Indian Journal of Fibre & Textile Research
Vol.35, March 2010, pp 45-49

Study of cotton ring-and compact-spun yarn fabrics: Part I –Effects of spinning variables on hand-related characteristics

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Received 25 March 2009; revised received and accepted 27 August 2009

The importance of yarn structural variants such as spinning draft, twist factor, yarn structure, and spindle speed in deciding the hand-related characteristics of woven cotton fabrics has been investigated using FAST evaluation system. The data indicate that the processing differences of each yarn type confer different extensibility, bending rigidity and shear rigidity values, and the differences in the yarn structure affect the fabric formability and other low deformation characteristics. Effects obtained by changing twist factor and spinning draft are found to be significant; however, by using an optimum spinning draft and varying twist factor, one can successfully produce fabrics with low rigidities and quite sufficient extensibility and formability. The spindle speed does not seem to affect the coercive shear rigidity in either ring- or compact-spun yarn fabrics. The handle response of fabrics woven with compact-spun yarns is quite satisfactory in many respects.

Keywords: Compact - spun yarn, Extensibility, Formability, Ring-spun yarn, Shear rigidity

1 Introduction

Compact spinning provides the potential to create a near-perfect yarn structure by applying air suction to condense the fibre stream in the main drafting zone, thereby virtually eliminating the spinning triangle[1-5]. Additionally, Basal[6] pointed out that the migration occurs at high levels for a compact yarn, and this leads to better yarn structure and quality. Research conducted so far on compact spinning mainly deals with the comparison of conventional and compact-spun yarn characteristics[7-10]. There are occasional references to the response of compact-spun yarns performance in downstream manufacturing operations[11,12]. However, information with regard to the relation between fabric hand and processing factors such as spinning draft, twist factor and spinning speed demands systematic investigation. This paper reports the results of experiments undertaken to establish a more in depth understanding of the influence of the cited parameters on the hand-related characteristics of cotton ring- and compact-spun yarn fabrics.

2 Materials and Methods

2.1 Preparation of Fabric Samples

Two sets of 14.7 tex yarns were spun from J-34 cotton (2.5% span length, 26.8mm; fineness, 1.8dtex; tenacity, 26.7 g/tex; and breaking extension, 6.5%) on ring and compact spinning machines with different twist factors ranging from 33.56 to 38.36. Lap was made on Lakshmi Rieters' blow room line and carded on Texmaco Howa card. The conversion to combed sliver was carried out by using Rieters' sliver lapper LE2/4a, Rieters' ribbon lapper LE4/7a and Rieters' comber E 7/4. The stock from the combing unit was drawn twice on a Lakshmi Rieters' draw frame DO/2S and converted into 0.8, 1.0 and 1.3 Ne rove using an O K K fly frame, which were used to produce 14.7 tex yarn on Rieters' G 5/1 ring frame using conventional and rotorcraft compact spinning mode (RoCos). The spindle speed and spinning draft were changed, while other production parameters were kept constant. Six different kinds of yarns were spun at two different speeds with three spinning drafts.

Experimental ring- and compact-spun yarns were separately used to produce plain woven fabrics on a Texmaco shuttle loom. The construction of the eighteen sets of fabrics was kept constant at 24 ends and 22 picks per centimeters (i.e. 60ends×56 picks per inch) for single 14.7 tex yarns. For all sets of fabrics, the warp used was the same with 2/9.8 tex. The details of the fabrics are given in Table 1. The fabrics were immersed in a solution containing 3 gpl sodium hydroxide and 1% non-ionic detergent (Wet Acid NI) at 100^0 C for 90 min. After the treatment, the samples were thoroughly washed with cold and hot water for

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Table 1— Specifications of fabric samples
[Yarn linear density, 14.7 tex]

Fabric ref. no.	Yarn type	Spinning draft	Twist factor	Yarn characteristics			
				Diameter×10^{-3}, cm		Hairs/10m	
				250[a]	291.66[a]	250[a]	291.66[a]
S_1	Ring	30	33.56	17.53	17.28	78	80
S_2	Ring	30	35.96	17.29	17.03	72	73
S_3	Ring	30	38.36	17.16	16.42	58	62
S_4	Ring	40	33.56	16.57	16.75	80	83
S_5	Ring	40	35.96	16.25	15.90	75	77
S_6	Ring	40	38.36	15.76	15.45	64	68
S_7	Ring	50	33.56	17.05	16.84	83	93
S_8	Ring	50	35.96	16.27	15.98	79	81
S_9	Ring	50	38.36	16.06	15.76	72	79
S_{10}	Compact	30	33.56	16.73	15.88	39	42
S_{11}	Compact	30	35.96	16.43	15.45	37	39
S_{12}	Compact	30	38.36	16.11	15.10	34	35
S_{13}	Compact	40	33.56	16.22	15.42	43	45
S_{14}	Compact	40	35.96	1`5.56	14.92	39	43
S_{15}	Compact	40	38.36	14.94	14.53	36	39
S_{16}	Compact	50	33.56	16.25	15.96	45	50
S_{17}	Compact	50	35.96	15.78	15.18	41	48
S_{18}	Compact	50	38.36	15.28	14.86	39	43

[a]Spindle speed, rps.

Table 2— ANOVA test results

Process parameter	*F*-ratio				
	Compressibility	Bending rigidity	Extensibility	Shear rigidity	Formability
Yarn structure	s	s	s	s	s
Spinning draft	s	s	ns	s	s
Twist factor	s	s	s	s	s
Spindle speed	ns	s	ns	ns	s

S—Significant; and ns—Non significant.

15 min each to remove adhered chemicals completely from the fabrics, neutralized with 2 gpl acetic acid, washed thoroughly and dried at 90°C.

2.2 Test Methods

All the yarns were tested for hairiness on Zweigles hairiness meter (Model G 565).The yarn diameter was measured by Leica Q500 MC at 100 randomly selected places along the length of the yarn. A sufficient length of the yarn was covered to take care of any variation.

All the cotton ring- and compact-spun yarn fabrics were tested for their extensibility, bending rigidity, shear rigidity, compression and formability using FAST evaluation system.

3 Results and Discussion

3.1 Yarn Characteristics

Table 1 shows the diameter and hairiness of experimental yarns with respect to different process parameters. As expected, the differences in packing densities of ring- and compact-spun yarns result in different diameters of these yarn structures. The yarn diameter is normally smaller at 40 spinning draft, irrespective of the yarn structure. For both ring-and compact-spun yarns, a decrease in diameters is produced when both twist factor and spindle speed are increased. The trend is consistent in all yarns, though the magnitudes of changes are different between yarns. When a comparison is made between the compact- and the ring- spun yarns, the former exhibit less hairiness which further reduces with the increase in both twist factor and spindle speed. Change in spinning draft also noticeably reduces hairiness, and the yarns spun with a low spinning draft are less hairy.

3.2 Fabric Handle

The influence of three experimental factors, viz. twist factor, level of spinning draft and spindle speed, on the handle characteristics of ring- and compact-spun yarn fabrics was assessed for significance using ANOVA analysis (Table 2); the confidence level used was 99%.

3.2.1 Compressibility

The fabric compressibility, which is a percentage change in fabric thickness at 2gfcm^{-2} and 100 gfcm^{-2}, was used for assessing fabric compression (Fig.1). The fact that different systems deliver different surface compressions also holds true for this investigation. Generally, ring-spun yarn fabrics exhibit considerably higher surface compression than the compact-spun yarn fabrics, and its variance depends on the processing parameters used. The lower surface compression of the compact-spun yarn fabrics is the outcome of the enhanced fibre integration in the yarn structure, which, in turn, leads to smaller yarn diameter and lower surface compression. The impact of twist factor on fabric surface compression is along the expected lines, a higher twist factor results in a lesser surface compression. On increase in spinning draft, the surface compression first decreases significantly and then increases. However, increasing the spindle speed from 250 rps to 291.66 rps results in marginal decrease in surface compression on account of reduced packing density.

3.2.2 Bending Rigidity

The mean values of bending rigidity for various ring-and compact-spun yarn fabrics are given in Fig.2. For all experimental combinations, the differences between bending rigidities for ring- and compact-spun yarn fabrics are significant, and in all cases the fabrics woven with compact –spun yarns have substantially higher bending rigidity than those woven with ring-spun yarn fabrics. The higher bending rigidity of the compact-spun yarn fabrics can be ascribed to the compactness of the structure which gives less freedom of movement during bending. The twist factor has a significant influence on the fabrics bending rigidity. Even after a modest increase in twist factor from 33.56 to 35.96, the bending rigidity increases by about 12.6-28.3% and 13.5-36.3% for ring- and compact-spun yarn fabrics respectively. With the increase in spindle speed, the bending rigidity increases further. Spinning draft has no essential influence on fabric rigidity, although fabrics woven with yarns produced with 40 spinning draft are stiffer regardless of the yarn structure.

3.2.3 Extensibility

A cursory look at Fig. 3 shows that for all experimental combinations, the ring-spun yarn fabrics tend to display substantially higher values of extensibility compared to that obtained for equivalent compact-spun yarn fabrics. A possible explanation for this trend may be the large difference in the inter-fibre friction and bulk of the ring- and compact-spun yarns, which, in turn, mask inter-fibre movement and fabric extensibility. There is an insignificant decrease in extensibility for the fabrics made from yarns produced under high spinning tension. The results of variance analysis indicate that for both the yarn structures, an

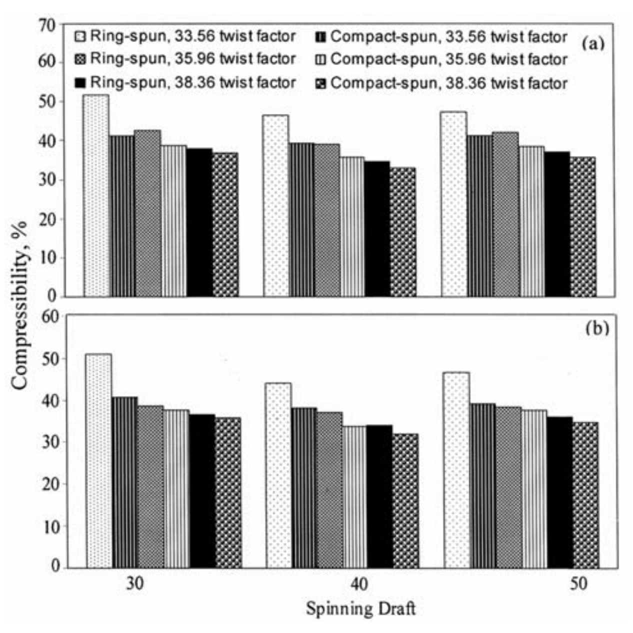

Fig. 1—Variation in compressibility (%) of ring- and compact-spun yarn fabrics [(a) spindle speed, 250 rps; and (b) spindle speed, 291.66 rps]

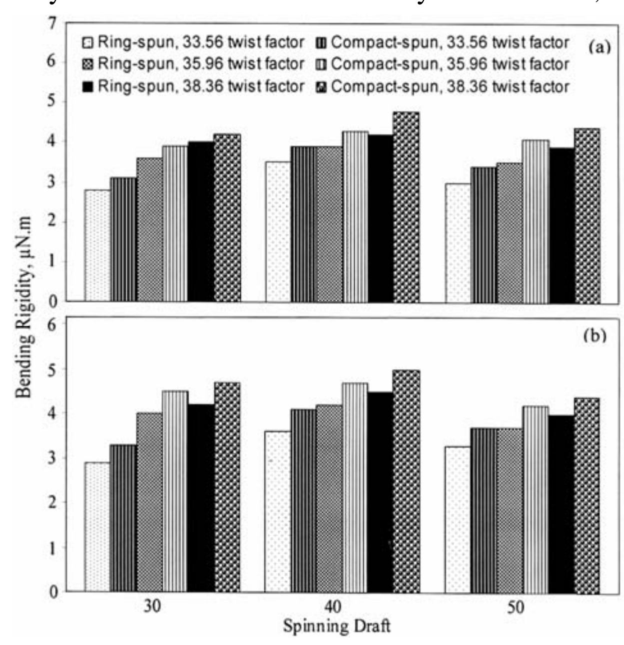

Fig. 2—Variation in bending rigidity (μN.m) of ring- and compact-spun yarn fabrics [(a) spindle speed, 250 rps; and (b) spindle speed, 291.66 rps]

increase in twist factor causes a noticeable decrease in fabric extensibility. Moreover, the extensibility values of fabrics made from yarns produced with different spinning drafts are close to each other, and in most cases the fabrics made of compact-spun yarns are less extensible than their ring-spun couples.

3.2.4 Shear Rigidity

Figure 4 illustrates the shear rigidity of various cotton fabrics. In general, ring-spun yarn fabrics possess much lower shear rigidity than compact-spun yarn fabrics. Since ring-spun yarns have larger bulk, they are liable to flatten more at the cross-over points in the fabric and thus hinder inter-yarn movement in the fabric substrate. Note that the values of shear rigidity for fabrics woven with high twist yarns are much smaller compared to the values for the equivalent fabrics made from low-twist yarns. This is consistent with the enhanced bias extensibility of fabrics with increasing twist factor. The bias extensibility of ring- and compact-spun yarn fabrics increases from 19% to 25.9 % and from 15.4% to 37% respectively with the increase in twist factor from 33.56 to 38.36. No specific influence caused by using higher spinning draft in both ring and compact spinning becomes apparent in the shear rigidity values of fabrics. Increasing spindle speed, however, unnoticeably reduces fabric shear rigidity, regardless of the yarn structure.

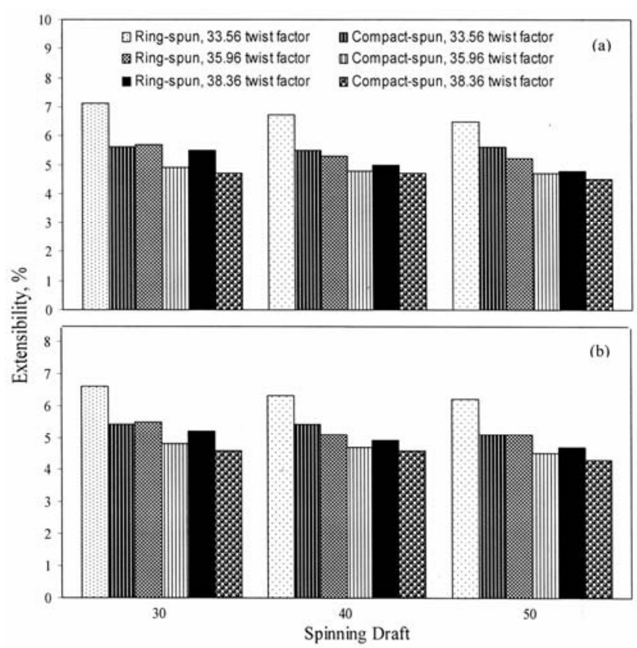

Fig. 3 – Variation in extensibility (%) of ring- and compact-spun yarn fabrics [(a) spindle speed, 250 rps; and (b) spindle speed, 291.66 rps]

3.2.5 Formability

Figure 5 shows the influence of processing factors on fabric formability, with the lower values corresponding to fabrics made from the ring-spun yarns and the higher values corresponding to the yarns produced with compact spinning system. These differences in formability are attributed to the

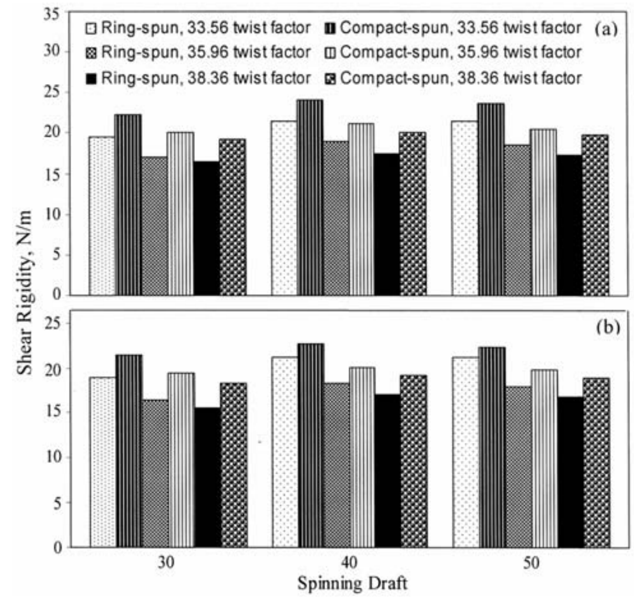

Fig. 4—Variation in shear rigidity (N/m) of ring- and compact-spun yarn fabrics [(a) spindle speed, 250 rps; and (b) spindle speed, 291.66 rps]

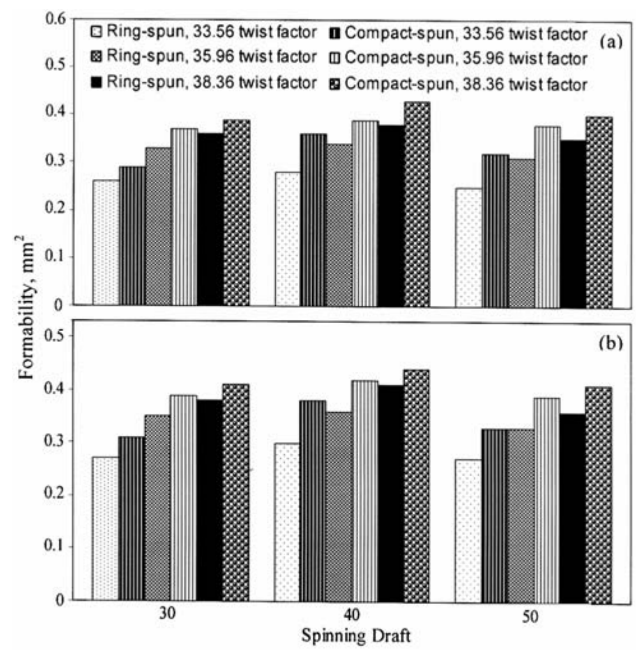

Fig. 5—Variation in formability (mm^2) of ring- and compact-spun yarn fabrics [(a) spindle speed, 250 rps; and (b) spindle speed, 291.66 rps]

differences in fabric extensibility and bending rigidity, as mentioned earlier. Formability measurements of fabrics woven with yarns spun with both low and high spinning draft are close to each other. However, in general, the formability values are remarkably higher for fabrics made from yarns spun with higher spindle speed. In addition, fabrics made from yarns produced with 38.36 twist factor display enhanced formability than their 33.56 twist factor couples.

4 Conclusions

4.1 The yarn structure is an important factor in determining fabric hand. Fabrics woven from compact-spun yarns are less extensible and possess considerably higher bending and shear rigidities and higher formability than equivalent fabrics made from conventional ring-spun yarns. The surface compression decreases with the increase in twist factor. For both types of fabrics, the surface compression reduces initially with increasing spinning draft but increases thereafter as the spinning draft is further increased beyond a particular limit.

4.2 The main differences in bending and shear rigidities of woven cotton fabrics originate from variations in spinning process. Invariably, the bending rigidity of compact-spun yarn fabrics is 5-14.2% higher than that of the ring-spun yarn fabrics. When compared with ring-spun yarn fabrics, the shear rigidity of compact yarn fabrics is 5.2-18.9% higher. An optimum spinning draft is certainly a pre-requisite for a good fabric. Spinning conditions obviously have a major influence and like other features, fabric bending and shear rigidities depend strongly on the yarn twist. An alteration in spindle speed also leads to a substantial increase in bending rigidity.

4.3 Compact spinning contributes to the production of good quality fabrics with reduced extensibility and enhanced formability. Increase in spindle speed has a positive influence on fabric formability but marginally affects fabric extensibility, and there is a similar behaviour with increasing twist factor. There is no specific relationship between fabrics characteristic features and spinning draft either for ring- or for compact-spun yarn fabrics.

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