Influence of friction ratio on quality of friction-spun yarns

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The effect of friction ratio on yarn quality has been studied for two different modes of yarn formation (DREF-II and DREF-III). It has been observed that for DREF-II yarns the tenacity follows a similar trend with friction ratio as it follows with twist for ring yarns, whereas the breaking extension tends to increase with the increase in friction ratio. However, the tenacity and breaking extension of DREF-III spun yarns remain more or less constant after an initial increase with the increase in friction ratio. Further, irrespective of friction ratio, the DREF-II yarns spun at lower delivery rates are more uniform whereas reverse is observed for DREF-III yarns.

Keywords: Acrylic yarn, DREF-II yarn, DREF-III yarn, Friction-spun yarn, Friction ratio, Yarn quality

1 Introduction

DREF-II friction-spun yarns are weaker than the equivalent ring- and rotor-spun yarns. The deficiency in strength is generally ascribed to the hooked and buckled disposition of constituent fibres, low packing and lesser degree of migration of fibres in the yarn. To overcome this weakness, DREF-III system of spinning has been developed. It produces a yarn where a parallel bundle of straight fibres, generally in excess of 50%, remains surrounded by helically wrapped sheath fibres, thus essentially producing a wrapped yarn structure. The most important parameters which would influence the strength of DREF-II and DREF-III yarns are:

- configuration and migration of fibres in DREF-II yarn, and
- the core-sheath ratio, tightness and frequency of wrapping in DREF-III yarn.

In DREF-II spinning, the way the fibres are assembled into a yarn leaves very little scope to further improve upon the configuration of fibres in it. However, the extent of migration can be expected to improve with spinning tension and friction ratio (the ratio of friction drum speed and delivery rate).

In case of DREF-III spinning, for a given core-sheath ratio, the tightness and frequency of wrapping can be easily manipulated through change in friction ratio. The role of friction ratio on strength, therefore, appears to be extremely important for both types of yarn. The present study was, therefore, aimed at investigating the role of friction ratio on yarn quality especially strength.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Acrylic fibres (1.5 denier; 51 mm length) were processed on Lakshmi Rieter blowroom line and MMC card to produce a card sliver of 3 ktex. Two drawing passages on Lakshmi Rieter DO/2S drawframe were given to the carded sliver to produce a finisher sliver of 3 ktex. A sufficient quantity of 59 tex yarn was spun using DREF-II mode of spinning by feeding 5 finisher slivers on DREF-III spinning machine. Similarly, an adequate quantity of yarn was spun using DREF-III mode of spinning, keeping the core-sheath ratio at 70 : 30. The delivery rate (100-250 m/min) and the friction drum speed (3000-5000 rpm) were varied in steps of 50 m/min and 1000 rpm respectively so as to have a wide range (1.7-7.1) of friction ratio. A
sufficient quantity of yarn was spun at all these friction ratios.

2.2 Measurement of Twist

Due to differential twist structure of friction-spun yarns it is difficult to measure yarn twist accurately. However, for comparison among the friction-spun yarns on a relative basis, the two methods, viz. detwist-retwist and twist to break, were employed for measuring yarn twist by Eureka single yarn twist tester.

2.2.1 Detwist - Retwist Method

The yarn samples of 10 in. standard length were detwisted by adding twist in the opposite direction so that the length of the yarn segment got extended. Twisting in the opposite direction was continued till the original length of 10 in. was again achieved due to contraction. The turns/in. was directly read from the counter dial of the instrument.

2.2.2 Twist to Break Method

The yarn samples of 10 in. standard length were twisted in the direction of original twist. Twisting was continued till the break and the number of turns required to break the yarn (N₁) was noted from the dial of the instrument. The test was repeated but this time twisting in a direction opposite to the direction of original twist and again the number of turns required to break the yarn (N₂) was noted from the dial of the instrument. The twist was then calculated by using the relationship:

\[ \text{Turns/in.} = \left( \frac{N_2 - N_1}{2} \right) \]

2.3 Measurement of Unevenness

The yarn unevenness was measured on Uster unevenness tester. The standard speeds and settings used were: Range, 100%; Material speed, 50 m/min; and Evaluation time, 2.5 min. The sensitivity levels used were: Thick places, +50%; Thin places, -50%; and Neps, +200%.

2.4 Measurement of Tensile Properties

Single yarn strength and breaking extension were measured on Instron (Model 1122) using 500 mm test length and 200 mm/min extension rate. Fifty observations were made for each sample.

2.5 Measurement of Abrasion Resistance

To have an idea of the structural integrity under repeated application of low stress, the abrasion resistance of the yarns was studied on Universal wear tester. A specimen in the form of a sheet of 40 parallel yarns (width, 1 in. and length, 9 in.) was prepared under uniform tension. The specimen was then subjected to unidirectional reciprocating flexing abrasion over a bar having specified dimensions, following the ASTM standard test method D 3885. The number of cycles required to rupture the specimen was noted.

3 Results and Discussion

3.1 Breaking Strength

Table 1 shows that the DREF-II yarn corresponding to friction ratio 4.2 is the strongest. The strength data (Fig. 1), plotted as a function of friction ratio, shows the nature of friction ratio-strength curve for DREF-II yarn to resemble twist-strength curve of ring yarn. Below and above the

<table>
<thead>
<tr>
<th>Friction ratio</th>
<th>Delivery rate (m/min)/drum speed (rpm)</th>
<th>DREF-II</th>
<th>DREF-III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tenacity cN/tex</td>
<td>Breaking extension %</td>
<td>Abrasion resistance cycles</td>
</tr>
<tr>
<td>1.7</td>
<td>250/3000</td>
<td>3.95</td>
<td>10.96</td>
</tr>
<tr>
<td>2.1</td>
<td>200/3000</td>
<td>7.19</td>
<td>15.54</td>
</tr>
<tr>
<td>2.3</td>
<td>250/4000</td>
<td>6.06</td>
<td>14.34</td>
</tr>
<tr>
<td>2.8</td>
<td>150/3000</td>
<td>9.49</td>
<td>17.77</td>
</tr>
<tr>
<td>2.8</td>
<td>200/4000</td>
<td>7.05</td>
<td>15.83</td>
</tr>
<tr>
<td>2.8</td>
<td>250/5000</td>
<td>6.67</td>
<td>14.54</td>
</tr>
<tr>
<td>3.5</td>
<td>200/5000</td>
<td>7.66</td>
<td>15.89</td>
</tr>
<tr>
<td>3.8</td>
<td>150/4000</td>
<td>8.64</td>
<td>17.61</td>
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<tr>
<td>4.2</td>
<td>100/3000</td>
<td>11.51</td>
<td>21.63</td>
</tr>
<tr>
<td>4.7</td>
<td>150/5000</td>
<td>8.33</td>
<td>17.01</td>
</tr>
<tr>
<td>5.7</td>
<td>100/4000</td>
<td>10.24</td>
<td>23.10</td>
</tr>
<tr>
<td>7.1</td>
<td>100/5000</td>
<td>8.39</td>
<td>21.14</td>
</tr>
</tbody>
</table>
optimum value (4.2 - 5.7) of friction ratio, the tenacity of DREF-II yarn shows a declining trend. For DREF-III yarn, the tenacity hardly changes with friction ratio and at friction ratio 2.1 and more, it is much above the tenacity of corresponding DREF-II yarns. It was practically impossible to spin a yarn at friction ratio of 1.7 when frequent interruption of spinning was observed and the yarn spun was found to be extremely weak (tenacity, 3.3 cN/tex). It may, therefore, be said that the tenacity of DREF-II yarns is more sensitive to friction ratio than that of DREF-III yarns. Once an adequate friction ratio is maintained that ensures uninterrupted spinning, no further gain in tenacity of DREF-III yarns is expected through manipulation of friction ratio.

To know how the yarn structure gets affected, the twist values of yarns were estimated. In case of DREF-II yarn, with the increase in friction ratio the level of twist in the yarn, estimated by both detwist-retwist and twist to break methods, increases continuously (Figs 2 and 3). Similar observations were also made by Stalder and Soliman. Friction ratio, therefore, can be considered to be equivalent to twist. The initial increase in strength with the increase in friction ratio can be ascribed to the increase in twist and probably a higher level of associated migration of fibres in the yarn structure. The decrease in strength beyond the optimum value can be attributed to the well-known obliquity effect of fibres.

For DREF-III yarn, the estimated twist (Figs 2 and 3) increases slowly at the beginning and remains more or less constant thereafter. The minimum strength at friction ratio 1.7 is probably due to the ineffective binding of surface fibres around the core (i.e. wrapping frequency below critical). As the ratio goes beyond 2.0, the binding becomes strong enough to reinforce the structure which enhances strength. Beyond the friction ratio 2.8, the reinforcement effect does not change much, as evidenced from the twist values too, thus maintaining yarn strength at a more or less constant level.
3.2 Breaking Extension

The breaking extension increases with the increase in friction ratio for DREF-II yarns (Fig. 4). For DREF-III yarns, it increases initially as the friction ratio is changed from 1.7 to 2.3 and thereafter it remains constant.

With the increase in friction ratio the helix angle of the fibres changes for DREF-II structure, as observed from the measured twist level also. This change in helical configurations of the fibres would enhance the breaking extension. In DREF-III structure, as the structural reinforcement improves with friction ratio, the breaking extension also increases since the fibres in core get extended more as they can bear more load before rupture. Once sufficient reinforcement is achieved, no further change in breaking extension is expected because of straight and parallel configurations of the majority fibres in the core. The tenacity values also show a similar trend.

3.3 Abrasion Resistance

Table 1 shows that DREF-III yarns are superior to DREF-II yarns in resistance to abrasion. For DREF-II yarns, the abrasion resistance is highest for the strongest yarn which also possesses reasonably high breaking extension. Yarns that show high breaking extension ( > 21%) also show high abrasion resistance (more than 300 cycles). It appears that the abrasion resistance is mainly decided by the level of breaking extension for DREF-II yarns. An extendable yarn can easily yield to relieve the abrasive stresses and, therefore, results in higher abrasion resistance.

In case of DREF-III yarns, since the breaking extension and tenacity levels remain more or less same except for the yarn produced at 1.7 friction ratio, not much change is observed in the abrasion resistance values of the yarns spun at different friction ratios.

3.4 Yarn Evenness

Table 2 shows that the evenness values (U%) are within a narrow range (10.0-13.6) for DREF-II yarns and that there is no correspondence between friction ratio and evenness. The lower values of U% correspond to 100-150 m/min delivery rate, and the higher values of U% correspond to 250 m/min delivery rate, irrespective of friction drum speed. Hence, evenness appears to be related to delivery rate only. At higher delivery rate, the feed rate also increases correspondingly which may result in inadequate opening of fibres by the opening rollers that run at a constant speed. Besides this, higher instability is expected during yarn formation at high delivery rates which may also result in improper integration of fibres into the yarn structure.

In case of DREF-III, a reverse trend is observed i.e. yarns are more uniform at higher delivery rates and less uniform at lower delivery rates. In this case, the regularity of core fibres which constitute 70% yarn is most important to affect the uniformity of final structure. At higher delivery rate, due to the higher inertia effects, as proposed
by Krause and Soliman\textsuperscript{10}, the irregularity generated by drafting system-I (apron drafting system) will be less and its reflection is observed in the final yarn since core constitutes a major part of the structure.

4 Conclusions

4.1 The tenacity of DREF-II yarns initially increases with the increase in friction ratio, reaches its optimum value (4.2 - 5.7) and then shows a decreasing trend, thereby resembling classical twist-strength curve associated with ring yarns. However, for DREF-III yarns, the strength remains more or less constant with the increase in friction ratio.

4.2 The breaking extension increases with the increase in friction ratio for DREF-II yarns, whereas it remains constant after an initial increase for DREF-III spun yarns.

4.3 DREF-III yarns are superior to DREF-II yarns in abrasion resistance.

4.4 Yarn evenness does not seem to have any correspondence with friction ratio. DREF-II yarns spun at lower delivery rates are more uniform. However, a reverse trend is observed for DREF-III yarns.

4.5 DREF-III yarns appear to be less sensitive to change in friction ratio than the DREF-II yarns.

References