Relationship between Single Fibre Strength and Behaviour of Yarns and Fabrics

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The physical characteristics and breaking strengths of fibres of wools of eight Indian and crossbred sheep and yarns and fabrics obtained therefrom have been investigated with the objective of establishing correlations, if any, between the characteristics of individual fibres and those of their yarns and fabrics. It is observed that fabric strength depends primarily on yarn strength. Fibre strength does not appear to affect fabric and yarn strengths to a significant extent.

About 50 years ago, Ball1 outlined the general relationship between the characteristics of cotton yarn and those of the raw cotton fibres. He showed that although the physical characteristics of the yarns depend to a considerable extent upon the characteristics of the constituent fibres, the relationship is not a direct one. Platt2-3 used the analytical approach and worked out mathematical expressions describing various fibre characteristics and their relationships with yarn characteristics. Other workers4-6 adopted an empirical approach to the problem and established statistical correlations between the observed cotton yarn characteristics and the measured fibre characteristics for the same cotton samples. The fibre data used were based on characteristics of the fibres in groups, bundles or bulk. Virgin et al.7 examined individual fibres from the samples for the various parameters under consideration and employed the average values of these parameters in deriving the statistical correlations.

Bastawisy et al.8 tried to relate fibre diameter and yarn strength in 12 varied wools (60 to 74s quality) spun under similar conditions to a count of 48s W with the same twist (16.0 t.p.i.) and tested these for tenacity; they related the tenacity with fibre diameter statistically.

In the present investigation, individual fibres from wool samples have been tested for the various parameters under consideration. An attempt has also been made to see the relationship between the breaking strengths of individual wool fibres, their yarns and fabrics.

Materials

Eight breed and breed crosses, viz. Chokla, Corriedale, Rambouillet × Chokla (50%), Rambouillet × Chokla (62.5%), Rambouillet × Chokla (75%), Rambouillet × Nali (50%), Merino × Chokla (50%) and Merino × Nali (50%), were taken. Six-monthly clips of these wools were obtained from the flocks being maintained at the farms of this institute. The number of native animals from which the wools were collected was around 500 and that of crossbreds around 100 each.

Methods

Out of each wool lot, samples for each fibre parameter were drawn separately by the zoning and halving method. Three sub-samples were drawn out of each bulk sample. The physical characteristics such as staple length, crimp/cm and fibre length were measured manually with the help of a measuring scale and a pair of forceps as per the Indian Standard Specification IS:1377-1959. Twenty wool staples were taken for measuring the staple length and crimp was counted over the whole length of the staple. The crimp/cm was then calculated by dividing the number of crimps with the staple length. Fibre length was determined by measuring 300 randomly selected fibres from each of the three sub-samples. The pooled mean length of 900 individual fibres alongwith CV% was noted. Fibre fineness (in µ) was measured as per the Indian Standard Specification IS:744-1966 by measuring fibre diameter with the help of a lanameter. Five hundred observations from each of the three sub-samples were recorded at 250 × magnification. The diameters of pure and medullated fibres were recorded as per the Indian Standard Specification IS:2899-1965 and the percentage was calculated separately.

One hundred individual dry fibres were drawn randomly to prepare a representative sample of an individual wool quality. These were subsequently tested for fibre strength (in g) on Instron as per the British Standard BS:3411-1971. The gauge length was kept at 20 mm, the ratio of crosshead to chart speed was 1:10 and the average of 100 observations was taken.

Warp and weft yarns of 18/2 and 11.5 Nm
respectively and fabrics prepared on worsted set of machinery were also tested on Instron. The warp and weft TM was 120 and 100 respectively. The gauge length was kept at 50 cm and for each lot, 100 observations (50 from warp and 50 from weft yarn) were taken as per the British Standard BS:1932-Part I:1965. For fabric testing, five observations were taken each way (warp and weft) as per the Indian Standard Specification IS:1969-1968. The sample size put under load was 75 x 200 mm. The crosshead speed was varied so as to break the sample under stress within 20 ± 3 sec. All the above testings were done under standard conditions of temperature (27 ± 1°C) and relative humidity (65 ± 5%).

Results

Results in respect of physical characteristics of different wool fibres are given in Table 1, and test results in respect of fibre, yarn and fabric strength are given in Table 2.

Statistical Analysis

For studying the contribution of fibre strength to yarn strength and in turn to fabric strength, the following statistical analysis has been carried out using the methods described elsewhere.

In order to test the relative contribution of yarn strength \( (X_1) \) and fibre strength \( (X_2) \) to the fabric strength \( (Y) \), multiple regression analysis has been applied.

The predicted multiple linear regression equation correlating the fabric strength from any wool with yarn and fibre strengths in warp direction is

\[
Y = 37.8172 + 0.0722X_1 + 0.8972X_2
\]

Initially to test whether both the \( X \)'s are related to \( Y \), the variance technique was used (Table 3).

By the extension of this analysis, tests of significance of the individual \( b \)'s (partial regression coefficients) have been made for testing each \( X \), after the effect of the other has been eliminated (Table 4).

From Table 3, the coefficient of multiple correlation is 0.8243, which is highly significant. This shows that the contribution of fibre and yarn strengths to fabric strength is 82.43%. The residual value is 2.9022. The standardized \( \beta \) coefficients, which show the relative importance of different variables, are as follows:

\[
\beta_{1X1,X2} \text{— Standardized partial regression coefficient of fabric strength on yarn strength = 0.7403.}
\]

\[
\beta_{2X1,X2} \text{— Standardized partial regression coefficient of fabric strength on fibre strength = 0.4249.}
\]

Table 1—Physical Characteristics of Different Types of Wool Fibres

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Wool</th>
<th>Staple length mm</th>
<th>Crimp per cm</th>
<th>Fibre length mm</th>
<th>Fibre diameter ( \mu )</th>
<th>Medullation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chokla</td>
<td>73.8</td>
<td>1.23</td>
<td>83.87 ± 1.43*39.0</td>
<td>32.27 ± 0.69(37.4)</td>
<td>29.90</td>
</tr>
<tr>
<td>2</td>
<td>R C 50</td>
<td>42.5</td>
<td>1.54</td>
<td>57.13 ± 0.88(27.4)</td>
<td>26.90 ± 0.77(37.5)</td>
<td>21.20</td>
</tr>
<tr>
<td>3</td>
<td>R C 62.5</td>
<td>46.2</td>
<td>1.57</td>
<td>56.47 ± 0.98(30.1)</td>
<td>22.09 ± 0.40(35.3)</td>
<td>4.89</td>
</tr>
<tr>
<td>4</td>
<td>R C 75</td>
<td>33.4</td>
<td>2.12</td>
<td>47.93 ± 1.18(42.5)</td>
<td>21.36 ± 0.38(30.3)</td>
<td>3.56</td>
</tr>
<tr>
<td>5</td>
<td>R N 50</td>
<td>39.9</td>
<td>1.36</td>
<td>55.70 ± 0.99(30.8)</td>
<td>26.49 ± 0.09(41.6)</td>
<td>25.93</td>
</tr>
<tr>
<td>6</td>
<td>Me N 50</td>
<td>32.9</td>
<td>1.96</td>
<td>59.28 ± 1.14(33.6)</td>
<td>25.49 ± 0.76(52.0)</td>
<td>16.38</td>
</tr>
<tr>
<td>7</td>
<td>Me C 50</td>
<td>37.7</td>
<td>1.91</td>
<td>60.55 ± 1.14(28.9)</td>
<td>25.60 ± 0.71(47.8)</td>
<td>16.80</td>
</tr>
<tr>
<td>8</td>
<td>Corriedale</td>
<td>47.5</td>
<td>2.06</td>
<td>78.98 ± 1.49(32.8)</td>
<td>24.25 ± 0.47(33.4)</td>
<td>5.20</td>
</tr>
</tbody>
</table>

*The values given after ± are standard errors.
†The values given in parenthesis are CV%.

Table 2—Strength of Wool Fibre, Yarn and Fabric

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Wool</th>
<th>Single fibre strength g</th>
<th>Single yarn strength</th>
<th>Breaking load on 75 x 200 mm strips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Warp g</td>
<td>Weft g</td>
<td>Warp kg</td>
</tr>
<tr>
<td>1</td>
<td>Chokla</td>
<td>11.68</td>
<td>661.0</td>
<td>399.6</td>
</tr>
<tr>
<td>2</td>
<td>R C 50</td>
<td>7.98</td>
<td>629.8</td>
<td>429.4</td>
</tr>
<tr>
<td>3</td>
<td>R C 62.5</td>
<td>7.43</td>
<td>739.4</td>
<td>478.3</td>
</tr>
<tr>
<td>4</td>
<td>R C 75</td>
<td>6.75</td>
<td>592.4</td>
<td>409.2</td>
</tr>
<tr>
<td>5</td>
<td>R N 50</td>
<td>13.91</td>
<td>623.6</td>
<td>294.6</td>
</tr>
<tr>
<td>6</td>
<td>Me N 50</td>
<td>12.02</td>
<td>628.8</td>
<td>490.4</td>
</tr>
<tr>
<td>7</td>
<td>Me C 50</td>
<td>13.29</td>
<td>751.4</td>
<td>474.4</td>
</tr>
<tr>
<td>8</td>
<td>Corriedale</td>
<td>10.39</td>
<td>713.0</td>
<td>369.0</td>
</tr>
</tbody>
</table>
The data in Table 4 show that the effect of fibre strength is non-significant, whereas the effect of yarn strength on fabric strength is significant at 5% level of significance. Since the effect of fibre strength is non-significant, the effect of yarn strength on fabric strength is given by the following equation after the elimination of the effect of fibre strength:

\[ Y = 43.0916 \pm 0.0783 X_1 \]

The data in Table 5 show that after the omission of fibre strength, the contribution of yarn strength to fabric strength is significant at 5% level of significance. The square of the coefficient of correlation is 0.6450, which is significant, showing that the contribution of yarn strength to fabric strength is 64.50%. The value of the regression coefficient of fabric strength on yarn strength is 0.0783, i.e.

\[ \beta_{XY} = 0.0783 \]

A similar attempt was made to see the influence of fibre and yarn strengths on fabric strength in weft direction. The predicted linear regression equation correlating the fabric strength in weft direction from any wool with yarn and fibre strengths is

\[ Y = -13.8449 + 0.1142 X_1 + 1.8607 X_2 \]

Comparing this equation with that for the warp direction, it is observed that weft yarn gives a lower value of \( Y \) for the same values of \( X_1 \) and \( X_2 \) when substituted in both the equations. This is quite natural, since weft yarns are comparatively weak because of the low twist employed while spinning.

Multiple regression analysis has been applied to test the relative contributions of \( X_1 \) and \( X_2 \) (Table 3). The coefficient of multiple correlation is 0.8726, which is highly significant, showing that the contribution of fibre and yarn strengths to fabric strength is 87.26%. The residual value is 3.5370. The standardized coefficients, which show the relative importance of the two variables, are as follows:

\[ \beta_{XY} \]—Standardized partial regression coefficient of fabric strength on yarn strength = 0.8958.

\[ \beta_{YX} \]—Standardized partial regression coefficient of fabric strength on fibre strength = 0.6109.

The data in Table 4 show that the effect of fibre strength on fabric strength is significant at 5% level of significance, whereas the effect of yarn strength on fabric strength is significant even at 1% level of significance.

After seeing the combined and individual effects of fibre and yarn strengths on fabric strength, an attempt was made to see the influence of fibre strength on yarn strength (Table 6).

The predicted linear regression equation correlating yarn and fibre strengths from any wool in warp direction is

\[ X_1 = 634.0339 + 3.1950 X_2 \]

The coefficient of correlation between yarn and fibre strengths is 0.1475, which is non-significant, showing that the fibre strength has got no significant effect on yarn strength. The value of regression coefficient is 3.195 and that of the residual is 63.6164.
The predicted linear regression equation correlating yarn and fibre strengths from any wool in weft direction is

\[ X_1 = 349.0337 - 6.6223X_2 \]

The coefficient of correlation between yarn and fibre strengths is \(-0.2770\), which is again non-significant, showing that the fibre strength has got no significant effect on yarn strength. The value of regression coefficient is \(-6.6223\) and that of the residual is \(68.2057\).

**Conclusion**

The combined effect of fibre and yarn strengths on fabric strength is significant. When considered separately, yarn strength has got a significant effect on fabric strength in both the warp and weft directions, whereas the effect of fibre strength is significant only in weft direction. This may be because of the fact that weft yarn might have had opened up fibres due to less twist.

The present analyses also indicate that in both the warp and weft ways, the influence of fibre strength on yarn strength is non-significant; this is in agreement with the findings of Turner\(^{10}\) who worked in a similar direction with cotton yarn and fibre. Virgin \(\textit{et al.}\)\(^{7}\) also opine that the yarn strength depends more on fibre length, fibre fineness and elastic modulus and less on fibre strength. This relation is due to the fact that with a finer fibre, which is generally weaker, the yarn contains a larger number of fibres in its cross-section for a given yarn number and twist multiplier, which implies more contact between constituent fibres and less fibre slippage when a load is applied.

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**References**