Influence of spin finish and opening roller speed on the characteristics of OE friction-spun acrylic yarns

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The influence of composition and level of spin finish and of opening roller speed on the characteristics of OE friction-spun yarns spun from acrylic fibres has been studied. It is observed that a change in composition or level of spin finish significantly affects the yarn twist, tenacity, mass irregularity, abrasion resistance and flexural rigidity. An increase in opening roller speed significantly increases the breaking extension but does not cause any systematic variation in other yarn characteristics except the mass irregularity and flexural rigidity, which show an initial decrease followed by an increase with the increase in opening roller speed.

Keywords : Acrylic yarn, DREF-II yarn, Fibre friction, Friction-spun yarn, Opening roller speed, Spin finish

1 Introduction

The processing behaviour of fibres during different stages of yarn formation largely depends on their surface characteristics. These characteristics are, therefore, of prime importance in a spinning system and friction spinning is no exception to it. Moreover, in friction spinning, twist is generated through frictional contact between fibre assembly and drum surfaces. Hence, higher fibre-to-metal friction and fibre-to-fibre friction are desired for getting a higher twist level and inter-fibre cohesion. However, a higher inter-fibre friction may adversely affect the performance of opening roller in fibre individualization. Further, more opening roller wrap-ups are encountered when a fibre contains a high lubricant level, while too low a lubricant level causes static problems at carding1. One will, therefore, have to be very careful in optimizing the frictional properties of fibres.

In the case of natural fibres, the inherent fibre properties are generally accepted as such while in the case of man-made fibres, there is an immense choice. As it is well known, a spin finish is applied during fibre manufacture. The ingredients and their proportion may vary depending on the type of fibre used and the requirements for processing. However, to improve the processability, it is recommended to use additional finish (some effective antistatic agent and lubricant) on the fibres during stacking. This may modify the fibre friction and may influence the fibre opening efficiency and rate of twist insertion in friction spinning system. Most of the published work on friction spinning is concentrated on the complex mechanism of yarn formation5-11 and its comparison with other systems12-17 while a few papers deal with the influence of process variables on the resultant yarn characteristics18-20. Although these studies do emphasize on fibre frictional properties, no data regarding the changes in fibre finish characteristics are reported so far21-22. The present work was, therefore, aimed at studying the influence of spin finish (a term used to denote added fibre finish during stacking) and opening roller speed on yarn twist and other characteristics of OE friction-spun acrylic yarns.
2 Materials and Methods

2.1 Preparation of Yarn Samples

LV40 and 2152P, widely used in the spinning mills, were mixed in three different proportions, viz. 100:0, 75:25 and 50:50, to get three different compositions of spin finish. Each of these compositions, after dissolving in a fixed quantity of water (4% over the weight of fibres), was sprayed as uniformly as possible on nine batches (5 kg each) of the acrylic fibres (51 mm, 1.67 dtex) at three different levels of 0.2%, 0.4% and 0.6% (owf). All the samples were processed on an MMC card and a Lakshmi Rieter DO/2S drawframe. Three drawing passages were given to the carded slivers and the linear density of drawn slivers was adjusted at 3 ktx. The drawn slivers were then spun into friction yarns of 98.4 tex on DREF-II spinning machine. The spinning particulars are given in Table 1.

2.2 Measurement of Coefficients of Friction

The coefficients of fibre-to-fibre and fibre-to-metal frictions were measured on an Instron tensile tester by using an extra attachment fabricated by Sengupta et al. Two fibre fringes with a uniform density of 5 mg/cm², as suggested by Lord, were placed one above the other and then a known weight of 40 g was placed on these fringes. The top fringe was attached to the load cell of the Instron by an inextensible cord through frictionless pulley. As the cross-head was made to move, the maximum frictional force developed between the fibre fringes at the point of slippage was recorded by the Instron. For measuring the fibre-to-metal friction, a single fringe was made to rest over a bare metal plate and the same operation was repeated to record the maximum resisting force at the time of slippage. From the values obtained, the coefficients of fibre-to-fibre and fibre-to-metal frictions were calculated using the Amontons' Law.

2.3 Measurement of Yarn Twist

Actual twist of OE friction-spun yarns cannot be measured easily and accurately due to their inhomogeneous twist structure. However, the apparent twist estimated by the commonly used laboratory methods can be used on a relative basis for comparison. This apparent twist of all the yarn samples was measured by detwist-retwist and twist-to-break methods using Eureka single yarn twist tester.

2.3.1 Detwist-Rewist Method

For all the yarn samples, a standard length of 254 mm was taken to measure the yarn twist. A minimum of twenty observations were made for each sample.

2.3.2 Twist-to-break Method

In this method, a yarn of 254 mm length was taken and twisted in the direction of original twist in the yarn. Twisting was continued till the break and the number of turns required to break the yarn (N₁) was noted. The test was repeated but this time twisting was done in a direction opposite to that of the original twist and again the number of turns required to break the yarn (N₂) was noted. The twist was then calculated by using the following relationship:

\[ \text{Twists/m} = (N₂ - N₁) \times 39.37 \]

2.4 Measurement of Yarn Diameter

Yarn diameter was measured using the Projectina (magnification, 28 ×). Sixty observations were made for each sample at random.

2.5 Measurement of Tensile Properties

Single yarn tenacity and breaking extension were measured on an Instron Tensile Tester (Model 4411) using 500 mm test specimen and 200 mm/min extension rate. Fifty observations were made for each sample.

2.6 Measurement of Yarn Unevenness and Imperfections

The yarn unevenness was measured on Uster Evenness Tester (UT-3) with a yarn speed of 100
m/min and evaluation time of 2 min. The sensitivity levels used were: Thick places, +50%; Thin places, -50%; and Neps, +200%.

2.7 Measurement of Abrasion Resistance
Resistance to abrasion was measured in terms of number of abrading cycles to rupture the specimen by Custom Scientific Abrasion Tester following the ASTM standard test method D 3885.

2.8 Measurement of Flexural Rigidity
Flexural rigidity was measured by using weighted ring-loop method suggested by Peirce24 and modified by Owen and Riding25.

3. Results and Discussion
Table 2 shows the changes in frictional coefficients of acrylic fibres with respect to the composition and level of spin finish. It is clear that 75:25 composition of LV40/2152P exhibits the highest values of fibre-to-fibre friction and fibre-to-metal friction at all levels of spin finish. The two coefficients of friction increase with an increase in the level of spin finish.

3.1 Yarn Twist
Table 3 shows the average twist values of different yarns.

<table>
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<tr>
<th>Yarn no.</th>
<th>Twist, tEx</th>
<th>Diameter, mm</th>
<th>Tenacity, g/tex</th>
<th>Breaking extension, %</th>
<th>CVa, %</th>
<th>Impediments/km</th>
<th>Abrasion resistance cycles, %</th>
<th>Flexural rigidity, mN-mm/m</th>
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<td>(7.43)</td>
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</table>

Values in parentheses indicate CV %
yarn samples when tested by detwist-retwist and twist-to-break methods. It is observed from Fig. 1 that for both the methods, 75:25 LV40/2152P spin finish yields the maximum yarn twist, and there occurs a marginal increase followed by a significant decrease in the apparent twist of OE friction-spun yarns with an increase in the level of spin finish, irrespective of composition of spin finish. The decrease in twist values has been found to be significant at both 1% and 5% levels of significance. An increase in opening roller speed also results in a slight increase in twist followed by a significant decrease in all the cases except at low level of spin finish (0.2%) where the twist increases continuously (Fig. 2).

In friction spinning, the amount of twist inserted in the yarn depends on the yarn delivery rate and the diameter of the fibre sleeve formed at the nip of the friction drums. In the present study, the yarn delivery rate was kept constant at 130 m/min while the diameter of fibre sleeve was influenced by, apart from the other factors, the stiffness of the fibrous material and the coefficient of friction between the drum and fibrous sleeve. With a higher friction between the two, i.e. larger coefficient of fibre-to-metal friction, the sleeve is pressed into the wedge or nip of the friction drums with a higher force, resulting in a smaller sleeve. On the other hand, poor fibre individualization, as a result of increased fibre-to-fibre friction, is expected to lead to a bigger fibre sleeve due to the higher stiffness of the larger fibre aggregates. The higher fibre-to-metal friction would increase the twist while the higher fibre-to-fibre friction would decrease it. Since both fibre-to-fibre and fibre-to-metal frictional coefficients are affected by a change in composition and level of spin finish, the effect of composition and level of spin finish is determined by the combination of these two effects. The initial increase in apparent twist with the increase in spin finish level up to 0.4% may be attributed to the increase due to the higher fibre-to-metal friction outweighing the decrease caused by the higher fibre-to-fibre friction. At higher level of spin finish (0.6%), the lower opening due to the increased inter-fibre friction may be playing a more dominant role, decreasing the yarn twist. Similar explanation may also be given for the highest twist achieved in case of 75:25 LV40/2152P spin finish.

In the case of opening roller speed, the continuous increase in yarn twist for low level of spin finish may be due to the better fibre opening at higher speeds, resulting in smaller sleeve diameter. While in case of higher fibre-to-fibre friction brought about by the increased level of spin finish (beyond 0.2%), an increase in the opening roller speed beyond 3400 rpm results in the irregular fibre opening accompanied by excessive fibre damage and poor fibre alignment. Consequently, the frictional conditions at the surface of friction drums change and may be responsible for the decrease in yarn twist.
3.2 Tenacity
The tenacity values of yarns spun at different levels of opening roller speed and spin finish with different compositions are shown in Table 3. The weakness in strength of OE DREF-II friction-spun yarns is quite evident from the results. Yarn tenacity varies within a narrow range of 5-6 g/tex for different spinning conditions. An increase in inter-fibre friction, by any means, is expected to increase the yarn strength. Contrary to this expectation, an increase in the spin finish level lowers the strength, the lowest yarn tenacity being observed at 0.4% level (Fig. 3). Moreover, comparatively stronger yarns are produced with a spin finish containing 50% LV40 and 50% 2152P instead of 75:25 (LV40/2152P) combination which has the maximum inter-fibre friction (Table 2). Such a trend is probably associated with the obliquity effect of the fibres at higher values of friction ratio (5.1 in this particular study), considered to be equivalent to twist\(^{20}\). This may not be apparent from the twist values given by the detwist-retwist and twist-to-break methods. When this twist is converted to actual twist as measured by optical method using the tracer fibre technique, it is observed that at higher twist levels the actual TM is around 7.5 (ref. 27). An increase in twist increases the intensity of the aforesaid obliquity effect, causing a further deterioration in yarn strength while a decrease in twist favours an increase in yarn tenacity.

The effect of opening roller speed on yarn strength (Fig. 4) is not so significant as expected. The yarns spun at a lower speed of 2850 rpm exhibit somewhat lower yarn strength but an increase in opening roller speed does not show any specific trend.

3.3 Breaking Extension
The influence of spin finish level and opening roller speed on breaking extension is shown in Figs. 5 and 6 respectively. No trend is observed in relation to spin finish but there is a significant increase in the values of breaking extension with the increase in opening roller speed. This may be attributed to the fact that the fibres subjected to higher degree of bending and buckling during assemblage, as a consequence of increased decelerating forces at higher opening roller speed, tend to straighten during tensile loading.

3.4 Mass Irregularity
Mass irregularity appears to be the most affected parameter of OE friction-spun yarns by the variables
under investigation. It increases significantly with the increase in spin finish level (Table 3 and Fig. 7) and out of the three different proportions of LV40 and 2152 P, the one (75:25) which results in maximum fibre-to-fibre friction (Table 2) produces the most irregular yarn. The coefficient of mass variation attains a value as high as 22.81%. Further, as per the expectations, Table 3 and Fig. 8 depict a general improvement in yarn unevenness with an increase in opening roller speed up to 3400 rpm. However, the yarn unevenness deteriorates when the speed is further increased to 3800 rpm except at 0.2% spin finish level at which it continuously improves. The deterioration in yarn unevenness is obviously due to the inefficient and irregular fibre opening either due to the lower opening roller speed or the higher inter-fibre friction on one side, and the poor fibre alignment and the excessive fibre damage at higher opening roller speed on the other side. The difficulties in fibre removal from the wire points of the opening roller at too low speeds and high fibre-to-metal friction also contribute to the higher coefficient of mass variation. In relation to the influence of opening roller speed, the results of this particular study agree with the earlier findings of Lo and Cheng who observed 3400 rpm as the optimum speed for various types of friction-spun yarns.

3.5 Imperfections
The measured values of thin places (-50%), thick places (+50%) and neps (+200%) are given in Table 3. It is observed that the imperfection indices follow almost the same pattern as that of coefficient of mass variation. The imperfections achieve their lowest values at the optimum opening roller speed of 3400 rpm in case of 0.4% and 0.6% levels of spin finish. In case of 0.2% level, a speed of 3800 rpm produces the minimum number of imperfections.

3.6 Abrasion Resistance
The results of abrasion resistance (Table 3 and Fig. 9) indicate that 100% LV40 spin finish produces the yarns with the maximum resistance to abrasion, irrespective of spin finish level. However, a significant decrease in the abrasion resistance of OE DREF-II friction-spun acrylic yarns is observed with the addition of 2152 P in the spin finish and increase in the level of spin finish. This is probably associated with the coefficient of fibre-to-metal friction. A lower friction between the fibres and a metal, as in case of 100% LV40 spin finish (Table 2), decreases the intensity of transmission of frictional force from the abrading surface to the fibres which decreases the rate of wear, thus improving the abrasion resistance. As the frictional coefficient of fibre and metal increases with the increase in spin finish level, the transmission of friction force improves and predominates over the concomitant increase in inter-fibre cohesion which resists the ejection of fibres from the yarn body during abrasion, thereby lowering the abrasion resistance.
3.7 Flexural Rigidity

Table 3 shows that the flexural rigidity is significantly affected by the opening roller speed and composition and level of spin finish. It decreases initially and then increases with the increase in spin finish level and opening roller speed. However, a decrease in the concentration of LV40 from 100% to 50% in the spin finish shows just the opposite trend, displaying maximum rigidity at 75% level. This is obviously due to the restricted freedom of fibre movement during bending as a consequence of increased inter-fibre cohesion at higher friction coefficient of single fibres.

Fig. 11 shows the lowest flexural rigidity at 0.4% level of spin finish while the corresponding lowest in relation to opening roller speed (Fig. 12) is at 3400 rpm which incidentally is also the optimum speed for various other characteristics of OE friction-spun acrylic yarns.

Flexural rigidity has also a close association with the yarn geometry. As a result of this, a higher twist in the yarn may result in a lower flexural rigidity in spite of the lower degree of freedom of fibre movement as described by Backer. The variation in flexural rigidity as shown in Figs. 11 and 12 can thus be explained on the basis of variations in yarn twist occurring as a result of increase in spin finish level and opening roller speed (Figs. 1 and 2). The corresponding changes in yarn diameter (Table 3) combined with fibre alignment may explain the trend in flexural rigidity at different levels of spin finish and opening roller speed.

4 Conclusions

4.1 The apparent yarn twist of OE friction-spun yarns changes appreciably with the change in composition and level of spin finish. On the other hand, an increase in opening roller speed shows different trends for yarn twist at different levels of spin finish.

4.2 A 50% concentration of 2152P in the spin finish produces comparatively stronger yarns in OE friction spinning system. However, the tenacity of OE DREF-II yarns show a decreasing trend as the spin finish level is increased from 0.2% to 0.4% followed by an increase with the further increase in level of spin finish. The influence of opening roller speed on yarn strength is not so significant.

4.3 In DREF-II yarns, the breaking extension does not show any definite trend with the change in composition or level of spin finish but it increases significantly with the increase in opening roller speed.

4.4 Among the different compositions of LV40/2152P spin finish, 75:25 LV40/2152P displays the maximum unevenness and imperfections for OE DREF-II friction-spun yarns. The irregularity increases with the increase in level of spin finish. There
is an improvement in the yarn evenness accompanied by decrease in imperfection levels with an increase in opening roller speed up to its optimum level (3400 rpm). The unevenness deteriorates beyond the optimum level of opening roller speed for most of the friction-spun yarns.

4.5 Increase in the proportion of 2152P in spin finish and that in the level of spin finish considerably decreases the abrasion resistance.

4.6 Change in opening roller speed does not show any systematic variation in the number of cycles to abrade.

4.7 Flexural rigidity is significantly affected by the opening roller speed and composition and level of spin finish. It decreases initially and then increases with the increase in spin finish level from 0.2% to 0.6% and opening roller speed from 2850 rpm to 3800 rpm. However, a decrease in the proportion of LV40 from 100% to 50% in the spin finish shows just the opposite trend.

References