Effect of yarn structure on cover factor in woven fabrics

DOI: 10.35530/IT.069.03.1416

ZUHAIB AHMAD
MOAZ ELDEEB
SHOAI IQBAL
ADNAN AHMED MAZARI

REZUMAT – ABSTRACT

Efectul structurii firului asupra factorului de acoperire al țesăturilor

Acest studiu experimental investighează, prin metoda de transmisie a luminii, efectul structurii firelor asupra factorului de acoperire al țesăturilor la diferite dispuneri ale firului de bătătură. Pentru a analiza acestă influență, au fost pregătite două tipuri diferite de seturi de țesături prin utilizarea firelor filate cu jet de aer și a firelor filate cu rotor cu aceleași densități liniare în direcția firelor de bătătură și cu menținerea firelor de urzeală neschimbate. Pentru fiecare țesătură, dispunerea firelor de bătătură a fost schimbată treptat. Diametrul secțiunii transversale al firelor și densitatea lor de compactare au fost analizate pentru găsirea diferențelor dintre cele două structuri de fire. Diametrul efectiv al firelor și densitatea de compactare sunt aproape identice pentru ambele fire, în timp ce pilozitatea este mai mare la firele filate cu jet de aer, comparativ cu firele filate cu rotor. Secțiunea transversală a firelor din tesatură a fost, de asemenea, analizată pentru a se examina deformarea firelor, care a fost relativ mai mare la firele filate cu jet de aer. La aceeași desime a firelor de bătătură, factorul de acoperire (CF) al țesăturii cu fire filate cu jet de aer este considerat a fi mai mare decât în cazul țesăturii cu fire filate cu rotor, iar această diferență scade pe măsură ce desimea firelor de bătătură din țesătură crește. Rezultatele analizei de corelație arată relația dintre factorul de acoperire și desimea firelor de bătătură. Analiza rezultatelor varianței evidențiază efectul semnificativ din punct de vedere statistic al sistemului de filare (fir filat cu jet de aer și fir filat cu rotor) și desimea firului de bătătură asupra factorului de acoperire al țesăturii.

Cuvinte-cheie: fir filat cu jet de aer, fir filat cu rotor, desimea firului de bătătură, factor de acoperire, țesătură

Effect of yarn structure on cover factor in woven fabrics

This experimental work investigates the effect of yarn structure on cover factor of fabrics at different weft settings by the light transmission method. To analyze the effect, two different types of fabric set have been prepared by using airjet and rotor yarns of the same linear densities in the weft direction and keeping the warp yarn unchanged. For each fabric, weft setting has been changed gradually. Cross-sectional diameter of yarn and its packing density has been analyzed to find out the differences between both yarn structures. The effective yarn diameter and packing density have been found to be almost same for both yarns while the hairiness is found to be higher in airjet yarn as compared to rotor yarn. Yarn cross-section in the fabric has also been analyzed to examine the deformation (flatness) in yarn, which was relatively higher in airjet yarns. At the same weft setting the cover factor (CF) of fabric woven by air jet yarn is found to be higher than fabric woven by rotor jet yarn, and this difference decreases as the weft setting increases in fabric. Correlation analysis results show the relation between the cover factor and weft setting. While analysis of variance results show statistically significant effect of spinning system (airjet and rotor yarn) and weft setting on the cover factor of woven fabric.

Keywords: airjet yarn, rotor yarn, weft setting, cover factor, woven fabric

INTRODUCTION

The end-use and performance requirements of woven fabrics are strongly related to their cover factors (CF) or in opposite terms, to their porosity and permeability [1–3]. Different features that are closely related to CF are weaving efficiency, fabric quality, thermo-physiological comfort of garments, air permeability and protection against ultraviolet radiation [4–6]. It is a basic feature of multiple base fabrics used in the elaboration of protective garments and textiles designed to protect the working environment or the natural environment.

Tapias et al. estimated the warp and weft CF and their mean yarn diameters automatically from microscope digital images of woven fabric samples [1]. While Szmyt and Mikolajczyk used light transmission technique to determine the CF on the basis of experimental and theoretical analysis for jacquard knitted fabrics [7]. Similarly Cardamone et al. employed digital image analysis technique to analyze fabric structural parameters [8] and Militky et al. reported that image analysis could be used for determination of air permeability of various weave structures and fiber types [9]. Whereas Nazir et al. developed a statistical model for predicting the air permeability and light transmission properties of woven cotton fabrics and determined the level of correlation between the two parameters [10].

Literature shows that there is a need to understand the effect of yarn structure (produced by different spinning systems)upon cover factor of woven fabrics. As they deform differently based on their structures in the woven fabrics, sothe purpose of this study is to get a better understanding about the effect of yarn structure in the woven fabrics at different weft settings during the CF measurements.

MATERIAL AND METHOD

Yarn and fabric production

16 tex yarns were produced by Rieterairjet and rotor spinning units using 100% viscose fibers. Satin fabric was made by using these spun yarns in weft. Satin weave was selected because of its easiness to make samples with high weft settings. Rapier loom with eight frames and weft insertion speed of 330 picks/min was used to weave two sets of fabrics having different weft setting. The warp tension was kept the same for all fabric samples. 6×2 tex twisted compact cotton ring spun yarn was used as warp, keeping the same density (setting) for both sets of fabrics, i.e. 58 ends/cm. To study the CF of air jet and rotor yarn woven fabrics, the weft setting for both sets were kept 10, 20, 30, 40 and 50 picks/cm. Yarns were preconditioned for 24 hours at standard temperature (20 ± 2°C) and relative humidity (65%) before yarn testing and fabric production.

Yarn testing

Uster 4 was used in order to measure yarn irregularity, imperfections, hairiness and shape factor. For each yarn sample the testing speed was kept 200 m/min for one minute and ten readings were recorded.

Cross-section of yarn

Image analysis method was used to measure the cross-sectional diameter of airjet and rotor yarn. Ten yarn samples were selected randomly from airjet and rotor yarn cones. These samples were immersed in a media and after hardening the block in which the textile sample was found, slices (sections) were produced by applying special technique. The micrometric slices (sections) were separated and examined under projection microscope equipped with a digital camera, which was later processed by LUCIA and Prize software to calculate the effective diameter and effective packing density of yarn. One section was obtained from each block [11].

In order to measure the geometry of the yarn cross-section in woven fabric, ten fabric samples were selected randomly from each fabric sample. After that, the same procedure (as described earlier for yarn) of impregnation in media, hardening of blocks and slicing was used. Later images were taken and processed by LUCIA software [11].

Shape of yarn

The shape of yarn cross-section in the fabric is shown in figure 1. The major diameter (*a*) of yarn in the plane approximately parallel to the fabric surface and minor diameter (*b*) of yarn in the plane approximately perpendicular to the fabric surface of the elliptical yarn can be measured. To check the flatness of yarn major diameter was measured for all fabric samples.

Cover factor of fabric

Cover factor (CF) is defined as the area of yarn in the solid unit cell rectangle [12]. The coefficient of CF is the characterization of the degree of area covered by the threads in the fabric. It can be written as:

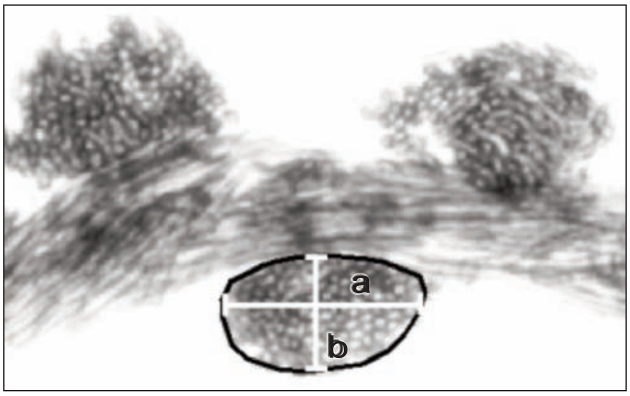

Fig. 1. Measuring method of yarn cross section

$$\text{cover factor (CF)} = \frac{\text{area covered by yarn}}{\text{whole accessible area}} \quad (1)$$

From pure geometrical point of view surface porosity can be evaluated from the cover factor of fabric [9].

$$\text{surface porosity (Ps)} = 1 - \text{cover factor} \quad (2)$$

The CF of a woven samples was determined by the principle of light transmission through the sample. A light microscope and system of the image analysis LUCIA was used for this measurement. The sample size was kept according to the dimensions of the width of bedding glass. It was passedin-between two bedding glasses and then put under the microscope. For each sample, 100 pictures were taken to measure CF of fabric at different weft settings for airjet and rotor yarn woven fabrics. Later, these images were transformed from the color image to a binary image so that the separation of areas covered by threads from areas without covering by threads was possible. The special threshold procedure was adopted for estimation ofthe relative pore area. The area was measured using LUCIA system for each fabric sample separately [13].

To check the significance of yarn type and weft setting on the cover factor of yarn in fabric, analysis of variance (ANOVA) was carried out using SAS PROC GLM (alpha level of 0.05).

RESULTS AND DISCUSSIONS

Realization of single yarn

The yarn properties for both airjet and rotor yarn can be seen in table 1. It can be analyzed that irregularity of rotor yarn is slightly higher than airjet yarn due to presence of irregular wrappings. Differences in thin and thick places are insignificant for both yarns, howeverneps in rotor yarns are found to be very high. The reason for this is the difference in structure as the airjet yarn has more parallel fibers in core and continuous wrapping around it, while in rotor yarn the fibers are not parallel in core and sheath, causing a bit irregular shape. Similarly the shape factor of rotor yarn is also slightly higher than its corresponding airjet yarn, which shows that airjet yarn is slightly more flat in shape than rotor yarn. The hairiness of rotor yarn is less as compared to airjet yarn, which may be

Table 1

AIRJET AND ROTOR YARN PROPERTIES								
Sample	**Count (Tex)**	**CV_m (%)**	**Thin (–50%/km)88**	**Thick (+50%/km)**	**Neps (+140%/km)**	**IPI / km**	**Hairiness (H)**	**Shape**
Airjet	16	14.12	35.6	29.2	166	230.8	3.96	0.80
Rotor	16	14.72	18.4	29.6	792.4	840.4	3.54	0.82

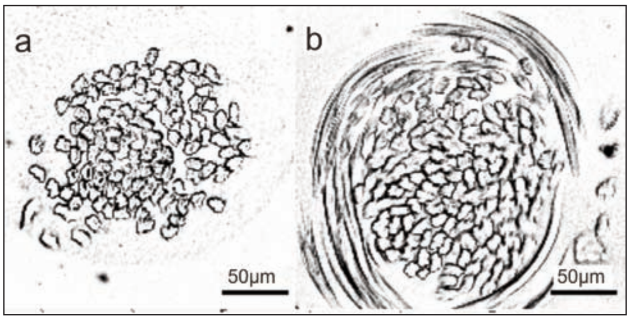

Fig. 2. Cross-sectional view of yarns (a) airjet (b) rotor

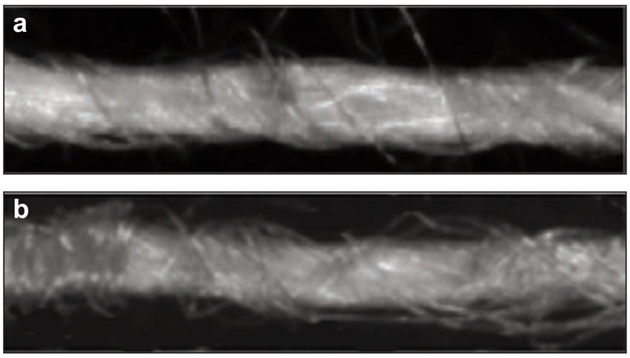

Fig. 3. Longitudinal view of yarns (a) airjet (b) rotor

due to the irregular belt shape wrapping which act as a binding of outer yarn to the core, while this is not the case in airjet yarn.

Figure 2 and 3 show the cross-sectional and longitudinal images of airjet and rotor yarn. It can be observed that in rotor yarn, wrapper fibers are irregularly wrapped around the core fibers with varying angles and some of them can be seen forming an angle of 90° taking the belt shape. While in airjet yarns, wrapping effect is much regular and wrapper fibers are identifiable forming a cap-like shape.

The average values of yarn cross-sectional results for both airjet and rotor yarns are shown in table 2. The effective diameter of airjet and rotor yarn is the same and the difference in effective packing density of both yarn systems is also insignificant. So it can be said that the fiber and yarn parameters for both yarns are almost the same.

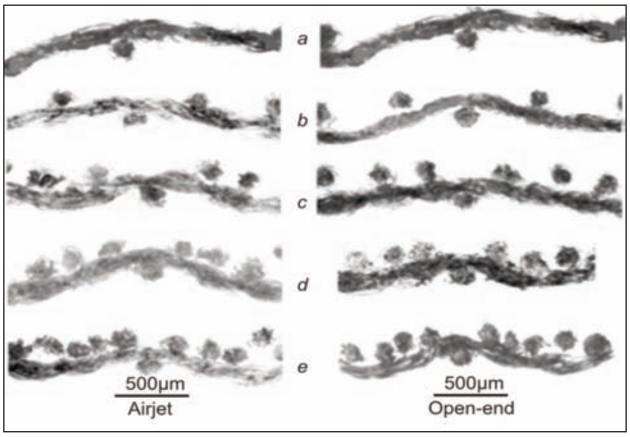

Fig. 4. Cross sectional images of airjet and rotor yarn woven fabrics with different weft settings: *a* – 10; *b* – 20; *c* – 30; *d* – 40; *e* – 50

Table 2

CROSS-SECTIONAL RESULTS OF YARN		
System	**Airjet**	**Rotor**
Fiber fineness [Tex]	0.13	0.13
Yarn fineness [Tex]	16	16
No. of fibers in cross-section [-]	118	127
Effective diameter [mm]	0.15	0.15
Effective packing density [-]	0.64	0.63

Realization of yarn into woven fabric

Figure 4 shows the cross-sectional images of airjet and rotor yarn woven fabric samples at different weft settings. It can be understood that with the increase in weft setting (pick density), free spaces in weft yarns reduces and forces on weft yarn in the intersecting region increases, which causes its deformation (flatness) in the fabric.

To study the effect of airjet and rotor yarn structure at different weft settings, the major diameter (flatness) of the elliptical shape of each yarn cross-section was measured and results are shown in figure 5. It can be seen that the flatness (major diameter) of airjet yarn is more than that of rotor yarn in the fabric because unlike rotor spun, the core fibers in airjet are arranged parallel to the yarn axis without twisting and are enclosed periodically by the wrapper fibers as described earlier. So upon same warp tension (force) airjet yarn have a tendency to deform more than rotor spun yarn in woven fabric.

Cover factor of fabric

Cover factor of the fabric was calculated by applying equation 1 as described earlier. The LUCIA system helped in measuring of the binary area fraction, which is the ratio of the binary area and total measured area. Similarly the porosity was calculated by using equation 2.

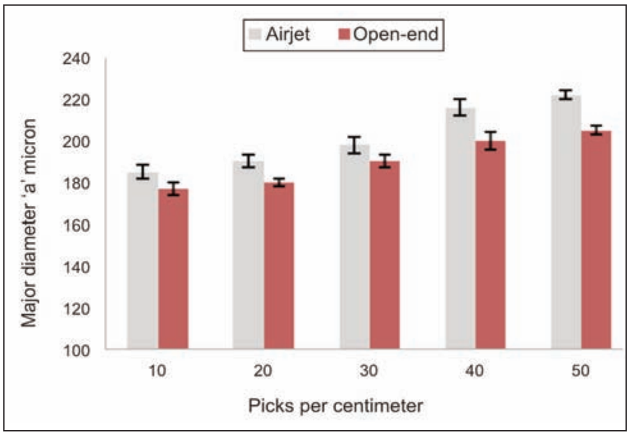

Fig. 5. Effect of weft setting on major diameter of airjet and rotor yarn in fabric

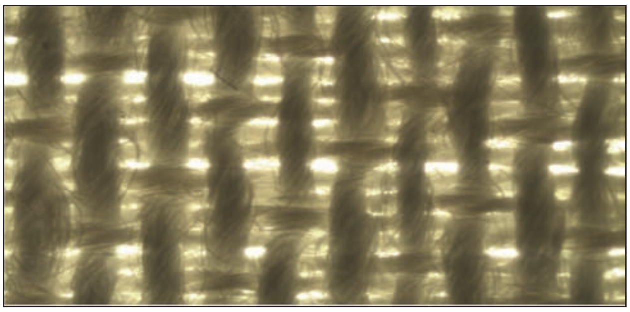

Fig. 6. Orignal image of fabric

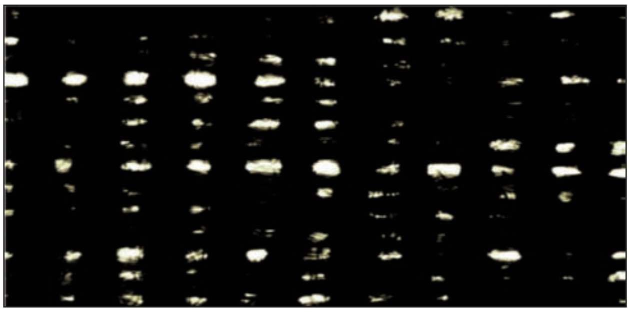

Fig. 7. Inverted image of fabric

In figure 6 and 7 the originaland inverted image of one fabricsample can be seen respectively. The white objects are corresponding to the area transmissible for light and black for the area which is not transmissible.

It can be seen in figure 8 that for both airjet and rotor yarn woven fabrics, the cover factor % is continually increasing as the weft setting increases. While upon

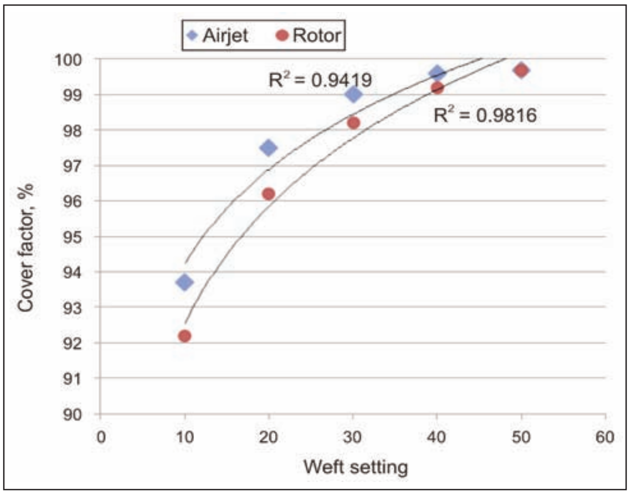

Fig. 8. CF of Airjet and Rotor yarn woven fabics at different weft setting

same weft setting the CF of airjet yarn woven fabric is higher than rotor yarn woven fabric and with the increase in weft density this differece reduces. There are two factors for this behavior, one is the hairiness, which is more in case of airjet yarn as compared to rotor yarn. It limits the transmission of light through a fabric, hence increasing CF of airjet fabrics. Whereas the other factor is the flatness of yarns in a fabric. Flatness of airjet yarn in woven fabrics is slightly more than rotor yarn as explained earlier in figure 5. The more flat yarn in the fabric, the more will be the hinderence for transmission of light through the fabric. Hence it is also a reason for higher CF of airjet fabrics. The logarithmic type model was used for parameter smoothing and a fitted line plot between the CF and weft setting exhibited a significant correlation with R-sq. value of 94.19% and 98.16 % for airjet and rotor yarn woven fabrics respectively, which shows abetter predictability of the model. The reason for non-linear curve in figure 8 is that, upon an increase in number of yarns (i.e; 10 picks/cm to 20 picks/cm), the yarn diameter also adds to the space and hence it limits the transmission of light through the fabric.

Table 3 also shows the values of CF and porosity of airjet and rotor yarn woven fabrics at different weft settings and it can be seen as the cover factor increases in woven fabric (with increase in weft settin, the porosity of fabric is decreasing in the same way.

It can be seen from the results in table 4 that the independent variables (yarn type and weft setting) and their interaction (Yarn type * weft setting) have a statistically significant effect on the dependent

Table 3

COVER FACTOR AND POROSITY OF AIRJET AND ROTOR YARN WOVEN FABRICS AT DIFFERENT WEFT SETTING

	AJ 10	AJ 20	AJ 30	AJ 40	AJ 50	R 10	R 20	R 30	R 40	R 50
Cover factor	93.7	97.5	99	99.6	99.7	92.2	96.2	98.2	99.2	99.7
Porosity	6.3	2.5	1	0.4	0.3	7.8	3.8	1.8	0.8	0.3
St.Dev	1.0	0.7	0.4	0.2	0.2	0.9	0.7	0.6	0.3	0.2

Table 4

ANNOVA RESULTS OF COVER FACTOR					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**P**
Yarn_type	169.168	1	169.168	226.512	.000
Weft_setting	6174.222	4	1543.555	2066.784	.000
Yarn_type * Weft_setting	80.589	4	20.147	26.977	.000

variable which is cover factor as p-value obtained from all factors is less than the alpha value (0.05).

CONCLUSION

The results presented here show thelight transmission properties of airjet and rotor yarn wovenfabricswhichdecreases with increase in weft settings in fabric or in contrary, it can be said that the cover factor of fabric increases as the weft setting in fabric increases but in a non-linear way. Whereas the fabrics woven by using airjet yarns have more cover factor than the competing rotor yarn woven fabrics at the same weft setting and it is due to the two facts, the hairiness of airjet yarn and flatness of airjet yarn in the fabric. The hairiness and flatness of airjet yarn have been found slightly more than rotor yarns because of the structural difference of both yarns. A strong correlation was found between thecover factor and weft setting of the airjet and rotor yarn woven fabrics. Similarly the input parameters (yarn type and weft setting) were observed to produce a strong effect on cover factor. Two way ANOVA results show the statistical significance of yarn type and weft setting on CF of fabric.

Acknowledgement

This work was supported by the SGS project of Technical University of Liberec, Czech Republic No. 21153.

BIBLIOGRAPHY

[1] Tàpias, M., Ralló, M., Escofe, J. *Automatic measurements of partial cover factors and yarn diameters in fabrics using image processing*, In: Textile Research Journal, pp. 1–14, 2010.

[2] Milašius, V., Milašius, R., Kumpikaité, E., Olšauskiené, A., Milašius, V., et al. *Influence of fabric structure on some technological and end-use properties,* In: Fibres & Textiles in Eastern Europe, vol. 2, no. 41, pp. 48–51, 2003.

[3] Surdu, L., Radulescu, I.-R., Ghituleasa, C., Subtirica, A., Mihai, C., Cioara, I., Ene, A. *Comfort properties of multilayer textile materials for clothing*, In: Industria Textila, vol. 64, no. 2, pp. 75–79, 2013.

[4] Seyam, A., El-Shiekh, A. *Mechanics of woven fabrics, Part III: critical review of weavability limit studies,* In: Textile Research Journal, vol. 7, no. 63, pp. 371–378, 1993.

[5] Olšauskienė, A., Milašius, R. *Dependence of air permeability on various integrated fabric firmness factors*, In: Materials Science (Medžiagotyra), no. 4, 2003.

[6] Algaba, I., Riva, A., Crews, P. *Influence of fiber type and fabric porosity on the UPF of summer fabrics,* In: AATCC review, vol. 4, no. 2, 2004.

[7] Szmyt, J., Mikolajczyk, Z. *Light transmission through decorative knitted fabrics in correlation with their fabric cover*, In: AUTEX Research Journal, vol. 10, no. 2, pp. 44–48, 2010.

[8] Cardamone, J.M., Damert, W.C., Phillips, J.G., Marmer, W.N. *Digital image analysis for fabric assessment*. In: Textile Research Journal , vol. 72, no. 10, pp. 906–916, 2002.

[9] Militký, J., Travnickova, M., Baj, V. A*ir permeability and light transmission of weaves*, In: International journal of clothing science and technology, vol. 11, pp. 116–125, 1999.

[10] Nazir, A., Hussain, T., Afzal, A., Faheem, S., Ibrahim, W., Bilal, M. *Prediction and correlation of air permeability and light transmission properties of woven cotton fabrics,* In: Autex Research Journal, 2015.

[11] Kremenakova, D. *Recommended procedure for preparation of samples. Soft and hard sections (slices). Internal Standard No. 46-108-01/01,* Liberec: Faculty of Textile, Technical University of Liberec, 2002.

[12] Marks, R. P. J. L. a. D. A. H. *An Introduction to textiles. Vol. III – Fabrics*, Bolton, UK: School of Textile Studies, Bolton Institute of Higher Education, 1993.

[13] Drasarova, J. *Covering of weaves, Internal standard No. 23-107-01/01,* Liberec: Faculty of Textile, Technical University of Liberec, 2002.

Authors:

ZUHAIB AHMAD[1], MOAZ ELDEEB[1], SHOAI IQBAL[1], ADNAN AHMED MAZARI[2]

[1] Technical University of Liberec, Faculty of Textile Engineering, Department of Textile Technologies
Studentská 2, 46117 Liberec, Czech Republic, moaz1983@mans.edu.eg, iqbal_shoaib@hotmail.com

[2] Technical University of Liberec, Faculty of Textile Engineering, Department of Textile Clothing
Studentská 2, 46117 Liberec, Czech Republic, adnanmazari86@gmail.com

Corresponding author:

ZUHAIB AHMAD
e-mail: zuhaibahmad.ntu@gmail.com