, Inkjet is the leading and the most relevant digital printing technology for textiles [6]. In comparison to screen printing, Inkjet has no limitation in format size, and its use reduces the time of making the product, from design to the press, accelerating the production itself [7]. Although, the better visual effect can be achieved with liquid UV Inkjet inks [8,9], in this paper focus is on screen printing.

Many factors, which are closely related to each other, influence on final print quality [10]. Print speed, squeegee hardness, squeegee pressure and the distance between the screen and printing substrate (snap-off distance) affect print quality. These parameters all affect the quality, but Pan et al. [11] pointed out that the greatest impact on the quality has squeegee hardness and printing speed. In addition to these parameters, printing screen mesh counts and fiber thickness affects the final ink density and tone value reproduction [12]. Ingram in his work [13] stated that printing form, ink and substrate influence on the reproduction quality of basic parameters, lines and dots. To achieve the appropriate quality, all the parameters mentioned above must be controlled.

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http://dx.doi.org/10.1016/j.applthermaleng.2015.07.013
1359-4311/

The most commonly used textile materials in screen printing technology are made of cotton [14]. Cotton material is widely used in textile industry because of its excellent properties, such as: air permeability, diffusion of moisture and heat, softness, hypoallergenic and antistatic properties [15], and also great thermal properties [16–18].

Printed textiles are often exposed to various influences such as light, washing, chemical reagents, and heat [19]. One of the most common impacts is the effect of heat. The consequence of the heat treatment is the change of reproduced colours [20]. The heat leads to changes in the applied ink and also in the structure of the material itself [21]. In the papers [22–24] is noted that the temperature can be transferred to the textile material in three ways: conduction, convection and by electromagnetic radiation.

Test for colour fastness to heat treatment could be carried out on the basis of international standard ISO 105-X11:1994 [25–29]. According to this standard, the gray scale (from one to five) is used for quality judgment. The quality of the treated prints can be also controlled using the spectrophotometric measurement [20] or image quality analysis. Print quality analysis beside colour includes other print quality attributes, including line quality, blurriness, raggedness, line width, darkness, micro (graininess) and macro (print mottle) uniformity, etc. [30]. The image quality analysis is performed using automated print quality systems to quantify quality attributes. The study [7] demonstrated the application of the image quality analysis for quality control of printed textile. Besides this automated system, there are also other image quality methods. For assessing print uniformity, GLCM [31] and Histogram Mottle Macro [32] methods could be used.

Based on a review of current literature and research we set a goal of this study. We investigated the influence of heat treatment on print uniformity (print mottle) of the screen printed textile materials. In order to quantify this parameter (print uniformity – print mottle), we used image quality analysis.

## 2. Materials and method

One textile knitted fabric with a single weave type was used. Material characterization was done according to the following standards: material composition (ISO 1833), fabric weight (ISO 3801) and thread count (ISO 7211-2). These properties are presented in Table 1.

Test chart used for the experiment consisted of one black square 25 × 25 mm for obtaining print uniformity. It was printed using screen printing technique, M&R Sportsman E-Series six-colour printing machine. Pan et al. [11] found that four main parameters have a crucial effect on screen print quality. These parameters were kept constant during the printing. Printing speed was 15 cm/s; squeegee hardness was 80 Shore Type A, printing pressure 275.8 $10^3$ Pa and 4 mm snap-off distance. Sericol Texopaque Classic OP Plastisol inks were used. Plastisol inks require additional fixation after printing. Ink fixation was done at a temperature of 160 °C, exposure time 150 s with thermal press MAGNET RV.

Printing form was made using three different printing screen mesh count: 90, 120 and 140 threads per cm, on aluminum tubing frames. Conventional exposure was used with linear positive films with optical density $D_{min} = 0.3$ and $D_{max} = 4.1$, measured with densitometer Viptronic150. Film screening was five times smaller than printing screen mesh count. Photosensitive Sericol Dirasol 915 emulsion was used. Light exposure was done using metal-halogen UV lamp (1000 W) at a 1 m distance from the mesh. Exposure time for each stencil was calculated using control tape Autotype Exposure Calculator by Sericol Company. Light exposure time for each stencil is represented in Table 2.

**Table 2**
Exposure time of stencils.

| Thread count (threads/cm) | 90 | 120 | 140 |
|---|---|---|---|
| Light exposure time (min) | 3 | 2.6 | 1.6 |

Samples were heat treated according to standard ISO 105-X11:1994, using thermal press MAGNET RV. Time (15s) and contact pressure (850 daN) were constant during the experiment. Samples were exposed to three different temperatures: 110 °C, 130 °C and 150 °C. In this way, the ironing process is simulated, which is an inevitable part of the use of any of printed textile material. The heating element was tested using thermovision camera to minimize or completely eliminate temperature variations. The surface of the heating element was cleaned and prepared for measurement. Fig. 1 represents characteristic values of temperatures used in this experiment. It can be seen that there are some variations in temperature of the heating element surface. In order to eliminate the possibility of variation in thermal load applied, all the samples were positioned in the same spot so they can be in contact with the center of the heating element where the temperature was constant.

Print uniformity was characterized according to two different methods, Histogram Mottle Macro [32] and Gray level co-occurrence matrix (GLCM) [31]. For assessing print mottle with image analysis method, printed samples need to be digitized. Therefore, after printing and every heat treatment, samples were scanned by scanner Canon CanoScan5600F at 600 spi. Scanned samples were transformed from RGB to Lab colour space and only $L^*$ channel was used for evaluation. Histogram Mottle Macro was applied in ImageJ and for GLCM calculations we used MATLAB software with a code proposed by Uppuluri [33].

Histogram Mottle Macro is a method developed by Maja Stanić, Tadeja Muck and Aleš Hladnik, and it measures the print mottle, or the amount of non uniformity in the grayscale image. The amount of non uniformity is calculated on the basis of the histogram of the image. It measures the difference between the upper $U_x$ and lower $L_x$ values of the image histogram ($NU = U_x - L_x$). $U_x$ is calculated as the mean of the intensities between median and maximum values of the histogram. $L_x$ is calculated as the mean of the intensities between minimum and median values of the histogram. The amount of the non uniformity is expressed as the non uniformity index (NU). The greater the NU index, the surface is non-uniform, i.e. there is more amount of mottle [32].

GLCM – also known as the gray-level spatial dependence matrix – is a matrix that keeps track of how often different combinations (pairs) of pixel intensity (gray level) values in a specific spatial relationship and distance, occur in an image [31]. When building

**Table 1**
Characteristics of the material used in the experiment.

| | Type of waves | Material composition (%) | Fabric weight (g/m$^2$) | Thread count (cm$^{-1}$) | |
|---|---|---|---|---|---|
| | | | | Warp | Weft |
| Material | Single | Cotton | 138 | 14 | 19 |
| Method | | ISO 1833 | ISO 3801 | ISO 7211-2 | |