Response of polyester-viscose blends to air-jet spinning

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Unlike ring yarns, air-jet yarns owe their surface cohesion to wrappers and their formation could be related not only to the turbulence in the two nozzles but also to the combined influence of the fibre properties and other process parameters. This paper reports the contribution of polyester fibre denier, spinning speed and second nozzle pressure to the characteristics of polyester-viscose yarns spun on Murata-jet spinner. It is observed that MJS yarns are slightly weaker, more even, have fewer imperfections and higher extension, flexural rigidity and elastic recovery. An increase in second nozzle pressure and spinning speed causes an increase in the yarn tenacity and flexural rigidity but has an adverse effect on yarn evenness. Breaking extension, on the other hand, decreases with increase in second nozzle pressure and decrease in spinning speed.

Keywords: Air-jet spinning, Murata-jet spinner, Polyester-viscose yarn, Yarn properties

1 Introduction
With the advent of air-jet spinning the ring spinning system faced another strong competitor, in addition to the rotor spinning system, from both economic and quality point of view particularly in medium and fine count range. The experience gained so far has confirmed that polyester, acrylic and blended yarns can be successfully processed on this system. However, the yarns produced are reported to have different structural characteristics. An elaborate study on the maximum potential of air-jet spinning technology would help engineer yarns for specific textile substrates. Some researchers have studied the effects of draft, nozzle pressure, take-up ratio and yarn linear speed on the characteristics of air-jet yarns. However, not much work has been reported on the combined influence of the fibre parameters and process variables. This paper aims at exploring this area in relation to the characteristics of air-jet yarns.

2 Materials and Methods
2.1 Preparation of Yarn Samples
Two sets of yarns of 12.3 tex were spun from two different blends of polyester and viscose rayon fibres on ring and air-jet spinning machines. The specifications of polyester and viscose fibres used are given in Table 1. The polyester fibres used in all the yarns were high tenacity type and had essentially the same characteristics except fibre linear density. For blending polyester and viscose fibres, a predetermined quantity of each of the two components was hand opened and a sandwiched blend was obtained. The multilayered fibre material was carded twice on a MMC card. The card slivers were drawn on a Laxmi Reiter draw frame 3. Three passages of drawing were given for all the blends, the linear density of finisher sliver being adjusted to 3.0 ktex. The slivers were spun into yarns on Murata air-jet spinner 802 MJS. The material and process parameters used to produce these yarn samples are given in Table 2. For ring spinning, the finished drawn sliver was converted into a suitable rove using an OKK roving frame. Equivalent yarns were spun on Laxmi Reiter ring frame G 5/1 using the following process parameters: Spindle speed, 13500 rpm; Total draft, 32; and Twist multiplier, 3.0.

| Table 1 – Specifications of polyester and viscose rayon fibres |
|-------------|-----------|------|-------|
| Fibre       | Fibre length (mm) | Fibre denier | Tenacity (g/den) | Breaking extension (%) |
| Polyester   | 51         | 1.0  | 5.18  | 24.1   |
| Polyester   | 51         | 1.4  | 5.25  | 24.8   |
| Viscose     | 51         | 1.4  | 2.01  | 18.5   |

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2.2 Tests

All the yarns were tested for single strand strength and breaking extension on an Instron, 500 mm long test specimens being elongated at 200 mm/min extension rate. Mean breaking strength and extension were averaged from 50 observations for each yarn sample. Yarn unevenness and imperfections were recorded by the Uster evenness tester. The flexural rigidity and elastic recovery of yarns were tested on weighing ring yarn stiffness tester by ring loop method.

3 Results and Discussion

3.1 Breaking Strength

Table 3 shows that the MJS yarns are about 14-18% weaker than the ring-spun yarns depending upon the fibre linear density, yarn composition, spinning speed and second nozzle pressure. The lower strength of MJS yarn can be attributed to its unique structure. For both MJS and ring yarns, the tenacity increases with increase in polyester fibre content owing to the higher tenacity and extension at break of this fibre. In MJS yarns, the tenacity increases with increasing spinning speed due to the longer wrapped-in length. Such a trend is expected due to the fact that the increased air flow at high speed causes the edge fibres to move away from the fibrous strand and assists these fibres to become long wrappings. Apart from fibre composition and production speed, the second nozzle pressure seems to make a significant contribution to the tenacity of MJS yarns. Some earlier studies have shown that the yarn tensile strength decreases with increase in second nozzle pressure. Contrary to this observation, the present study shows that within the second nozzle pressure range of 3.5-4.5 kg/cm² the tenacity increases with increase in pressure. This can only be attributed to increase in transverse forces. Since there is no effective migration of the core fibres, the transverse forces necessary for the inter-fibre cohesion required to sustain external loading are provided by the wrapper fibres wound on the surface of the core fibres. These transverse forces would depend on the number of wrappings, mean length per wrapping and wrapped-in length. As expected, increase in fibre fineness results in a higher tenacity for both ring and MJS yarns.

3.2 Breaking Extension

The values of breaking extension for ring and MJS yarns (Table 3) show that, in general, the
MJS yarns are more extensible than their ring counterparts. The breaking extension of ring and MJS yarns tends to drop as the polyester fibre linear density is increased. The breaking extension considerably decreases with increase in second nozzle pressure due to greater compactness owing to increased transverse forces. This is born out by the fact that the yarn diameter which can be taken as an indication of compactness, decreases with increasing second nozzle pressure irrespective of fibre linear density and yarn composition. For 80:20 polyester viscose yarn spun from polyester fibres of 1.0 denier using the nozzle pressure of 3.5, 4.0 and 4.5 kg/cm² the yarn diameters were found to be 0.145, 0.141 and 0.137 mm respectively. Increase in spinning speed results in a higher breaking extension for MJS yarns. Since the tensile behaviour of MJS yarns critically depends on the wrappers for inter-fibre cohesion, their formation is a combined effect governed, to a large extent, by the fibre parameters, stiffness of the fibre-mix and process variables. With regard to the contribution of process parameters to breaking load and extension at break of polyester MJS yarns, Chasmawala et al. reported a close association between yarn structural parameters and tensile characteristics.

3.3 Yarn Unevenness

Table 3 shows that the MJS yarns are more even and have less imperfections than the corresponding ring yarns. The lower unevenness of MJS yarn can be attributed to the higher drafting speeds wherein the inertia effect allows fibres to be pulled out without much disturbance in the adjoining fibres. The formation of high amplitude drafting waves is thus clearly avoided as less number of fibres can move out of turn. The polyester fibre content hardly affects the unevenness of MJS yarns. The U% values tend to increase with an increase in both polyester fibre linear density and second nozzle pressure. In spinning yarns from coarse fibres, less fibres are presented at the front roller nip so that the fibres are individualized, which, in turn, increase the production of edge fibres. In addition to this, the number of fibres in strand cross-section considerably decreases with increase in polyester fibre denier. This partly explains the slightly more unevenness observed for MJS yarns spun from coarse polyester fibres at high second nozzle pressure. Apart from the fibre denier and nozzle pressure, the production speed also appears to contribute to yarn unevenness. For all the yarns, U% increases as the production speed is increased. The increase in unevenness of MJS yarns can be attributed to the greater disturbance due to increased air-flow at front roller nip at increasing production speed.

3.4 Imperfections

The imperfection values for ring and MJS yarns (Table 4) show that for both these yarns, the thick
Table 5 – Effect of fibre denier, spinning speed and second nozzle pressure on flexural rigidity and elastic recovery of polyester-viscose ring and MJS yarns

<table>
<thead>
<tr>
<th>Yarn ref. No.</th>
<th>Ring yarn Flexural rigidity × 10¹, g.cm⁻²</th>
<th>MJS yarn Flexural rigidity × 10¹, g.cm⁻²</th>
<th>Ring yarn Elastic recovery, %</th>
<th>MJS yarn Elastic recovery, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>8.8</td>
<td>11.2</td>
<td>12.8</td>
<td>13.1</td>
</tr>
<tr>
<td>S2</td>
<td>8.6</td>
<td>10.8</td>
<td>11.9</td>
<td>13.3</td>
</tr>
<tr>
<td>S3</td>
<td>8.7</td>
<td>10.4</td>
<td>11.8</td>
<td>12.8</td>
</tr>
<tr>
<td>S4</td>
<td>8.26</td>
<td>9.7</td>
<td>10.8</td>
<td>12.3</td>
</tr>
<tr>
<td>S5</td>
<td>8.2</td>
<td>8.74</td>
<td>10.2</td>
<td>11.2</td>
</tr>
<tr>
<td>S6</td>
<td>7.8</td>
<td>9.4</td>
<td>11.6</td>
<td>12.4</td>
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<tr>
<td>S7</td>
<td>7.8</td>
<td>9.2</td>
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<tr>
<td>S8</td>
<td>7.8</td>
<td>9.1</td>
<td>9.4</td>
<td>10.7</td>
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</tbody>
</table>

Yarn linear density, 12.3 tex; and ¹Second nozzle pressure in kg/cm²

and thin places slightly increase with the increase in fibre denier, as expected. Incidentally, the second nozzle pressure does not affect imperfections, the latter, however, alter with spinning speed. As is evident from the test results, the thick places and neps are less in yarns spun at low spinning speed and increase as the spinning speed is increased. Thin places, on the other hand, appear to decrease with increasing spinning speed. The total imperfections show very slight difference at different spinning speeds and fibre deniers.

3.5 Flexural Rigidity

Table 5 shows that the MJS yarns are stiffer than the ring-spun yarns, irrespective of fibre linear density and yarn composition. In MJS yarns, the fibres in the core lie parallel to the yarn axis and the sheath fibres wrap around them. The parallel fibre core tends to act as a group as the wrappers considerably restrict the freedom of their movement during bending. Hence, the flexural rigidity indices for MJS yarns are considerably higher than those for the equivalent ring yarns.

For both ring and air-jet yarns, the flexural rigidity increases with decrease in polyester fibre denier; the flexural rigidity being inversely proportional to the bending rigidity and is in line with the accepted fact that fine denier fibres have lower bending rigidity².⁵. Furthermore, an increase in the polyester fibre content results in an increase in flexural rigidity due to the higher modulus of polyester fibres. Table 5 also shows that the flexural rigidity of MJS yarns increases with increase in both spinning speed and the second nozzle pressure. This can be accounted for by the role played by the wrapper fibres. In MJS yarns, the degree of the freedom of fibre movement, which is largely determined by the inter-fibre friction, is impaired by the transverse forces. At higher spinning speed and higher second nozzle pressure, the number of wrapper fibres and the wrapped-in length increase, causing a lower degree of freedom of fibre movement and hence a higher flexural rigidity.

3.6 Elastic Recovery

Table 5 shows that the ring yarns have higher elastic recovery than the MJS yarns owing to the longer length of the fibre available per unit length in the former. Like in ring yarns, the elastic recovery of MJS yarns is higher for yarns having higher polyester fibre content and it shows no significant change with increase in the second nozzle pressure. Surprisingly, the variation in spinning speed hardly affects the elastic recovery of MJS yarns, although yarns spun at higher production speed exhibit slightly higher elastic recovery. The apparent behaviour can be ascribed to the variability of strains associated with the presence of wrapper fibres⁶.

4 Conclusions

4.1 MJS yarns are slightly weaker but more extensible as compared to their ring counterparts. The tenacity of all the yarns increases with increase in fibre fineness, polyester fibre content, spinning speed and second nozzle pressure. However, the breaking extension decreases with an increase in
the second nozzle pressure and decrease in spinning speed.

4.2 MJS yarns, at all spinning speeds, are more even than the ring yarns. However, yarn evenness deteriorates with increasing polyester fibre denier, second nozzle pressure and spinning speed.

4.3 MJS yarns have fewer imperfections than the ring-spun yarns and show no significant change with increase in second nozzle pressure. However, an increase in spinning speed results in an increase in thick places and neps but decrease in thin places.

4.4 MJS yarns have considerably higher flexural rigidity and elastic recovery, which further increases with increase in polyester fibre fineness. An increase in second nozzle pressure and spinning speed increases the flexural rigidity but has no significant effect on elastic recovery.

References