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An Investigation about Tensile Strength, Pilling and Abrasion Properties of Woven Fabrics Made from Conventional and Compact Ring-Spun Yarns

Abstract

Most of the scientific studies on compact spinning, which is a modified version of ring spinning, have hitherto been focused on the properties of yarns and knitted fabrics. Yarns are subjected to intense mechanical stresses such as those during sizing, warping and weaving until the woven fabrics are produced. In this paper, tensile strength, pilling and abrasion properties of plain woven fabrics made from 100% combed cotton ring and compact yarns were investigated. Pilling properties were determined according to two different pilling test methods, and the abrasion properties were determined according to mass losses (%). According to results, the structural differences between ring and compact spun yarns had a significant influence on fabric properties. Fabrics woven from compact yarns were found to have higher tensile strength and pilling and abrasion resistances than fabrics woven from ring yarns.

Key words: *ring, compact, woven fabric, tensile strength, pilling, abrasion.*

Introduction

Compact spinning, which is a modified version of ring-spinning, produces a novel yarn structure, and the development of compact spinning has set new standards in yarn structure [1, 17]. By the launch of compact spinning, the development stage is oriented to better fibre utilisation and quality rather than higher productivity [12], perhaps for the first time in the history of staple fibre spinning.

In conventional ring spinning, the zone between the nip line of the pair of delivery rollers and the twisted end of the yarn is called the ‘spinning triangle’. This represents the critical weak spot of the ring spinning process. In this zone, the fibre assembly contains no twist. The edge fibres splay out from this zone, and make little or no contribution to the yarn strength. Furthermore, the edge fibres lead to the familiar problem of yarn hairiness [9, 11].

In compact spinning, the fibres which have left the drafting system are guided via the perforated drums or lattice aprons over the openings of the suction slots. Following the air flow, the fibres move sideways and are consequently condensed. This condensing has such a favourable effect on the ratio of the width of the condensed fibre to yarn diameter that the spinning triangle is nearly eliminated. When spinning without a spinning triangle, almost all the fibres are incorporated into the yarn structure under the same tension. As the twist insertion takes place very close to the nip line, even short fibres can take up tension. This results in increased strength, as more fibres contribute to the yarn strength. The utilisation degree of fibres can thus be increased. This leads to significant advantages such as increasing yarn strength, yarn abrasion resistance and reducing yarn hairiness [2, 7, 10, 13, 16, 17].

The yarns produced by the compact and ring spinning systems have major structural differences that are expected to impact on tensile strength, pilling and abrasion resistance. Most of the literature published has focused either on the comparison of the tensile and hairiness properties of ring and compact spun yarns, or on the tensile, pilling and abrasion properties of knitted fabrics made from ring and compact spun yarns [2, 7, 8, 11, 13 - 15]. In our study, woven fabrics were produced in order to investigate the effects of ring and compact spinning systems on tensile strength, pilling and abrasion resistances of plain woven fabrics.

Experimental

The tensile strength, pilling and abrasion properties of plain woven fabrics made from ring and compact yarns were investigated. For this purpose, ring and compact yarns with three different yarn counts (linear densities), 19.7 tex (Ne30), 14.8 tex (Ne40), 11.8 tex (Ne50), were produced on a Rieter G33 ring and a Rieter K44 Compact spinning machine respectively. All the yarns were spun with the same twist factor α_m = 134 (α_e= 4.43) and from the same batch of American Upland type cotton fibres and. Tests were performed on the yarns produced to determine their properties; we used the Uster Tensorapid 3 for strength tests, the Uster Tester 3 for mass irregularity and yarn faults and the Zweigle G566 for hairiness. The properties of the yarns are presented in Table 1.

Table 1. *Properties of yarns which were used in production of the fabrics.*

Test Instrument	Yarn Properties	Yarn Type (tex/α_m)					
		Ring	Compact	Ring	Compact	Ring	Compact
		(19.7/134)		(14.8/134)		(11.8/134)	
Tensorapid 3	Tenacitiy, cN/tex	15.35	18.22	14.84	17.36	13.79	16.34
	Elongation, %	4.45	5.25	4.17	5.12	3.63	3.84
Uster Tester 3	% CV_{mass}	11.63	11.18	13.80	13.00	14.42	14.20
	-%50 Thin Pl.	1	0	7	4	33	19
	+%50 Thick Pl.	6	9	25	90	59	101
	+%200 Neps	23	23	86	85	121	111
Zweigle G566	Class 1 mm	16042	13813	12875	11197	13200	10278
	Class 2 mm	3204	3220	2793	2110	2979	1428
	S3-value ($\Sigma \geq$ 3 mm)	1874	544	1723	295	1696	215

The warping, sizing and weaving processes were performed on a Yamada YS-6 sample sizing machine, a Suzuki sample warping machine and a Toyota JA4SF air jet weaving machine respectively. During the processes, all the process parameters were kept constant for each compact and ring yarn type. After weaving, the woven fabrics were desized in an open-width continuous washing range by using an enzymatic washing liquor under mill conditions. Table 2 shows the construction properties and the codes of the fabric samples. The samples were coded in accordance with the spinning system (R for ring and C for compact) and yarn count.

The tensile strength experiments of woven fabrics were carried out on an Instron 4301 tensile tester. Five samples were taken from the warp and weft directions of each type of fabric. In accordance with standard ISO 13934 [6], the distance between the jaws was 200 mm, and the gauge speed of the Instron was 100 mm/min.

The pilling resistance test of fabric samples were performed on both a Martindale Pilling & Abrasion Tester and on an ICI Pilling-Box Pilling Tester. The reason for testing the samples on both testers is to observe the changes in the surfaces of fabrics subjected to rubbing according to two different principles. While the Martindale tester is designed to give a controlled amount of rubbing motion between fabric surfaces at low pressures in continuously changing directions, the ICI Pilling-Box is designed to subject the fabric samples to a random rubbing motion with a mildly abrasive material. The pilling and abrasion tests were carried out in the factory mentioned in this paper's Acknowledgment. Therefore the tests were conducted in accordance with standards which are used in the factory, commonly used and accepted by the industry. From each fabric type, four samples were tested on the Martindale tester in accordance with standard ASTM D-4970 [3]. Tests on four samples, taken from the warp and weft directions of the fabrics, were conducted on the ICI Pilling-Box according to standard BS 5811 [4]. After 2,000 rubbing cycles for the Martindale tester and 14,000 turns for the ICI Pilling-Box, the pilling properties of the samples were evaluated by comparing their visual appearance with standard photographs. Samples were rated on a scale of 1 to 5 (1 for the worst, 5 for the best). Photographs of the yarns (40× magnified) and of the fabrics after pilling tests performed on the Martindale tester (10× magnified) are also presented.

Abrasion resistance tests on the fabric samples were conducted on the Martindale pilling and abrasion tester in accordance with standards BS EN ISO 12947-2 and 3 [5]. Four samples from each fabric type were used to determine the mass losses at the end of 5,000, 7,500 and 10,000 cycles, taking into consideration that the first yarn breaking occurred between 11,000 and 19,250 cycles. After 10,000 cycles, the sample surfaces were checked at intervals of 1,000 cycles. During the experiments, the measure-

Table 2. *Construction properties and codes of the fabrics.*

Fabric group	Fabric code	Warp yarn	Weft yarn	Density and fabric weight at finished fabrics		
				Warp/cm	Weft/cm	Fabric weight, g/m^2
1	R30	19.7 tex Ring	19.7 tex Ring	52	26	180
	C30	19.7 tex Compact	19.7 tex Compact	52	26	186
2	R40	14.8 tex Ring	14.8 tex Ring	52	25	128
	C40	14.8 tex Compact	14.8 tex Compact	52	25	131
3	R50	11.8 tex Ring	11.8 tex Ring	53	26	100
	C50	11.8 tex Compact	11.8 tex Compact	53	26	104

Table 3. *Tensile strength test results of the fabrics.*

Fabric Group	Fabric Code	Warp direction				Weft direction			
		Breaking load, N		Break. elongation, %		Breaking load, N		Break. elongation, %	
		Mean Value	CV, %	Mean Value	CV, %	Mean Value	CV, %	Mean Value	CV, %
1	R30	831.8	6.87	13.77	4.28	424.7	1.72	11.31	1.41
	C30	952.8	2.86	16.70	2.69	488.6	1.94	13.31	2.25
2	R40	627.1	8.13	9.68	12.70	258.6	2.97	8.41	1.38
	C40	713.4	5.77	10.64	2.25	329.2	2.52	11.63	3.86
3	R50	600.4	1.65	8.34	5.99	220.2	2.58	11.41	2.89
	C50	660.3	4.46	8.91	3.01	253.6	1.41	13.40	7.08

Table 4. *Analysis of variance results for breaking load and breaking elongation values of the fabrics; *) significant at α = 0.05, **) significant at α = 0.01, ***) significant at α = 0.001.*

Fabric group	P values			
	Warp direction		Weft direction	
	Breaking load, N	Break. elongation, %	Breaking load, N	Break. elongation, %
1	0,0027 **	0,0000 ***	0,0000 ***	0,0000 ***
2	0,0186 *	0,0141 *	0,0000 ***	0,0000 ***
3	0,0021 **	0,0245 *	0,0000 ***	0,0022 **

Table 5. *The pilling test results of the fabrics on ICI Pilling Box and Martindale tester.*

Fabric group	Fabric code	Evaluation	
		Martindale A&P Tester	ICI Pilling Box
1	C30	3/4	4/5
	R30	1/2	3
2	C40	4	4/5
	R40	2/3	3/4
3	C50	4	5
	R50	2	3/4

Table 6. *Results of abrasion cycles to first yarn breakage.*

Fabric group	Fabric code	Abrasion cycles to first yarn breakage	
		Mean value of 4 samples	% CV
1	C30	18625	3.55
	R30	17813	4.64
2	C40	14813	5.74
	R40	13938	6.28
3	C50	13688	8.08
	R50	12750	9.20

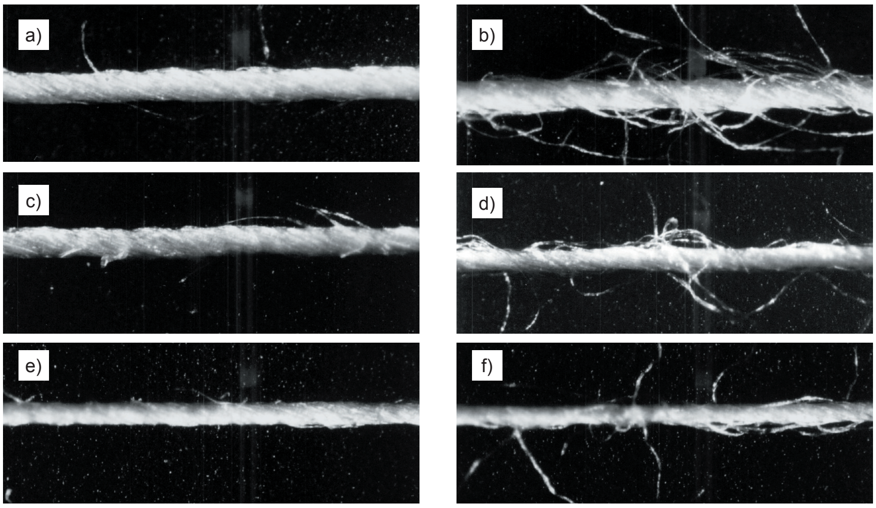

Figure 1. The appearances of compact(a, c, e) and ring(b, d, f) spun yarns; a, b - 19.7 tex, c, d - 14.8 tex, e, f - 11.8 tex; $\alpha_m = 134$.

ments were reduced to 250 cycles in the yarns very close to break, in order to take precise results as the first yarn breakage appeared. The results were also tested for significance in differences with the Costat statistical package.

Results and discussion

Fabric strength

The results of the tensile strength experiments on woven fabrics are presented in Table 3. The tensile strength values obtained in both the warp and weft directions of the fabrics woven from compact yarns were higher than those obtained from fabrics woven from ring yarns. The differences between the tensile strength values of fabrics woven from compact and ring yarns changed similarly with the differences obtained between the yarns. Statistical differences were obtained between the fabrics woven from compact and ring yarns at the same comparison groups (Table 4).

Pilling

The pilling test results of the fabrics on the ICI Pilling-Box and on the Martindale tester are presented in Table 5. Woven fabrics made from compact yarns were significantly more pill-resistant than those made from ring yarns. This suggested that the hairier ring spun yarns (Table 1) caused the fabric surfaces to pill more. In other words, the well-aligned and compact structure of compact yarns did not allow easy fibre pull-out, which led to higher pilling resistances. In addition, the visual comparison of the fabric surfaces after pilling clearly showed the advantages of the compact yarn structure in which the marginal fibres were better integrated in the body of the yarn (Figure 1). These findings supported the theory which indicates that the pilling properties of the fabric are highly related with the hairiness property of yarns used to construct the fabric. Moreover, an increase in the number of longer hairs in the yarn has a decisive influence on pilling formation. The significant differences between the S3 values of compact and ring spun yarns (Table 1) supported these results. With regard to the yarn count, the pilling rates of the fabrics tended to increase with finer yarn counts. This tendency was observed in a similar manner for both ring and compact yarns. The increased pilling rates in the fabrics with finer yarns can be attributed to the fact that finer yarns have lower hairiness values than the coarser yarns (Table 1).

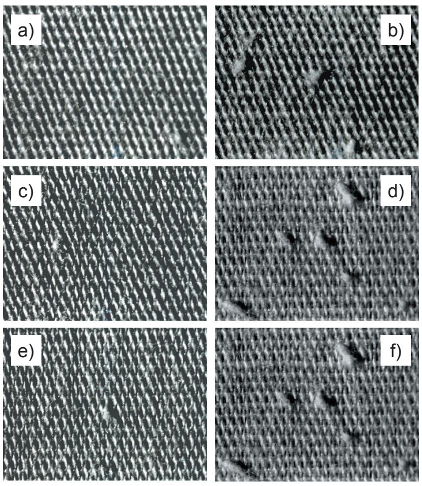

Figure 2. The appearances of the fabrics after pilling test on Martindale tester; Group 1: a) C30, b) R30; Group 2: c) C40, d) R40; Group 3: e) C50, f) R50.

Table 7. Analysis of variance results for cycles to first yarn brekage of the fabrics; ns - non significant.

Fabric group	P values
1	0.1775 ns
2	0.2016 ns
3	0.2890 ns

Figure 2 shows the appearances of six woven fabrics after 2000 rubbing cycles on the Martindale tester. The appearances of the fabrics woven from compact spun and finer yarns indicated that their tendency to pilling was lower than the fabrics woven from ring spun and coarser yarns.

After the rubbing action was completed, the appearances of the fabrics woven from ring spun yarns showed higher pilling tendency than the fabrics woven from compact spun yarns. Moreover, it is clearly visible from the photographs that the pill formation has a tendency to decrease as the yarns get finer and less hairy.

Abrasion

The abrasion behaviours of the fabrics were investigated according to yarn breakages and percent weight losses. We determined in which cycles the first yarn breakages occurred in the fabrics. The weight loss values (%) of the fabric samples after certain cycle numbers were calculated. The results are given in Table 6 and Figure 3 (see page 42) .

The highest yarn breakage cycle numbers were obtained in the fabrics woven from compact yarns (C30, C40 and C50). However, variances of the first yarn breakage cycle numbers were also high for each fabric type, showing that there were statistically insignificant differences between the cycles of first yarn breakages of the fabrics woven either from compact or ring yarns (Table 7).

When the weight loss values (%) obtained at the fabrics after 5000, 7500 and 10,000 cycles were considered, the fabrics woven from compact yarns (C30, C40 and C50) were found to have less abrasion between the ratio of 19.3% and 43.0% than the fabrics woven from ring yarns (R30, R40 and R50). Variance analysis results showed that these differences were statistically significant (Table 8). The only exception was the weight loss values (%) after 5000 cycles in fabric group 3. This observation might have been obtained because of the lower fabric weights and decreased precision of

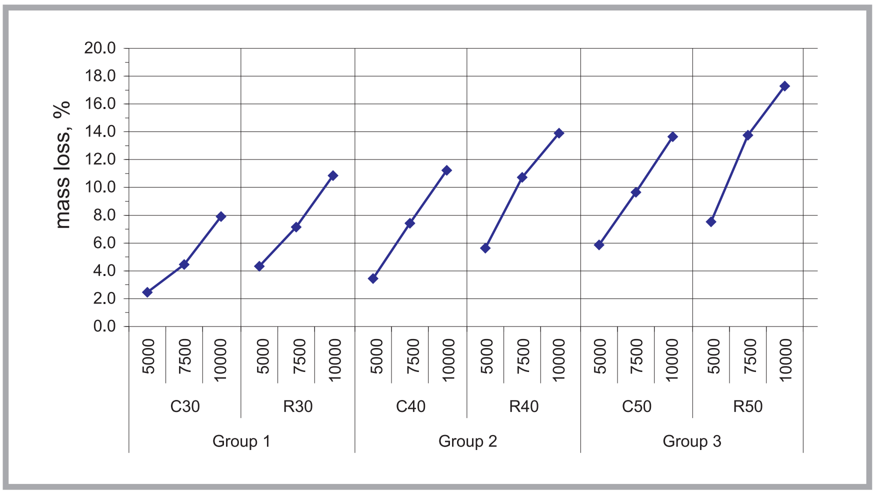

Figure 3. *Mean mass loss (%) values versus rubbing cycles of the fabrics.*

Table 8. *Analysis of variance results for mass loss values (%) of the fabrics; ns - non significant, *) significant at α=0.05, **) significant at α=0.01.*

Fabric group	P values					
	After 5000 cycles		After 7500 cycles		After 10000 cycles	
1	0.0014	**	0.0032	**	0.0022	**
2	0.0091	**	0.0025	**	0.0137	**
3	0.0856	ns	0.0104	*	0.0347	*

measurement in this group.

When considering yarn forms and friction against yarn guide or against another yarn, compact yarns are expected to have lower friction values because of their uniform and less hairy structures, and as a result a higher abrasion resistance is expected. Compact yarns are reported to have 40-50% higher abrasion resistance than ring yarns in terms of weight loss [10]. The better abrasion resistance (20–40%) of fabrics produced from compact yarns than those produced from ring yarns in turns of weight losses showed that the results were parallel with the ones obtained in yarn form.

Conclusions

- The tensile strength, pilling and abrasion behaviours of the fabrics woven from compact and ring yarns were investigated. Compact yarns have better fibre orientation than ring yarns, which results in better yarn properties and performance improvements in knitted fabrics, especially those made from compact yarns. According to results obtained in this research, the better properties of compact yarns carried their advantages to woven fabric properties after weaving preparation and weaving processes, even when they were under heavy mechanical forces.
- Fabrics woven from compact yarns had higher tensile strengths than those woven from ring yarns. It is obvious that the higher tensile strength of compact yarns caused higher strength values in fabrics woven from those yarns. The differences between the strength values of fabrics were similar to the differences in strength between yarns.
- When pilling behaviour was taken into account, it was observed that fabrics woven from compact yarns were found to have higher pilling resistances than those woven from ring yarns.
- According to the abrasion test results of the fabrics, ring fabrics showed significant differences than compact fabrics when the weight losses (%) at certain cycles were considered. However, no significant differences were obtained between the compact and ring fabrics at the cycles of first yarn breakage. The reason for this may be the possibility that the breakage of any yarn on the fabric's surface is high after a certain level of abrasion.

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