Effect of friction drum speed and yarn delivery rate combination for a constant friction ratio on quality of friction-spun yarns

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Received 29 August 2000; accepted 17 October 2000

For a constant friction ratio, the combination of friction drum speed and yarn delivery rate significantly affect the quality of friction-spun yarns. The increase in combination values, in general, deteriorates the quality of DREF-II yarns in respect of tenacity, breaking extension, abrasion resistance and unevenness. However, in case of DREF-III yarns, these characteristics show an improvement when drum speed and delivery rate are proportionately increased to maintain the given constant friction ratio.

Keywords : Acrylic yarn, DREF-II yarn, DREF-III yarn, Friction drum speed, Friction-spun yarn, Friction ratio, Yarn delivery rate, Yarn quality

1 Introduction
Friction drum speed and yarn delivery rate are two important machine parameters in friction spinning. The influence of friction drum speed and yarn delivery rate on yarn characteristics has been studied separately and in combination (friction ratio) by a number of authors[1-10]. However, such information with regard to their combination at constant friction ratio is inadequate. In the present paper, which is in fact a supplement to our earlier paper[1], the effect of friction drum speed and yarn delivery rate combination at constant friction ratio on characteristics of both DREF-II and DREF-III friction-spun yarns has been studied.

2 Materials and Methods
2.1 Preparation of Yarn Samples
Acrylic fibres of 51 mm length and 1.67 dtex fineness were processed on Lakshmi Rieter blowroom line and MMC card to produce a card sliver of 3 ktx. Two drawing passages on Lakshmi Rieter DO/2S drawframe were given to the carded sliver to produce a finisher sliver of 3 ktx. Sufficient quantity of 59 tex yarn was spun using DREF-III mode of spinning, keeping the core-sheath ratio at 70:30. Similarly, adequate quantity of yarn was spun using DREF-II mode of spinning on the same DREF-III spinning machine by feeding 5 finisher slivers to the pair of opening rollers in drafting unit-II and making the apron drafting system (drafting unit-I) inoperative.

The friction drum speed (3000-5000 rpm) and the delivery rate (150-250 m/min) were varied in steps of 1000 rpm and 50 m/min respectively so as to have three different combinations, viz. 3000/150, 4000/200 and 5000/250, for a constant friction ratio of 2.8 as shown in Table 1. Sufficient quantity of yarn was spun at all the three combinations.

2.2 Test Methods
All the yarn samples were tested for single yarn

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| Drum speed, rpm | Delivery rate, m/min | Friction ratio |
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strength and breaking extension on an Instron tensile tester (Model 1122) using 500 mm test length and 200 mm/min extension rate. At least, fifty observations were made for each sample. The abrasion resistance of the yarns was measured on Universal wear tester. A specimen in the form of a sheet of 40 parallel yarns (25 mm wide and 230 mm long) 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 observed. The results were averaged over ten observations. Yarn unevenness was measured on Uster evenness tester with a material speed of 50 m/min and evaluation time of 2.5 min. Since the actual twist of friction-spun yarn cannot be measured easily and accurately, the apparent twist of all the yarn samples was measured by detwist-retwist and twist-to-break methods using Eureka single yarn twist tester. The number of observations was 30 or more in each case. This number was higher than that required for 95% probability level with 5% error of estimation.

3 Results and Discussion

3.1 Breaking Strength

The breaking strength of different yarn samples is given in Table 2. It is interesting to observe that DREF-II friction yarns spun at the same friction ratio (2.8) but with different combinations of delivery rate and drum speed exhibit significantly lower tenacity values when spun with a higher drum speed and delivery rate. However, in case of DREF-III yarns the reverse is observed (Fig. 1). For the same friction ratio, the apparent twist estimated to know structural effects decreases for both types of yarns (Fig. 2) at higher values of drum speed and delivery rate combination.

In DREF-II system, the increase in drum speed and delivery rate shows opposing effect on yarn twist. At higher drum speed, more number of turns are received by the yarn body due to the higher rotational speed of the fibre sleeve, thus increasing the twist. However, a higher rotational speed would tend to increase the sleeve diameter, thus reducing the rate of twist insertion to some extent. On the other hand, higher delivery rate results in lower yarn twist due to the reduced time of residence for the fibres to get twisted at the nip of friction drums. Putting it in another way, a given number of turns in a unit time are taken up by the greater length of yarn. Possibly, the fibre sleeve also expands due to the greater stiffness of bigger fibre aggregates owing to the less fibre opening or opening.

<table>
<thead>
<tr>
<th>Yarn</th>
<th>Drum speed, rpm/Delivery rate, m/min</th>
<th>Tenacity, cN/tex</th>
<th>Breaking extension, %</th>
<th>Abrasion resistance cycles</th>
<th>Unevenness, U%</th>
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<tbody>
<tr>
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<td>3000/150</td>
<td>9.49</td>
<td>17.77</td>
<td>172</td>
<td>10.07</td>
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<td></td>
<td>4000/200</td>
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<td>15.83</td>
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<td>11.15</td>
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<td></td>
<td>5000/250</td>
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Fig. 1—Influence of drum speed and delivery rate combination for a constant friction ratio on tenacity of friction-spun yarns (a) DREF-II and (b) DREF-III.

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Table 2—Influence of drum speed and delivery rate combination at constant friction ratio on tenacity, breaking extension, abrasion resistance and unevenness of friction-spun yarns (Yarn linear density, 59 tex; and constant friction ratio, 2.8)

A specimen in the form of a sheet of 40 parallel yarns (25 mm wide and 230 mm long) 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 observed. The results were averaged over ten observations. Yarn unevenness was measured on Uster evenness tester with a material speed of 50 m/min and evaluation time of 2.5 min. Since the actual twist of friction-spun yarn cannot be measured easily and accurately, the apparent twist of all the yarn samples was measured by detwist-retwist and twist-to-break methods using Eureka single yarn twist tester. The number of observations was 30 or more in each case. This number was higher than that required for 95% probability level with 5% error of estimation.

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Fig. 2—Influence of drum speed and delivery rate combination for a constant friction ratio on estimated twist of friction-spun yarns (a) DREF-II and (b) DREF-III

separation at higher input speeds. It appears, therefore, that the delivery rate plays a dominant role in comparison to drum speed. This explains the decrease in twist and consequently the yarn tenacity when the drum speed and delivery rate are proportionately increased for a given constant friction ratio. One can also observe from the results of DREF-II yarns as shown in earlier publication\(^1\) that the twist, in general, increases by only 10-20\% with the increase in drum speed of 1000 rpm (141 m/min) whereas the increase of only 50 m/min in delivery rate causes the twist to drop by 20-40\%.

The decrease in twist at higher delivery rate and drum speed (Fig. 2) seems to be at variance with the increase in tenacity. This can be explained by considering the sheath-core interaction. The tensile strength of DREF-III yarns, for a given core-sheath ratio, depends on the effectiveness of wrappings made by the sheath fibres over the core. It may be observed that the direction of movement of the two fibre streams, viz. core and sheath, before joining at the nip of friction drums is perpendicular to each other. Had the core been stationary, the sheath fibres would have wrapped over it at an angle of 90° which results in less wrapped-in length. The movement of core fibres along the yarn axis reduces the wrapping angle of the sheath fibres, thereby increasing the winding pitch, wrapped-in length and probably the wrapping pressure over the core cross-section, making the wrappings more effective as has also been shown by a number of authors\(^{11-13}\) in case of air-jet spun yarns. Since in DREF-III system, the speed of core fibres is almost the same as the yarn delivery rate, an increase in the yarn delivery rate would decrease the twist angle of sheath fibres, resulting in uniform distribution of increased wrapping pressure over a longer length and hence increase in yarn strength. The decrease in fibre helix angle with the increase in delivery rate has also been reported by Alagha et al.\(^6\) for OE friction-spun yarns.

3.2 Breaking Extension

Fig. 3 shows that for a constant friction ratio, an increase in the delivery rate with a corresponding increase in drum speed decreases the breaking extension of DREF-II yarns whereas for DREF-III yarns, it follows a similar trend as shown with the change in friction ratio\(^1\). The breaking extension increases when the drum speed and delivery rate combination is changed from 3000/150 to 4000/200 and then remains constant with the further increase in combination values to 5000/250.

For DREF-II structure, the changes in helix angle of the fibres with the change in drum speed and delivery rate combination, as shown by the measured twist (Fig. 2), account for the higher breaking extension of the yarns spun at low drum speed and delivery rate in the combination for a constant friction ratio. In a DREF-III structure, the improvement in
structural reinforcement increases the breaking extension as more fibres in the core get extended before rupture. Once the sufficient reinforcement is achieved, not much change in breaking extension is expected. The increased breaking extension at higher combination values of delivery rate and drum speed for a constant friction ratio can also be attributed to the better reinforcement of core fibres due to the reasons given earlier.

3.3 Abrasion Resistance

Table 2 shows that the variation in drum speed and delivery rate combination for a constant friction ratio has a considerable effect on the abrasion resistance of friction-spun yarns. Lower values of drum speed and delivery rate combination result in maximum resistance to abrasion for DREF-II yarns whereas for DREF-III structure, a reverse trend is observed, i.e., yarns spun at higher values of drum speed and delivery rate exhibit more number of cycles to rupture the specimen (Fig. 4).

The abrasion resistance of friction-spun yarns is mainly decided by the level of tenacity and breaking extension. A stronger and more extendable yarn can easily yield to relieve the abrasive stress, leading to higher abrasion resistance. The differences in abrasion resistance of the yarns spun at the same friction ratio but with different combinations of delivery rate and drum speed may also be explained on the basis of their breaking extension and tenacity values.

3.4 Yarn Unevenness

Table 2 shows the influence of drum speed and delivery rate combination on the unevenness of both DREF-II and DREF-III friction-spun yarns. Like other characteristics, unevenness also exhibits opposite trends for the two types of friction yarns. It increases for DREF-II yarns while decreases for DREF-III yarns (Fig. 5) when the friction drum speed and yarn delivery rates are simultaneously increased to maintain a constant friction ratio.

For DREF-II yarns, the increase in unevenness may be because of the following two reasons: the inadequate opening of fibres by the opening rollers at higher feed rate and the improper integration of fibres into yarn during yarn formation at higher delivery rate. The increased uniformity of DREF-III yarns at higher values of drum speed and delivery rate for a constant friction ratio can be attributed to the increased regularity of core as a result of lesser irregularity generated by the drafting system-I (apron drafting system) due to the higher inertia effect proposed by Krause and Soliman.

4 Conclusions

4.1 For the same friction ratio, the tenacity decreases with the increase in drum speed and corresponding delivery rate for DREF-II yarn but it increases for DREF-III yarns.

4.2 An increase in drum speed and delivery rate combination for a constant friction ratio results in lower breaking extension of DREF-II yarns but the breaking extension remains constant for DREF-III yarns, except for an initial increase.
4.3 Abrasion resistance of DREF-II yarns is maximum at the lowest values of drum speed and delivery rate combination for a given constant friction ratio while that of DREF-III yarns improves as the friction drum speed and yarn delivery rate increase to maintain the constant friction ratio.

4.4 In general, the unevenness increases for DREF-II yarns but it decreases for DREF-III yarns when the friction drum speed and yarn delivery rates are simultaneously increased to maintain a constant friction ratio.

References