Influence of draw-off nozzle profile on bulk and related properties of acrylic-cotton OE rotor-spun yarns

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The knitting potential of acrylic-cotton OE rotor-spun yarns has been assessed. The knot strength ratio and loop strength ratio have been used as important factors in evaluating the knittability. Both the ratios increase with the increase in acrylic content and exceed the performance requirement limit for knitting. The knittability of acrylic-majority yarns is superior to that of cotton-majority yarns, although the acrylic-majority yarns are more stiffer. Additional advantages of acrylic-majority yarns are their lower twist liveliness, higher elongation, higher bulk and lower hairiness.

Keywords: Acrylic-cotton yarn, Draw-off nozzle, Flexural rigidity, Knot strength ratio, Loop strength ratio, Rotor-spun yarn, Yarn bulk

1 Introduction
The textile industry is well aware of the potential of rotor spinning. Over the recent years, it has virtually dominated the industrial scene in the coarse yarn segment and can produce the perfect yarns for knitting. Evidence of this development is provided by the knitted fabrics which are being used in a wide range of applications where the woven fabrics showed undisputed sway. In both natural and man-made fibre sectors, the rotor spinning system is perfect to spin acceptable yarns for certain applications, and the structural features of these yarns depend mainly on the properties of constituent fibres and process parameters used. It is obvious that these yarns would need different treatments during preparation process for successful knitting and also to produce good quality knits. It is, therefore, worthwhile to predict the behaviour of these yarns prior to processing and usage. A comprehensive bibliography of the considerable literature on OE rotor spinning has already been reported in the publication by Harrison*. Numerous reports have been published on the application and use of OE rotor-spun yarns during knitting**. However, not much work has been reported on the knitting potential of acrylic-cotton OE rotor-spun yarns. Trials have been conducted at TITS, Bhiwani, to ascertain this objective and the initial results obtained have already been published*. Further investigation on the assessment of knitting potential of acrylic-cotton OE rotor-spun yarns has now been carried out and the results are reported in this paper.

2 Materials and Methods
2.1 Preparation of Yarn Samples
Two sets of yarns of 29.5 and 42.2 tex were spun from blends of non-shrinkable acrylic and cotton fibres on rotor spinning machine with different twist factors ranging from 30.04 to 37.31. The fibre details are given in Table 1. The blending of acrylic and combed cotton was done in the opening room. The conversion to drawn slivers was carried out by using a MMC card and a Lakshmi Rieter's draw frame DO/6. Two drawing passages were given to card slivers. The linear density of drawn slivers was adjusted to 3 g/m. The drawn slivers were spun into yarns on Ingolstadt Rotor Spinner RU11/RU80 (4620). The machine parameters used for the spinning of rotor yarns included a 48 mm rotor running at 50,000 rpm, a saw-tooth opening roller (type of clothing, OS/21; teeth/cm², 24; and face angle, 2°).

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Table 1 — Specifications of acrylic and cotton fibres

<table>
<thead>
<tr>
<th>Fibre</th>
<th>Fibre length (mm)</th>
<th>Fibre linear density (dtex)</th>
<th>Bundle strength (g/ tex)</th>
<th>Breaking extension (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>38.0</td>
<td>1.66</td>
<td>25.3</td>
<td>33.2</td>
</tr>
<tr>
<td>Cotton</td>
<td>29.4**</td>
<td>1.59</td>
<td>22.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

**Span length, 2.5%
100°), an opening roller speed of 8000 rpm, and two draw-off nozzles—notched (exterior diam., 15.5 mm; and interior diam., 3 mm) and spiral (exterior diam., 20 mm; and interior diam., 3 mm).

2.2 Steam Relaxation Treatment

All the yarns were bulked in skein form in a laboratory strazor machine using wet steam. Skeins of 100 m were prepared on a wrap reel and laced at five points. The lacings were kept completely loose so as not to hinder the relaxation process in the yarn during shrinkage. The skeins were then hung loosely in the machine from a fabric covered stand at 102°C for 40 min and finally dried under atmospheric condition.

2.3 Test Methods

2.3.1 Tensile Properties

The yarns were tested for knot and loop strength ratios on an Instron tensile tester (Model 4411) according to BS 1932 procedure. For knot strength ratio, 60-70 m long specimen, in the middle of which a single overhand knot has been tied, was elongated until it broke and the breaking load was recorded. The knot strength ratio was then calculated as the ratio of knot breaking load to the yarn breaking load. In case of loop strength ratio, a length of the yarn from the test specimen was formed into a loop. The two ends of the yarn, close together and parallel to each other, were clamped in one jaw of the tester. A second length of the yarn was passed through the loop to form another looped length and its two ends were clamped in the other jaw so that the point of contact of the two loops is approximately midway between the gripping points. Two interlinked looped lengths of yarn were then extended until breakage of one loop occurred and the breaking load was recorded. The ratio of the loop breaking load to twice the yarn breaking load was taken as a measure of loop strength ratio.

2.3.2 Flexural Rigidity and Elastic Recovery

Yarn rigidity and elastic recovery were determined on a weighted ring yarn stiffness tester using the ring loop method. Fifty observations were made for each yarn sample.

2.3.3 Hairiness

Yarn hairiness was recorded by Zweigle hairiness meter. Forty test specimens were used for each yarn sample.

2.3.4 Yarn Bulk

Yarn diameter was determined by projection microscope and the data were used to calculate the bulk or volume of the yarns. Sixty observations were made for each yarn sample.

2.3.5 Residual Shrinkage and Snarling Twist

BSI test methods were followed for measuring the residual shrinkage and snarling twist of rotor-spun yarns. Fifty observations were made on each yarn sample for each property.

3 Results and Discussion

3.1 Effect of Process Parameters

3.1.1 Bulk

Fig. 1 shows that, in general, the most bulky yarns are those spun from the higher proportion of acrylic fibres owing to the lower specific gravity of acrylic fibre. The yarn bulk reduces when the yarn linear density is decreased and at the same time when the yarn twist is increased. The higher bulk corresponds to the spiral nozzle which produces a false twist effect. As a result, the proportion of wrapper fibres increases, which, in turn, leads to higher yarn bulk. On the other hand, the yarn bulk increases considerably after steaming process. The increase in bulk is more marked in the yarns spun with higher acrylic content. Such an increase arises due to the higher shrinkage potential of acrylic fibre (Table 2).

Fig. 1—Variation in bulk with tex twist factor [(a) notched nozzle, and (b) spiral nozzle]
3.1.2 Flexural Rigidity

Fig. 2 shows the values of flexural rigidity with respect to different process parameters. The flexural rigidity is slightly dependent on the profile of draw-off nozzle. In Fig. 2, it is clearly visible that virtually all the data for flexural rigidity relative to draw-off nozzle lie in a narrow range. The spiral nozzle yields higher flexural rigidity. The higher flexural rigidity is the outcome of the increase in the incidence of wrapper fibres due to the increased false twist, which impedes the freedom of fibre movement. Blend composition and twist factor also affect the flexural rigidity. As can be seen from Fig. 2, the values of flexural rigidity are considerably higher for acrylic-majority yarns and increase with the increase in twist factor owing to the increase in incidence of wrapper fibres. Very remarkably, the flexural rigidity values are significantly higher for coarse yarns.

3.1.3 Elastic Recovery

Fig. 3 shows that the elastic recovery is considerably higher, as expected, for coarse yarns and it increases as the acrylic content is increased. An increase in twist factor hardly affects the elastic recovery. The yarns spun with a spiral nozzle exhibit slightly lower elastic recovery due to more unfavourable formation of wrapper fibres in the yarn which leads to unequal distribution of yarn strain on fibres.

<table>
<thead>
<tr>
<th>Yarn linear density tex</th>
<th>Fibre composition (acrylic: cotton)</th>
<th>Twist factor</th>
<th>Residual shrinkage, %</th>
<th>Snarling turns/cm</th>
<th>Hairs/10m</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>30.04</td>
<td>15.83</td>
<td>1.40 (2.22)</td>
<td>652</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>33.48</td>
<td>16.46</td>
<td>1.52 (1.75)</td>
<td>538</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>37.31</td>
<td>17.23</td>
<td>1.73 (1.88)</td>
<td>487</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>30.04</td>
<td>8.53</td>
<td>1.52 (1.98)</td>
<td>673</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>33.48</td>
<td>9.24</td>
<td>1.60 (1.95)</td>
<td>597</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>37.31</td>
<td>10.02</td>
<td>1.75 (1.74)</td>
<td>532</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>30.04</td>
<td>4.47</td>
<td>1.76 (1.73)</td>
<td>608</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>33.48</td>
<td>5.29</td>
<td>1.92 (1.49)</td>
<td>688</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>37.31</td>
<td>6.15</td>
<td>2.14 (2.11)</td>
<td>672</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>30.04</td>
<td>9.54</td>
<td>1.39 (2.10)</td>
<td>784</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>33.48</td>
<td>10.86</td>
<td>1.52 (1.55)</td>
<td>703</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>37.31</td>
<td>12.27</td>
<td>1.60 (2.50)</td>
<td>599</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>30.04</td>
<td>5.24</td>
<td>1.72 (2.08)</td>
<td>903</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>33.48</td>
<td>6.32</td>
<td>1.87 (2.04)</td>
<td>814</td>
</tr>
<tr>
<td>29.5</td>
<td>100:0</td>
<td>37.31</td>
<td>7.53</td>
<td>2.00 (1.78)</td>
<td>747</td>
</tr>
</tbody>
</table>

Table 2—Influence of fibre composition, twist factor and draw-off nozzle type on residual shrinkage, snarling tendency and hairiness of acrylic-cotton OE rotor-spun yarns

Values in parentheses indicate CV %.
along its length and thus show the loss in elastic recovery.

3.1.4 Snarling Tendency

Snarling tendency is an index of the liveliness of a yarn and is of marked significance to downstream processing. A low snarling tendency is desirable in the knitting as well as in the preparation processes of weaving if problems of structural instability against extension, spirality and mottled appearance of fabrics are to be avoided. Results for the snarling twist of acrylic-cotton OE rotor yarns with varying blend ratios and twist factors are shown in Table 2. It is found that the snarling tendency of cotton-majority yarns is considerably higher than that of the equivalent yarns spun from all acrylic and 70:30 acrylic-cotton blends. As a consequence of the higher content of short fibres in 30:70 acrylic-cotton blends, fewer bellybands are formed in the rotor spinning process, which result in a higher snarling tendency. Variation in the draw-off nozzle has little effect on the snarling twist of acrylic-cotton rotor yarns, although the yarns produced with spiral nozzle are slightly less prone to snarling. For all the yarns, the snarling tendency generally increases with the increase in twist factor.

3.1.5 Hairiness

The average hairiness of yarns spun from 100:0, 70:30 and 30:70 acrylic-cotton blends in respect of twist factor and draw-off nozzle is given in Table 2. Expectedly, the yarns spun from acrylic-majority blends are relatively less hairy than the yarns made from higher cotton content. The flexural rigidities of both acrylic and cotton fibres could help explain this behaviour. Also, the change of hairiness related to yarn linear density is evident in all the blends; the coarser the yarn, the higher the hairiness. Change in the draw-off nozzle also reduces both short and long hairs. The spiral nozzle produces less hairs at a constant machine twist. The higher proportion of fibre wrappings associated with spiral nozzle prevents the formation of hairs.

3.1.6 Tensile Properties

Figs 4-9 show the results of tensile test. The knot strength ratio and loop strength ratio are used to evaluate theknittability of acrylic-cotton OE rotor spun yarns. As expected, both knot and loop strength ratios are considerably lower than the yarn tenacity, and these increase with the increase in acrylic content. On the other hand, both knot and loop strength ratios
Fig. 4—Variation in tenacity with tex twist factor [(a) notched nozzle, and (b) spiral nozzle]

Fig. 5—Variation in knot strength ratio with tex twist factor [(a) notched nozzle, and (b) spiral nozzle]

Fig. 6—Variation in loop strength ratio with tex twist factor [(a) notched nozzle, and (b) spiral nozzle]

Fig. 7—Variation in breaking extension with tex twist factor [(a) notched nozzle, and (b) spiral nozzle]
decrease steadily as the twist factor is increased from 30.04 to 37.31. The effect of draw-off nozzle is along the expected lines; a spiral nozzle results in lower values of single strand, knotted and looped yarns strength, presumably due to the higher false twist effect. As the false twist is much increased, primarily due to the bigger diameter and spiral shape of the draw-off nozzle, the tying-in zone is increased in length, which, in turn, causes an increase in the incidence of wrapper fibres, leading to lower values of strength. It is also noticed that the knot strength ratio and loop strength ratio of all the yarns exceed 0.85 (Figs 5 and 6) which indicates that the acrylic-cotton OE rotor-spun yarns are suitable for knitting as both knot and loop strengths are considered important factors in determining knitability.

The breaking extension of acrylic-cotton rotor yarns varies between 6.12% and 19.66% depending upon the process parameters used. In knotted and looped specimens, the breaking extension varies from 5.94% to 18.91% and from 5.22% to 17.59% respectively. The influence of twist factor on breaking extension is similar to that on yarn tenacity. Although the spiral nozzle has little influence on the breaking extension of cotton-majority yarns, it markedly lowers the breaking extension of acrylic-majority yarns due to the increase in false twist, which ultimately makes the yarn more compact. This compactness results in loss in breaking extension.

4 Conclusions

4.1 Yarn bulk and residual shrinkage are considerably higher for acrylic-majority yarns and they increase with the increase in yarn linear density. The use of higher twist factor and notched nozzle decreases the yarn bulk. However, the bulk increases considerably after steaming.

4.2 The change in yarn twist and draw-off nozzle has little influence on elastic recovery, although the yarns spun with spiral nozzle and higher twist factor are more rigid. Flexural rigidity and elastic recovery increase significantly with the increase in both acrylic content and yarn linear density.

4.3 The snarling tendency of cotton-majority yarns is higher than that of their acrylic-majority counterparts. The snarling tendency is highly dependent on the twist factor and draw-off nozzle, and the yarns produced with relatively higher twist factor and notched nozzle show higher snarling tendency.

4.4 Hairiness of acrylic-majority OE rotor yarns is considerably less than that of the cotton-majority
yarns and it further decreases significantly with the decrease in yarn linear density. An increase in twist factor also decreases the hairiness. The draw-off nozzle profile is an important factor in controlling flexural rigidity, and a higher false twist results in less hairiness.

4.5 Fibre composition, yarn linear density and draw-off nozzle have a marked influence on yarn knot and loop strength ratios. Both these characteristics register lower values when acrylic-content and yarn linear density decrease, and at the same time when the nozzle produces a false twist effect. Nevertheless, all the yarns do exhibit fairly higher values of knot strength ratio and loop strength ratio, which are important factors in their superior knitting performance.

References