The effect of sheath-fibre denier and twist on the characteristics of core-spun yarns, with a constant polyester core, was studied. Core-spun yarns with the same core component but with finer-denier viscose sheath fibre gave a higher strength and an overall higher yarn quality index. Alteration of twist did not affect the number of neps, which however decreased with increase in fibre denier. Thick places increased with increase in fibre denier. Flex abrasion resistance decreased with decrease in twist, but was higher for yarns spun with finer-denier sheath fibre.

Keywords: Core-spun yarn, Fibre denier, Polyester-viscose yarn, Viscose-polyester yarn, Yarn characteristics, Yarn twist

Introduction

Several researchers have studied, theoretically and experimentally, the effect of twist, core-sheath ratio, single or double rove fed, or pretension on the characteristics of core-spun yarns separately. Not much work, however, has been done on the combined effect of various process variables. Hence the present study on the effect of fibre linear density and twist on the characteristics of core-spun yarns with non-elastic cores.

Materials and Methods

Preparation of Yarn Samples

Three core yarn samples of 16s nominal count were spun from 100% polyester core (72 denier/24 filaments) and 100% viscose (sheath) of three different deniers, 1.5, 2.0 and 4.0. Four twist multipliers, 2.8, 3.2, 3.5 and 3.8, were used for each yarn sample with Z twist.

Pure viscose staple of different deniers was hand-opened and sandwiched well to obtain a homogeneous mixing. The samples were then processed on a M-M-C card followed by two passages of O.K.K. draw frame. The drawn slivers were processed on a O.K.K. Simplex to prepare a roving of 1.62 hank with a total draft of 10.5. The specifications of viscose fibres are given in Table 1. The pretension core component (polyester) was guided to the front roller nip between two rovings, which were kept separated until drawing, on a Texmaco ring frame. All the three core yarns of 16s nominal count were spun with four different levels of twist multipliers.

Tests

The yarn breaking strength and elongation were determined on an Uster single yarn tester. The yarn irregularity ($U_{\%}$) was measured on an Uster evenness tester. The lea strength was found out by using half leas, as the preliminary trials showed that in some cases the full lea strength exceeded 200 lb, which is the maximum range of lea strength available in the tester in our laboratory. The yarn hairiness and yarn diameter were measured on a Projectina. The abrasion resistance of yarns was determined on a Taber abrasion tester by using flex abrasion mechanism. The yarn count was determined with a Knowle's balance.

Results and Discussion

Breaking Strength and Breaking Elongation

Table 2 shows that breaking strengths and TM values agree with the theoretically determined values given by Balasubramanian and Bhatnagar. In core-spinning, reduction in optimum twist is obtained and, as a result, there is an improvement in strength at low twist levels. The peculiar nature of the relationship may be attributed to two opposing factors. With core yarns the presence of a continuous filament reduces the slippage of sheath components, and consequently leads to improvements in strength mainly at low twist. With increase in twist the improvement in strength vanishes because of the diminishing influence of friction and increasing effects of non-simultaneity in the occurrence of breaks.

<table>
<thead>
<tr>
<th>Table 1 – Specifications of Viscose Fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre denier</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>1.5</td>
</tr>
<tr>
<td>2.0</td>
</tr>
<tr>
<td>4.0</td>
</tr>
</tbody>
</table>
TYAGI et al.: EFFECT OF TWIST AND FIBRE DENSITY ON CHARACTERISTICS OF CORE-SPUN YARNS

Table 2—Effect of Twist and Fibre Linear Density on Yarn Breaking Strength, Breaking Elongation, Count CV%, Lea Strength CV%, Yarn Quality Index and Lea CSP

<table>
<thead>
<tr>
<th>Yarn ref. No.</th>
<th>Yarn count</th>
<th>TM</th>
<th>Breaking load g</th>
<th>Tenacity g/tex</th>
<th>Breaking extension %</th>
<th>Count CV%</th>
<th>Lea strength lb</th>
<th>Lea CSP</th>
<th>Lea strength CV%</th>
<th>YQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>16s</td>
<td>15.78</td>
<td>2.8</td>
<td>729.80</td>
<td>19.75</td>
<td>13.67</td>
<td>1.91</td>
<td>174.00</td>
<td>2745.72</td>
<td>4.09</td>
</tr>
<tr>
<td>S1</td>
<td>16s</td>
<td>15.63</td>
<td>3.2</td>
<td>787.80</td>
<td>21.34</td>
<td>13.80</td>
<td>2.01</td>
<td>178.50</td>
<td>2789.95</td>
<td>5.89</td>
</tr>
<tr>
<td>S1</td>
<td>16s</td>
<td>15.55</td>
<td>3.5</td>
<td>717.80</td>
<td>19.44</td>
<td>13.70</td>
<td>2.03</td>
<td>117.33</td>
<td>2757.48</td>
<td>6.63</td>
</tr>
<tr>
<td>S1</td>
<td>16s</td>
<td>15.62</td>
<td>3.8</td>
<td>705.30</td>
<td>19.10</td>
<td>13.20</td>
<td>2.10</td>
<td>169.33</td>
<td>2644.94</td>
<td>6.40</td>
</tr>
<tr>
<td>S2</td>
<td>16s</td>
<td>15.59</td>
<td>2.8</td>
<td>690.30</td>
<td>18.70</td>
<td>11.90</td>
<td>2.34</td>
<td>170.60</td>
<td>2659.65</td>
<td>5.11</td>
</tr>
<tr>
<td>S2</td>
<td>16s</td>
<td>15.64</td>
<td>3.2</td>
<td>706.55</td>
<td>19.17</td>
<td>14.48</td>
<td>2.05</td>
<td>171.70</td>
<td>2685.39</td>
<td>7.38</td>
</tr>
<tr>
<td>S2</td>
<td>16s</td>
<td>15.56</td>
<td>3.5</td>
<td>690.30</td>
<td>18.70</td>
<td>13.55</td>
<td>2.86</td>
<td>171.70</td>
<td>2671.65</td>
<td>7.17</td>
</tr>
<tr>
<td>S2</td>
<td>16s</td>
<td>15.50</td>
<td>3.8</td>
<td>686.55</td>
<td>18.50</td>
<td>12.42</td>
<td>2.20</td>
<td>167.12</td>
<td>2590.36</td>
<td>7.80</td>
</tr>
<tr>
<td>S3</td>
<td>16s</td>
<td>15.78</td>
<td>2.8</td>
<td>583.64</td>
<td>13.76</td>
<td>11.60</td>
<td>2.40</td>
<td>162.64</td>
<td>2566.46</td>
<td>6.04</td>
</tr>
<tr>
<td>S3</td>
<td>16s</td>
<td>15.58</td>
<td>3.2</td>
<td>547.80</td>
<td>14.84</td>
<td>12.23</td>
<td>2.23</td>
<td>167.16</td>
<td>2604.35</td>
<td>7.21</td>
</tr>
<tr>
<td>S3</td>
<td>16s</td>
<td>15.68</td>
<td>3.5</td>
<td>627.80</td>
<td>17.01</td>
<td>11.17</td>
<td>2.27</td>
<td>164.60</td>
<td>2580.43</td>
<td>7.12</td>
</tr>
<tr>
<td>S3</td>
<td>16s</td>
<td>15.80</td>
<td>3.8</td>
<td>609.05</td>
<td>16.50</td>
<td>11.30</td>
<td>2.32</td>
<td>160.29</td>
<td>2532.58</td>
<td>6.98</td>
</tr>
</tbody>
</table>

S1, S2, and S3—Core-spun yarns spun with 1.5, 2.0 and 4.0 denier viscose fibres in sheath respectively.

The strength loss at higher twist levels is also due to the difference in breaking extension because of which the polyester filament and viscose fibre do not break simultaneously. At the time of breakage of viscose fibre the stress shared by polyester filament is much lower and thus in such conditions the addition of filaments should lead to a fall in strength because it does not contribute in any other way to higher strength.

In the case of core-spun yarns the break is of catastrophic type and the first break and rupture are indistinguishable except at low twist and short-specimen lengths. At low twist there is not sufficient cohesion between the filament and staple fibre, which allows the tension to fall as a result of slippage. With a short specimen length, because of reduced overlap the frictional load is expected to be smaller and the coefficient of friction and surface area per unit mass. Empirically, the maximum strength is expressed as: 

\[ B = L_1 / US \]

where \( B \) is the fibre length; \( U \), the coefficient of friction; and \( S \), the surface area per unit mass.

As shown by this relationship, for a given fibre length the maximum yarn strength depends upon the specific surface, which accords well with test results.

On the other hand, the breaking elongation is low in weak yarns (Table 2) and continues to follow the same trend as strength with twist. The increasing breaking extension may be attributed to the contraction of yarn following the release of twist and tension: the fibres on the surface of the yarn following a longer path are assumed to be under strain during twisting and then subsequently to contract to under-strained length with the resultant buckling of the centre core, leading to additional extension of centre core before they are extended to break.

The breaking extension increases with fibre fineness for all levels of twist. The test results (Table 2) show 13.67%, extension for yarn spun with 1.5 denier sheath in comparison with 11.9% and 11.6% breaking extensions for the yarns spun with 2.0 and 3.0 denier sheath fibres respectively. This can be attributed to the resistance to torsion which increases with increase in fibre fineness, i.e. decrease in fibre denier.

3.2 Yarn Count and Strength CV

Table 2 shows no significant change in yarn count CV with alteration in twist. This can be attributed to
the fact that an increase in twist level has very little
effect on the contraction factor of constant core-spun
yarn, which restricts the high twist contraction of
sheath, and the resultant twist contraction is of a lower
magnitude. Apart from twist the yarn count variation
is affected by the linear density of sheath fibres. It is
observed that CV(%) of yarn strength increases as fibre
denier increases.

The results on the effect of twist and fibre denier on
strength CV show that strength CV increases with
increase in twist level.

3.3 Yarn Quality Index

To investigate the effect of twist and fibre linear
density on the overall yarn quality, a composite yarn
quality index (YQI), based on Barella's formula as
given below, was calculated:

\[
YQI = \frac{\text{Single thread tenacity} \times \text{Breaking elongation (}\%\text{)}}{\text{Uster U } \%
}\]

where thread tenacity is in g/tex.

Table 2 shows that the overall YQI follows a trend
similar to that of yarn tenacity.

3.4 Yarn Evenness

Table 3 shows a consistent trend of deterioration in
yarn evenness (PMD) with increase in twist level. The
high twist level gives a higher crimp to the yarn which
offsets the effect due to the mechanical hindrance,
resulting in higher values of yarn PMD. Yarns spun
from sheath fibres of finer denier give better evenness
than the yarns constituting the coarse fibre in sheath.

*percentage mean deviation

for all twist levels. This finding accords with the
equation given by Peirce, relating the number of
fibres in the cross-section to the variation in the linear
density of strand, which is as follows:

\[
V_r = \frac{100}{\sqrt{n}}
\]

where \( V_r \) is the coefficient variation of linear density
of strand; and \( n \), the number of fibres in yarn cross­
section.

An examination of the yarn imperfection test results
shows that alteration of twist does not have any effect
on the number of neps, which however decreases with
increase in fibre denier (sheath). The decreased nepping
tendency with increased fibre denier may be attributed
to the higher resistance to bending of a coarse fibre
than that of a fine fibre.

Further, the number of thick places is also found to
increase with increase in fibre denier. This may due to
the poor control of fibre exercised during the drafting
on account of decreased cohesive force, which
decreases directly in proportion to the number of fibres
in strand cross-section. Yarn sample S1, being spun
from the finer-denier staple, has a higher number of
fibres per unit yarn cross-section, resulting in higher
cohesive forces during drafting.

3.5 Yarn Diameter

Table 3 gives the results of a comparative study of
the effect of twist and fibre linear density on the
diameter of core-spun yarns. The table shows that yarn
diameter, in general, decreases with increase in twist
level in core-spun yarns owing to the increased packing

<table>
<thead>
<tr>
<th>Yarn ref. count</th>
<th>TM</th>
<th>Imperfections, 125 m</th>
<th>U(%)</th>
<th>Yarn hairiness (Av. no. of protruding ends, 3 cm)</th>
<th>Abrasion resistance cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Thick places</td>
<td>Thin places</td>
<td>Nep</td>
<td>cm</td>
<td>No. of fibres between 0-1.5 cm, 1.5-3 cm, 3 cm and above</td>
</tr>
<tr>
<td>16s</td>
<td>2.8</td>
<td>5</td>
<td>19</td>
<td>10.35</td>
<td>0.0227, 74, 42, 20</td>
</tr>
<tr>
<td>16s</td>
<td>3.2</td>
<td>4</td>
<td>20</td>
<td>10.33</td>
<td>0.0222, 67, 39, 16</td>
</tr>
<tr>
<td>S1</td>
<td>3.5</td>
<td>9</td>
<td>15</td>
<td>10.82</td>
<td>0.0220, 71, 34, 18</td>
</tr>
<tr>
<td>S1</td>
<td>3.8</td>
<td>7</td>
<td>19</td>
<td>10.95</td>
<td>0.0212, 65, 34, 14</td>
</tr>
<tr>
<td>16s</td>
<td>2.8</td>
<td>6</td>
<td>17</td>
<td>11.00</td>
<td>0.0229, 68, 41, 12</td>
</tr>
<tr>
<td>16s</td>
<td>3.2</td>
<td>8</td>
<td>18</td>
<td>11.15</td>
<td>0.0223, 62, 37, 15</td>
</tr>
<tr>
<td>S2</td>
<td>3.5</td>
<td>9</td>
<td>16</td>
<td>11.23</td>
<td>0.0221, 59, 29, 8</td>
</tr>
<tr>
<td>S2</td>
<td>3.8</td>
<td>10</td>
<td>20</td>
<td>11.32</td>
<td>0.0214, 53, 31, 11</td>
</tr>
<tr>
<td>16s</td>
<td>2.8</td>
<td>27</td>
<td>9</td>
<td>14.10</td>
<td>0.0267, 45, 27, 10</td>
</tr>
<tr>
<td>16s</td>
<td>3.2</td>
<td>29</td>
<td>6</td>
<td>14.50</td>
<td>0.0239, 43, 24, 7</td>
</tr>
<tr>
<td>S3</td>
<td>3.5</td>
<td>34</td>
<td>15</td>
<td>14.80</td>
<td>0.0224, 51, 29, 9</td>
</tr>
<tr>
<td>S3</td>
<td>3.8</td>
<td>37</td>
<td>15</td>
<td>14.80</td>
<td>0.0221, 47, 22, 6</td>
</tr>
</tbody>
</table>

Yarns S1-S3 correspond to the yarns given in Table 2.
coefficient, which, in turn, reduces the yarn specific volume and yarn diameter.6

On the other hand, the yarn diameter is affected by fibre denier for all levels of twist. As shown in Table 3, the yarn diameter is higher for yarns spun with a coarse-denier fibre in sheath against that of finer denier, which is due to the fact that coarse fibre gives low packing density and low yarn density, which ultimately increase the yarn diameter or vice versa.

3.6 Yarn Hairiness

Table 3 shows that fibre linear density has a direct bearing on the hairiness of core-spun yarns, which in the present study was measured in terms of the number of protruding ends per unit length.

The effect of twist on the hairiness of core-spun yarns was also studied. No specific relationship between the number of protruding ends per unit length and yarn twist was observed. This is in agreement with the theory of Pillay7 and Barella et al.8 that the number of protruding ends is independent of twist.

However, it may be noted that yarn hairiness of spun yarns decreases with increase in twist, which can be explained by assuming that twist in the yarn will run close to the front roll nip in the case of higher twist than that of the lower twist, resulting in an improved control over the emerging fibres, i.e. reduction in yarn hairiness.7

The effect of fibre denier on hairiness shows a consistent trend of reduction in the number of protruding fibres for yarns spun with a sheath component of coarser denier. This may be attributed to increased cohesive force on account of increased number of fibres in yarn cross-section, which is governed by fibre denier. Thus, the yarn sample S1, spun with 1.5 denier viscose, shows a higher flex abrasion resistance than the yarn samples S2 and S3 spun from 2 and 4 denier fibres respectively.

4 Conclusions

4.1 In core-spinning, a lower optimum twist is obtained which leads to improvement in strength. Core-spun yarns with the same core component but finer-denier viscose sheath fibre give a higher strength than yarns spun with coarse-denier fibres, for all levels of twist.

4.2 The breaking elongation is low in weak yarns and continues to follow a trend similar to that of strength with twist. It increases with fibre fineness for all levels of twist.

4.3 Yarn count CV does not change significantly with twist but increases as the sheath fibre denier increases.

4.4 Full lea strength CV % of core-spun yarns increases with increase in twist.

4.5 The overall yarn quality index shows a trend similar to that of yarn tenacity.

4.6 There is a consistent trend of deterioration in yarn evenness with increase in twist level. Yarns spun from finer-denier sheath fibres give better evenness than yarns constituting coarse fibres in sheath, for all twist levels.

4.7 Alteration in twist does not affect the number of neps, which however decreases with increase in fibre denier. The number of thick places increases with increase in fibre denier.

4.8 In core-spun yarn, yarn diameter, in general, decreases with increase in twist level and is higher for yarns spun with coarse-denier fibres in sheath.

4.9 There is no relationship between the number of protruding ends per unit length and yarn twist, but there is a consistent reduction in the number of protruding fibres for yarns spun with a sheath fibre of coarser-denier.

4.10 Flex abrasion resistance decreases with decrease in twist level, it is higher for yarns spun with finer-denier fibres in sheath.

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References