Influence of core-sheath ratio and core type on DREF-III friction-spun core yarns

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Received 9 August 1999; revised received 3 November 1999; accepted 16 December 1999

DREF-III friction-spun core yarns have been produced by wrapping a fibrous sheath of viscose rayon fibres around three different polyester cores, viz. fibrous bundle, twisted fibre assembly with Z and S directions, and continuous multifilament yarn, at varying level of core-sheath ratio. It has been observed that the yarn tenacity, breaking extension and the resistance to abrasion increase with the increase in the proportion of core fibres up to 70%, irrespective of the core type, but the sheath-slipping resistance, in general, improves with the increase in sheath content. Further, Z-twisted fibrous core produces strongest yarn with comparable sheath-slipping resistance while the yarns spun with multifilament exhibit highest breaking extension and resistance to abrasion. The introduction of normal parallel fibres as core shows an increased sheath-slipping resistance for DREF-III friction-spun core yarns. Core contents as well as type of core do not show any relationship with yarn unevenness.

Keywords: Abrasion resistance, Core-spun yarn, DREF-spun yarn, Friction spinning, Polyester/viscose yarn, Sheath-slipping resistance, Yarn twist

1 Introduction

Core-spun yarns have the advantage of covering the continuous filament component (like polyester or nylon) by staple fibres. This confers them a spun yarn look with desirable surface characteristics such as easy-care and comfort. The core-spun yarns are also suitable for a variety of industrial applications. Although the core-coverage and the sheath strip resistance of the conventional core yarns have been less than the desirable and the outer sheath of staple fibres can slip due to abrasion during their subsequent mechanical processing and end-use applications, the core spinning has been the subject of many studies. These studies show a number of different methods of filament-core yarn production and also list the properties and applications of core yarns. Recently, cotton-wrapped staple-core and filament-core yarns of reportedly much improved core-coverage, strip-resistance, hand and bulk have been developed and patented by U S Department of Agriculture. These yarns have been reported to exhibit 95% core coverage and an excellent strip resistance (almost no skinning tendency or dislodging of sheath from core), which essentially are the two most important parameters or properties of any core yarn.

The commercial introduction of friction-spinning technology by Dr Ernst Fehrer in the seventies has renewed the interest of the research workers in core yarns. In common with other systems of core-yarn production, DREF-II is capable of producing filament core-spun yarns. In DREF-III friction spinning system, besides the continuous filament, staple fibres can also be introduced in the core by feeding a sliver to the apron drafting system provided on the machine. In addition, the core and sheath elements can be independently controlled to allow the selective combination and placement of different materials. While a few researchers have made comparison amongst the yarns produced by the friction- spinning systems and the conventional ring- and rotor-yarns, others have compared the friction-spun yarns produced without core and with different core materials. The influences of core-sheath ratio and several process parameters on friction-spun yarn characteristics have also been
Table 1—Specifications of raw materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Length mm</th>
<th>Fineness dtex</th>
<th>No. of filaments</th>
<th>Individual filament fineness dtex</th>
<th>Tenacity cN/tex</th>
<th>Breaking extension %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscose rayon fibre</td>
<td>51</td>
<td>1.67</td>
<td>-</td>
<td>-</td>
<td>18.73</td>
<td>11.40</td>
</tr>
<tr>
<td>Polyester fibre</td>
<td>51</td>
<td>1.56</td>
<td>-</td>
<td>-</td>
<td>42.79</td>
<td>18.80</td>
</tr>
<tr>
<td>Polyester filament</td>
<td>-</td>
<td>88.89</td>
<td>34</td>
<td>2.61</td>
<td>31.43</td>
<td>24.37</td>
</tr>
</tbody>
</table>

Though the literature does cite studies concerning the influence of spinning parameters on sheath slippage besides other properties of DREF-II and DREF-III friction-spun filament-core yarns, there is hardly any study which deals with the changes occurring in the DREF-III friction-spun core yarn characteristics with a change in the type of core component. The present study aims at investigating the effect of the core type and core-sheath ratio on the characteristics of DREF-III friction-spun core yarns.

2 Materials and Methods

2.1 Materials

Polyester multifilament yarns and polyester staple fibres were chosen for core while viscose rayon fibres were selected for the sheath component. To facilitate the measurement of sheath-sliping resistance or strip resistance of core yarns, different colours were used for the core and sheath components (purple and golden respectively). The specifications of the fibres and yarns used in the study are given in Table 1.

2.2 Methods

2.2.1 Preparation of Yarn Samples

Polyester and viscose rayon fibres were processed separately through a Lakshmi Rieter blowroom line and carded on an MMC card. The card slivers were given two passages of drawing on a Lakshmi Rieter draw frame LR DO/2S model to produce finished slivers of 3.0 tex.

For the preparation of yarn to be incorporated as core, a part of the polyester sliver was converted into roving on a Texmaco Howa simplex machine. The roving was spun into yarns of different linear densities (Table 2) using the same twist factor of 2.9 but in two different twist directions, viz. Z and S, on a Texmaco ring frame. The linear density of each of these yarns was adjusted to get the desired percentage of core in the DREF-III core-spun yarn.

Twenty-four yarn samples of two different linear densities (59.0 tex and 36.9 tex) were spun on the DREF-III spinning machine using different forms of
core (drafted fibres, ring-spun yarns and multifilament yarns) and varying core-sheath ratios (Table 2). Owing to certain constraints related to spinning limitations (frequent interruptions in yarn formation process, particularly for normal drafted core), the core-sheath ratio for the three different forms of core materials could not be matched for all combinations. However, for all the yarns, five slivers of viscose rayon fibres (dyed in golden colour) were fed to opening roller drafting unit so as to form the sheath, and roller drafting unit was utilized for feeding polyester (dyed in purple colour) as core in different forms, viz. staple fibres, spun yarns and multifilament yarns. For staple fibre core, a sliver was drafted in the normal way while for spun and multifilament yarns, the feeding was done at the back of the front pair of drafting rollers. The spinning drum speed and delivery rate were maintained at constant levels of 4000 rpm and 200 m/min respectively.

2.2.2 Measurement of Breaking Strength and Elongation

Single yarn strength and elongation-at-break were measured on an Instron tensile strength tester using a gauge length of 500 mm and crosshead speed of 200 mm/min. A minimum of fifty observations were made for each sample.

2.2.3 Measurement of Sheath-slipping Resistance and Abrasion Resistance

Universal wear tester was employed for measuring sheath-slipping resistance. A 25 mm wide and 230 mm long sheet of 40 parallel yarns, prepared under uniform tension, was subjected to unidirectional reciprocating flexing abrasion over a bar having specified dimensions under the constant conditions of pressure and tension. Starting with 50 cycles of abrasion, the number of cycles was increased in steps of 50 and after each increment the specimen was examined for the removal of golden coloured sheath from the purple core surface. This was continued till no golden fibres were seen over the yarn core. Within this last range of 50 cycles and beginning with its lower limit, the specimen was tested after each increment of 10 cycles so as to get a comparatively narrow range for the number of cycles required to strip almost all the sheath fibres from the core surface. A typical photograph of a particular yarn sample showing how the yarn looks like after the complete removal of sheath fibres is shown in Fig. 1. Ten tests were made in this way and the results were averaged to express the sheath-slipping resistance within a narrow range of ten abrading cycles.

Similar tests were performed for abrasion resistance but instead of recording the number of cycles to expose the core, as described in the earlier case, the number of cycles required to cause the yarn rupture was observed following the ASTM standard test method D 3885.

2.2.4 Measurement of Yarn Unevenness and Imperfections

The yarn unevenness and imperfections were tested on Uster evenness tester at a speed of 50 m/min for a test duration of 2.5 min.

3 Results and Discussion

3.1 Yarn Tenacity

The tenacity values at different core-sheath ratios for different core types are shown in Table 3. It may be observed that the tenacity increases with the increase in core component, irrespective of the core type. However, for the yarn having drafted fibres as core, the tenacity attains a maximum at 70:30 core-sheath ratio and then decreases substantially with the further decrease in sheath fibres to 20%. The initial increase in tenacity with the increase in core content may be ascribed to the increase in the number of load bearing straight fibres; these polyester fibres in the core also happen to be the stronger ones. The decrease in strength of these yarns above 70% core content is because of the lower magnitude of transverse pressure due to inadequate number of
### Table 3—Influence of core-sheath ratio and core type on tenacity and breaking extension of DREF-III friction-spun core yarns

<table>
<thead>
<tr>
<th>Core-sheath ratio</th>
<th>Tenacity, cN/tex</th>
<th>Breaking extension, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30:70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>40:60</td>
<td>12.84</td>
<td>15.11</td>
</tr>
<tr>
<td>45:55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(18.85)</td>
<td>(7.73)</td>
</tr>
<tr>
<td>60:40</td>
<td>17.19</td>
<td>18.24</td>
</tr>
<tr>
<td></td>
<td>(9.59)</td>
<td>(7.49)</td>
</tr>
<tr>
<td>70:30</td>
<td>20.27</td>
<td>22.21</td>
</tr>
<tr>
<td></td>
<td>(9.51)</td>
<td>(5.68)</td>
</tr>
<tr>
<td>80:20</td>
<td>13.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(40.53)</td>
<td></td>
</tr>
</tbody>
</table>

*a Yarn linear density, tex. The figures in the parentheses indicate CV%.

sheath fibres which probably fail to generate sufficient inter-fibre friction and thus facilitate slippage. Such results have also been observed by other researchers. The continuous increase in tenacity of yarns having twisted or multifilament yarn in core is obviously due to the increase in the proportion of this stronger component in the yarn cross-section. The role of sheath fibres is insignificant in these cases.

It is also evident from Table 3 and Fig. 2 that for the same core-sheath ratio, the filament core produces the weakest yarns as compared to other forms of cores. This may be assigned to the lower intrinsic tenacity of the filaments forming the core (Table 1).

For the same core-sheath ratio, a comparison among the yarns having non-filament core shows that tenacity is highest for the core of Z-twisted yarn. The tenacities of the yarns having cores of drafted fibres and S-twisted yarn are close to each other. The structure of the yarn with Z-twist yarn core gets further reinforced by the Z-wrapped sheath fibres and thus can bear greater load. It should be noted that in DREF-III spinning system, when a core of Z-twist yarn is subjected to false twisting by the friction drums as it passes over them, it receives S-twist in the segment between the feed rollers and friction drums and thus it untwists or opens out. The extent of such opening will depend upon the difference between the original Z-twist in yarn and the S-twist generated by the false twisting action of the friction drums. When such a structure is introduced in the core, better reinforcement of core and sheath is expected as the core yarn regains its Z-twist.

With S-twisted yarn in the core, the sheath and the core having opposite twist directions will decrease the reinforcing effect, as expected had they been in the same direction. This is because when such a structure is extended, the tangential stress development in the fibres will have opposite sense in sheath and core. The sheath fibres are also likely to
be loose on core and hence for a given extension or strain in yarn, the distribution of strain in the fibres would be more wide and so would be their corresponding stress values. This means that the structure would behave more like a disoriented fibre assembly, leading to failure at a lesser load and a lower tenacity. The tenacity of yarn with drafted fibre core (only 10-15% lower than that of the yarn with Z-twisted core) proves that the presence of adequate number of sheath fibres ensures development of adequate radial pressure to hold the core fibres together when the yarn is strained. This restricts the fibre slippage and the compact core would enable greater number of core fibres to break instead of slip, i.e. more number of fibres would contribute their tenacity to the yarn tenacity.

As expected, the finer yams exhibit higher tenacity (Table 3) for all levels of core-sheath ratio due to the increase in sheath fibres twist as a result of smaller sleeve diameter at the nip of friction drums which, in turn, is expected to generate higher transverse pressure on the core fibres, resulting in higher inter-fibre friction.

### 3.2 Breaking Extension

Table 3 and Fig. 3 show that the breaking extension is low in the yams spun with lower core component and it invariably increases with the increase in core component up to 70% for all the three types of core. A further increase in the percentage of core content in the drafted fibre core yarns decreases the breaking extension significantly. The increase in breaking extension is attributed to the greater contribution of intrinsic fibre extension to the yarn extension due to greater cohesion in the yarn core, the component which determines the breaking extension of yarn. The increased breaking extension for multifilament core yarns at higher level of core is due to more number of filaments in the core which delays the onset of rupture of the composite yarn due to sizable core percentage. The helical configurations of core due to trapped false twist may also contribute to the higher extension of DREF-III yarns. Since the inter-fibre cohesion in core is affected by the transverse pressure exerted by the sheath fibres on the core, the breaking extension decreases when there is an inadequate number of sheath fibres. This accounts for the decrease in breaking extension in staple fibres core when the core content is increased to 80%.

For the same core-sheath ratio, the yarns with multifilament core exhibit highest breaking extension followed by the yarns with twisted fibres core and the yarns with normal staple fibres core (Table 3). This is obviously due to the higher extensibility of the multifilament yarns in comparison to staple fibres used in the core (Table 1).

The reason for the greater breaking extension of the DREF-III yams produced with Z-twisted or S-twisted cores as compared to that of the yams produced with drafted fibres core lies in the fact that the core fibres are already twisted in yarn core which add further to the extensibility of the core yarns.

### 3.3 Sheath-slipping Resistance

The sheath-slipping resistance results, expressed in terms of number of cycles required to remove all the sheath fibres to expose the core at the rubbing portion, are given in Table 4. These results indicate a narrow range of 10 cycles in which the sheath-slipping resistance falls. The midpoint of each range is plotted in the form of a bar in Fig. 4. It is seen from this figure that an increase in the sheath content with the corresponding decrease in core, in general, decreases the sheath-slipping problem or the skinning tendency (term used by Standring and Westrop), irrespective of the form of core. For the same core-sheath ratio (60:40), the feeding of untwisted parallel fibres as core exhibits highest sheath-slipping resistance followed by the yams produced with Z-twisted, continuous multifilament and S-twisted cores respectively. Coarser yams have greater resistance to the skinning tendency of sheath fibres during abrasion.

As described earlier, the mechanism of yarn formation in DREF-III spinning system is such that
Table 4—Influence of core-sheath ratio and core type on sheath slipping-resistance and abrasion resistance of DREF-III friction-spun core yarns

<table>
<thead>
<tr>
<th>Core-sheath ratio</th>
<th>Sheath-sliping resistance, cycles</th>
<th>Abrasion resistance, cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Twisted yarn</td>
</tr>
<tr>
<td></td>
<td>fibres</td>
<td>Z-twisted</td>
</tr>
<tr>
<td>15:85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30:70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>40:60</td>
<td>-</td>
<td>325-335</td>
</tr>
<tr>
<td>45:55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50:50</td>
<td>350-360</td>
<td>300-310</td>
</tr>
<tr>
<td>60:40</td>
<td>320-330</td>
<td>245-255</td>
</tr>
<tr>
<td>70:30</td>
<td>280-290</td>
<td>225-235</td>
</tr>
<tr>
<td>80:20</td>
<td>260-270</td>
<td>-</td>
</tr>
</tbody>
</table>

* Yarn linear density, tex.

Fig. 4—Influence of core-sheath ratio and core type on sheathslipping resistance of DREF-III friction-spun core yarns

the core gets false twisted before being wrapped by the sheath fibres fed through a set of opening rollers of drafting unit-II and that the direction of false twist between the core feeding front rollers of apron drafting system (drafting unit-I) and the friction drums is opposite to that of the sheath twist. As the sheath fibres are normally wrapped in Z-twist direction, the direction of false twist in the section of core between front roller of drafting unit-I and friction drums would be S. For such a system, when a Z-twisted structure is fed as a core, it may disintegrate partially between the friction drums and the apron drafting system, depending upon the difference between the original Z-twist and the S-twist generated by the friction drums as a consequence of false-twisting action. At times, this interrupts the yarn formation process. However, such opening out of Z-twisted structure would leave opportunity for the sheath fibre ends to get into the core yarn body and subsequently locked at the core-sheath interface when the false twist reasserts to stabilize the structure as it comes out of the nip of friction drums. The interfacial bond between core and sheath fibres would therefore improve, leading the sheath fibres to withstand greater number of abrasion cycles before being dislodged from the core surface. This effect may be more pronounced while feeding normal drafted parallel fibres as core, especially in case of discrete staple fibres as shown by the highest sheath-slipping resistance for such yarns. Such binding between core and sheath would expectedly be poor with core of S-twisted yarn and smooth continuous filaments due to their compactness during false twisting.

The reason for greater number of cycles to completely expose the core in case of higher sheath content obviously lies in better sheath-core binding.

For finer yarns, though the sheath twist increases due to reduction in sleeve size at the nip of the drums, which, in turn, increases the radial pressure and consequently the interfacial bond between sheath and core, an improvement in the sheath-slipping resistance is expected. A lower number of cycles in this case can be attributed to the overall decrease in the absolute number of sheath fibres in finer yarns in comparison to that in coarser yarns.
Table 5—Influence of core-sheath ratio and core type on unevenness and imperfections of DREF-III friction-spun core yarns

<table>
<thead>
<tr>
<th>Core-shear ratio</th>
<th>Unevenness. 1%</th>
<th>Total imperfections/km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal fibres</td>
<td>Twisted yarn Z-twisted</td>
</tr>
<tr>
<td>15:85</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>30:70</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>40:60</td>
<td>-</td>
<td>12.21</td>
</tr>
<tr>
<td>45:55</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>50:50</td>
<td>11.94</td>
<td>12.09</td>
</tr>
<tr>
<td>60:40</td>
<td>12.16</td>
<td>12.28</td>
</tr>
<tr>
<td>70:30</td>
<td>12.28</td>
<td>12.13</td>
</tr>
<tr>
<td>80:20</td>
<td>12.56</td>
<td>-</td>
</tr>
</tbody>
</table>

* Yarn linear density, 59.0 tex

3.4 Abrasion Resistance

Table 4 and Fig. 5 show that both the core type and core-sheath ratio have a significant influence on the abrasion resistance of DREF-III friction-spun yarns. For all the four different core types, an increase in the proportion of core fibres up to 70% increases the number of cycles to abrade the yarn specimen.

The yarn with multifilament core is the most resistant to abrasion followed by the yarns with Z-twisted, S-twisted and normal staple-fibres cores respectively. Despite similar strength, a great difference is observed between the abrasion resistance of the yarns with S-twisted and drafted fibres cores. Such a difference in abrasion behaviour can be explained in terms of the composite structure of the yarns. When a repeated abrasive stress is applied, the structure disintegrates fast in the case of the yarn with parallel fibres in the core. Here, as the protective sheath fibres wear away due to repeated abrasion, the core immediately disintegrates as the two opposite directions of entrapped false twist in the core combine to make the core twistless. With pretwisted core, an improvement is definitely expected. However, with Z-twisted core along with Z-wrapped sheath, the structure reinforcement being better, more abrasive cycles would be required to cause failure. With S-twisted core, the interfacial bond between core and Z-wrapped sheath is not likely to be strong as explained earlier. As a result, the sheath wears away fast, exposing the twisted core to abrasive stress. However, being twisted it does not disintegrate as quickly as normal parallel core fibres do.

In the case of filament core yarn when the sheath fibres are worn off after repeated cycles, the filament core still remains strong enough to sustain repeated abrasive stresses. The continuous length, higher breaking extension and easy flattening (being devoid of twist) contribute towards higher abrasion resistance of the yarn.

3.5 Yarn Unevenness and Imperfections

Table 5 shows the values of yarn unevenness and imperfections for all the yarns in relation to core-sheath ratio and core type. It may be observed that the U% for all the yarns is more or less around 12% and that neither the core-sheath ratio nor the core type has any particular influence on the yarn unevenness. The imperfections also do not show any specific trend with the change in core type or core-sheath ratio.

4 Conclusions

4.1 Yarn tenacity, breaking extension and the resistance to abrasion of DREF-III yarns increase with the increase in proportion of core fibres up to
normal drafted staple fibres or spun yarn improves
the yarn breaking extension and abrasion resistance,
but the tenacity is found to be the lowest with
multifilament core due to the lower intrinsic tenacity
of the filaments.

4.2 DREF-III friction-spun yarns produced with
normal drafted staple fibres core exhibit the highest
sheath-slip resistance followed by the yarns
produced with Z-twisted fibrous core, continuous
multifilament core and S-twisted fibrous core.

4.3 An increase in sheath content, in general,
decreases the problem of sheath slippage over core
surface during abrasion.

4.4 No significant effect is observed for yarn
unevenness with the change in core-sheath ratio or
core type. Imperfections also do not show any
particular trend.

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