INFLUENCE OF VARIOUS TONES OF COLORS ON MEASURING POROSITY OF KNITTED FABRICS PRINTED BY SUBLIMATION

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Abstract
The pores can be characterized as small air spaces in structure of a knitted fabric. By comparing of area of pores with the area of knitted fabrics, we are able to determine the index of porosity. The porosity of the knitted fabric has the decisive influence on the properties and usage of the knitted fabric. Therefore, it is necessary to express it theoretically and measure it experimental. The aim of measurement was to evaluate the influence of the color tone printing for measuring porosity. The given measurements of the porosity were done with utilization of the image analysis compounded from Nikon microscope, CCD camera and NIS Elements software. The porosity of knitted fabrics was measured on difference color areas. The result of these experimental measurements was expression of dependence between the porosity of the knitted fabrics and the number of the pores at the knitted fabric. The attention was also paid to shapes as well as size of pores in the given knitted fabric.

Keywords: porosity, color tone, knitted fabric, sublimation printing, image analysis

1 Introduction

Sublimation printing is a local staining, mostly on textile materials,that is completely different from other types of printing. The trade-off with using the sublimation process i that for the chemistry to work, it must be used with substrate that have a high polyester content (at least 50%) [8]. The more polyester in the substrate, the better quality of the image. There are used entirely disperse dyes for sublimation printing. They are characterized by a very small molecule, soluble in water and sublimes at higher temperatures [4]. Sublimation printing belongs to the so-called transfer printing, consist the following steps. In the first step there is the dye printed on transfer paper. This specially treated paper does not absorb the dye and thereby helps to transfer the maximum amount of dye on the substrate surface. In the second step there is the transfer paper placed on a substrate, on which we want to transform the image and after that, heat and pressure is applied using a heat press. During the heat transfer process, the molecules of the sublimation dyes turn from a solid to a gaseous state and penetrate the surface of the fabric. When the fabric cools, the dyes return to their solid state and are permanently impregnated into the fabric. Temperatures used range from 190°C to 215°C. At these temperatures and under high pressure the gas in the inks explode impregnating the fabric, leaving the permanent non fading design [9]. Because of high temperature applied in this process, only polyester is suitable on this type of printing. Its melting point is higher than the temperature in the process itself. Because the sublimation process dyes the fibers of a garment, instead of putting a layer of two on top of the fabric, the image cannot crack, peel, or wear off [8]. Particular advantage of sublimation printing a is that the given process is after transfering done and there is no need for any further treatment as in conventional printing. Indisputable advantage of transfer printing is also from an environmental standpoint, that is low water consumption [5]. Another important advantage is the possibility of printing on finished clothing such as T-shirts, swimwear, sports jerseys [8].Given sport clothes are very difficult on their comfort proporties, especially on physiological properties. Already mentioned sublimation process may affect these properties. One of the properties that is the subject of our measurement is porosity**.** The porosity in flat knitted textiles is defined as a void part of the textile's full volume [10]. The size of pores may affect printing quality, but also applied sublimation printing may affect the size of pores, changing its physiological properties. To find out how sublimation printing affects porosity is necessary to perform measurement that is based on light passing through the holes in knitted fabrics.The given measurements of the porosity were done with utilization of the image analysis compounded from Nikon microscope, CCD camera and NIS Elements software [6]. The aim of measurement was to evaluate the influence of the color tone printing for measuring porosity. The porosity of knitted fabrics was measured on difference color areas, witch were compared each other.

2 Experimental part

Materials used

The porosity measurement has been realized on filling weft knitted fabrics (Fig.1). Used knitted fabric has been made of two types of length units multifililament yarn shaped in the false twist form, where the measured linear density of basic multifilament yarn was 13 tex and linear density of filling multifiliament yarn was 14 tex. The basic knitted fabric has been knitted in a plain single jersey binding [1, 2].

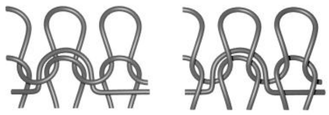

Fig. 1 *Face side and back side of knitted structure*

Multifilamentn yarn filling was bound to the basic knitted fabric by cardigan loops form. Laying filling multifilament yarn has been in a 1:2 with enforcing in every other row. The binding of knitted fabric formed in this way is much thicker, warmer and more closer. Face side of knitted fabric, which has been printed by sublimation printing had been treated so that it achieve the best possible quality of the final pattern. Porosity measurement was done on both printed and unprinted knitted fabric to determine what influence does porosity of sublimation printing on knitted fabrics.

Table 1 *Base parameters of knitted fabics when H_s- columns density, H_r - line density, h – thickness, ρ_S – surface weight, ρ_V – bulk weight*

Sample	H_S [0,1m]	H_V [0,1m]	*h* [mm]	ρ_S [kg.m^{-2}]	ρ_V [kg.m^{-3}]
Non-sublimated knitted fabrics	157	123	0,80	0,216	270,479
Sublimated knitted fabrics	154	125	0,70	0,214	305,952

Method used

Porosity measurement has been done on the image analysis of Nis Elements composed of a microscope, CCD camera and PC (Fig. 2). Nis Element process multi-dimensional image with support for capture, display, external control and management of measured data [7]. The main aim of using this device for our application was the possibility of measuring the geometric dimensions of the captured image. In our case there has been scaned area of binding points between the holes in knitted fabric. Microscope lens was adjusted to capture the largest area of knitted fabric. Because the measured area was big enough and it captured a sufficient number of pores were more than sufficient to do only 25 measurement for each knitted fabric. To simplify measurement in Nis Elements program has been necessary to create a macro consisting from the file of many commands as for example thresholding the image, creating of binary image, various kinds of cleaning the image, the measurement area and measurement of a particular object. Measured values were subsequently processed using the statistical program QC Expert [3]. Before the measurement there was set up a gray histogram and parameters of RGB values. Binary image was created from color picture using threshold porosity measurements were made at that binary image at the preset threshold.

Fig. 2 *Image analysis of Nis Elements equipment*

3 Results and discussion

Porosity measurements were made on both unprinted and printed knitted bafric by image analysis Nis Element. For both knitted fabrics were made 25 measurements. Measurements were carried out under the following conditions:

- image area 263090μm^2
- threshold value 200

CCD camera intensity and exposure settings:

- format for live preview 8- bit 1280x1024
- format for capturing 8- bit 1280x1024
- speed of the transfer 12MHz
- gain 2,5

Microscope settings:

- 38-fold zoom
- intensity of passing light without specimen - 250
- range of intensities of passing light through specimen 45 – 55

From results of the measurements is not seen significant difference between the pore sizes of observed knitted fabrics (Table 2).

Table 2 *Resulting values p_o - porosity, n – number of pores, s - pores surface on the knitted fabric*

Parameter	non-sublimated			sublimated		
	p_o [0..1]	n	s [μm^2]	p_o [0..1]	n	s [μm^2]
Average	0,033	106	8592	0,03	102	7899
Standard deviation	0,0035	7,49	907	0,037	7,2	984
Confidence interval low	0,031	104	8218	0,0285	99	7493
Confidence interval high	0,034	110	8967	0,0316	105	8305

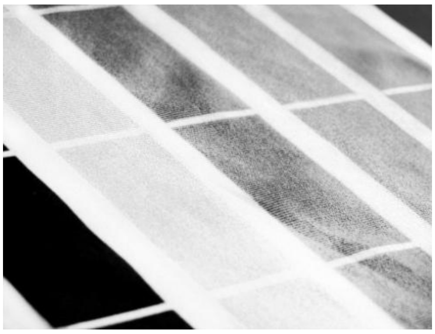

Fig. 3 *Face side of knitted fabric after sublimation with various colors*

Therefore, measurements were repeated on the various samples sublimated with following colors: black, green, blue, pink, red and yellow (Fig. 3). The aim was to determine the impact of the color on the measured value of porosity. From previous measurements follows that the final intensity of exposure depends on the colorfulness of the sample. For darker colored fabric samples tested, the intensity of exposure is lower, which affects the measurement results of porosity. That factor was eliminated from measurements by setting of intensive offset to 100 at zero saturation images. So we have achieved quite a balanced picture knitted fabrics for all colors. Captured image was transformed into the binary image with a threshold value the 69th. As possible to the pores in the thresholding we take into account the linkages of knitted fabrics where are not walls of the loop. The reason this solution is that the pores in this type of knitting links are hidden. The measurements show that all of the colors except black are the results of similar measurements of porosity. The lowest porosity values were measured in the black sample. The results are shown in the tab.3 and fig. 5,6. Fig.4 shows the difference in porosity between light and dark colors.

Table 3 *Resulting values: p_o - porosity, n – number of pores, s - pores surface on the knitted fabric*

Color of the knitted fabric	p_o [0..1]	s [μm^2]	n
Non printing	3,9	1979	59
Printing black	2,74	2203	33
Printing green	15,35	5003	92
Printing blue	17,77	4215	126
Printing yellow	16,34	6401	123
Printing red	19,87	6883	130
Printing white	3,7	2195	78
Printing pink	18,7	4636	12

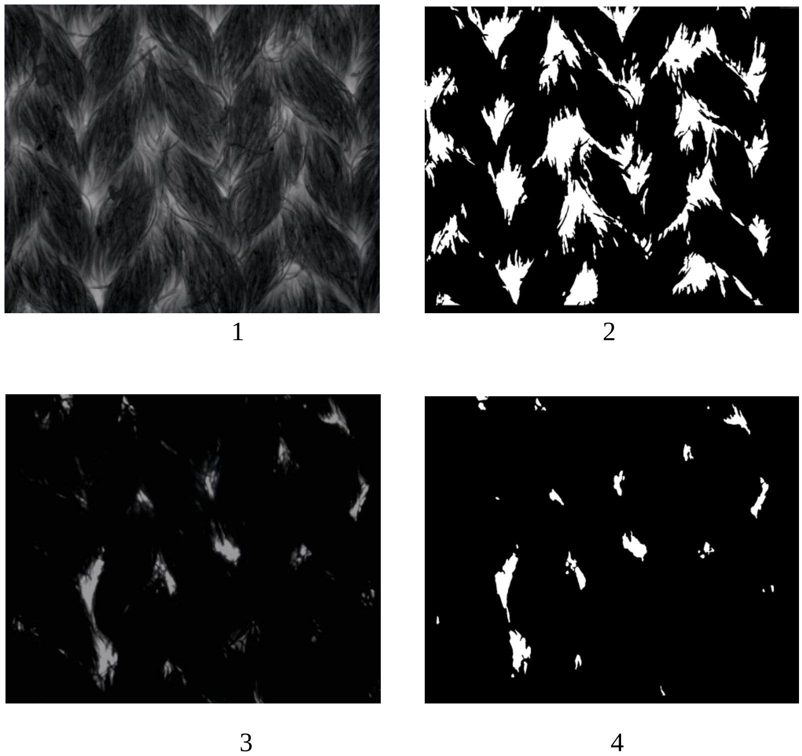

Fig. 4 *Microscopic image of red knitted fabric -1, black knitted fabric-3, microscopic binary image of red knitted fabric-2 and black knitted fabric.*

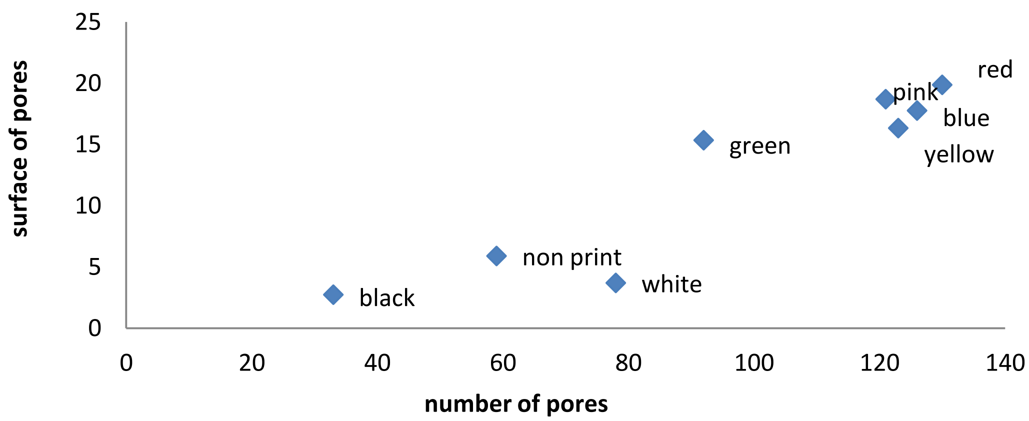

Fig. 5 *Influence of passing light on various kinds of colors*

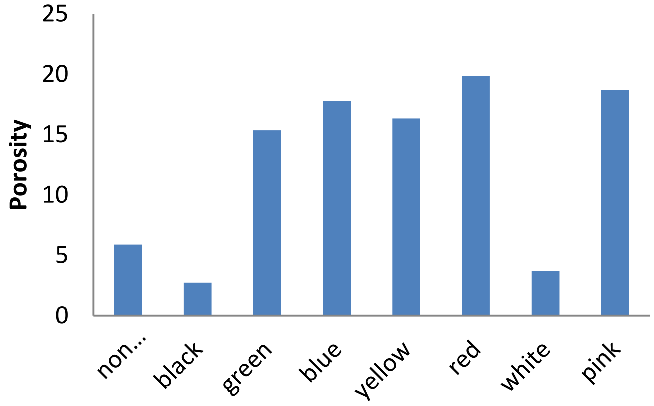

Fig. 6 *Histogram of porosity for various colors on knitted fabric*

4 Conclusion

From porosity measurements results of knitted fabrics arise the following conclusions:

1. Influence of sublimation printing on surface porosity measured by image analysis Nis Element was entirely negligible.
2. The porosity measurement also depents on the type of knitted structure. Knitted structure where filling yarn is used is more closed as knitted structure without filling yarn. Measurement of surface porosity by image analysis in transmitted light through optical devices is problematic and inaccurate.
3. Given type of measurement is more applicable for knitted structure that is made of one basic yarn. This kind measurement is also not suitable for filling and velure knitted structure, because they are more thicker and bulkier.
4. It was verified that the porosity measurement method is suitable for fabrics with low thickness.
5. Measurement of porosity was negatively affected by the color of sample. Black color reduces the value of the measured porosity. Also, lower values of porosity were measured on unprinted knitted fabric.

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