Tearing strength of cotton fabrics in relation to certain process and loom parameters

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Tearing strength of cotton fabrics made of ring- as well as compact-spun weft yarns has been studied in relation to certain process and loom parameters. It is observed that the fabrics made of compact-spun weft yarns are more tear resistant. The tearing strength further improves particularly in the weft-way direction with the increase in weft yarn linear density and weft tex twist factor. There is an initial increase in strength followed by a decrease as the number of picks/inch is increased in the cotton fabrics made of compact-spun yarns. However, for the fabrics made of ring yarns, it shows a general decreasing trend. The 2/2 designs are found to be superior in warp-way but inferior in weft-way directions. The fabrics woven on air-jet looms show lower tearing strength than those woven on projectile looms. The mechanical finish as well as the variation in shed opening do not affect the tearing strength of cotton fabrics produced from compact-spun weft yarns.

Keywords: Compact-spun yarns, Cotton, Pick density, Tearing strength, Woven fabrics, Yarn withdrawal force

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1 Introduction

Tearing strength is one of the important aspects of a finished fabric. It refers to the rupture of a fabric progressively along a line, thread by thread. With the development of garment industry, the measurement of tearing strength is gaining a fairly wide importance these days as it is directly involved in the assessment of serviceability of the fabric in use.

Tearing strength of a fabric mainly depends on fibre, yarn and fabric characteristics along with mechanical and chemical finishing treatments given to the fabric. Over the years, the research has been directed to investigate the influence of yarn parameters (single yarn strength, linear density, uniformity, smoothness, extensibility, twist and type of yarn)\textsuperscript{1-9} and fabric parameters (weave, fabric sett, crimp and weight/m²)\textsuperscript{1,5,7-13} on tearing strength. A few studies\textsuperscript{10,12} related to the effect of fibre characteristics have also been reported. Most of the studies are based on the use of yarns spun on ring spinning technology.

Compact spinning is a modified version of ring spinning process that is developed recently to produce yarns of better quality and smooth structure through better utilization of fibre properties.\textsuperscript{14-18} Though the tearing strength of the fabrics produced from such yarns is quoted to be higher\textsuperscript{14,15}, the published literature does not reveal any data or systematic study pertaining to the use of these yarns particularly with reference to tearing strength of fabrics. The present study, therefore, aims at investigating the influence of certain process and loom parameters on tearing strength of cotton fabrics made of ring- and compact-spun yarns.

2 Materials and Methods

2.1 Raw Materials

Three different varieties of cotton were used for the present study. The specifications of these cottons are given in Table 1.

2.2 Preparation of Yarn Samples

The preparation of yarn samples was divided into two parts: (i) Part I — Nine yarn samples of three different linear densities (27, 30 and 33 tex) were spun from 100% J-34 cotton (2.5 % span length, 4.6 micronaire, 7.9 % elongation), while another set of three was made from S-6 cotton (28.45 micronaire, 6.9 % elongation).

<table>
<thead>
<tr>
<th>Property</th>
<th>J-34 Cotton</th>
<th>J-34 Cotton\textsuperscript{a}</th>
<th>S-6 Cotton</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 % Span length, mm</td>
<td>26.80</td>
<td>28.45</td>
<td>30.18</td>
</tr>
<tr>
<td>Micronaire, μg/inch</td>
<td>4.6</td>
<td>4.84</td>
<td>4.6</td>
</tr>
<tr>
<td>Uniformity ratio, %</td>
<td>81.20</td>
<td>82.2</td>
<td>83.3</td>
</tr>
<tr>
<td>Strength, g/tex</td>
<td>26.70</td>
<td>31.0</td>
<td>33.4</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>8.5</td>
<td>6.9</td>
<td>7.9</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Used to produce a 50/50 mix with S-6 cotton.
26.80 mm; 4.6 microgram/inch fineness; 26.70 g/tex strength and 8.5% elongation) on ring spinning system. The fibres were processed through a Trumac blow room line and carded on a Lakshmi Rieter LC-100 card. The carded sliver was given two passages of drawing to produce a finished sliver of 4.92 ktex. The finished sliver was converted into rove of 0.59 ktex on a Lakshmi Rieter LF 1400A simplex machine. The rove was then drafted and twisted on a Lakshmi Rieter LG 5/1 ring frame to produce the yarns of 27, 30 and 33 tex linear densities using three different tex twist factors, namely 39.6, 44.0 and 48.4. (ii) Part II — Two different varieties of cotton, viz. J-34 and S-6, of compatible fibre properties (Table 1) were mixed in equal proportion to produce the yarns of same linear density (30 tex) with similar tex twist factor (44.0) on ring as well as compact spinning systems. The processing sequence followed was: LR blow room line, LC 100 card, LR draw frame for pre drawing, Rieter’s LE 2/4a sliver lapper, Rieter’s LE 4/7a ribbon lapper, Rieter’s E7/4 comber, L/R RSB 851 drawframe, LF 1400A simplex machine and Lakshmi Rieter’s LG 5/1 ring frame. Suessen’s Elite spinning machine was used for the production of compact spun yarns.

The entire list of yarn samples produced and the corresponding variables are given in Table 2.

### Table 2 — Yarn samples and corresponding variables

<table>
<thead>
<tr>
<th>Yarn ref. no.</th>
<th>Mixing Type of yarn</th>
<th>Yarn linear density tex</th>
<th>Tex twist factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>J-34 Carded ring-spun</td>
<td>33</td>
<td>39.6</td>
</tr>
<tr>
<td>Y2</td>
<td>J-34 Carded ring-spun</td>
<td>33</td>
<td>44.0</td>
</tr>
<tr>
<td>Y3</td>
<td>J-34 Carded ring-spun</td>
<td>33</td>
<td>48.4</td>
</tr>
<tr>
<td>Y4</td>
<td>J-34 Carded ring-spun</td>
<td>30</td>
<td>39.6</td>
</tr>
<tr>
<td>Y5</td>
<td>J-34 Carded ring-spun</td>
<td>30</td>
<td>44.0</td>
</tr>
<tr>
<td>Y6</td>
<td>J-34 Carded ring-spun</td>
<td>30</td>
<td>48.4</td>
</tr>
<tr>
<td>Y7</td>
<td>J-34 Carded ring-spun</td>
<td>27</td>
<td>39.6</td>
</tr>
<tr>
<td>Y8</td>
<td>J-34 Carded ring-spun</td>
<td>27</td>
<td>44.0</td>
</tr>
<tr>
<td>Y9</td>
<td>J-34 Carded ring-spun</td>
<td>27</td>
<td>48.4</td>
</tr>
<tr>
<td>Y10</td>
<td>J-34/S-6 (50:50) Combed ring-spun</td>
<td>30</td>
<td>44.0</td>
</tr>
<tr>
<td>Y11</td>
<td>J-34/S-6 (50:50) Compact-spun (Elite)</td>
<td>30</td>
<td>44.0</td>
</tr>
</tbody>
</table>

### 2.3 Preparation of Fabric Samples

All the eleven yarn samples (Table 2) were used as weft to weave twenty nine fabric samples of varying design and pick density on two different types of looms, viz projectile (Sulzer) and air-jet (Picanol). The details are given in Table 3. All the fabric samples were also processed and finished under similar industrial conditions. Three fabric samples were also processed mechanically through a peaching machine to study the effect of mechanical finish on tearing strength of fabrics.

### 2.4 Yarn Tests

#### 2.4.1 Single Yarn Strength and Breaking Elongation

The Instron tensile strength tester (Model 4411) was employed for measuring single yarn strength and breaking elongation. The tests were carried out using 500 mm gauge length at an extension rate of 200 mm/min. A minimum of fifty observations was taken for each sample.

### 2.5 Fabric Tests

#### 2.5.1 Measurement of Tearing Strength

Tearing strength of the fabric samples was determined by using Elmendorf tearing tester in accordance with ASTM Standard Test Method D 1424. A template was used to cut fabric strips of 100 ± 2 mm length and 63 ± 0.15 mm width. The critical dimension, i.e. the distance to be torn, was taken as 43 ± 0.15 mm and the observation was recorded from the scale of the tester. The tearing strength was then calculated by using the following formula:

\[
\text{Tearing strength (g)} = 64 \times \text{Scale reading}
\]

Both warp-way and weft-way strips were tested for each sample and ten observations were taken in each case.

#### 2.5.2 Yarn Withdrawal Force

To get an idea of yarn-to-yarn friction, the maximum force required to withdraw/pull the yarn from a fabric was determined on an Instron tensile strength tester (Model 4411) using a gauge length of 70 mm and extension rate of 400 mm/min. The fabric clamp was used as the bottom jaw to hold the fabric specimen while the yarn clamp was used as the top jaw to pull the individual yarns from this fabric specimen.
Fabric specimens were cut to the specified size of 180 mm long and 50 mm wide with the help of scale. Leaving 50 mm from one end of the longer side to allow the specimen to be gripped by the fabric clamps, and another 13 mm for a clearance from the clamp line, a transverse cut of 25 mm was made across the width of the specimen. The specimen was then marked across its width at a distance of 50 mm from the traverse cut and all the crossing threads in the remaining portion of the specimen were unravelled, so that the length of each freed longitudinal yarn from the marked line was 64 mm. Then, the yarns were withdrawn one by one by clamping them in the yarn clamps, the rear end of the specimen in the fabric form being already gripped by a pair of fabric jaws, by moving the yarn clamps at a fixed speed and maximum load was recorded through a PC interfaced with the instrument. Yarn withdrawal force was determined for both warp and weft. Ten observations were taken from two strips of each.

3 Results and Discussion

3.1 Effect of Type of Weft Yarn

Table 4 shows the effect of type of weft yarn on the tearing strength of cotton fabrics. It is observed that the fabrics made of compact-spun yarns are more tear-resistant than those made of ring-spun yarns. The tearing strength of these fabrics is found to be higher in both warp as well as weft direction. The difference between the values of tearing strength, being 8.2-33.2% for weft-way strength as against 0.1-10.6%
for warp-way strength, is found to be significant both at 5% and 1% levels of significance.

As is well known, tearing strength is a function of yarn strength, number of load-bearing elements, distribution of load and ease of slippage among the yarns in the delta zone (del-shaped opening) formed at the point of tear. Accordingly, the type of yarn used influences the tearing strength by virtue of its single thread strength, smoothness or roughness (which affects ease of slippage and fabric deformation), extensibility and uniformity. A greater smoothness permits greater fabric distortion and allows more yarns to carry the load as they tend to group together with greater freedom of movement or ease of slippage, leading to higher tearing strength. Higher tearing strength of the fabrics made of compact-spun yarns (weft) may also be ascribed to the similar effects as the compact-spun yarns are reported to be smoother than ring-spun yarns.\textsuperscript{14,15}

Lower values of yarn withdrawal force for the fabrics made of such yarns (Table 4) also confirm their greater smoothness.

Being in weft, the greater strength and extensibility of these yarns (Table 5) contribute further to enhance the weft-way tearing strength of cotton fabrics.

### Table 5 — Yarn characteristics

<table>
<thead>
<tr>
<th>Yarn ref. no.</th>
<th>Single yarn strength, gf</th>
<th>Tenacity g/tex</th>
<th>Extension %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y\textsubscript{1}</td>
<td>415</td>
<td>12.46</td>
<td>4.30</td>
</tr>
<tr>
<td>Y\textsubscript{2}</td>
<td>501</td>
<td>14.92</td>
<td>4.88</td>
</tr>
<tr>
<td>Y\textsubscript{3}</td>
<td>503</td>
<td>14.86</td>
<td>4.91</td>
</tr>
<tr>
<td>Y\textsubscript{4}</td>
<td>409</td>
<td>13.54</td>
<td>3.92</td>
</tr>
<tr>
<td>Y\textsubscript{5}</td>
<td>427</td>
<td>13.98</td>
<td>4.27</td>
</tr>
<tr>
<td>Y\textsubscript{6}</td>
<td>461</td>
<td>15.01</td>
<td>4.85</td>
</tr>
<tr>
<td>Y\textsubscript{7}</td>
<td>361</td>
<td>13.25</td>
<td>3.84</td>
</tr>
<tr>
<td>Y\textsubscript{8}</td>
<td>407</td>
<td>14.84</td>
<td>4.44</td>
</tr>
<tr>
<td>Y\textsubscript{9}</td>
<td>422</td>
<td>15.20</td>
<td>4.96</td>
</tr>
<tr>
<td>Y\textsubscript{10}</td>
<td>438</td>
<td>14.66</td>
<td>5.09</td>
</tr>
<tr>
<td>Y\textsubscript{11}</td>
<td>501</td>
<td>17.09</td>
<td>5.19</td>
</tr>
</tbody>
</table>

### Fig. 1 — Effect of weft yarn linear density and tex twist factor on tearing strength of cotton fabrics and yarn withdrawal force

Figure 1 reveals opposite trends for warp-way and weft-way tearing strengths of cotton fabrics in relation to weft yarn linear density. While the former decreases, the latter increases as the weft yarn becomes coarser for all the three levels of tex twist.

### 3.2 Effect of Weft Yarn Linear Density

Figure 1 reveals opposite trends for warp-way and weft-way tearing strengths of cotton fabrics in relation to weft yarn linear density. While the former decreases, the latter increases as the weft yarn becomes coarser for all the three levels of tex twist.
factor. The relationship in both the cases is found to be statistically significant at 5% level of significance.

Increase in weft yarn linear density restricts the freedom of movement of threads as a result of increase in yarn diameter so that the grouping tendency of the threads is reduced. Increase in yarn withdrawal force (Fig. 1) for such a fabric structure limits the delta zone to a smaller area and depth; bring fewer yarn into action to support the load, thereby reducing the tearing strength.

It may, however, be noted that the yarn withdrawal force increases in both warp and weft directions with the increase in weft yarn linear density which fails to explain the observed trends for weft-way tearing strength. The increase in this direction may be attributed to the increased shearing strength of the single yarns brought about by increased number of fibres in the yarn cross-section for coarser yarns. Similar observations were also made by a number of other researchers.²,6

3.3 Effect of Weft Tex twist Factor

Figure 1 and Table 4 show insignificant effect of weft tex twist factor on warp-way tearing strength. However, the effect is significant for weft-way tearing strength that increases continuously with weft tex twist factor. This is obviously due to the increased yarn strength and breaking extension (Table 5) and reduced yarn diameter that lead to more freedom of yarn movement.⁹ Considering yarn withdrawal force for weft yarns as a matter of latter aspect, a decreasing trend is observed with twist factor, thus confirming the findings.

3.4 Effect of Weave/Design

The tearing strength data of fabric samples woven in two different twill designs, viz. 3/1 and 2/2, is shown in Table 4. On comparing the warp and weft tearing strengths of otherwise similar fabrics (S₆, S₁₇, S₂₄) and (S₁₀, S₂₁, S₂₈), 2/2 design is found to be superior in warp but inferior in weft direction of samples made of three different types of weft yarns.

Several researchers²⁴⁻⁹ have reported that for a given set of yarns and texture, a fabric with longer floats generally exhibits higher tearing strength due to greater ease of yarn slippage and fabric distortion, causing more yarns to share the load. The same appears to be true for the present study also.

Since the ease of yarn slippage and fabric distortion is closely related to yarn withdrawal force, the grouping of threads is expected to be more for warp in 2/2 design and for weft in 3/1 design because of the lower withdrawal force required in the two and hence the higher tearing strength.

3.5 Effect of Pick Density

Figure 2 shows the effect of pick density on tearing strength of fabrics made of three different types of cotton yarns along with corresponding values of yarn withdrawal force. Except for the weft-way tearing strength of fabrics made of compact-spun yarns, a general tendency is observed for the fabrics to loose strength with the increase in pick density. This is in conformity with the findings of earlier studies.¹⁻⁸,¹¹ The weft-way tearing strength of fabrics made of compact-spun yarns initially increases as the picks/inch are increased from 54 to 58 and then decreases with further increase in pick density from 58 picks/inch to 62 picks/inch.

The decrease in tearing strength may be ascribed to the fact that the increase in pick density increases the yarn withdrawal force due to the increase in cover factor, number of interlacements or frictional points per unit area of the fabric and lower freedom of yarn movement. All these factors, in fact, tend to jam the fabric structure earlier in the direction of tear ahead of delta zone, causing fewer yarns or even single yarn in
the del to break, leading to lower realization of tearing strength. It appears that the smooth, strong compact-spun yarns in the weft delay the onset of jamming conditions of fabric structure and rather initially improve the tearing strength due to their increased single yarn strength, ease of slippage and grouping tendency of yarns.

3.6 Effect of Type of Loom

Figure 3 depicts the tearing strength of similar fabrics (w. r. t. same construction, design and other parameters) woven on two different types of loom, viz. projectile and air-jet. Interestingly, the fabrics woven on air-jet loom exhibit significantly lower tearing strength in both warp and weft directions.

The differences in weft-way tearing strength may be explained on the basis of yarn withdrawal force, which is found to be more in weft for the air-jet loom. On an air-jet loom, there occurs a significant loss of twist in the weft yarn because of the presence of free leading end. This twist loss results in lower weft yarn strength simultaneously loosening the yarn structure, which may lead to its easy flattening in the fabric, thereby increasing fabric cover and the frictional contacts between warp and weft.

As stated earlier also, the increased cover and the reduced freedom of yarn movement tend to create fabric jamming earlier in the del, thus contributing to lower warp-way tearing strength of fabrics woven on air-jet loom.

3.7 Effect of Level of Shed Opening

The effect of level of shed opening on the tearing strength of cotton fabrics made of different types of weft yarn is shown in Fig. 4. The fabrics produced with wider shed opening are found to have lower tearing strength. However, the analysis of the recorded values for these fabric samples reveals significant effect for only one type of weft yarn, i.e. ring-spun 100% J-34 cotton yarn.

The loss in tearing strength for a wider shed opening may be associated with improvement in fabric cover and higher yarn withdrawal force. The strength loss that takes place in warp threads originating from their greater loading and stretching at wider shed may also contribute, to some extent, in the decrease of tearing strength. The higher single yarn strength of the other two types of yarn, viz. ring-spun and compact-spun 50/50 J-34/S-6 cotton yarns (Table 5), probably outweigh the loss in tearing strength caused by improved cover and lower warp yarn strength.
3.8 Effect of Mechanical Finish

The analysis of the values of tearing strength of unpeached (4614, 4768, 5190 gf in warp direction and 3162, 3362, 4173 gf in weft direction) and peached (4531, 4762, 5235 gf in warp direction and 3262, 3501, 4017 gf in weft direction) cotton fabrics of three different types (Table 4) indicates insignificant effect of mechanical finish. The corresponding values of yarn withdrawal force of unpeached (237.3, 267.2, 261.7 gf in warp direction and 168.4, 156.8, 152.6 gf in weft direction) and peached (243.4, 266.0, 239.2 gf in warp direction and 173.9, 179.4, 164.8 gf in weft direction) fabrics given in Table 4 also confirm this effect.

4 Conclusions

4.1 The use of compact-spun yarns as weft results in higher tearing strength of cotton fabrics as compared to that of ring-spun yarn weft fabrics.

4.2 The increase in weft yarn linear density increases weft-wise but decreases warp-wise tearing strength of cotton fabrics.

4.3 Increase in weft tex twist factor increases the weft-way tearing strength of cotton fabrics. However, the effect on warp-way tearing strength is insignificant.

4.4 2/2 twill weave fabrics are more tear resistant than 3/1 twill weave fabrics in warp direction. However, the reverse is true for the weft-way tearing strength.

4.5 In general, the tearing strength of cotton fabrics decreases continuously with the increase in pick density. However, for compact-spun yarns, as the number of picks/inch are increased in the fabric, the weft-way tearing strength exhibits an increasing trend initially followed by a decrease.

4.6 The fabrics woven on air-jet loom have significantly lower tearing strength than the fabrics woven on projectile loom.

4.7 The fabrics produced with wider shed opening exhibit lower tearing strength for ring-spun 100% J-34 yarn weft. However, variation in shed opening does not affect the tearing strength of fabrics when compact-spun yarns are used as weft.

4.8 The mechanical finish does not affect the tearing strength of cotton fabrics significantly.

References