Comparison of Physical and Mechanical Properties of Ring and Rotor Yarn Fabrics

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The properties of ring-spun and rotor-spun yarns and of the fabrics woven from these yarns have been compared. The greater bulk (diameter) of the rotor-spun yarn compared to ring-spun yarn resulted in greater crimp, fabric thickness, crease recovery, and air-permeability. Rotor-spun yarn fabrics possessed greater strength and lower elongation than ring-spun fabrics in spite of the lower strength and greater elongation at yarn level. Water absorption for rotor yarn was greater than for ring yarn but the rotor yarn fabrics absorbed more water than ring fabrics at greater fabric cover. Increase in twist multiplier of rotor yarn reduced its diameter and water absorption. Increase in twist multiplier of weft yarn in fabric reduced fabric thickness and water absorption but increased crease recovery and air permeability.

The importance of the rotor spinning process for cotton and its blends lies in the elimination of speed- and ring-frames and in some cases even conventional winding. The economics of this system, especially for coarse yarns, is indisputable where downtime due to doffing is considerably high. Though extensive work has been done on the yarn formation and yarn properties, not much work is reported on the properties of fabrics woven from rotor-spun yarns, except for investigations by Mohamed & Lord, Nick, and Morris & Prato. In this study a comparison is made of the properties of ring-spun and rotor-spun yarns and of the fabrics woven from these yarns.

Yarns produced from the two systems differ principally in bulk and structure. The present study is therefore aimed at making comparisons between the fabric properties as affected by these parameters.

Experimental Procedure

Materials—Yarn (20 Ne) was spun with a 4.5 twist multiplier (TM) for ring yarn on the conventional ring frame and with 5, 6 and 7 TMs for rotor-spun yarns on a BO-40 machine from the same mixing (60% J-34, 10% 320F, 20% comber waste and 10% viscose).

Plain weave fabrics were woven using (i) 4.5 TM ring yarn in warp and weft directions; and (ii) 6 TM rotor yarn in warp direction and 5, 6 and 7 TM rotor yarns respectively in the weft direction. In all, 12 different fabrics were prepared with 68 ends per in and 44, 54 and 62 picks per in. The fabrics were desized, washed and ironed for conducting the tests.

Tests—Yarn breaking strength and elongation were determined on an Uster single-yarn tester. The yarn irregularity was measured on an Uster evenness tester in terms of U%.

Yarn diameter and fabric thickness at zero load were obtained from load-compression tests on an Instron tensile tester.

The crimp of yarn in the fabric was determined by marking yarns 10 in on the fabric, removing the yarns carefully, and performing the load-elongation tests at 10 in gauge length on the Instron tensile tester. Extrapolation of the later part of load-elongation curve to zero load gives decrimping extension from which crimp can be calculated.

The crease recovery angle was measured after loading with a 2 kg weight for 3 min and allowing it to recover for 1 min.

The air-permeability at 10 mm water head was measured on a Shirley air-permeability tester.

The abrasion resistance of yarn and fabrics was studied by measuring the loss in weight of the material by abrading with a fine-grain emery paper for 40 cycles on a Martindale abrasion tester. The instrument was modified for yarn work by allowing abrasion only along the yarn axis.

The uptake of water by yarn/fabric immersed in water for 30 s and drip-dried for 2 min was found by weighing.

The load-elongation behaviour of the fabrics was determined on an Instron tensile tester.

Results and Discussion

Yarn characteristics—Table 1 gives the breaking strength, elongation, evenness, and estimated diameter from load-compression behaviour.

The rotor yarns show an increase in strength, with a
Table 1—Characteristics of Yarns

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Tex</th>
<th>Twist* multiplier</th>
<th>Breaking strength g/ tex</th>
<th>Breaking elongation, %</th>
<th>Strength CV%</th>
<th>Uster U%</th>
<th>Diameter cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ring</td>
<td>29.5</td>
<td>4.5</td>
<td>10.8</td>
<td>6.2</td>
<td>12.1</td>
<td>17.0</td>
<td>.0208</td>
</tr>
<tr>
<td>Open-end</td>
<td>29.5</td>
<td>5.0</td>
<td>8.5</td>
<td>6.4</td>
<td>11.1</td>
<td>12.1</td>
<td>.0268</td>
</tr>
<tr>
<td>Open-end</td>
<td>29.5</td>
<td>6.0</td>
<td>9.3</td>
<td>7.3</td>
<td>10.1</td>
<td>9.5</td>
<td>.0252</td>
</tr>
<tr>
<td>Open-end</td>
<td>29.5</td>
<td>7.0</td>
<td>8.5</td>
<td>5.8</td>
<td>11.9</td>
<td>11.2</td>
<td>.0211</td>
</tr>
</tbody>
</table>

*Based on cotton system.

The breaking elongation increased with increase in TM in a manner similar to that for strength and gave maximum breaking elongation for 6 TM yarn. The breaking elongation for rotor yarn was greater than that for the ring-spun yarn except for 7 TM. Increase in twist helps in increasing cohesive/lateral forces which impede inter-fibre slippage; initially twist increase helps in the extension of the fibre but excessive additions of twist may strain the fibre and reduce breaking extension.

The irregularity (U%) of rotor yarns was lower than that of ring-spun yarns, being lowest for 6 TM yarn. A better evenness of rotor yarn is obtained by the layering of fibres in the rotor. However, this results in a lower coefficient of variation of strength.

The zero-load yarn diameter for rotor yarns decreased with increase in TM but it was more than that for ring yarns. This confirmed that the rotor-spun yarns have greater bulk (up to 30%) than ring-spun yarns.

Fabric characteristics—Rotor yarn fabrics made from 6 TM weft yarn possessed yarn/fabric properties better than, or similar to, those made from 5 or 7 TM weft yarn; so a comparison of rotor yarn fabrics woven from 6 TM weft yarn was made with ring-spun yarn fabrics.

Crimp—Fig. 1 shows that rotor yarn fabrics possess more crimp in warp and weft directions than ring yarn fabrics but the difference between the crimp values for the two types of fabrics reduces at high picks per in. This might be due to greater bulk/diameter of the rotor yarn.

The weft crimp is greater than warp crimp and both of them increase with increase in picks per in. This trend is due to lower thread spacing between warp yarns; the warp threads are generally under greater tension than weft threads and therefore cause a comparatively greater bending of weft yarn in the fabric.

Fig. 2 shows that the increase of twist in the weft yarn leads to no significant change in the warp/weft crimp of the fabric.

Fabric thickness—Fig. 3 shows that the thickness of the fabric increases with increase in picks per in and the thickness of rotor yarn fabrics is greater than that of ring yarn fabrics. This is obviously due to the greater diameter and crimp of rotor yarns.

Crease recovery—Fig. 4 shows that the crease recovery angle of rotor yarn fabrics is greater than that of ring yarn fabrics and the difference between the two fabrics increases at higher picks per in. This finding does not accord with that of Lord et al.1. It is therefore suggested that greater yarn bulk, more crimp and fabric thickness tend to make rotor yarn fabric more resilient, or an energy-storing system, and thus help improve crease recovery.
Fig. 2—Effect of weft twist multiplier on crimp

Fig. 3—Effect of picks/in on thickness

The warp-way crease recovery increases and the weft-way crease recovery decreases with increase in picks per in (Fig. 4). During the creasing of warp, the yarn is bent over the weft yarn and the cross threads (wefts) displace to relieve the strain. The inter-yarn movement retards recovery because of friction. Obviously, the inter-yarn movement will decrease with increase in picks per in and could lead to storage of energy because of thread compression. The reduction in weft-way crease recovery with increase in picks per in could be explained as due to increase in the inter-yarn force and the resultant yarn movement in creasing, ultimately leading to frictional energy loss; the warp yarn movement is not affected by increase in picks per in.

Fig. 4—Effect of picks/in on crease recovery

Table 2—Air-Permeability of Fabrics (cc/s)

<table>
<thead>
<tr>
<th>Picks/in</th>
<th>Ring fabric</th>
<th>Rotor fabric with weft yarn of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 TM</td>
<td>6 TM</td>
</tr>
<tr>
<td>48</td>
<td>105</td>
<td>97</td>
</tr>
<tr>
<td>60</td>
<td>58</td>
<td>57</td>
</tr>
<tr>
<td>70</td>
<td>33</td>
<td>40</td>
</tr>
</tbody>
</table>

Air-permeability—Table 2 shows that the air-permeability of rotor yarn fabrics is greater than that of ring yarn fabrics (except at lower picks per in for 5 TM weft yarn). This agrees with the reported result1. The air-permeability of a fabric is affected by the diameter, structure, crimp and flattening of yarn in the fabric. The higher air-permeability through rotor yarn fabrics in spite of greater yarn bulk may be due to air flow through wrapper fibres and to the flexibility provided by the yarn due to higher crimp.

Air-permeability decreased for all fabrics with increase in picks per in. Rotor yarn fabrics showed more air-permeability with increase in weft TM. These results are self-explanatory.

Fabric strength and elongation—Warp-way load-elongation behaviours of rotor and ring yarn fabrics are shown in Fig. 5. It is observed that the rotor yarn fabrics have more breaking tenacity and less elongation than the ring yarn fabrics. Table 3 shows that the breaking tenacity (warp-way) of rotor yarn fabrics is statistically greater than that of ring yarn fabrics. In fact, the rotor yarn fabric prepared using 6 TM yarn, both as warp and weft, gave a higher breaking tenacity in both the directions. This result is
Table 3—Load-Elongation Properties of Fabrics

<table>
<thead>
<tr>
<th>Property</th>
<th>Picks/in</th>
<th>Ring fabric</th>
<th>5 TM</th>
<th>6 TM</th>
<th>7 TM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>W</td>
<td>F</td>
<td>W</td>
<td>F</td>
</tr>
<tr>
<td>Breaking tenacity, g/tex</td>
<td>48</td>
<td>11.2</td>
<td>15.9</td>
<td>13.6*</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>11.4</td>
<td>14.8</td>
<td>15.1*</td>
<td>15.7</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>12.0</td>
<td>15.0</td>
<td>15.9*</td>
<td>14.6</td>
</tr>
<tr>
<td>Breaking extension, %</td>
<td>48</td>
<td>31.5</td>
<td>13.5</td>
<td>24.0</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>32.0</td>
<td>16.0</td>
<td>26.0</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>32.5</td>
<td>20.0</td>
<td>24.6</td>
<td>17.0</td>
</tr>
<tr>
<td>Work of rupture, g-cm/thread</td>
<td>48</td>
<td>232</td>
<td>140</td>
<td>153</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>238</td>
<td>173</td>
<td>176</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>240</td>
<td>193</td>
<td>183</td>
<td>181</td>
</tr>
</tbody>
</table>

W, Warp; F, Weft.
*Statistically significant with respect to ring fabrics.

Fig. 5—Warp-way load-elongation behaviours of fabrics

contrary to the comparisons at yarn level and the results reported elsewhere. It is possible that the non-load-bearing wrapper fibres in the rotor yarn get trapped in the fabric structure and contribute to strength and elongation. This is an important finding, though at variance with earlier findings.

With increase in picks per in, the fabric tenacity increased in the warp direction but decreased in the weft direction. These changes are of greater magnitude in the case of rotor yarn fabrics.

These results, testifying to the principal role of fabric structure, show that the fabric assistance is greater for rotor yarn in the fabric (Table 4).

The breaking elongation and work of rupture for the ring fabrics are greater than those for the rotor yarn fabrics.

Abrasion resistance—Table 5 shows that the loss in weight due to abrasion for rotor yarns increases with increase in twist multiplier but is less than that for ring yarns. Rotor yarn fabrics, when abraded, also exhibit low weight loss over the range of picks per in studied. The abrasion resistance of fabrics improves with increase in picks per in, particularly for the ring fabrics. The superiority of rotor yarn fabrics over the ring fabrics for open construction is clear from the table.
The improved abrasion resistance of rotor yarn could be due to the wrapper fibres which have mobility on the yarn core and thus avoid abrasion with the abradent. In the fabric the wrapper fibres are trapped, and rotor yarns by flattening give a greater area of contact between the abradent and fabric and thus reduce weight loss. The improvement in abrasion resistance with increase in picks per in is well established; it is due to increased intersections.

Water uptake — The amount of water absorbed (%) by rotor yarn was maximum for 5 TM and reduced with increase in twist to a value still greater than that for ring yarn (Table 5). This demonstrates the role played by the air space (inter-fibre) within the rotor yarn.

The water absorption of rotor yarn fabrics was lower than that of ring fabrics at lower picks per in but vice versa at higher picks per in. This is another interesting role of the fabric structure. Water is absorbed by the fabric in the inter-yarn/inter-fibre spaces and by the fibre. Because of its greater bulk, the rotor yarn, presumably, covers the inter-yarn spaces intimately and affects the water absorption. For dense constructions, the inter-yarn spaces are small and water can be absorbed by direct contact with the yarn surface. Because rotor yarn has a higher surface area than ring yarn, water absorption is higher for rotor yarn fabrics. The water absorption decreased with increase in picks per in for all fabrics except rotor yarn fabrics with 6 and 7 TM weft yarn. This suggests that the water absorption by the fabric is affected by inter-yarn spaces at lower fabric cover and by inter-fibre spaces at higher fabric cover.

Conclusions

1. Rotor yarn fabrics give more fabric assistance than ring fabrics. The tensile strength of rotor yarn fabrics is better than, or comparable with, that of ring fabrics in spite of the lower strength of rotor yarns.

2. The work of rupture of ring fabrics is more than that of rotor yarn fabrics.

3. The air-permeability of rotor yarn fabrics with low TM weft yarn is comparable with that of ring fabrics. Rotor yarn fabrics with high TM weft yarn give more air-permeability than ring yarn fabrics.

4. The water uptake of rotor yarn is greater than that of ring yarn, but in fabric, only for higher picks per in, the rotor yarn absorbs more water than ring fabrics.

5. The abrasion resistance of rotor yarns is better than that of ring yarns. Rotor yarn fabrics give better abrasion resistance than ring fabrics at lower picks per in. At higher picks per in, the abrasion resistances of both fabrics improve, and the values are comparable.

References