Studies on the properties of dref-spun acrylic yarns

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The properties of dref-spun acrylic yarns having polyester, nylon and polypropylene multifilament yarns as core and of 100% acrylic yarn without core have been studied. It is observed that the tenacity and work of rupture of core-spun acrylic yarns are higher than that of 100% acrylic yarn, whereas the breaking elongation of all the yarns is more or less same. Nylon core yarn apparently exhibits slippage between sheath fibres and core during the application of tensile load. Packing coefficient values indicate that the structures of core-spun acrylic yarns are less compact than that of acrylic yarn. Introduction of core filament improves the regularity of friction-spun yarns.

Keywords: Acrylic yarn, Dref spinning, Flexural rigidity, Multifilament yarn, Nylon, Packing coefficient, Polyester, Polypropylene, Tenacity

1 Introduction
Since its advent the friction spinning has attracted, to a great extent, the textile engineers due to its very high delivery speed and soft handling of the yarn. The friction-spun yarns are bulkier than the ring- and rotor-spun yarns and the system is suitable for spinning of coarse yarns. The friction-spun yarns are very useful for terry towels, weft yarns, pile yarns, stuffer yarns, blankets, furnishings and technical textiles. The properties of friction-spun yarn, ring-spun yarn and yarns spun on other systems have been compared by some workers. Louis et al. observed that friction-spun yarns are weakest when compared with ring, rotor and dref-3 spun cotton yarns. Brockman found maximum strength in wrap spinning followed by ring, air-jet, rotor and friction spinning respectively for 20s Ne yarn made from 65:35 polyester-cotton blend. Mass irregularity of friction-spun yarn is higher than those of spun on other spinning systems. Further, the friction-spun yarns are more hairy than all other yarns. Padmanabhan and Ramakrishnan observed that the filament core dref-3 spun yarn is stronger than 100% cotton yarn and cotton-core yarn. Gebauer and Schlossarek reported the properties of dref-3 spun multicomponent polyester (Trevira) yarns where Trevira multifilament and monofilament yarns were used as core. They observed that monofilament does not serve any purpose for improving the strength of the yarn.

A disadvantage of the core yarns is that the staple fibre sheath may slip along the filament core when being pulled to pass over or rubbed by machine parts during further mechanical processing. Miao et al. studied the influence of spinning parameters on core yarn, sheath slippage and other properties. They observed that in case of dref-2 spun core yarn, a low filament pretension is preferable for spinning core yarn with good sheath slipping resistance. Twisting the filament before core yarn spinning also significantly affects the sheath slipping resistance. To increase sheath slipping resistance, the filament pre-twist should be in the same direction as the sheath twist. However, not much work has been reported in the literature on the influence of properties of filament core on the properties of core-spun dref yarn. A detailed study in this direction has become essential for maximum commercial exploitation of
potentialities for specific use of the engineered yarns.

The present work was aimed at evaluating the various properties of dref-spun 100% acrylic yarn as well as core-spun acrylic yarns. The efforts have been made to assess the influence of core filament characteristics on the physical properties of core-spun dref-2 yarn. Polyester, nylon 6 and polypropylene multifilament yarns were used as core and acrylic staple fibre as sheath material.

2 Materials and Methods

2.1 Materials

Acrylic staple fibre (1.5 denier, 51 mm length) top of 25.2 cN/tex average single fibre strength and 28% average elongation was used as sheath material.

Polyester (90 dtex, 32 filaments), nylon 6 (80 dtex, 24 filaments) and polypropylene (100 dtex, 24 filaments) textured multifilament yarns were used as core materials. The physical properties of the multifilament yarns are shown in Table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Polyester</th>
<th>Nylon 6</th>
<th>Polypropylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear density, dtex</td>
<td>90</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Tenacity, cN/tex</td>
<td>34.65</td>
<td>32.40</td>
<td>34.70</td>
</tr>
<tr>
<td>Strength CV %</td>
<td>2.32</td>
<td>11.16</td>
<td>3.53</td>
</tr>
<tr>
<td>Breaking extension %</td>
<td>21.55</td>
<td>27.34</td>
<td>39.76</td>
</tr>
<tr>
<td>Elongation at F max %</td>
<td>19.04</td>
<td>23.53</td>
<td>23.51</td>
</tr>
<tr>
<td>Specific work of rupture, m/tex - m</td>
<td>38.93</td>
<td>52.46</td>
<td>50.90</td>
</tr>
<tr>
<td>Modulus at 0.5% extension, cN/tex</td>
<td>348.80</td>
<td>460.30</td>
<td>208.00</td>
</tr>
<tr>
<td>Force decay*, %</td>
<td>20.80</td>
<td>20.30</td>
<td>30.00</td>
</tr>
</tbody>
</table>

*Force decay (%) at load equivalent to 1% extension

2.2 Methods

2.2.1 Preparation of Yarn Samples

Yarn samples were prepared on the three-headed dref-2 laboratory model spinning frame at a delivery speed of 130 m/min, inlet speed of 2.2 m/min and spinning drum speed of 3400 rpm. Four types of yarn, namely polyester-acrylic, nylon-acrylic, polypropylene-acrylic core-sheath yarns and acrylic staple fibre yarn without core, were prepared. In case of core-spun yarns, the core filament yarn was fed axially to the spinning drum through a core yarn feed system attached to the machine.

2.2.2 Evaluation of Tensile Properties

Zwick universal tensile tester was used to evaluate the tensile properties. Breaking load and breaking extension of multifilament yarns and dref yarns were measured at 300 mm/min cross-head speed with 500 mm gauge length. The average of 50 test results was taken for each sample.

For evaluation of stress-relaxation, the yarn was stretched up to 1% extension and allowed to relax for 5 min at the same condition. The percentage of force decay was calculated by the following formula:

$$\text{Stress relaxation (\%)} = \left(\frac{l_0 - l_t}{l_0}\right) \times 100$$

where \(l_0\) is the initial load on yarn at 1% extension; and \(l_t\), the load on yarn at 1% extension at time \(t\) (5 min.).

To observe the tensile behaviour of core component inside the yarn matrix of the composite yarn, the sheath fibres were removed from two ends of the yarn sample and then the bare filament core was clamped with the jaws of the tensile tester. The cross-head speed and gauge length were maintained as mentioned above.

2.2.3 Measurement of Bending Rigidity

The bending rigidity, expressed as specific flexural rigidity, was measured by the ring-loop method as suggested by Carlene 6. Ten tests were carried out for each sample. Specific flexural rigidity was determined using the following formula:

$$\text{Specific flexural rigidity} = \left\{0.0047 \ W \ (2\pi \ r)^2 \ \cos\theta / \tan\theta \right\} \ (\text{tex})^2$$

where \(W\) is the weight (mg) of rider hung to deflect the bottom loop; \(r\), the radius of ring loop; \(\theta = 493 \times d / 2\pi \ r\); and \(d\), the deflection of the bottom end of ring loop under action of load.

2.2.4 Evaluation of Packing Coefficient

Packing coefficient of dref yarns was computed from the ratio of the bulk density of yarn and fibre density. Yarns diameter was measured in projection microscope with a magnification of 40 under constant tension. Fibre density in core-spun dref yarn was calculated using the following formula:
Fibre density of core-spun yarn = \[
\frac{100}{\text{% of acrylic fibre density of acrylic fibre} + \text{% of filament density of filament}}
\]

### 2.2.5 Evaluation of Mass Irregularity and Hairiness

Uster yarn evenness tester (model UT-3) was used to evaluate yarn mass irregularity imperfections and hairiness index at a speed of 200 m/min for 2.5 min. Three tests were carried out for each sample.

### 3 Results and Discussion

#### 3.1 Effect of Physical Properties of Core Filament

##### 3.1.1 Tenacity, Elongation and Work of Rupture

Table 1 shows that the tenacity of nylon 6 filament is slightly lower than those of polyester and polypropylene. Polyester and polypropylene filaments show almost same tenacity. A similar trend is also observed in case of dref-spun yarns (Table 2).

Elongation of all the three core-spun yarns is more or less same though the three filaments show a wide variation in their elongation properties. The typical load-elongation curves for the four types of dref-spun yarn are shown in Fig. 1. It is interesting to observe that even though the tenacity of acrylic yarn without core is significantly lower than those of the other three samples, its elongation is more or less same. Fig. 1 shows that when a core-spun yarn is extended by an applied load, initially both core and sheath components share the load simultaneously. The sheath component, which consists of twisted staple fibres, is subjected to strain up to breaking point at first due to slippage between the staple fibres. As soon as the sheath component disintegrates the core element has to bear a very high load and catastrophic break occurs. Work of rupture (WOR) gives the combined effect of tenacity and breaking elongation of a yarn. Table 2 shows that WOR of

![Fig.1—Load-extension curves for various dref-spun yarns](image)

#### Table 2—Physical properties of dref-spun yarns

<table>
<thead>
<tr>
<th>Core-spun acrylic yarn</th>
<th>Polyester core</th>
<th>Nylon core</th>
<th>Polypropylene core</th>
<th>100% Acrylic yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear density, tex</td>
<td>146</td>
<td>147</td>
<td>147</td>
<td>145</td>
</tr>
<tr>
<td>Core:sheath ratio</td>
<td>6.94</td>
<td>5.95</td>
<td>7.93</td>
<td>0.100</td>
</tr>
<tr>
<td>Tenacity, cN/tex</td>
<td>7.33</td>
<td>6.98</td>
<td>7.80</td>
<td>5.65</td>
</tr>
<tr>
<td>Strength CV %</td>
<td>7.14</td>
<td>8.07</td>
<td>4.02</td>
<td>11.24</td>
</tr>
<tr>
<td>Elongation at Fmax, %</td>
<td>20.00</td>
<td>21.66</td>
<td>20.51</td>
<td>19.40</td>
</tr>
<tr>
<td>Specific work of rupture, mJ/tex</td>
<td>8.22</td>
<td>8.16</td>
<td>9.25</td>
<td>5.93</td>
</tr>
<tr>
<td>Modulus at 0.5% extension, cN/tex</td>
<td>82.20</td>
<td>42.20</td>
<td>59.90</td>
<td>33.10</td>
</tr>
<tr>
<td>% Force decay*</td>
<td>31.48</td>
<td>30.00</td>
<td>36.14</td>
<td>37.50</td>
</tr>
<tr>
<td>Specific flexural rigidity×10, mN (mm/tex)²</td>
<td>1.35</td>
<td>0.54</td>
<td>1.26</td>
<td>0.80</td>
</tr>
<tr>
<td>Packing coefficient</td>
<td>0.476</td>
<td>0.494</td>
<td>0.422</td>
<td>0.688</td>
</tr>
<tr>
<td>Mass irregularity (U/I), %</td>
<td>9.30</td>
<td>9.25</td>
<td>8.86</td>
<td>11.10</td>
</tr>
<tr>
<td>Thin places: (-50%)</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Thick places (+50%)</td>
<td>9</td>
<td>12</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Nepels (+200%)</td>
<td>53</td>
<td>68</td>
<td>55</td>
<td>41</td>
</tr>
<tr>
<td>Hairiness index</td>
<td>13.0</td>
<td>13.61</td>
<td>13.18</td>
<td>13.2</td>
</tr>
</tbody>
</table>

*Force decay (%) at load equivalent to 1% extension
core-spun yarns is much higher than that of the acrylic yarn.

3.1.2 Modulus at Initial Stage of Extension

Even though the nylon filament shows higher modulus as compared to the other two filaments before spinning, the dref-spun yarn made out of it shows much lower modulus than the other two dref-spun yarns (Table 2). It may be observed from Fig. 2 that nylon core shows frequent stick-slip effect from very initial stage of stress development during loading. The sliding of acrylic sheath fibres over nylon surface may be the reason for low initial modulus of nylon core acrylic yarn.

3.1.3 Stress Relaxation

Stress relaxation gives an indication of the dimensional stability of yarn and fabric made out of it. Acrylic yarn without core shows maximum stress relaxation (Table 2). This may be due to the poor orientation of staple fibres in the yarn matrix. On the other hand, the presence of parallel bundle of filaments which are oriented along yarn axis might have helped to reduce the extent of force decay in the core-spun yarn. The results show that the stress relaxation of core-spun yarn is directly related to the stress relaxation of filament yarn used as core. Stress relaxation is highest in case of polypropylene multifilament followed by polyester and nylon and a similar behaviour has also been observed in case of core-spun yarns. It may be assumed that at low extension, the tensile behaviour of filament yarn is a dominant factor of the stress decay of core-spun yarn. The reasons may be that when a core-spun yarn is held extended at low extension, the major amount of the stress developed in the core-spun yarn is shared by the continuous parallel filaments and at the same time the slippage of staple fibres is restricted, to some extent, by the core filament yarn as the staple fibres wrapped round the filament.

3.2 Specific Flexural Rigidity

In weaving and tufting, the yarns are generally subjected to bending through a large angle and therefore rigidity of yarn is an important factor in determining the equilibrium state of the final structure. It may be observed from Table 2 that the specific flexural rigidity of core spun yarns is apparently dependent on their initial modulus. In

Fig.2—Rupture of core filament bundle held under the jaws of the tensile tester after the removal of sheath fibres at the gripping portions. case of nylon core yarn, the specific flexural rigidity is lower than those of other two core-spun yarns. A similar trend is also observed in case of their initial modulus values. This is because of the slippage of sheath fibres on the nylon core.

3.3 Packing Coefficient

The packing of fibres in acrylic staple fibre yarn without core is denser as compared to that in core-spun yarns (Table 2). Among the three types of core-spun yarn, nylon-core yarn shows the highest value of packing coefficient followed by polyester and polypropylene core yarns, though the differences are marginal.

3.4 Yarn Mass Irregularity, Imperfections and Hairiness Index

The mass irregularity ($U_m$ %) of all the three types of dref-spun core yarn is more or less similar (Table 2). No significant differences are observed in number of imperfections for the dref-spun yarns. It is also observed from Table 2 that acrylic staple fibre yarn is highly irregular as compared to core-spun yarns. This is because of more instability in yarn formation in case of acrylic yarn. Hairiness index values of all the four types of yarn are more or less same.

4 Conclusions

4.1 Tenacity and work of rupture of core-spun acrylic yarns are higher than those of acrylic yarn
without core though the breaking elongation is more or less same for all types of yarn.

4.2 Use of filament results in an increase in regularity of yarn in respect of mass irregularity and strength CV %.

4.3 Acrylic staple fibre yarn without core exhibits more compact structure as compared to core-spun acrylic yarns.

4.4 More slippage between sheath fibres and multifilament core apparently occurs when the nylon core spun yarn is subjected to tensile force.

4.5 Nylon core gives considerably lower flexural rigidity of the resultant yarn.

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References