
Assessment of Inter-Yarn Zone Porosity of Plain Weave Fabrics

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ABSTRACT

In this research software was designed for assessing the inter-yarn zone fabric porosity of Tencel plain weave fabrics in terms of flow of dye liquor by using Matlab. Fabric images were captured at constant light intensity and magnification using an optical microscope and image analysis software. The captured images were first converted into monochrome image and then into binary image at specific threshold value (150). The percentage of white pixels in the binary image were calculated which assessed the fabric porosity in percentage. The loosely woven fabric gives higher percentage of fabric porosity as compared to the tightly woven fabric. This software has potential to calculate the fabric porosity of plain weave fabric manufactured from any type of raw material.

Key Words: Porosity, Inter-Yarn, Matlab, Threshold.

1. INTRODUCTION

Fabric properties such as cover factor and porosity are very important for assessing the behaviour of flow of dye liquor in between the yarns (inter-yarn pores) and between the individual filaments of the yarns of the fabric (intra-yarn pores) [1]. The maximum liquor passes through the inter-yarn zone of fabric [2]. However, the adsorption and absorption of any liquid, gas and solid materials into the fabric depend on the inter-yarn and intra-yarn porosity [3-4], type of weave and its structure. Moreover, dye liquor can easily pass into the loosely woven fabrics as compared to tightly woven fabrics. It is because when tightly woven fabrics composed of hydrophilic yarns wet, swells the yarns, increase the compactness and act as a barrier for liquid to flow [5].

Therefore, for predicting the liquor flow into the fabric, much work has been done on the assessment of fabric porosity. It was assessed by geometrical formulas [6-8] and by image processing and analysis techniques. An

area of pores was calculated using geometrical expression as a perpendicular projection of the yarns of the woven fabric (Equation (1)); however, this classical 2-D model of porosity was insufficient for a tightly woven fabric. Another geometrical expression of calculating the inter-yarn porosity of the woven fabric is given in Equation (2).

$$\text{Porosity, \%} = 100 \left[1 - (k_1 + k_2 - k_1 k_2) \right] \quad (1)$$

$$\text{Porosity} = \frac{p_1 p_2}{(p_1 + d_1)(p_2 + d_2)} \quad (2)$$

Where K_1 is warp cover factor, K_2 is weft cover factor, d_1 is dia of warp yarn, d_2 is dia of weft yarn, p_1 is warp spacing, and p_2 is weft spacing.

Additionally, others have introduced geometrical expressions. It helps to predict the fabric porosity values, however, the accuracy of the results depend on its

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expressions. The calculation of yarns diameter, ends and picks per cm, and yarn distance is tiring and time consuming job depends on the operator efficiency. Work has been carried out to evaluate the fabric appearance [9], thread density, yarn density, weave pattern, fabric count, yarn skewness [10-11] and fabric cover factor [12-13] using Fourier transfer technique. Other image processing and analysis functions such as iteration programme were used to identify the weave repeat, drawing harness draft and chain draft [14]. The average illuminate and percentage illuminate functions were designed on Matlab software to assess the fabric porosity [15].

Hence, the research was carried out on analysis of fabric parameters but not much work has been done on analysis the relationship between the fabric properties and dyeing behaviour. Therefore, this paper is more focused on the relationship between the fabric property such as porosity or cover factor and the dyeing behaviour using image processing and analysis functions. It is an advanced method of estimating the fabric cover factor as compared to the determination technique which uses geometrical expressions based on the yarn count and yarn size [16]. This method has the potential to measure the fabric porosity of plain weave fabric made from any type of textile material.

2. MATERIALS

Tencel plain weave fabrics of nine different fabric weights GSM (Gram Square Meter) as shown in Table 1 were supplied by Lenzing AG, Austria. Tencel fabrics have same warp yarns linear density (14.4 tex); but the linear density of weft yarns of group B samples (20.6 tex) is different. The fabrics were then dyed with Levafix Blue CA dyes

TABLE 1. CONSTRUCTION OF TENCEL PLAIN WEAVE FABRICS

Sample	Group-A					Group-B			
	1	2	3	4	5	1	2	3	4
GSM	110	115	132	140	145	124	135	157	163
Porosity (%)	21.5	19.7	15.4	13.6	11.5	19.7	17	11.9	9.5

(0.5% dye conc) by pad-steam, continuous dyeing method at 40°C liquor temperature with a 1 min dwell time after caustic treatment [17].

3. METHODS

A software programme was designed using Matlab 2009a version for measuring the percent porosity. Fabric images were taken by using optical microscope Leitz Diaplan microscope at a magnification of 160x and constant transmission of light intensity (3). Twenty images were taken from each fabric side by side, before and after dyeing, in order to avoid the weaving variations.

The fabric coloured images (Fig. 1 (a)) were first converted into monochrome images (0-256 scale, where 0 is black and 256 is white). As shown in Fig. 1(b), the pore areas of monochrome image are given a greying effect, resulting in low and incorrect values of the fabric porosity. Therefore, in order to minimize the error caused by the greying effect, in this program, loops were used to convert the grey image into a binary image (black and white) according to a pre-decided threshold value (150) as shown in Fig. 1(c). The threshold value of 150 was decided after studying the fabric images at different threshold values ranging from 40-220 and then further confirmed by two different assessors. The software was designed to convert all the pixels that had a value of more than or equal to 150 threshold value into white pixels and less than to 150 threshold value into black (0) pixels. The percentage of white pixels gave the fabric porosity. For comparison, inter-yarn zone porosity was also calculated using geometrical expression as shown in Equation (1).

4. RESULTS AND DISCUSSION

The fabric porosity in percent was measured using Matlab software, as discussed in Section 3. It is apparent from the graphs (Fig. 2) the loosely woven fabrics have high porosity as compared to tightly woven fabrics in both groups A and B. The geometrical %P (Porosity Percentage)

is very high in both groups; this is due to the %P values being derived from the formulas. These geometrical formulas are very useful for estimating the %P, but current research shows that they do not give exact porosity percentages (inter-yarn zone). Fabric images captured

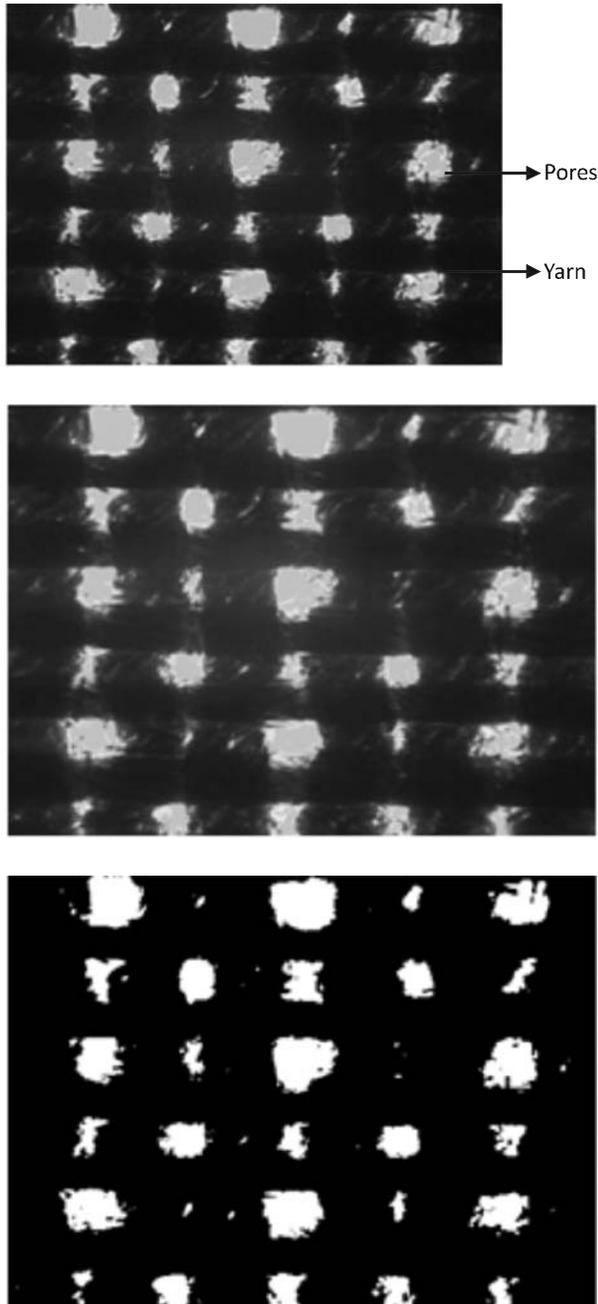


FIG. 1. FABRIC IMAGES OF TENCEL PLAIN WEAVE FABRIC OF 115 GSM

using microscope show the actual fabric image, yarn positioning and condition such as yarn hairiness after woven. The %P of the fabric decreases with processing such as scoured fabric has slightly higher than the dyed fabric. The difference in %P after processing seems to be slightly higher in loosely woven fabric (110 GSM), where porosity is decreased by more than 3% in group A. It is observed from the images that fabric of 110 GSM has very irregular and large pores. The tightly woven fabrics show very insignificant differences in %P values both in group A and B. On the contrary, the porosity of group A's fabrics

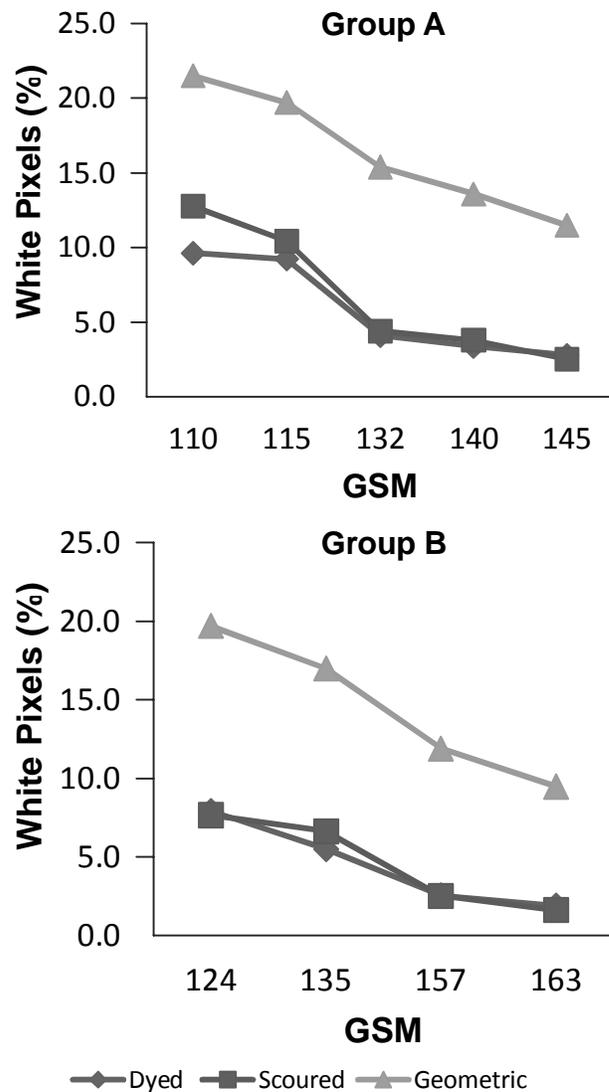


FIG. 2. PERCENTAGE BRIGHT PIXELS OF PLAIN WEAVE FABRICS

are higher than the group B's fabrics due to the difference of linear density of weft yarns.

The method of assessing the %P of fabric at constant intensity of light source is very helpful to investigate the dyeing behaviour in terms of liquor flow inside the fabric. The fabric images were taken with constant intensity of light transmission which behaves the same dye liquor flow for all the woven fabrics. As the % white pixels or porosity decreases with fabric weight, similarly the behaviour of liquid flow is being changed or decreased with fabric weight. Therefore, amount of dye in the fabric is inversely proportional to the fabric weight. For example: in the group A, where all the warp and weft yarns have the same linear density, their differ in ends and picks per cm causes change

in the flow of liquid or light in between the yarns and at the intersection points of the fabric, resulting in the variation of colour depth (Figs. 3 (a-b)).

The dye molecules vary in size, geometry, and reactivity within the same class of dye. Some dyes are very small in size and can easily penetrate inside the filaments of the yarns of the woven fabric but others do not because of their structure. The smaller the pores in the fabric the more difficult it is for the dye to diffuse inside the fabric, more force is required to penetrate in the fabric. For dyeing the fabrics not only is the correct recipe and procedure required, but knowledge of fabric parameters is also necessary, so that the dyers can get right-first-time and uniform shade.

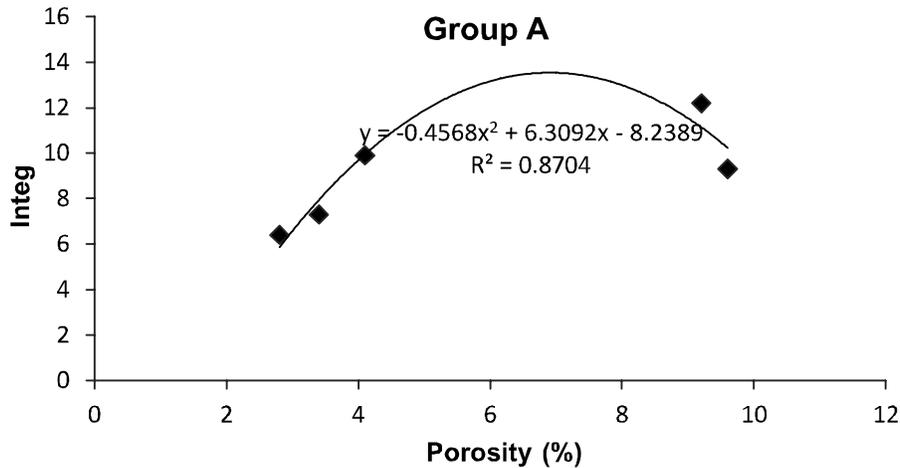


FIG. 3(a). INTEG VERSUS POROSITY

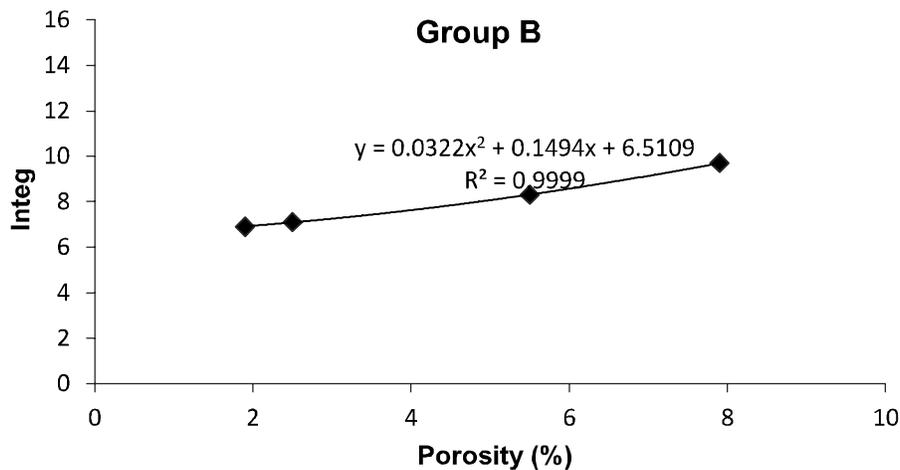


FIG. 3(b). INTEG VERSUS POROSITY

Fig. 3(a) shows an optimum correlation (87%) between the %P and Integ values (colour depth), it decreases with fabric weight. Again very loose weave fabric 110 GSM shows lower Integ value because of irregular and non-uniform pores distribution as discussed in above paragraph. Tight weave fabrics (140 and 145 GSM) show less difference in %P (Fig. 2) and Integ values (Fig. 3(a)), both points close to each other. Similar results are shown in Fig. 3(b), %P decreases with fabric weight. It gives 99% correlation with %P and colour depth. Using two degree polynomial equations, dyers can predict the Integ versus porosity value of the woven fabrics that have same construction used in this research.

Hence, fabric inter-yarn zone %P was measured at constant light intensity using image processing technique gives more reliable results as compare to the geometrical formulas. In addition, it helps to predict the flow of dye liquor in the inter-yarn zone and the colour depth of the woven fabric, depends on the dye chemistry and dyeing method.

5. CONCLUSION

Fabric porosity (inter-yarn zone) assessed using image processing is more accurate and quick method. The fabric images (twenty each) were captured at constant light source and magnification. Fabric coloured images (RGB) were first converted into monochrome image and then binary image using Matlab software. The percentage of white pixels were then calculated which gives the %P. The %P calculated at constant light source helps to estimate the flow of dye liquor in the fabric. The fabrics that have high percentage of white pixels are easy to dye because of the ease of liquor flow as compare to the fabrics which have less percentage of white pixels depending on the dyeing method and dye chemistry. Fabric porosity assessed using Matlab software, shows 87 and 99% corelationship with dyed

fabric. The fabrics that have high porosity give high Integ values depending on the fabric pores size and its distribution.

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