Improvement in tensile characteristics of dref-III yarn by enhancing structural integrity through modification in feed

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Received 3 October 2004; revised received and accepted 8 April 2005

The efforts have been made to improve the structure of dref-III friction-spun yarn by incorporating some modifications in the feeding zone of drafting unit-I, so that the core structure gets more consolidated with less transverse pressure exerted by the surface structure. The structure and tensile characteristics of yarns obtained after modification have been thoroughly studied and compared with the yarns made without modifications. It is observed that the tensile characteristics, namely tenacity, breaking extension, initial modulus and work of rupture, improve significantly by incorporating modification in the feed region.

Keywords: Dref-III yarn, Drafting unit, Polyester, Tensile properties

IPC Code: Int. Cl. 8 D01H 5/00, D02G 3/00

1 Introduction

Structure of dref-III yarns has already been well established as core/sheath type. The core fibres are the main load bearing component, which are held compactly by the transverse pressure exerted by the surface fibres and thus resist slippage. The increase in the proportion of core component would increase the strength, provided the transverse pressure exerted by the surface fibres is adequate, after which any further increase in core component would reduce the strength due to inadequacy in transverse pressure owing to the very small proportion of surface fibres. Although several studies\textsuperscript{1,7} have been made to optimize the tensile characteristics of dref-III yarns with respect to different materials, processes and machine parameters, no major improvement has yet been made either in the machine or in processing to improve the tensile characteristics of the dref-III yarns. In the present work, some modifications have been incorporated in the feed region of drafting unit-I and its effect on structure and tensile characteristics of yarn studied. Instead of feeding a single sliver, as is used in the normal case, it is split up into two strands and passed through separate guides.

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2 Materials and Methods

2.1 Dref-III Friction-spun Yarns with Normal Feed

Polyester yarns were produced on a dref-III friction spinning machine. A single polyester sliver was fed through drafting unit-I for forming the core structure. Five polyester slivers were fed through drafting unit-II for forming the surface structure.

Different yarns with core/sheath ratio of 40/60, 50/50, 60/40, 70/30, 80/20 and 90/10 were produced, maintaining the yarn count at 59.06 tex in all the cases.

2.2 Dref-III Friction-spun Yarns with Modified Feed

The feed sliver was split up into two parts by a triangular shaped polished metallic body before feeding into drafting unit-I and drafted separately up to the front roller by passing through separate guides at a distance of 3mm from each other. Two drafted strands were twisted individually and together after emerging from the front roller nip (Fig. 1). Yarns with all core/sheath ratios, as in case of normal feed, have been prepared with this modification in the feeding zone of drafting unit-I.

2.3 Sample Preparation for Photographic Observation

For photographic observation, yarn samples were prepared by feeding two separate slivers (Fig. 1) of black and yellow dyed polyester fibres of the same type as used in case of the parent yarn samples. Sliver hank was made finer to 1.6 ktx in this case.
The sliver of 1.6 ktex has also been made in Platt-Sacco Lowell miniature draw frame with following process parameters:

(i) 1st passage–40 g fibre form a lap of 19.17 ktex with draft 9.
(ii) 2nd passage–19.17 ktex feed with draft 9 and delivery sliver 2.13 ktex.
(iii) 3rd passage–2.13 ktex sliver of 6 ends with draft 8 and delivery sliver 1.6 ktex.

Yarns were prepared using both normal feed (both the slivers through the same guide) and modified feed (slivers through separate guide) systems. Yarn samples were also produced with white polyester in the core and black dyed polyester in the surface using both normal and modified feed systems.

The process parameters used for preparing yarns on dref-III friction spinning machine were: spinning drum speed, 3750 rpm; carding drum speed, 12000 rpm; delivery speed, 100 m/min; count of yarn produced, 59.06 tex; nip distance, 0.1 mm; and back suction pressure, 350 mbar. The in-lot speeds of drafting units I and II have been changed with the change in core/sheath ratio on the basis of standard calculations for dref-III, as shown below:

\[ \frac{V_I}{V_{II}} = \frac{(D \times p \times t)}{(1000 \times n \times k)} \]

where \(D\) is the delivery speed in m/min; \(t\), the required yarn count in tex; \(p\), the fraction of core/sheath fibres; \(n\), the number of slivers; \(k\), the weight of the slivers in ktex; and \(V_I / V_{II}\), the in-lot speed of drafting unit I/II.

### 2.4 Test Methods

#### 2.4.1 Tensile Characteristics

Tensile characteristics of the yarns were tested on Instron Tensile Strength tester (4301), keeping the gauge length at 100 mm and cross-head speed at 50 mm/min. Cross-head to chart speed ratio was kept at 1:4. Fifty tests were conducted for each yarn sample and the average values were calculated for different tensile characteristics, such as tenacity, breaking extension, initial modulus and specific work of rupture.

#### 2.4.2 Twist to Break the Yarn

All the dref-III yarn samples were twisted in the same direction of rotation of twist, given by the spinning drums to the yarns in SDL Yarn Twist Tester and the amount of twists per inch to break the yarn was determined. The average value of twists per inch and its CV % was calculated for each sample.

#### 2.4.3 Packing Coefficient

For the measurement of packing coefficient of yarns, the diameter of each yarn sample was measured on a Projectina projection microscope. For this purpose, yarns were first mounted on glass slides under a tension of 0.5 g/tex. Twenty-five such slides were made for each yarn under investigation. Yarn was then viewed under microscope with a magnification of ×30. About 200 readings were taken for each yarn sample and the average values of actual yarn diameter were calculated. The packing coefficient was calculated using the following formula:

\[ \text{Packing coefficient} = \frac{V_f}{V_y} \]

where \(V_f\) is the specific volume of fibres in cc/g; and \(V_y\), the specific volume of yarn in cc/g which is equal to \((\pi d^2 / 4) \times (10^3 / T)\) cc/g, here \(d\) is the diameter of yarn in cm and \(T\), the yarn count in tex.

#### 2.4.4 Methods used for Photographic Observation

The Wild Leitz M3Z CombiSterco Microscope attached with CCD camera was used for taking photographs. For taking photographs in longitudinal direction, the yarns were mounted in a trough containing tricresyl phosphate for optically dissolving the surface white polyester fibres. Care was taken to ensure that the yarns were always kept immersed in the liquid. Photographs were taken with a magnification of ×40 in all the cases.

For taking cross-sections, yarns were clamped in a metallic container. The container was then filled with a polymerizing mixture of epoxy (resin and hardener)
and di-butylphthalate (plasticizer). Polymerization was carried out at room temperature for 24 h until the mixture had hardened suitably for cutting. Sections of about 30-40 microns were then cut for each sample on a hand microtome using a sharp razor blade. Good sections were then selected for each yarn sample and photographs were taken with a magnification of \( \times 40 \).

2.4.5 Test of Significance

For comparison of the test results, test of significance (T-test) was performed in all the cases to observe that any difference between the test results after changing each process parameter is significant at 95% confidence level or not.

3 Results and Discussion

3.1 Fibre Configuration in Core Structure

Fibre configuration in the core structure has been studied after optically dissolving the surface fibres. In case of normal feed, the two strands (black and yellow) are found to lie mostly parallel to each other with the fibres in each strand also being parallel to each other. Few core fibres from both the strands are found to wrap around the core structure by part of their length of the yarns. The wrapping is found to be in Z direction, mostly in all the cases. The above phenomenon may be observed in Fig.2. In case of modified feed, the two strands of fibres are found to lie in a helical configuration indicating mutual twisting between the two strands (Fig.3). The twist is mostly in Z direction along the length of yarn. But occasionally S twists are also found in segments along the length of yarn. In the change over segments, the fibres from the core are found to warp the core structure tightly as may be observed from Fig.4. However, this change in the direction of twist resulting in a structure similar to that of a self-twisted yarn does not occur at regular intervals. Trailling part of the core fibres projecting free from the core structure receives the true twist in Z direction (direction of twist in the delivery side). The tendency of the core fibres to project partly from the core structure (trailing part) is likely to be enhanced by the disposition of strands at an angle at the point of twisting as they come out of the front roller nip. Tendency of wrapping by the partially projected core fibres may be due to the reason that with lower surface content, the core structure is more exposed, thus having more chance to be in direct contact with the rotating cylinders.

Cross-sectional views of the yarns with both normal and modified feeds are shown in Figs 2-6. Core structure of the yarns with modified feed is always found to be more tightly wrapped by the surface fibres as compared to the yarns with normal feed.

3.2 Twist to Break

The study was undertaken to have an idea about the twist retained in the core structure. Yarns were twisted till break in the direction same in which the core strands are twisted. It may be observed from Table 1 that the twist to break values gradually decrease with the increase in core content in both normal and modified feeds. This may probably be due

![Fig. 2 — Core structure in case of normal feed with different core/sheath ratios [(a) 70/30, (b) 80/20 and (c) 90/10](image)]

![Fig. 3 — Core structure in case of modified feed with different core/sheath ratios [(a) 70/30, (b) 80/20 and (c) 90/10](image)]
Table I—Effect of modified feed on twist to break and the packing coefficient of 100% polyester dref-III yarn at different core contents

<table>
<thead>
<tr>
<th>Core-sheath ratio</th>
<th>Twists/inch to break</th>
<th>Packing coefficient</th>
<th>% Increase after modification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Modified</td>
<td>Normal</td>
</tr>
<tr>
<td>40:60</td>
<td>41.02(8.2)*</td>
<td>39.08(5.20)*</td>
<td>0.35(10.35)</td>
</tr>
<tr>
<td>50:50</td>
<td>37.54(7.2)</td>
<td>36.98(4.20)</td>
<td>0.39(9.7)</td>
</tr>
<tr>
<td>60:40</td>
<td>35.80(6.50)</td>
<td>34.82(3.20)</td>
<td>0.40(7.65)</td>
</tr>
<tr>
<td>70:30</td>
<td>33.78(4.71)*</td>
<td>29.08(3.07)*</td>
<td>0.41(10.35)</td>
</tr>
<tr>
<td>80:20</td>
<td>28.05(3.54)*</td>
<td>24.05(2.71)*</td>
<td>0.43(11.56)</td>
</tr>
<tr>
<td>90:10</td>
<td>24.08(2.90)</td>
<td>19.40(1.73)</td>
<td>0.34(13.25)</td>
</tr>
</tbody>
</table>

Values within parentheses denote respective CV %.
Significant at 95% confidence level.

Fig. 4 — Wrapping the core structure by the core fibres in case of modified feed with different core/sheath ratios [(a) 70/30, (b) 80/20 and (c) 90/10]

Fig. 5—Cross-sectional view of yarns in case of normal feed with different core/sheath ratios [(a) 60/40, (b) 70/30 (c) 80/20 and (d) 90/10]

Fig. 6—Cross-sectional view of yarns in case of modified feed with different core/sheath ratios [(a) 60/40, (b) 70/30, (c) 80/20 and (d) 90/10]

to the increase in thickness of core structure, leading to more torsional rigidity of the strand, which needs lower turns to break. Also, with the increase in thickness of the strand, the angle of helix is higher at the same level of twist, causing the strand to be saturated with twist. In case of modified feed, the twist to break values are always lower than the corresponding yarns with normal feed. This also shows the presence of twist in the core structure, which is also evidenced from Fig. 3. In Table 1, twist
to break CV % values are also found to decrease with the increase in core content in both the cases, which may be due to the higher regularity of the strands caused by lower draft at drafting unit-I. Comparatively lower CV % values are also observed in case of modified feed at all levels of core content. This clearly shows that the consolidation of the structure is more homogeneous along the length in case of yarns with modified feed.

3.3 Packing Coefficient

Packing coefficient values of dref-III friction-spun yarns are given in Table 1. It is observed that in case of normal feed the packing coefficient value gradually increases up to an optimum core content (80%) and then decreases. The increase in packing coefficient is due to the lower proportion of highly disoriented surface fibres and more proportion of highly oriented and parallel core fibres. Decrease in packing coefficient after an optimum core content may be due to very small proportion of surface fibres, which fail to consolidate the core structure, as may be observed from Fig. 5d. Higher packing coefficient values are observed in case of modified feed at all core contents. Also, the improvement in packing coefficient is observed even at a core content of 90%. In fact, the improvement in packing coefficient with the modification in feed is more pronounced at higher core contents. Higher packing coefficient in case of modified feed may be due to better consolidation of the core structure, as may be observed from the Figs 5 and 6. Higher improvement in packing coefficient at higher core contents may be due to the fact that in case of modified feed the packing coefficient of the yarn increases at a higher rate with the increase in core content, which is reverse in case of normal feed. Higher the core content, the thicker is the individual strands and, therefore, more transverse pressure is likely to be developed on twisting the strands together in case of modified feed.

3.4 Tensile Characteristics

Tables 2 and 3 show that the tenacity of yarns improves with the increase in core content in both normal and modified feeds. This may be due to the increase in number of load bearing core fibres. Tenacity of yarn with normal feed is found to decrease after 80% core content, whereas in case of modified feed the tenacity is found to increase even up to 90% core content. Moreover, at all levels of core content, yarns with modified feed show higher values as compared to those with normal feed. The

| Table 2—Effect of modified feed on tensile characteristics of 100% polyester, dref-III yarn at different core percentage |
|-------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Core content (%) | Normal | Modified | Normal | Modified |
| 40-60 | 21.07 (6.51) | 23.09 (6.10) | 21.07 (6.51) | 23.09 (6.10) |
| 60-40 | 23.74 (6.87) | 26.63 (6.60) | 23.74 (6.87) | 26.63 (6.60) |
| 70-30 | 29.27 (6.89) | 33.33 (6.23) | 29.27 (6.89) | 33.33 (6.23) |
| 80-20 | 29.24 (6.89) | 33.33 (6.23) | 29.24 (6.89) | 33.33 (6.23) |
| 90-10 | 18.72 (2.24) | 35.12 (6.46) | 18.72 (2.24) | 35.12 (6.46) |

Values in parentheses denote respective CV %.

Significant at 95% confidence level:
fall in strength at 90% core content in case of normal feed may be due to the lack of consolidation of the core structure, as may be evidenced from low packing coefficient value (Table 1). Lack of consolidation of core structure is also clearly evidenced from Figs 5 and 6. In case of modified feed, two separate strands emerge in the twisting zone at an angle and try to be twisted together. Although due to false twisting phenomenon, the strands are likely to be detwisted again, some twists are found to be retained in the ultimate core structure, as may be evidenced from Fig.3. Due to twist, the core structure of the yarns with modified feed is found to be more integrated, resulting in higher resistance to slippage. Comparatively weaker ‘twist change-over’ segments are also found to be tightly wrapped by the fibres from the core structure, as may be observed from Fig.4. Also, the yarns are found to be consolidated more homogeneously along the length, as may be observed from lower twist to break CY% (Table 1). Due to the above-mentioned reasons, the strength of yarns with modified feed is always found to be higher than the yarns with normal feed. Improvement in strength with modification in the feed is found to be significant mostly in all the cases, as may be observed from Table 3.

Breaking extension values of yarns produced with and without modifications in the feeding zone are given in Table 2. Breaking extension values do not show any particular trend with the variation in core content in both the cases. In case of normal feed, a much lower value is observed with 90% core content, which may be due to lack of consolidation of the core structure because of very low surface content (Fig. 5d). Higher breaking extension values are always observed in case of modified feed at all levels of core content which may be due to the twisted core structure. The two strands are found to lie in a helical manner in case of modified feed as compared to parallel strand of fibres in case of normal feed. Higher breaking extension values in case of modified feed may thus be due to the helical configurations of the strands. Improvement in the breaking extension values with the modification in feed zone is always found to be significant (Table 3).

Initial modulus values of both the yarns are given in Table 2. Yarns with modified feed always show higher values as compared to those with normal feed. The reason for this may probably be due to the twisted core structure, as may be observed from the higher packing coefficient values (Table 1). The increase in initial modulus with the increase in core content is probably due to the increase in proportion of load bearing fibres. A drastic fall in the initial modulus value is observed at 90% core content in case of normal feed. This may be due to poor consolidation of the core structure caused by inadequacy in the number of surface fibres. The improvement in initial modulus values with the improvement in the feed zone is observed to be significant mostly in all the cases, as may be observed from Table 3.

Table 2 shows the specific work of rupture values for the yarns produced with normal and modified feeds. Yarns with modified feed always show higher values as compared to those with normal feed. Resultant effect of higher tenacity, breaking extension and initial modulus is clearly reflected in the specific work of rupture values. Expectedly, the increasing trend is observed in specific work of rupture values with the increase in core content, except in case of yarns with normal feed at 90% core content. The drastic fall in the specific work of rupture value in this case may be due to poor consolidation of the core structure caused by lack of adequate number of surface fibres. Improvement in the specific work of rupture values is also found to be significant in majority of the cases (Table 3).
4 Conclusions

Structures of the yarns are found to improve significantly by the modification in feeding. The core structure instead of containing parallel fibres is found to be composed of two strands that are mutually twisted together. Although twist imparted by the rotating cylinders is essentially a false twist, some twist is found to be retained in the core structure. The twist is found to be mainly in Z direction, although in some places it is changed into S direction. Moreover, the consolidation of the structure is found to be more uniform along the length of the yarn which is reflected from lower 'twist to break CV %' of the yarn produced with modified feed. Due to this improvement in structure, the packing coefficient of yarns is found to improve, more predominantly, at higher core contents. As a result of the improvement in structure, all the tensile characteristics improve significantly. Strength of yarn attains an optimum value at 80% core content in case of normal feed but by the incorporation of modification in feed, the strength of yarns improves even at 90% core content. Breaking extension of the yarns also improves on modification in feed, probably due to more homogeneity in strain distribution along the length of yarn and also due to the twisted core structure of the yarns. Initial modulus and specific work of rupture of the yarns also improve with the modification in feed.

References