Performance and low-stress characteristics of polyester-cotton MVS yarns

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The effect of twisting jet pressure, nozzle distance, delivery speed, yarn linear density and fibre composition on the performance and low-stress characteristics of polyester-cotton Murata vortex spun yarns has been studied. The coarser yarns produced using the same conditions exhibit higher abrasion resistance, tensile energy and compressional energy but lower per cent decay. Higher jet pressure and wider nozzle distance offer considerable advantages in respect of structural integrity, abrasion resistance and resilience but there is deterioration in these characteristics at a very high jet pressure. Tensile energy initially increases with the increase in jet pressure and nozzle distance and then drops when jet pressure is further increased. Compressional energy, on the other hand, exhibits a decrease followed by an increase with the increasing jet pressure. Structural integrity and abrasion resistance deteriorate with the increasing delivery speed.

Keywords: Abrasion resistance, Air-jet spinning, Compressional energy, Murata vortex spun yarn, Polyester-cotton yarn

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1 Introduction

With the commercialization of air-jet spinning in early eighties, extensive research work was carried out by researchers to optimize the material and process parameters with a view to improve the yarn characteristics. However, most of the work was confined to tensile and regularity characteristics of yarns spun on MJS or MTS spinning machines. Moreover, the work was carried out at very low production speeds. However, the information on performance and low-stress characteristics of the jet-spin yarns is less extensive. Sengupta et al. studied the effect of slack and tension annealing on the structural integrity, abrasion resistance and tensile characteristics of ring- and jet-spun yarns. Basu et al. studied the effect of fibre length and denier and yarn linear density on the abrasion resistance, flexural rigidity, coefficient of friction and compressional energy of the yarns spun on ring and air-jet spinning systems. Bhortakcke et al. investigated the influence of fibre dimensions and delivery speed on the abrasion resistance, compressional energy and compressional resilience of air-jet yarn fabrics.

2 Materials and Methods

2.1 Sample Preparation

Two sets of yarns (14.7 and 19.6 tex) were spun from the blends of polyester and combed cotton fibres on the air-jet spinner MVS 810. The specifications of the polyester and cotton fibres used in the study are given in Table 1. A predetermined quantity of polyester and combed cotton fibres was mixed and processed on a Lakshmi Rieters' blowroom line, Lakshmi Rieters' card C 1/3 and a draw frame DO/6. Three drawing passages were given to the carded slivers to produce finisher sliver of 3.0 ktx. The drawn slivers were spun into yarns on Murata vortex spinner using Box and Behnkan experimental plan (Table 2). The actual values corresponding to coded levels are given in Table 3. The order of spinning yarn samples was randomized to avoid any systematic

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Mukhopadhyay et al. investigated the effect of first nozzle pressure, gauge length, main draft and condenser width on low-stress characteristics of polyester-viscose MJS yarns. The present study aims at investigating the role of process variables in influencing the performance and low-stress characteristics of Murata vortex spun yarns.
error. The following second order polynomial was fitted to ascertain the relationship between the response and the independent variables:

\[ Y = b_0 + \sum_{i=1}^{3} b_i x_i + \sum_{j=1}^{3} b_j x_j^2 + \sum_{i=1}^{3} b_{ij} x_i x_j \]

where \( Y \) is the measured response; \( b_0, b_i, b_j \) and \( b_{ij} \) are the coefficients of the regression equation; and \( i \) and \( j \), the integers with \( i < j \). The regression coefficients of the response \( Y \) were found using the experimental results.

### Table 1—Specifications of polyester and cotton fibres

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Polyester fibre</th>
<th>Cotton fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, mm</td>
<td>44</td>
<td>36.02*</td>
</tr>
<tr>
<td>Linear density, dtex</td>
<td>1.33</td>
<td>1.42</td>
</tr>
<tr>
<td>Tenacity, cN/hex</td>
<td>52.88</td>
<td>28.6</td>
</tr>
<tr>
<td>Breaking extension, %</td>
<td>18.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

*2.5% Span length

### Table 2—Experimental plan for the variables used

<table>
<thead>
<tr>
<th>Combination No.</th>
<th>Level of the variable</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Twisting jet pressure</td>
<td>Delivery speed</td>
<td>Nozzle distance*</td>
</tr>
<tr>
<td></td>
<td>((x_1))</td>
<td>((x_2))</td>
<td>((x_3))</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>-1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>5</td>
<td>-1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>7</td>
<td>-1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Distance between twisting jet and nip of front delivery roller

### Table 3—Actual values corresponding to coded levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Twisting jet pressure ((x_1))</th>
<th>Delivery speed ((x_2))</th>
<th>Nozzle distance ((x_3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>4</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>270</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>290</td>
<td>22</td>
</tr>
</tbody>
</table>

### 2.2 Test Methods

#### 2.2.1 Structural Integrity

All the yarns were tested for cyclic loading using 200 mm test specimen and 20 mm/min cross-head speed. The upper limit was fixed at 2% strain and twenty cycles were fixed on the Instron universal tester. The performance was assessed in terms of percentage decay using the following expression:

\[ \text{Percentage decay} = \frac{1}{(A_1 - A_{20})/A_1} \times 100 \]

where \( A_1 \) and \( A_{20} \) are the areas under the curves for first and twentieth cycles.

#### 2.2.2 Abrasion Resistance

The number of abrasion cycles required to break the specimen was measured using CSI abrasion tester. Twenty readings were recorded for each sample.

#### 2.2.3 Tensile Energy

The tensile energy required to extend the specimen to 2% strain was measured on the Instron universal tester using 500 mm gauge length and 50 mm/min cross-head speed.

#### 2.2.4 Compressional Energy

All the yarns were tested for compressional energy on the Instron universal tester according to the method suggested by Basu et al. A parallel array of yarn was compressed between two parallel compression plates to a pressure of 2.5 g/cm\(^2\) (anvil diam., 120 mm; and foot diam., 40 mm). The initial separation between the plates was kept at 10 mm and cross-head speed as 0.5 mm/min. The tensile resilience and compressional resilience were calculated by expressing unloading curve area as percentage of loading curve area.

### 3 Results and Discussion

#### 3.1 Statistical Analysis

Tables 4 and 5 show the various yarn characteristics and their response surface equations along with the square of multiple correlation coefficients. Only significant terms have been included in the final equations by using forward stepwise regression procedure. The negative coefficient of a variable in a response surface equation indicates that a particular characteristic decreases with the increase in that variable while a positive coefficient of the variable indicates that the characteristic increases with
enlarged reproductive sections also reduce the % decay. However, the % decay
stippled during load cycling. However, the % decay
decrease, which ultimately decrease the height of strips.
besides the proportion of unreplicated sections also
can be observed in young regular specimens.
2.2.3. The proportion in early distance from 2 cm to
with the increase in nozzle distance from 2 cm to
density shows a marked decrease in % decay.
lower on account of the increased regular wadgets
height of pressure of 6 km/h, the increase becomes
possible of the stippled during load cycling. Al
where with increasing pressure restrict the
heights with increasing pressure
and higher incidence of wadgets
reduced with the increase in nozzle
distance and density, the increase in % decay
increases significantly in the 2.2.3.
increased from 4 km/h to 6 km/h, the
increase increases from 4 km/h to 6 km/h, which
be accounted for by the following
increase the prooin of the MWS system. On an average, a
improvement in the density increases
increase in the density, which
increase with the increase in nozzle
distance and density, reduces the % decay.

Table 4-Experimental results for various yarn characteristics

<table>
<thead>
<tr>
<th>Combination</th>
<th>Structured Agglomeration</th>
<th>Texture of Axial Resistance</th>
<th>Tenacity Energy, cN/tex</th>
<th>Tenacity Resilience, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>462</td>
<td>292</td>
<td>806</td>
<td>908</td>
</tr>
<tr>
<td>2</td>
<td>452</td>
<td>292</td>
<td>806</td>
<td>908</td>
</tr>
<tr>
<td>3</td>
<td>452</td>
<td>292</td>
<td>806</td>
<td>908</td>
</tr>
<tr>
<td>4</td>
<td>452</td>
<td>292</td>
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<td>908</td>
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<tr>
<td>5</td>
<td>452</td>
<td>292</td>
<td>806</td>
<td>908</td>
</tr>
<tr>
<td>6</td>
<td>452</td>
<td>292</td>
<td>806</td>
<td>908</td>
</tr>
</tbody>
</table>

% Vol:

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Table 5—Response surface equations for various yarn properties

<table>
<thead>
<tr>
<th>Response</th>
<th>Yarn linear density, tex (polyester/cotton blend ratio)</th>
<th>Response surface equation</th>
<th>Squared multiple regression coefficient ($R^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural integrity % decay</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$48.20+2.02x_1-1.44x_2+1.67x_3-1.70x_2^2+1.05x_3^2$</td>
<td>0.85 0.90 0.89 0.87 0.88 0.90</td>
</tr>
<tr>
<td>Abrasion resistance cycles</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$457.54-12.01x_1-6.25x_2+7.99x_3+24.38x_3^2+4.87x_3^2$</td>
<td>0.92 0.93 0.84 0.89 0.92 0.93</td>
</tr>
<tr>
<td>Tensile energy g/mm</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$526.84-25.55x_1-6.14x_2^2+8.39x_3^2$</td>
<td>0.92 0.92 0.82 0.92 0.82 0.92</td>
</tr>
<tr>
<td>Tensile resilience %</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$60.49-23.34x_1-5.17x_2^2+8.11x_3^2-32.15x_3^2$</td>
<td>0.98 0.98 0.98 0.98 0.98</td>
</tr>
<tr>
<td>Compressional energy g/mm</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$62.84-1.75x_1+1.29x_2^2+2.99x_3^2$</td>
<td>0.78 0.78 0.78 0.78 0.78</td>
</tr>
<tr>
<td>Compressional resilience %</td>
<td>19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35 19.6/80/20 14.7/65/35</td>
<td>$60.51-1.45x_1+1.61x_3^2$</td>
<td>0.64 0.64 0.64 0.64 0.64</td>
</tr>
</tbody>
</table>

Fig.1—Variation in structural integrity with twisting jet pressure and nozzle distance [(a) 19.6 tex yarn, and (b) 14.7 tex yarn]

shows little increase as nozzle distance is further increased to 22mm. This may be accounted to the little drop in the long regular wrappings at 22mm nozzle distance. The structural integrity is found to be inferior for the fine yarns spun from low polyester content and it further deteriorates with the increase in delivery speed.

3.4 Abrasion Resistance

Tables 4 and 5 and Fig. 2 show the results of abrasion test. The fact that the coarser yarns exhibit higher abrasion resistance also holds true for polyester-cotton MVS yarns. The increase in jet pressure from 4 kg/cm² to 5 kg/cm² leads to increase in abrasion resistance but the abrasion resistance...
Fig. 2—Variation in abrasion resistance with twisting jet pressure and delivery speed [(a) 19.6 tex yarn, and (b) 14.7 tex yarn]

Fig. 3—Variation in tensile energy with twisting jet pressure and delivery speed [(a) 19.6 tex yarn, and (b) 14.7 tex yarn]

decreases significantly with further increase in jet pressure. Such a trend can again be attributed to the afore-mentioned facts. An increase in nozzle distance further improves the abrasion resistance on account of the increase in long regular wrappings and decrease in unwrapped sections. Furthermore, the abrasion resistance is considerably higher in yarns with higher polyester content and it decreases with the increase in delivery speed, possibly due to poor and improper wrappings formed at higher delivery speeds.

3.5 Tensile Energy

The response surface equations for tensile energy (Table 5) indicate that the jet pressure has maximum influence on tensile energy followed by nozzle distance and delivery speed. Invariably, the coarser yarns exhibit higher tensile energy than the finer yarns. The influence of jet pressure is quite predictable, with higher jet pressure resulting in higher tensile energy. Such a behaviour of tensile energy could arise due to the increase in tight regular wrappings and wrapper fibres, which results in a compact and rigid structure. But at very high jet pressure, the tensile energy shows a decrease on account of the increase in the incidence of wild fibres. Besides, the conversion of tight regular wrappings into irregular ones also decreases the tensile energy. The tensile energy further increases with the increase in nozzle distance due to increase in long regular wrappings and wrapper fibres, leading to buildup of stresses when extended up to 2% strain. The increase in delivery speed reduces the yarn tensile energy; the latter however shows no significant change with the change in fibre composition.

3.6 Tensile Resilience

Fig. 4 shows the effect of jet pressure and nozzle distance on the tensile resilience of MVS yarns. The figure clearly shows that the tensile resilience increases with the increase in nozzle distance. This could possibly be due to the fact that both wrapper fibres and long wrappings increase with the increase
in nozzle distance. However, the tensile resilience initially increases with the increase in jet pressure up to 5 kg/cm² but decreases thereafter with further increase in jet pressure. The lower tensile resilience values at lower jet pressure are due to poor regular wrappings. An increase in jet pressure leads to tight regular wrappings, which, in turn, hinder the slide past of fibres over each other. The decrease in tensile resilience at high jet pressure of 6 kg/cm² may be due to the formation of loose structure caused by the irregular wrappings and wild fibres. The use of higher delivery speed also results in lowering of tensile
resilience, irrespective of the jet pressure and nozzle distance.

3.7 Compressional Energy

The association of compressional energy with different process variables is shown in Tables 4 and 5. Fig. 5 shows that the compressional energy of polyester-cotton MVS yarns tends to decrease when the jet pressure is increased from 4 kg/cm² to 5 kg/cm². However, a further increase in jet pressure causes significant increase in compressional energy. With the increase in jet pressure, both tight regular wrappings and wrapper fibres increase which make the yarn rigid and more compact; the latter leads to decrease in compressional energy. On the other hand, the increase in jet pressure results in tight wrappings with crimped core, leading to a wavy structure and thus a gain in compressional energy. The gain is counteracted by the loss due to the increased rigidity and compactness of structure and hence a lower compressional energy. The increase in compressional energy at higher jet pressure of 6 kg/cm² may result due to the bulky and loose structure caused by irregular wrappings and wild fibres. With the increase in nozzle distance, the long regular wrappings increase and the unwrapped sections decrease. Consequently, the yarn becomes rigid and more compact making it difficult to further compress. Further, coarse yarns require more energy to compress, as expected.

3.8 Compressional Resilience

As is evident from the response surface equations in Table 5, the influence of jet pressure on compressional resilience is similar to that on tensile resilience. The increased nozzle distance, in general, improves the compressional resilience due to the formation of compact structure and thus higher buoyancy of the fibrous strand. The effect of yarn linear density and fibre composition on compressional resilience is minimal.

4 Conclusions

4.1 Higher polyester content offers significant advantages in air-jet spinning in regard to abrasion resistance and structural integrity. Both jet pressure and nozzle distance have a marked influence on performance characteristics. With increasing jet pressure, the structural integrity and abrasion resistance improve initially but deteriorate thereafter as the jet pressure is further raised beyond a particular limit. Wider nozzle distance generally improves the performance characteristics. Coarse yarns display higher values of structural integrity and abrasion resistance.

4.2 In general, the fine yarns yield lower tensile energy as compared to coarse yarns. The tensile energy increases initially when the jet pressure increases and it decreases thereafter as jet pressure is further increased. The tensile energy is highly dependent on the nozzle distance and delivery speed; the yarns produced with lower delivery speed and wider nozzle distance show higher tensile energy.

4.3 The compressional energy of MVS yarns decreases initially when jet pressure increases from 4.0 kg/cm² to 5.0 kg/cm² and it increases thereafter as the jet pressure is further increased to 6.0 kg/cm². Wider nozzle distance and finer yarns result in lower compressional energy.

4.4 In general, the tensile and compressional resilience initially improve with the increase in both nozzle distance and jet pressure and then deteriorate on further increase in jet pressure from 5.0 kg/cm² to 6.0 kg/cm². A lower delivery speed is needed to improve the tensile and compressional resilience.

References