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COMPARISON BETWEEN MECHANICAL PROPERTIES OF FABRICS WOVEN FROM COMPACT AND RING SPUN YARNS

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Abstract:

Due to the elimination of spinning triangle in compact spun yarns, its mechanical and physical properties differ significantly from ring spun yarns. The difference between the two spun yarns is reflected in the properties of fabrics woven from both. This study is aimed to compare the mechanical properties of fabrics which are produced from yarns spun from 100% Egyptian cotton, Giza 86 on these systems. Statistical analysis revealed that there is no significant difference between both type of fabrics regarding tear strength and abrasion resistance. But in relation to tensile strength, air permeability and stiffness, compact fabrics were superior to ring fabrics.

Key words:

Compact yarn, Ring spun yarn, Compact fabric, Ring fabric, Breaking load and Elongation, Fabric Stiffness, Fabric air permeability.

Introduction

It has been reported [1-4] that the structure and mechanical properties of compact yarns are different from that of ring yarns. Many researchers [5-8] have pointed out that the main factor which is responsible for the different in the structure is, the spinning triangle; the zone between the line of contact of the pair of delivery rollers and the twisted end of the yarn. In this zone, the fiber assembly contains no twist. Edge fibers splay out from this zone-ring spinning in particular, and make little or no contribution to the yarn strength. The spinning triangle is the critical weak spot of the ring spinning process [9]. The spinning triangle prevents the edge fibers from being completely incorporated into the yarn body. However, in compact spinning, the drafted fibers emerging from the nip line of the front roller of the drafting arrangement are condensed in a line, hence the spinning triangle is very negligible [10].

Several studies have been compared the properties of compact spun yarns versus conventional ring-spun yarns [11, 12, 13]. These studies revealed the consistent results of reduced yarn hairiness, the ability to produce yarns of enhanced strength and elongation properties even with a lesser amount of twist, which enables increased production speeds to be reached in favor of the compact spinning system. The difference between compact and ring yarns in yarn strength, elongation and hairiness values is higher with carded yarns than with combed yarns [14].

It was found that tenacity and elongation of compact spun yarns are 17%, and 20% respectively higher than that of ring yarns [15], which can be attributed to better fiber cohesion [16]. The ring yarns are normally some 15% bulkier and it is also more hairy [15], which tends to reflect in the produced fabrics.

Due to the increased capital investments for compact spinning system, it is necessary to clear how much deserve this system especially in the gained improved properties. The present study is intended to compare the properties of compact and ring spun fabrics made from Egyptian cotton.

Materials

Through this study eighteen fabric samples were produced. The half of fabric samples were woven from filling compact spun yarns, and the remainder were produced from filling ring spun yarns. The filling yarn counts of each fabric sample are 30/1, 40/1, and 50/1 Ne. Each filling yarn was spun with three twist factors, i.e. 3.6, 4, and 4.2 respectively. All fabric samples were produced from 100% Egyptian cotton of Giza 86, whose characteristics were described in Table1. The levels of the factors in this study were depicted in Table 2.

Table 1. Characteristics of Giza 86 cotton fibers.

Parameter	Value
Micronaire value	4.5
Mean length (mm)	29.5
Uniformity Index (%)	88.7
Strength (g/tex)	43
Elongation (%)	6.4
Maturity Ratio	0.98
Fineness (mtex)	167

Weaving

All fabric samples were woven on a Picanol (PAT-A) air -jet weaving machine with profiled reed and auxiliary nozzles, at a loom speed of 760 ppm, air pressure of main nozzle 5 bar and 3 bar for auxiliary ones. The particulars of the woven fabric samples were as follows:

- Fabric width 160 cm,
- Fabric structure: plain 1/1,
- Warp density: 68 ends / inch,
- Weft density: 68 picks / inch,
- Warp yarn count: 40/1 Ne.

Laboratory Testing

Physical and mechanical tests were carried out in weft direction after conditioning of the fabrics for 24 hours under the standard

Table 2. Levels of the factors used in this study.

Spinning Method	Yarn Count (Ne)	Twist Multiplier
Ring Spinning	30	3.6
		4
		4.2
	40	3.6
		4
		4.2
	50	3.6
		4
		4.2
Compact Spinning	30	3.6
		4
		4.2
	40	3.6
		4
		4.2
	50	3.6
		4
		4.2

atmospheric conditions (20 ± 2 °C temperature, 65 ± 2% relative humidity). Ten individual readings were averaged for each fabric property. The fabrics were tested for the following characteristics; breaking load, breaking extension, tearing strength, abrasion resistance, air permeability and fabric stiffness.

The tensile strength measurements of the plain fabrics were carried out on a Cloth strength instrument (Asano Kikai Seisaku Co. Ltd) in accordance with ASTM D1682; and the air permeability tests were performed on a permeameter instrument No. 869 in accordance with ASTM D737 For the stiffness tests of the fabrics, a Curley type stiffness tester was used following ASTM D1388, while in the case of tearing test, an Intensity tearing tester (Elemendorf type) was used according to ASTM D1424. Abrasion resistance of fabric samples was evaluated by the number of revolutions at which the fabric breakage occurred, this test was done on universal wear tester No.882 under weight of 8.9 Newton and following ASTM D1175.

Statistical Analysis

To explore the effects of filling yarn count, twist factor, and spinning method on the different fabric properties; a 3 × 3 × 2 factorial design was performed. All test results were assessed at significance level $0.05 \le \alpha \le 0.01$. To predict the mechanical property of each fabric sample woven from both spinning techniques, i.e. compact and ring spinning, at different filling yarn counts and twist factors, a multiple non-linear regression analysis was executed. The regression relationship between different fabric properties and levels of filling yarn counts and twist factors has the following non-linear form;

$$Y = a_0 + a1\, x + a_2\, y + a_3\, x^2 + a_4\, y^2 + a_5\, x\, y$$

Where:

Y - fabric property, i.e. braking load, extension , air permeability, etc,
x - Filling yarn count (Ne),
y - Twist factor,
a_0 - constant,
a_1, a_2, a_3, a_4, a_5 - regression coefficients

The validation of the regression models was performed using the coefficient of determination, R^2,. R-square (the coefficient of determination), measures the reduction in the total variation of the dependent variable (fabric properties) due to the multiple independent variables (yarn count and twist factor).

Results and Discussion

Breaking load

The results of fabric breaking load were depicted in Figures 1 and 2. The statistical analysis proved that filling yarn count and twist factor has a significant influence on breaking load of fabrics woven from compact and ring spun yarns. It is shown that twist factor has a positive effect on fabric breaking load, on the contrary filling yarn count has a negative influence on fabric breaking load. The statistical analysis also revealed that breaking load of compact and ring fabrics differs significantly. Fabrics woven with compact yarns had higher breaking loads than those woven with ring yarns.

Increasing filling yarn count from 30 Ne to 50 Ne leads to a decrease of breaking loads by 15 kg and 17 kg for compact and ring fabrics respectively. It is also proved that the average values of breaking load of compact and ring fabrics are 46.8 kg and 42 kg respectively. Higher breaking load of compact fabrics may be related to increasing fiber extent inside the yarn due to elimination of spinning triangle in this spinning technique.

The regression relationship which correlates breaking load to filling yarn count and twist factor for compact fabrics is as follows:

Fabric breaking load (Kg) =
= $1260-2.107*x-621.985*y+0.002*x^2+0.236*x*y+82.222*y^2$

Whereas in the case of ring fabrics the regression line has the following form:

Fabric breaking load (Kg) =
= $1018-2.719*x-491.302*y+0.012*x^2+0.196*x*y+65.278*y^2$

The statistical analysis proved that the coefficient of determination for the two models is 0.98 and 0.98 for both types of fabrics, which means that these models fit the data very well.

Breaking extension

In determining the effect of twist factor and filling yarn count on breaking extension of fabrics woven from compact and ring spun yarns, the results (Figures 3 and 4) verify that there is a positive correlation between twist factor and breaking extension of compact and ring fabrics, by contrast a negative correlation was detected between filling yarn count and fabric breaking extension.

The statistical analysis proved that breaking extension of compact and ring fabrics differs significantly at 0.01 significance level. Fabric samples woven from compact yarns had breaking extension more than that woven from ring spun yarns. This is because the elimination of spinning triangle,

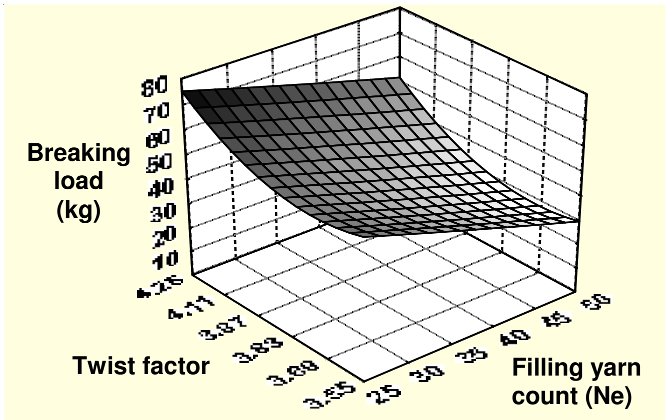

Figure 1. Response surface of breaking load versus filling yarn count and twist factor for compact fabric.

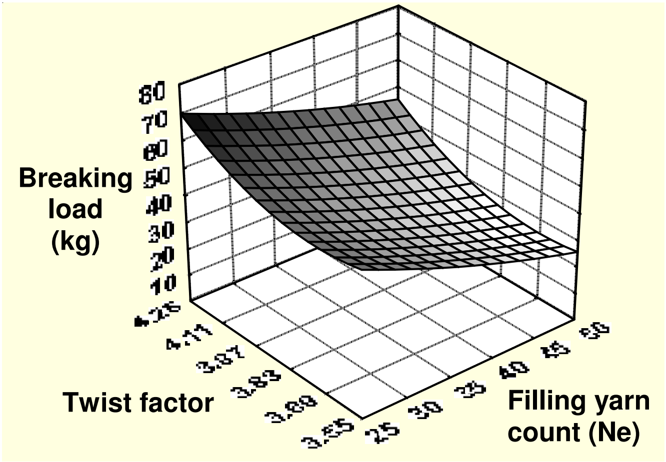

Figure 2. Response surface of breaking load versus filling yarn count and twist factor for ring fabric.

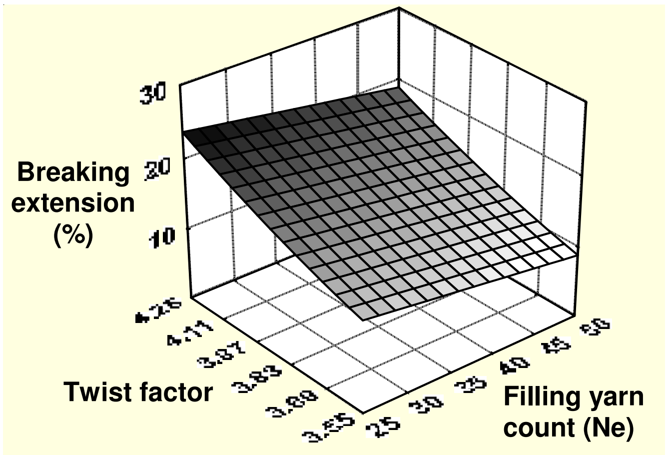

Figure 3. Response surface of breaking extension versus filling yarn count and twist factor for compact fabric.

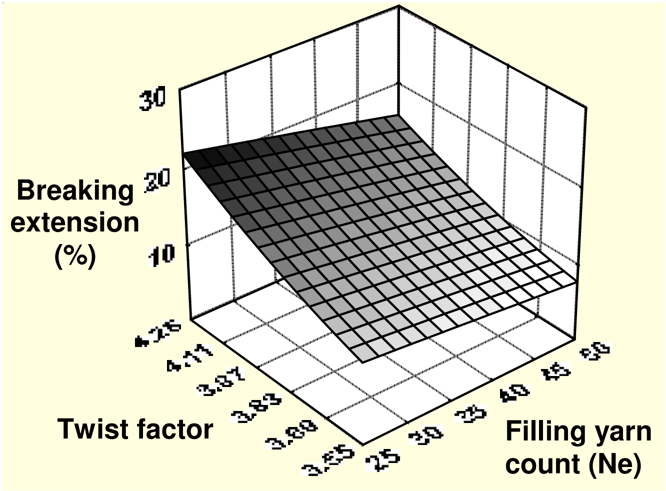

Figure 4. Response surface of breaking extension versus filling yarn count and twist factor for ring fabric.

which in turn the fibers in compact yarn cross section will be loaded more uniformly than fibers in the ring yarns. The statistical analysis proved that breaking extension of compact and ring fabrics was 16 % and 11.3 % respectively.
The multiple regression model that correlates breaking extension of compact fabric to twist factor and filling yarn count was found to be of the second order and of the following form:

Breaking extension (%) =
$$= 44.796 - 28.004\, y - 0.046\, x{*}y + 5.694\, y^2$$

In the case of ring fabrics, the regression model which correlates breaking extension with independent variables has the following form:

Breaking extension (%) =
$$= 49.418 + 0.606\, x - 36.338\, y - 0.196\, x{*}y + 7.361\, y^2$$

These regression models demonstrate a very good fit with a high R^2 values of 0.98 and 0.95 for compact and ring fabrics respectively. These statistical models can be used to predict breaking extension for both types of fabrics at different levels of twist factors and filling yarn counts

Tear strength

Tests were achieved in warp direction in order to apply loads on weft yarns that are spun from both ring and compact systems. Tear strength of compact and ring fabric samples versus filling yarn count and twist factor were plotted in figures 5 and 6. The statistical analysis showed that twist factor has no significant effect on fabric tear strength, but the filling yarn count was found to have a significant influence at 0.01 significance level on tear strength for both fabric samples. The higher the filling yarn count, the lower the tear strength is.

The statistical analysis also proved that the differences between tear strength values for compact and ring fabrics were insignificant, but in most cases fabrics woven with compact spun yarns had slightly higher values than those woven with ring spun yarns. It was found that tear strength of compact fabrics is more than that of ring fabrics by 5%

The statistical analysis also proved that the regression relationship which correlates tear strength of compact fabrics with yarn count and twist factor is as follows:

Tear strength (gm) =
$$= 67930 - 1346\, x - 16100\, y + 11\, x^2 + 80.9\, x{*}y + 1514\, y^2$$

Whereas in the case of ring fabrics the relationship between tear strength and the independent variable has the following form:

Tear strength (gm) =
$$= 31890 - 1231\, x + 500\, y + 11.7\, x^2 + 43.2\, x{*}y - 377.8\, y^2$$

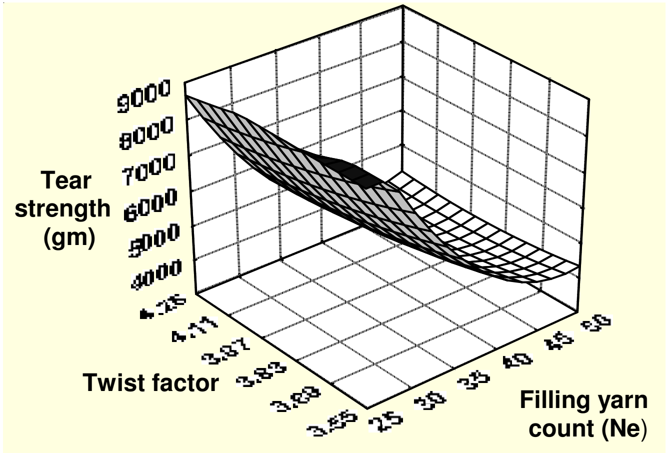

Figure 5. Response surface of tear strength versus filling yarn count and twist factor for compact fabric.

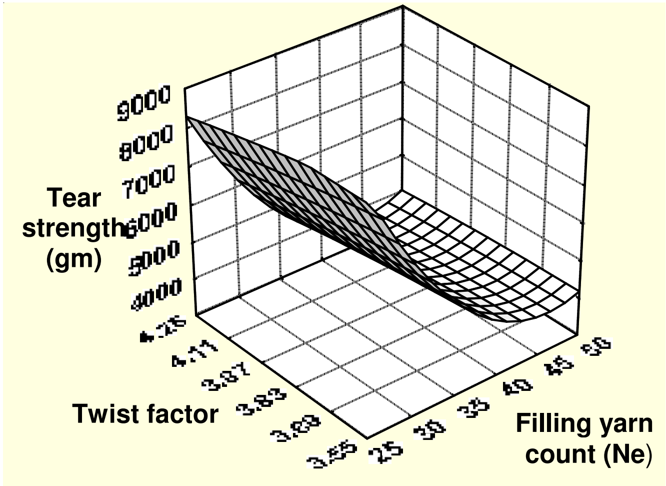

Figure 6. Response surface of tear strength versus filling yarn count and twist factor for ring fabric.

The coefficient of determination for these models are 0.93 and 0.95 for compact and ring fabrics respectively.

Stiffness

Stiffness is a property of material to resist the deformation under stress. The plots of stiffness of compact and ring fabrics versus filling yarn count and twist factor were presented in Figures 7 and 8. The statistical analysis showed that fabric stiffness is significantly affected by yarn count and twist factor for both types of fabrics. It is shown that the positive correlation between fabric stiffness and twist factor is clear. As the twist factor increases the stiffness of both types of fabrics react in the same manner. On the other hand the negative correlation between fabric stiffness and filling yarn count is detected.

The statistical analysis showed that the stiffness of compact and ring fabrics differs significantly at 0.05 significance level. It is shown that fabrics woven from compact yarns are stiffer than those woven from ring yarns. This may be related to the condensed fibers in the compact yarn cross section, which results in higher packing density of these yarns compared to ring yarns, which in turn leads to produce stiffer yarns. The statistical analysis proved that the average value of stiffness of compact and ring fabric is 589 mg and 570 mg respectively. The multiple regression model which correlates the stiffness of compact fabric to the independent variables has the following form:

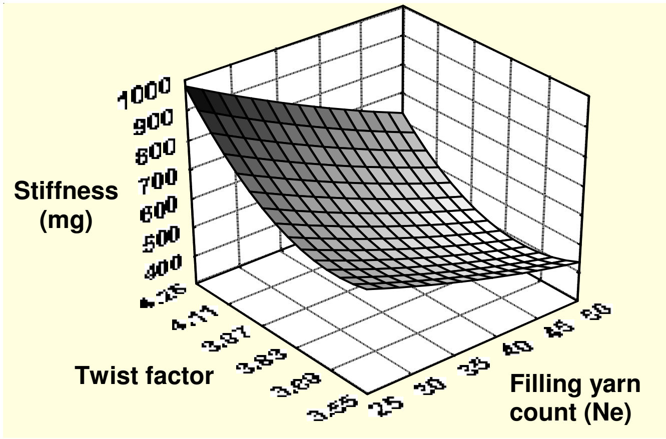

Figure 7. Response surface of stiffness versus filling yarn count and twist factor for compact fabric.

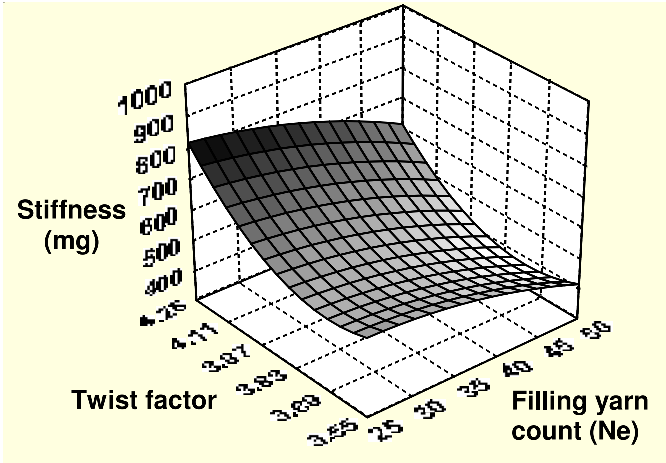

Figure 8. Response surface of stiffness versus filling yarn count and twist factor for ring fabric.

Fabric stiffness (mg) =
$= 14130 + 11\,x - 7332\,y + 0.1 * x^2 - 7.7\,x * y + 1024\,y^2$

For ring fabrics the regression relationship between stiffness and the independent variables is as follows:

Fabric stiffness (mg) =
$= 13120 + 23.13\,x - 6947\,y - 0.2\,x^2 - 3.8\,x * y + 950.6\,y^2$

These models demonstrate a very fit with values of R^2 0.98 and 0.95 for compact and ring fabrics respectively.

Air permeability

Air permeability is mainly affected by two parameters, porosity and fabric thickness. The density of warp and weft yarns are the same for all the compared samples. The parameters which could affect the air permeability are spinning system, yarn count, and twist factor. These could affect the fabric porosity. The results of air permeability versus filling yarn count and twist factor for compact and ring fabrics are introduced in Figures 9 and 10.

It is noticed that filling yarn count and twist factor had a profound effect on air permeability for both types of fabrics. The positive correlation between twist factor and air permeability is very clear. In fact, the air permeability increases swiftly with the increase in the twist factor.

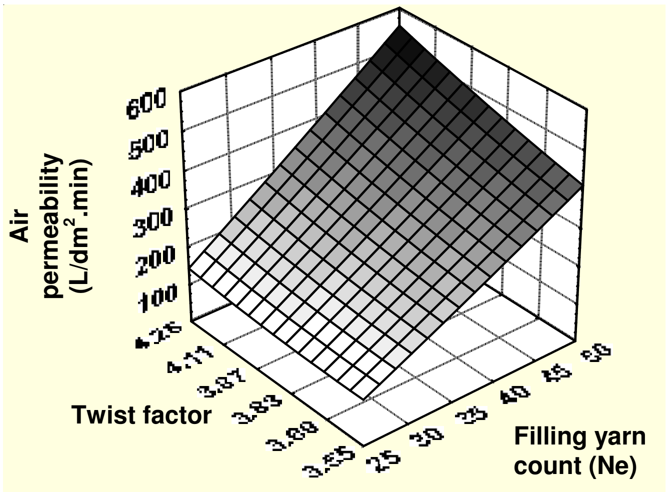

Figure 9. Response surface of air permeability versus filling yarn count and twist factor for compact fabric.

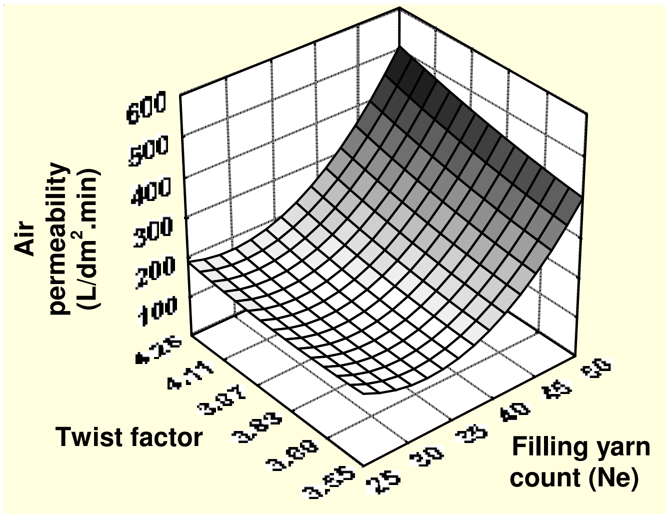

Figure 10. Response surface of air permeability versus filling yarn count and twist factor for ring fabric.

A positive correlation between filling yarn count and air permeability was detected. As the filling yarn count increases the air permeability reacts in the same manner.

It is also apparent the air permeability of compact and ring fabrics differ significantly. Fabric samples woven from compact yarns were more permeable than those woven from ring yarns. This may be related to two phases; the first one the more hairiness associated with ring spun yarns blocks the pores in the fabrics. On the other hand, the more bulkier of ring yarns compared to compact ones may be a hinder of the air flow through ring fabrics. The statistical analysis proved that the average value of air permeability of compact fabrics is more than that of ring fabrics by 24%.

The regression model which governs the relationship between air permeability of compact fabric and the independent variables is as follows:

$$\text{Air permeability (L/dm2.min)} = 1209 - 14.497\,x - 580.4\,y + 0.02\,x^2 + 6.9\,x{*}y + 56.6\,y^2$$

For the ring fabric, the regression relationship has the following form:

$$\text{Air permeability (L/dm2.min)} = 2756 - 71.5\,x - 817.7\,y + 0.82\,x^2 + 5.4\,x{*}y + 89.5\,y^2$$

The calculated R^2 values for these models are 0.98 and 0.96 for compact and ring fabrics respectively.

Abrasion resistance

In this study the resistance of compact and ring fabrics to abrading forces was conduced only on samples of filling yarn count 40 Ne with different twist factors. The number of abrasion cycles at which fabric breakage occurred is registered. The related test results were tabulated in Table 3. The statistical analysis revealed that there is no significant difference between both types of fabrics regarding abrasion resistance. But In general, compact fabrics showed slightly abrasion resistance higher than ring fabrics.

Table 3. Abrasion cycles of compact and ring fabrics.

Spinning technique	Twist factor	Abrasion cycles
Ring spinning	3.6	1275
	4	1150
	4.2	1080
Compact spinning	3.6	1350
	4	1225
	4.2	1115

Conclusion

In this study, we have shown that filling yarn count and twist factor have a significant influence on most mechanical properties of compact and ring fabrics. It is also proved that compact and ring fabrics differ significantly regarding fabric properties except for abrasion resistance and tear strength. The statistical analysis showed that compact fabrics have more tensile strength and extension than ring fabrics. It is also concluded that compact fabrics are more permeable and stiffer than those made from ring spun yarns.

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