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Influence of Weave Design and Yarn Types on Mechanical and Surface Properties of Woven Fabric

DOI: 10.5604/01.3001.0010.7795

Abstract
The purpose of this study was to examine the effect of spinning technologies and weave design on fabric mechanical and surface properties. For this purpose, ring spun (combed, carded) and open-end (OE) techniques were used to manufacture yarns of polyester cotton (50:50) which were used in the weft, and 100% cotton yarn in the warp. Plain, twill, and satin weave designs were selected to construct woven samples on a projectile loom. The variation in fabric tensile strength is obvious with respect to weave designs. Higher interlacing of yarn produces more crimp in the load bearing, which may cause lower breaking strength and fewer broad floats. The mechanical and surface properties of these fabric samples were investigated and statistical analysis was performed, which showed a significant effect of the spinning technique and weave design on these properties.

Key words: *PC yarn, ring spun, open-end, weave design, abrasion, pilling.*

Introduction

Modern yarn manufacturing technologies are challenging traditional ring spun technology in fabric manufacturing, but conventional yarns are still produced [1]. Open-end yarns are different from ring spun yarn, reflected in the fabric structure and behaviour. Using OE yarns as a direct replacement for ring yarns is likely to give less than optimum performance [2]. OE yarn has a higher twist multiple and is bulkier, which does not allow to attain as good a cover factor in the fabric as might be expected [3].

Ring spun yarns have higher tensile strength than OE yarn with the same twist [4, 5]. In fabric, long yarn floats and the amount of interlacing affects the abrasion resistance of woven fabrics by means of mass loss [6]. Ring spun yarn lowers the end breakage rate during weaving due to the real twist and good fibre orientation in the core and surface [7]. But in OE yarns, wrapper fibres are irregularly wrapped around the core fibres with varying angles. OE yarn can be successfully used in home textiles, since this might be a way to optimise the absorbency rate and economic advantage [8].

Pilling is a surface defect of fabric which causes loose fibres to begin to push out from the shallow of the cloth during washing and wearing [9]. In the case of tensile strength, fabric construction influences this property more significantly than yarn type [10]. Similarly abrasion resistance is a physical property which depends on factors such as the combination of fibre, construction, yarn count, fabric thickness, yarn twist, and float length in the woven fabric [11].

The aim of this study was to characterise the factors that influence the behaviour of fabric with ring spun and OE yarns [12]. Also the effect of weave design on fabric mechanical and aesthetic properties was analyzed. The novelty of this work is defining the structural combination of yarn with respect to tensile properties of the fabric along with weave design.

Materials and methods

Yarn and fabric production

30 tex yarns were manufactured by ring spinning (combed, carded), whereas rotor spinning technology was used for OE yarn. Polyester cotton (50:50), plain (1/1), twill (3/1) and satin (4/1) weave fabrics were made by using these yarns in the weft. The weave design is given in ***Figure 1***. A Sulzer Ruti (P-7100) projectile loom (Switzerland) equipped with a tappet mechanism was used to weave these fabrics at a weft insertion speed of 250 picks/min. 30 tex twisted compact cotton ring spun yarn was used as warp with a warp density of 50.4/cm and weft density of 23.6/cm, which was kept the same for all sets of fabrics. Nine different samples were produced using different input variables e.g; spinning technique and weave design.

Yarns were kept in a conditioning room for 24 hours at standard temperature (20 ± 2 °C) and relative humidity (65%) before yarn testing and fabric production. Some physical properties of the yarn are given in ***Table 1***. A Lea strength tester (China) and fast count system (Zweigle N-266) were used to measure the count Lea strength product (CLSP) and yarn count, respectively. An Uster 4 (Switzerland) was used to obtain CV% and imperfections. The testing speed was kept at 200 m/min for one minute and ten readings per yarn sample were recorded. The twist of each yarn was measured by a MesdanLab twist tester (Italy) in accordance with ASTM D1422. Ten samples from each yarn were tested for twist measurements.

Tensile strength (ISO 13934-1:1999)

The breaking strength is a measure of the resistance of the fabric to a tensile load or stress. A fabric test specimen of specified dimensions was extended at a constant rate until it ruptured. Then the maximum at rupture was recorded. Each specimen was cut to 50 ± 0.5 mm width and 300 mm length with the long dimension parallel to the direction of testing and force application. Five tests were performed for each fabric sample and their average measured.

Abrasion resistance (ASTM D-3886-99)

An abrasion resistance tester was set at 28 kPa (4 psi) air pressure with a load of 454g (1 lb) on the abradant. Samples were attached to the rotation mechanism with clamps. After completion

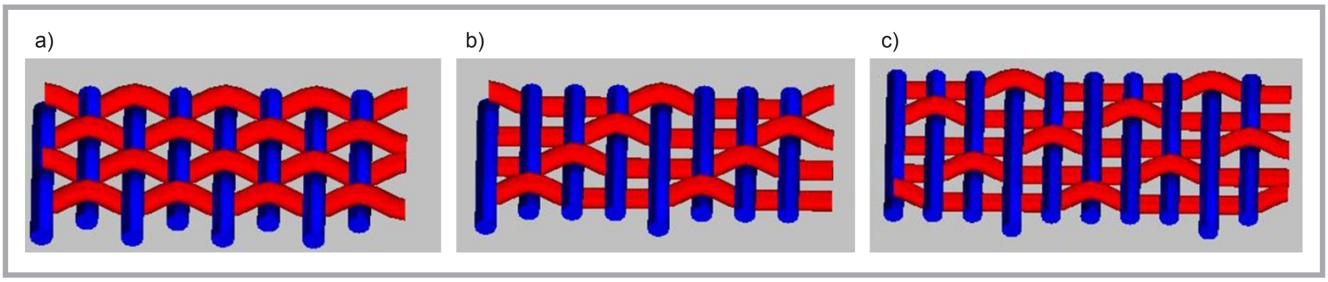

Figure 1. Weave design: a) plain, b) twill and c) satin.

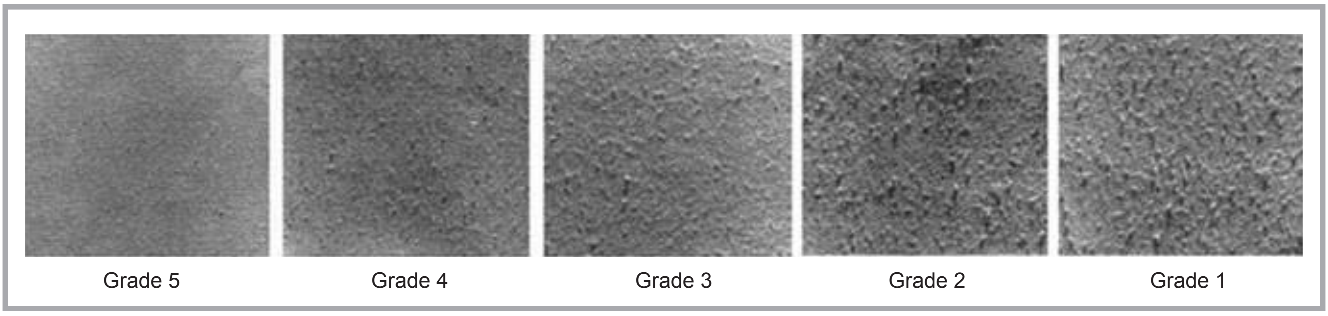

Figure 2. Standard photographs for pilling assessment: 5) no pilling, 4) slight pilling, 3) moderate pilling, 2) severe pilling and 1) very severe pilling.

of the experiment, the specimens were disengaged and underwent pilling grading. Five tests were performed for each fabric sample and their average number of strokes measured. If the value of the number of strokes is higher, then it means that the fabric is more abrasion resistant.

ICI pilling box test (ISO 12945-1:2000) Specimens were mounted on polyurethane tubes and tumbled randomly in a cork-linked box at a constant rotational speed. Fuzzing and pilling were assessed visually after a defined period of tumbling. The usual number of revolutions used in the test is 18,000, which takes 5 hours. The specimens were removed from the tubes and assessed against a pilling scale of 1-5 (***Figure 2***).

Analysis of variance

To check the significance of the spinning technique and weave on fabric tensile properties, an analysis of variance (ANOVA) was carried out using SAS PROC GLM (alpha level of 0.05).

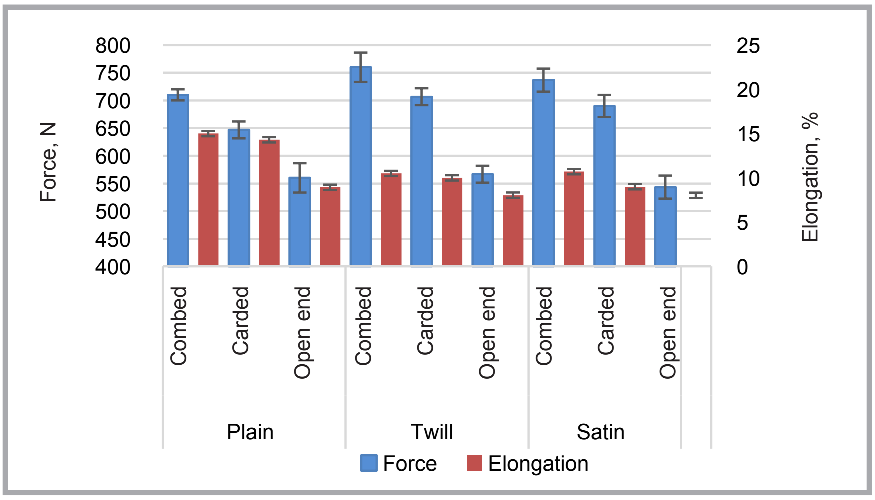

Figure 3. Tensile strength and elongation of woven samples along weft.

Results and discussions

Tensile strength

It can be observed from ***Figure 3*** that the weft-wise tensile strength and elongation of woven fabric using combed yarn was respectively higher as compared to other fabrics. For all weave designs, OE fabric showed less tensile strength and elongation than the ring spun (combed and carded) fabrics. As in OE spun yarns, wrapper fibres were irregularly wrapped around the core fibres with varying an-

Table1. Properties of warp and weft yarns.

Yarn code	Yarn type	Yarn count, tex (ASTM D1907)	Count CV% (ASTM D1907)	Strength (CLSP) (ASTM D1578)	Imperfection index (IPIs)	Twists per meter (ASTM D1422)
Weft	Combed	30	1.8	3200	100	493
	Carded	30	1.8	2900	180	599
	Open-end	30	2	2000	300	704
Warp	Carded	30	2	2300	200	600

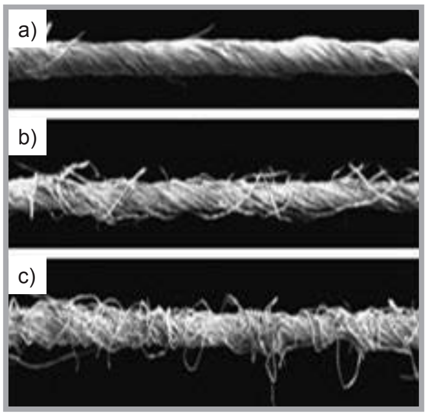

Figure 4. Longitudinal view of a) combed, b) carded and c) OE yarn.

gles, and core fibres were twisted as well, while fibres in ring spun yarns were arranged in a helix and the resultant yarn had a uniform fibre core. Similarly the combed yarn has more uniformity of its boundary surface and more strength as a certain number of short fibres were removed from it during the process of combing to make better yarn than that of the carded yarn system. Optical microscopic images of combed, carded and OE yarns can be seen in ***Figure 4*** for better understanding.

Moreover the tensile strength of plain weave is less than that of twill weave and satin weave [13]. As in weave design, it can be seen that plain weave has more contact friction, crimp and binding effect than twill and satin weave, which is evident in ***Figure 1***. These parameters gave more bending and weak points under a tensile load, thus the plain weave structure exhibited significantly lower tensile strength as compared to twill and satin weave fabric samples [14].

The elongation of plain weave is higher than for twill weave and satin weave due to more interlacement. Moreover the higher number of crimps provided more elongation in plain weave than in twill and satin [14]. These results also suggest that weave design has a highly significant influence on the tensile strength and elongation of PC blended fabric. It can be seen from the results in ***Table 2*** that the independent variables (weave design and yarn type) are statistically significant (S). Furthermore interaction (weave*yarn type) also has a significant (S) effect on the dependent variables, that is tensile strength and elongation as $P < 0.05$.

Abrasion resistance

The abrasion resistance of fabric made up of ring spun (combed and carded) and OE yarn in the weft in relation to the weave types can be observed in ***Figures 5*** and ***6***. Statistical comparison of the yarn type indicated that as the yarn was in good alignment there was good abrasion resistance. Therefore better abrasion resistance (20-40%) of fabrics was produced from ring spun (combed and carded) yarns than from OE yarns [15], the reason for which is their structural difference, which has already been described.

As the circular clamp on the abrasion tester makes a reciprocal motion, it is direction dependent on the weave. Along the warp-wise direction satin and twill fabric were more affected by the abradant than plain fabric, especially when fabricated with combed yarn. As in the case of twill and satin weave fabrics, long float warp yarns were aligned in the direction of the stroke movement when the fabric was mounted on a diaphragm along the warp-wise direction. Similarly when the fabric was mounted along the weft-wise direction the longer floats of the twill and satin weave fabric samples were exposed more to the abradant, and hence it abraded (fibre is worn off in the abrasion area) the specimen in a lower number of strokes. The phase of the structure is also an important phenomenon in the abrasion resistance property. The results related that long floats and less interlacement reduced the abrasion resistance of the fabrics by increasing the mass loss [6].

The analysis of variance for abrasion resistance (warp-wise and weft-wise) is given in ***Table 2***. Along warp and weft directions, the weave design and yarn type revealed the significant effect of the values. Likewise their interaction (weave*yarn type) also has a statistically significant effect on the abrasion resistance.

Pilling

The average pilling results can be seen graphically in ***Figure 7*** for plain, twill and satin weave and for combed carded and OE yarn. The yarn type and weave design both affected the pilling of fabric. Pilling on fabric was due to fibre mobility action within the yarn. Yarn dimensional stability

Table 2. ANOVA results for woven fabric samples.

	Tensile Strength	Abrasion resistance warp-wise	Abrasion resistance warp-wise
Weave	s	s	s
Yarn Type	s	s	s
Weave * Yarn type	s	s	s
ns = not significance, s = significance			

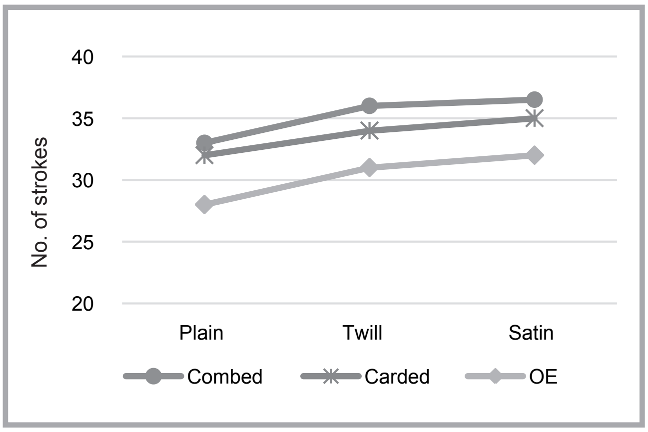

Figure 5. Abrasion resistance of woven fabrics (warp-wise).

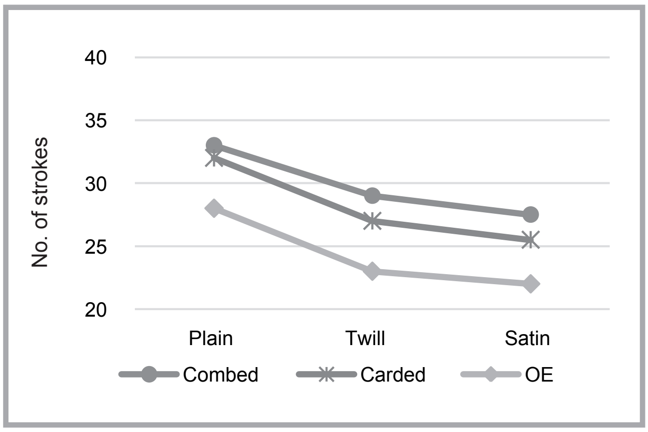

Figure 6. Abrasion resistance of woven fabrics (weft-wise).

gave less fibre mobility and, consequently, less pilling appeared on the surface of the fabric. It can also be said that the entangled balls (pills) were from fibres sloughing off onto the fabric surface. In the results in ***Figure 7***, the pilling scale grading (***Figure 2***) was partially formed pills to no pills for the PC ring spun carded and combed yarn in the case of plain weave, whereas slight pilling was found for OE yarn in the fabric. For open-end PC yarn, the pilling scale grading was moderate pilling to partially formed pills regarding twill weave, while there was moderate pilling in the case of satin weave fabric.

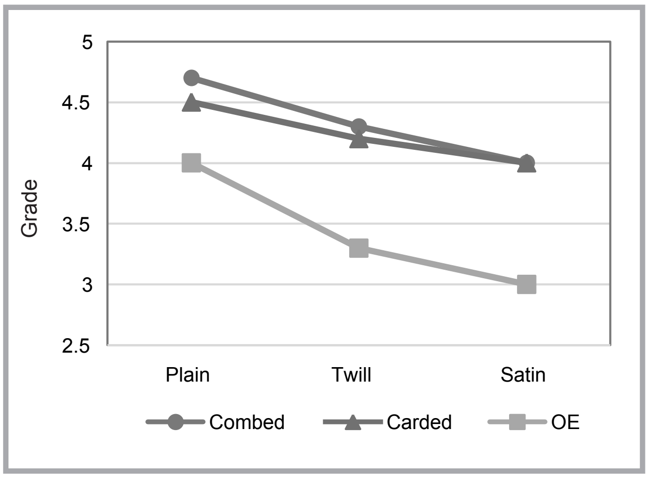

Figure 7. *Pilling effect of woven samples.*

Twill weave showed slight pilling to no pill for the PC ring spun combed and carded yarn in weft insertion. The twill and satin woven fabric exhibited substantially more pills than the plain woven fabric because of the greater amount of interlacing and short float lengths in the plain woven fabric, as shown in ***Figure 1***, which reduces the opportunity for free ends to emerge on the fabric surface, thus reducing pilling.

Conslusions

The following findings are made from this study.

- Ring spun yarns have better fibre orientation than OE yarn, which resulted in better yarn properties and performance improvements in the woven fabrics, especially those made from combed ring spun yarn. Fabrics woven from combed ring spun yarns had higher tensile strength and elongation than those woven from carded ring yarns and OE yarn. Similarly plain weave shows lower strength and elongation than twill and satin weave.
- Regarding the abrasion resistance of the fabrics, it was obvious from the results that combed yarn fabrics are more resistant than carded and OE fabrics. As the test method is direction dependent, in the case of twill and satin weave, results are opposite in the warp-wise and weft-wise directions due to rubbing exposure of the float length with the abradant, whereas interlacing in plain weave is the same along the warp and weft directions, thus there is no effect on it.
- When pilling behaviour was taken into account, it was observed that fabrics woven from ring spun yarns were found to have higher pilling resistances than those woven from open-end PC yarns, and twill and satin weave shows slight pilling as compared to plain weave fabrics, as they have more contact area on their surface, which increases the possibility of free ends emerging on the fabric surface and, thus, converting to pills.
- Two way ANOVA results presented the statistical significance of weave design and yarn type, contingent upon the tensile strength and abrasion resistance of the fabric.

It could be helpful to understand the effect of spinning types and weave on the strength as well as the abrasion and pilling resistance of fabrics.

Acknowledgements

This work was supported by the project "Hybridní materiály pro hierarchické struktury" ("Hybrid Materials for Hierarchical Structures") in Technical University of Liberec (TUL), with OP VVV: Excelentní výzkum and Reg. č.: CZ. 02.1.01/0.0/0.0/16_019/0000843.

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Received 05.01.2017 Reviewed 08.08.2017