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MEASURED SOFTNESS CHARACTERISTICS OF SPUN YARNS REPRESENTING DIFFERENT SPINNING TECHNOLOGIES

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Abstract

This work measured the bending and compression properties of 100% cotton and cotton/polyester yarns representing ring, rotor, friction, and airjet spinning systems. Bending properties were measured using the KES-F bending tester while compression properties were measured using the KES-F compression tester. The observed differences in the compression properties of both the cotton and polyester/cotton yarns were on the expected lines. While bending rigidity values agreed with what one would expect based on yarn structural differences, the bending hysteresis values were found to be highly variable and were difficult to measure accurately.

Introduction

Almost all the new spinning technologies introduced in recent years give unique yarn structures that exhibit many structural variations and differences in mechanical behavior (2-4). The different levels of deficiency in tactile quality exhibited by these new yarns (2-5) are believed to be dictated by their structure related yarn properties such as initial tensile modulus, compression modulus, bending rigidity, and coefficient of surface friction, among others. This work has been planned with the following objectives in mind:

1. Compare the compression behavior of yarns representing different spinning systems, as measured by the Kawabata compression tester.
2. Compare the bending behavior of spun yarns representing different spinning systems, as measured by the Kawabata bending tester.
3. Study the extent of agreement among the bending rigidity values measured using three different test methods.

Materials and Methods

Test Materials

Particulars of the experimental yarns are given in Table 1. The cotton yarns represented ring, rotor and OE friction spinning systems, while the cotton/polyester yarns represented ring, rotor and airjet spinning systems, and all six yarns had the same nominal count (18s Ne). To avoid yarn property differences arising due to fiber property differences, the cotton yarns were made from a single cotton sliver and the cotton/polyester yarns were made from a single cotton/polyester sliver. The yarns were produced under commercial manufacturing conditions (i.e., at optimal production rates) and the twist levels used were those considered optimum for each spinning system.

Test Methods

Compression Test. We used Kawabata compression tester to measure the compression properties of yarns. The average compression parameters were computed on the basis of 25 compression tests for each yarn. The compression properties were measured by placing the yarn along a marked line on the diameter of the circular platform, under a known pretension, and then allowing the plunger to move down and compress the yarn to a pressure of 50g/cm^2. The pretension was applied by fixing one end of the yarn to the stationary platform by means of an adhesive tape and then hanging a weight of 8g to the other end of the yarn. Care was taken to prevent twist loss while suspending the yarn under the plunger of the compression tester. The recovery properties were measured by relieving the compressive load at the same rate at which it was applied. The pressure versus compression behavior was plotted for both downward and upward movements of the plunger and the plots were used to compute the following compression parameters:

- WC: Work done in compression (g/cm, measured as the area under the compression curve).
- WC': Work recovered on relieving the compressive load (g/cm, measured as the area under the recovery curve)
- RC%: Percent compressive resilience (%), computed as the ratio of the work recovered to the work done (100WC'/WC).
- LC: Linearity of compression curve (no units, a value close to zero indicates relative ease of compression, while a value of 1.0 indicates perfectly linear compression behavior).
- EMC%: Percent thickness (diameter) reduction under a compressive load of 50 g/cm^2.
- TO: Initial thickness (yarn thickness under a compressive load of 0.01g/cm^2 - mm).

KES-F Bending Test. We used the Kawabata bending tester to measure the bending properties of yarns. Since the instrument is designed to measure the bending properties of flat fabrics, we bent a flat sheet of yarn, as opposed to bending a single yarn or a yarn bundle. We prepared 20cm by10cm rectangular paper frames, which carried a 15 cm by 1cm wide hollow portion in the center (please see FIGURE 2). The paper frames were taped to the corner of a smooth table before mounting threads on them. The threads were mounted across the 1cm gap of the hollow frame by fixing one end of the yarn to the top of the frame with an adhesive tape and suspending the other end across the 1 cm wide opening by means of a 5 gram tension weight. After suspension, the yarn was fixed to the other end of the frame, again by an adhesive tape, and the excess length of yarn hanging from the frame was cut off. All frames carried 4 threads per cm or 60 threads within the 15 cm opening of the frame.

After mounting all the 60 threads on the paper frame, the threads were again sealed to the frame on either side of the 1 cm wide opening by long pieces of adhesive tape that stretched across the entire 20 cm length of the frame. To measure the combined bending modulus of the 60 threads, each paper frame was slid in the gap between the front and back set of clamps of the bending tester until the yarns were positioned in the 1cm gap between the front and back set of clamps. After this, the clamping screws were tightened, and the side limbs of the hollow paper frame were cut off, leaving only the layered threads between the clamps. The threads were bent between the clamps between the curvatures +2.5 cm^{-1} and -2.5 cm^{-1}. Thus both bending modulus, B and bending hysteresis, 2HB were measured by simultaneously bending and de-bending 60 yarn segments. A total of ten frames were prepared for each yarn, thereby representing 600 randomly selected yarn segments in the bending test of each yarn. The bending parameters (B and 2HB) were computed as follows:

Bending rigidity, B = slope of the bending moment Vs curvature curve, measured between the bending curvatures of $\pm 0.5\ cm^{-1}$ and $\pm 1.5\ cm^{-1}$.
Bending hysteresis, 2HB = hysteresis width, measured at a curvature of $\pm 1.0\ cm^{-1}$.

Results and Discussion

Bending Properties of Different Yarns

The influence of the spinning system on the yarn bending property is illustrated through box plots so that the entire distribution of the measured property parameter of one yarn can be compared with that of the other yarns. The height of the rectangle of each box plot represents the inter-quartile range (mid 50% values) of the measured property parameter. The vertical line above the rectangle represents the fourth quartile while the vertical line below the rectangle represents the first quartile. The horizontal line inside the rectangle represents the median value of the measured parameter, while the dark circle represents the mean value of the parameter.

From Figures 2 and 3 and Table 2, it is clear that the cotton yarn representing OE friction spinning shows higher bending modulus and bending hysteresis values compared to the ring and rotor yarns. It is also clear that the rotor yarn accounts for a greater variation in bending rigidity compared to both the ring and friction yarns. Figures 4 and 5 suggest that all three P/C yarns differ in their bending modulus and bending hysteresis properties and that the ring yarn has the lowest values for bending modulus and bending hysteresis, followed by the rotor and airjet yarns. A comparison of the bending behavior of cotton yarns with that of P/C yarns suggests that the bending properties of the cotton yarns representing ring, rotor and friction spinning systems are closer than the bending properties of P/C yarns representing ring, rotor and airjet spinning systems. Thus the average bending rigidity of the P/C airjet yarn is roughly thrice that of the P/C ring yarn, while the average bending rigidity of the cotton friction yarn is only about 1.3 times that of the cotton ring yarn.

Compression Behavior of Different Yarns

Among the measured properties, compression energy (WC), percentage thickness reduction under a peak compressive load of 50 g/cm^2 (EMC%), and compression linearity (LC) relate to the compressive softness of the yarn (1, 6). Higher softness is reflected by higher values of WC, higher values of EMC%, and lower values of LC (1,6). While softer materials tend to be less resilient, in the case of spun yarns, yarn structural parameters such as intensity of migration, density of fiber packing, fiber extent, etc., can also be expected to influence the measured compressive resilience of the yarn. Thus the use of compressive resilience (RC%) values to infer about yarn softness is perhaps not desirable here. Figures 6-9 present a comparison of the compression properties of the cotton yarns, while Figures 10-13 compare the behavior of P/C yarns. Table 2 describes the statistical significance of the differences in measured properties of the yarns representing different spinning systems. It is clear that the measured compression properties of the three cotton yarns representing ring, rotor, and friction spinning systems exhibit significant differences. Also all three measured compression properties (WC, EMC% and LC) suggest that ring yarn is the softest yarn in the group, followed by the rotor and friction yarns. The measured compression parameters of the P/C yarns, however, fail to support a similar interpretation about the softness of the ring yarn, even though the measured LC, EMC%, and RC% values of the ring yarn are significantly different from that of rotor and airjet yarns. Thus while the three P/C yarns exhibited relatively large differences in bending behavior, they exhibited relatively small differences in compression behavior, compared to the cotton yarns.

References

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Table 1. Experimental Yarns.

S. No	Experimental Yarn	Yarn Count (Ne)
1	Ring spun cotton	18s
2	Rotor spun cotton	18s
3	Friction (OE) spun cotton	18s
4	P/C Ring spun (50:50)	18s
5	P/C Rotor spun (50:50)	18s
6	P/C Airjet spun (50:50)	18s

Table 2. Results of Anova Test for Untreated Yarns.

Parameters in ANOVA Test	P-value	Significance at 95%	Deviating Yarn/s
B values of cotton yarns	0.004	YES	Friction
2HB values of cotton yarns	0.000	YES	Friction
B values of P/C yarns	0.000	YES	Airjet, Rotor
2HB values of P/C yarns	0.000	YES	Airjet, Rotor
LC of cotton yarns	0.004	YES	Friction, Rotor
WC of cotton yarns	0.000	YES	Friction
RC% of cotton yarns	0.019	YES	Friction, Rotor
EMC% of cotton yarns	0.000	YES	Friction, Rotor
LC of P/C yarns	0.005	YES	Airjet, Rotor
WC of P/C yarns	0.156	NO	-
RC% of P/C yarns	0.001	YES	Airjet, Rotor
EMC% of P/C yarns	0.038	YES	Airjet, Rotor

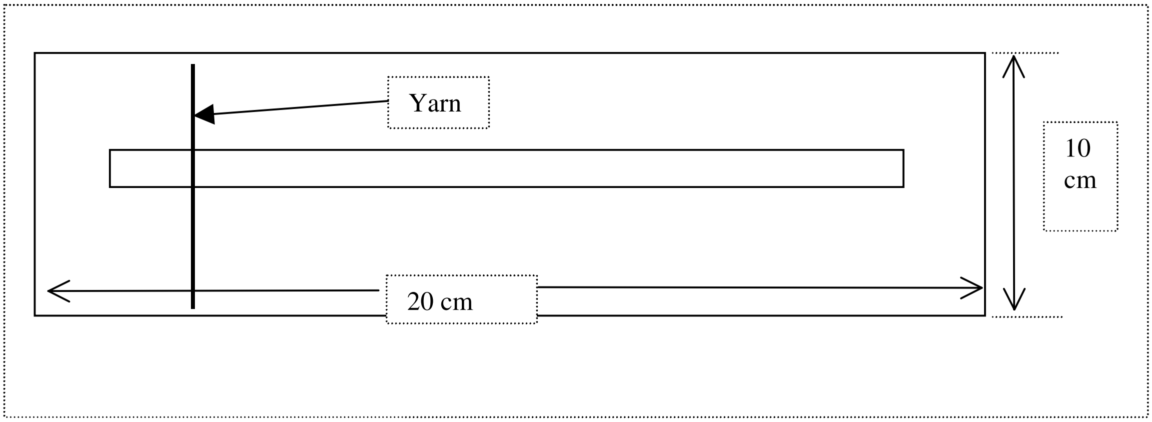

Figure 1. Illustration f the Paper Frame used to Mount Yarns for the Bending Test.

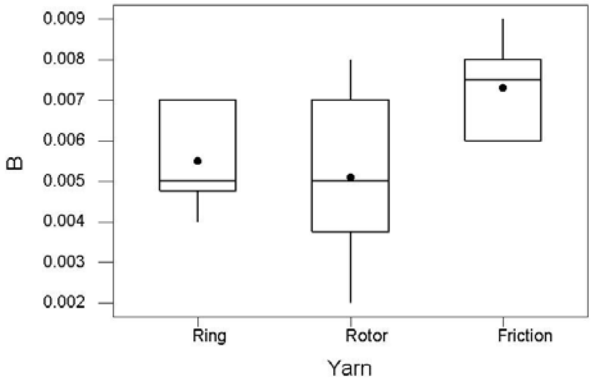

Figure 2. Bending Modulus, B of Cotton Yarns.

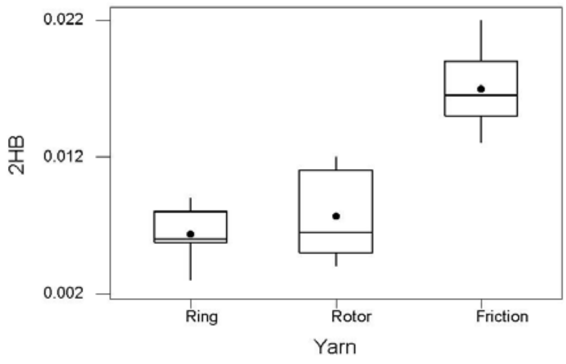

Figure 3. Bending Hysteresis 2HB of Cotton Yarns.

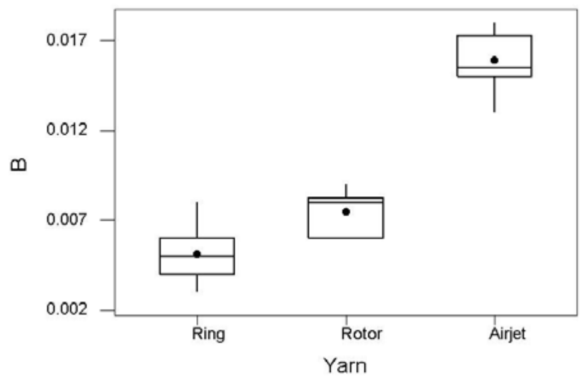

Figure 4. Bending Modulus, B of P/C Yarns.

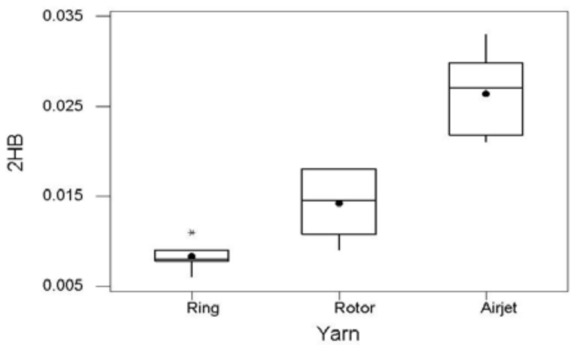

Figure 5. Bending Hysteresis, 2HB of P/C Yarns.

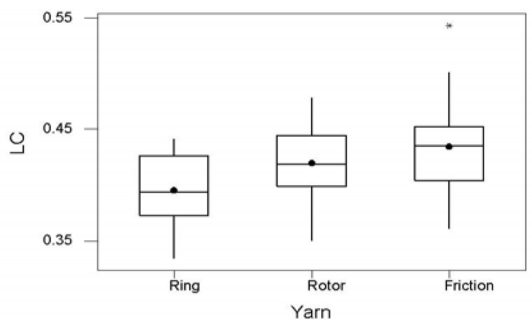

Figure 6. Compression Linearity, Lc Of Cotton Yarns.

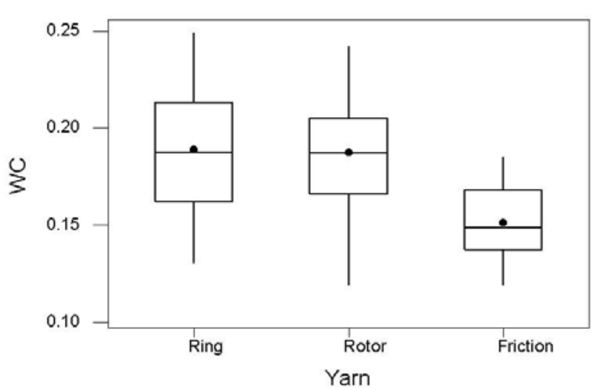

Figure 7. Compression Energy, WC of Cotton Yarns.

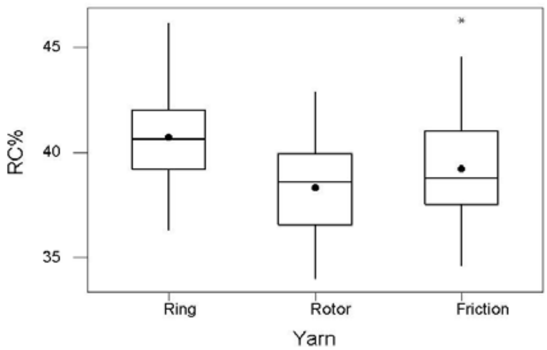

Figure 8. Compression Resilience, RC% of Cotton Yarns.

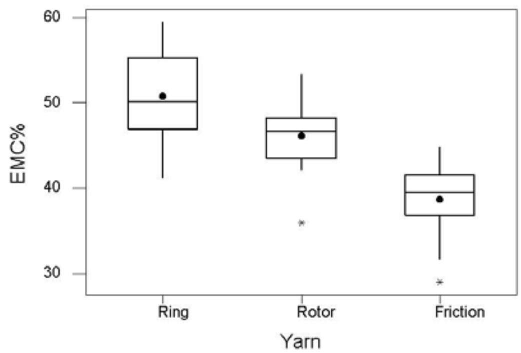

Figure 9. Thickness Compression, EMC% of Cotton Yarns.

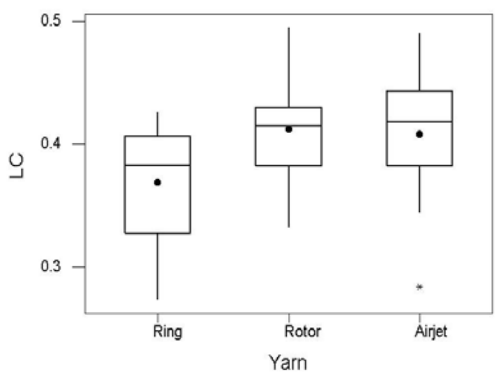

Figure 10. Compression Linearity, LC of P/C Yarns.

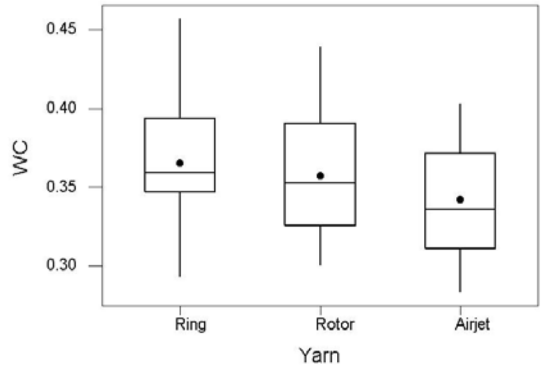

Figure 11. Compression Energy, WC of P/C Yarns.

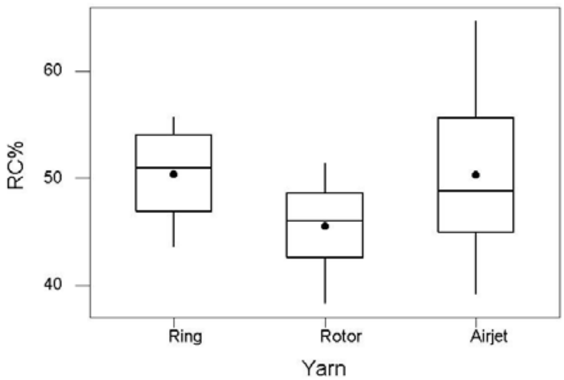

FIGURE 12. Compressive Resilie4ce, RC% of P/C Yarns.

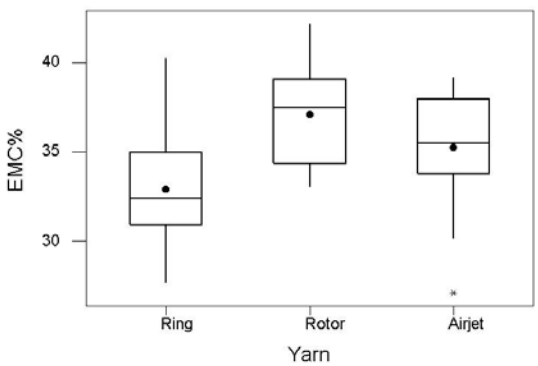

Figure 13. Thickness Compression, EMC% of P/C Yarns.