Influence of some process parameters on the properties of polyester jet-spun yarns

G K Tyagi & Dhirendra Sharma

The Technological Institute of Textile & Sciences, Bhiwani 127 021, India

Received 16 August 2000; accepted 22 September 2000

The influence of fibre denier, ribbon width, main draft and yarn linear density on the properties of polyester jet-spun yarns has been studied by using factorial design. It is observed that the ribbon width has a direct effect on the tensile properties of MJS yarns, depending on the fibre and yarn linear densities. The use of higher main draft substantially improves the tensile properties but adversely affects the evenness, rigidity and hairiness.

Keywords: Air-jet spinning, Flexural rigidity, Main draft, Polyester yarn, Ribbon width

1 Introduction

Following the advent of commercial air-jet spinning machine in 1981 by Murata, there has been extensive research on enhancing the effectiveness of the technology in terms of both raw material and yarn quality. Grosberg et al. studied the effect of take up ratio, ribbon width and yarn linear density on tenacity of air-jet spun yarns. Chasmawala et al. investigated the effect of main draft on characteristics of MJS yarns. The effect of feed ratio and fibre dimensions on characteristics of MJS yarns has also been investigated. Rajamanickam et al. have shown the effect of yarn linear density on the properties of MJS yarns. In almost all these studies, researchers have tried to observe the general effect of machine parameters on yarn properties using a direct approach, wherein some factors are varied keeping the others constant. The conclusions drawn are valid as long as the process conditions are met in practice. However, in case of any deviation in any of the process variables which were kept constant in the experimental study, the conclusions may or may not hold true depending upon the influence of the variable. In the present paper, an attempt has been made to apply the factorial design approach to optimize main draft and ribbon width for polyester MJS yarns spun to different linear densities from the fibres of different fineness.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Two sets of yarns of 14.7 and 19.6 tex were prepared from each of 1.11 dtex and 1.56 dtex polyester fibres on Murata air-jet spinner. The specifications of the polyester fibres used in the study are given in Table 1. The conversion to drawn sliver was carried out on a MMC carding machine and a Lakshmi Rieters’ draw frame DO/6. Two drawing passages were given to the carded sliver. The linear density of drawn sliver was set to 3.0 ktex. The drawn slivers were spun into yarns on Murata air-jet spinner (802 MJS) using the experimental plan given in Table 2. The actual values of the selected variables corresponding to the coded levels are given in Table 3.

2.2 Tests

All the yarns were tested for tenacity and breaking elongation on Instron tensile tester, 500mm test specimen being elongated at 200mm/min extension rate. Thirty(30) observations were made for each yarn sample. Yarn unevenness and imperfections were recorded using the Keissoki evenness tester KET 80B (testing speed, 200 m/min and duration, 2.5 min). Yarn hairiness was determined by Zweigle hairiness tester and ten replications were made for each sample.

Table 1—Specifications of polyester fibres

<table>
<thead>
<tr>
<th>Length</th>
<th>Linear density</th>
<th>Tenacity</th>
<th>Breaking extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>dtex</td>
<td>cN/tex</td>
<td>%</td>
</tr>
<tr>
<td>51</td>
<td>1.11</td>
<td>44.5</td>
<td>25.4</td>
</tr>
<tr>
<td>51</td>
<td>1.56</td>
<td>43.8</td>
<td>26.7</td>
</tr>
</tbody>
</table>

*Present address: MLV Textile Institute, Bhiwara 311 001, India
To whom all the correspondence should be addressed.
Phone: 40092; Fax: 091-01482-40393;
E-mail: mlvti@jpl.dot.net.in
The flexural rigidity was measured by ring loop method.

**3 Results and Discussion**

3.1 Statistical Analysis

Table 4 shows the effect of individual factors and their interactions in determining the various yarn properties. The test of significance was carried out at 95% confidence level and the interactions studied up to third order. The response surface equations for the yarn properties along with the correlation coefficient between calculated and experimental results are shown in Table 5. The goodness of fit of these models was assessed by F-ratios and their associated P-values (corresponding to 4, 31 d.f.) obtained from the analysis of variance of the corresponding regression equations. The P-values for all the 5 equations are less than 0.001, thus rejecting the null hypothesis that the constants and coefficients are simultaneously equal to zero. The squared multiple correlation \( R^2 \) is slightly poor for breaking extension, but its values for tenacity, rigidity, unevenness and imperfections indicate that approximately 74%, 96%, 94% and 64% variations can be accounted for by the linear predictions for these parameters respectively.

3.2 Tensile Properties

The dependence of yarn tenacity and breaking extension on different factors is shown in Figs 1 & 2 and Table 4. The yarn linear density interacts with ribbon width, and the third order interaction among the yarn linear density, fibre linear density and ribbon width is significant. It can be seen that the MJS yarns spun from 1.11 dtex polyester fibre are stronger and more extensible than the yarns spun from 1.56 dtex fibre under the identical processing condition. In

![Graphs showing variation in tenacity with fibre denier, ribbon width, main draft and yarn linear density](image-url)
Table 4 — ANOVA test results

<table>
<thead>
<tr>
<th>Factors</th>
<th>Yarn properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tenacity</td>
</tr>
<tr>
<td>Yarn linear density (A)</td>
<td>s</td>
</tr>
<tr>
<td>Fibre linear density (B)</td>
<td>s</td>
</tr>
<tr>
<td>Main draft (C)</td>
<td>s</td>
</tr>
<tr>
<td>Ribbon width (D)</td>
<td>s</td>
</tr>
<tr>
<td>A*B</td>
<td>ns</td>
</tr>
<tr>
<td>A*C</td>
<td>ns</td>
</tr>
<tr>
<td>A*D</td>
<td>ns</td>
</tr>
<tr>
<td>B*C</td>
<td>ns</td>
</tr>
<tr>
<td>B*D</td>
<td>ns</td>
</tr>
<tr>
<td>C*D</td>
<td>ns</td>
</tr>
<tr>
<td>A<em>B</em>C</td>
<td>ns</td>
</tr>
<tr>
<td>A<em>B</em>D</td>
<td>ns</td>
</tr>
<tr>
<td>A<em>C</em>D</td>
<td>ns</td>
</tr>
<tr>
<td>B<em>C</em>D</td>
<td>ns</td>
</tr>
</tbody>
</table>

s—Significant at 95% confidence level, and ns—Non-significant at 95% confidence level.

Table 5 — Response surface equations for various yarn properties

<table>
<thead>
<tr>
<th>Response</th>
<th>Response surface equation</th>
<th>Multiple regression coefficient (R)</th>
<th>R²</th>
<th>Goodness of fit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yarn tenacity, cN/tex</td>
<td>27.42 + 0.61x₁ - 1.82x₂ + 0.17x₃ + 0.22x₄</td>
<td>0.86</td>
<td>0.74</td>
<td>21.36</td>
</tr>
<tr>
<td>Breaking extension, %</td>
<td>13.72 - 0.21x₁ - 0.79x₂ + 0.10x₃ - 0.11x₄</td>
<td>0.73</td>
<td>0.53</td>
<td>8.84</td>
</tr>
<tr>
<td>Flexural rigidity x 10³, g. cm²</td>
<td>2.23 + 0.26x₁ + 0.87x₂ + 0.05x₃ + 0.35x₄</td>
<td>0.73</td>
<td>0.53</td>
<td>8.84</td>
</tr>
<tr>
<td>Unevenness, U%</td>
<td>9.49 + 0.38x₁ + 1.58x₂ + 0.15x₃ + 0.39x₄</td>
<td>0.97</td>
<td>0.94</td>
<td>115.1</td>
</tr>
<tr>
<td>Imperfections/1000m</td>
<td>72.56 + 0.10x₁ + 0.48x₂ + 0.25x₃ + 0.87x₄</td>
<td>0.80</td>
<td>0.64</td>
<td>13.73</td>
</tr>
</tbody>
</table>

Fig. 2 — Variation in breaking elongation with fibre denier, ribbon width, main draft and yarn linear density.

regard to condenser size, the yarn tenacity shows distinct trends for 14.7 and 19.6 tex yarns. In the case of 19.6 tex yarns, the tenacity is lower, as expected, for narrower condenser. However, for 14.7 tex yarns spun with 1.56 dtex fibres, the tenacity increases initially and decreases thereafter with the increase in condenser width. The tenacity of 14.7 tex yarns spun from 1.11 dtex fibres, on the other hand, decreases sharply as the condenser width increases from 3mm to 5mm. The relatively low tenacity values obtained with wider condenser are direct consequence of the yarn structure. The tenacity of MJS yarn is imparted by the wrapper fibres that hold core fibres and hence prevent slippage. A wider condenser produces too many wrappers but fewer core fibres. As a result, the ratio of core-to-wrapper fibres becomes lower, thereby making the yarn weaker. The increase in main draft improves the tensile characteristics, which deteriorate with the increase in yarn linear density.
3.3 Unevenness

The effect of fibre linear density, ribbon width, main draft, yarn linear density and their interactions in deciding yarn unevenness is shown in Fig. 3 and Table 4. The fibre linear density interacts with main draft in determining the evenness of the jet-spun yarns. It is observed that the yarn unevenness increases as the ribbon width increases from 3mm to 5mm. The high yarn unevenness with wider condenser can be attributed to the greater incidence of wrapper fibres. The influence of main draft is quite predictable, higher main draft produces less even yarns. The deterioration in yarn evenness is caused by the increased incidence of wrapper fibres, which adversely affect the unevenness due to their contribution to short term mass irregularity. On the other hand, yarn unevenness is lower, as usual, for coarse yarns and it increases with the increase in fibre linear density.

3.4 Flexural Rigidity

Fig. 4 shows the influence of processing factors on flexural rigidity. The flexural rigidity values are lower for the yarns spun from 1.11 dtex polyester staple and higher for those spun from 1.56 dtex fibres. The higher main draft results in the higher values of flexural rigidity. An obvious reason for the higher flexural rigidity is the increase in the number of wrapper fibres that hinder the free movement of core fibres in the yarns, thus resulting in higher rigidity. The use of narrower condenser reduces the flexural rigidity, the latter, however increases with the increase in yarn linear density.

3.5 Hairiness

The variation in hairiness with fibre fineness, yarn linear density, ribbon width and main draft is shown in Fig. 5. Hairiness is virtually more in yarns spun with 1.56 dtex fibre than the equivalent yarns having 1.11 dtex fibres. This more hairiness is related to the higher bending stiffness of coarse fibre. Yarn linear density interacts with main draft as well as with ribbon width to decide the smaller number of hairs/m. Ribbon width also has a profound influence on the hairiness.

3.6 Imperfections

The influence of main draft and ribbon width on the number of imperfections is similar to that of yarn unevenness. There is significant third order interaction among yarn linear density, main draft and ribbon width to determine total number of imperfections. As can be observed from Fig. 6, the MJS yarns spun with higher values of main draft have
more thick and thin places which further increase with the increase in ribbon width. Further, nep indices are also substantially higher with ribbon width and main draft but no consistent trend is observed. The general increase in the incidence of imperfections with the increase in main draft or ribbon width is due to the increase in incidence of wrapper fibres.

4 Conclusions

4.1 The ribbon width has a considerable effect on the tensile properties of polyester MJS yarns. When the ribbon width increases from 3mm to 5mm, the tenacity and breaking extension of 19.6 tex yarn increase sharply. For 14.7 tex yarn, these characteristics register higher values at 3mm ribbon width for 1.11 dtex fibres and at 4mm ribbon width for 1.56 dtex fibres. The increase in main draft results in significant improvement in tensile properties.

4.2 MJS yarns spun with a narrower condenser at all levels of main draft are more regular. However, the yarns produced with high main draft show deterioration in evenness and imperfections.

4.3 The yarns spun with higher values of main draft show the highest rigidity. The use of narrower condenser helps to produce less rigid yarns. Fine fibres assist in further lowering of rigidity, irrespective of the processing parameters used.

4.4 The yarn hairiness increases with the increase in both main draft and ribbon width.

4.5 Approximately 74%, 53%, 96%, 94% and 64% of the variations in tenacity, breaking extension, rigidity, unevenness and imperfections respectively can be accounted for by the linear predictions for these parameters.

References