Bundle Tenacity of Wool Fibres at Different Test Lengths

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The bundle tenacity of wool fibres has been determined at different gauge lengths (0, 0.5, 1, 2 and 4 cm) for 10 varieties of wool. The bundle tenacity (S) and test length (L) are found to obey a logarithmic relationship of the form: \[ S = A(L + 1)^B \]
where \( A \) is the intrinsic strength at nominal zero test length; and \( B \), the degree of imperfection. The value of \( B \) is found to be a varietal characteristic unrelated to fibre length, fineness and strength at zero test length.

The strength of textile strands is known to decrease with increase in test length. The fall in strength has been attributed to the presence of weak links dispersed along the length of the strands. A theoretical expression for predicting the strength at higher test lengths has been derived by Peirce in terms of the strength at one test length and its coefficient of variation among different specimens of the same sample. Empirical formulae representing logarithmic relationships between strength and test length have been reported by some earlier workers for single cotton fibres as well as cotton fibre bundles. Further, it has been established in the case of cotton that the strength-gauge length relationship is characteristic of the variety, and that cottons belonging to \( G. \) barbadense species are relatively more uniform. Hardly any information on the variation of strength with test length is available in the case of wool fibres, although it has been noted that the bundle strength of wool falls by about 17% when the test length is increased from 0 to 5 mm. No systematic study seems to have been made on wool fibres. The purpose of the present work was to study the dependence of strength on test length for different varieties of Indian and exotic wools. Fibres were tested in bundle form using a "constant-rate traverse" machine at test lengths ranging from 0 to 4 cm.

Materials and Methods

Wool samples—The samples comprised five Indian and five exotic wools. The latter included three USDA calibration wools. All samples, except the calibration wools, were degreased with petroleum ether and washed thoroughly with a safe detergent.

Preparation of bundles for strength test—The ASTM procedure for preparing wool fibre bundles was employed with a slight modification to achieve better fibre parallelization. In the procedure adopted, use was made of a device shown in Fig 1. It consists of a pair of combs (a,b), one finer than the other, slid into parallel grooves cut on a wooden block (c). A 3 mm thick bakelite strip (d) with rubber lining and having a width equal to the particular gauge length chosen for the test is placed on the wooden block closest to the finer comb. A tuft of combed wool fibres is held at one end by a piece of adhesive tape. After removing loose fibres, the tuft is drawn across the two combs and held taught with the thumb (t) and forefinger (f) in such a way that the bundle of straight and parallel fibres rests on the bakelite strip under adequate tension. An identical bakelite strip, also with rubber lining, is now placed over the tuft, while the latter still remains gently taut. The bakelite strips with the tuft in between are tightly clamped and the composite is removed from the device. A second piece of adhesive tape is fixed to the free end of the tuft close to the edges of the bakelite strips. The clamps are removed to release the fibre tuft, which is now held by two strips of tape separated by a distance equal to the desired test length. Any broken fibre present in the tuft is removed with tweezers.

Bundle strength test—The bundles prepared in the above manner, which contained about 200 fibres in the
case of fine varieties and about 400 in the case of fine ones, were conditioned at 65% RH in a desiccator after predrying at about 30% RH to ensure the attainment of equilibrium at 65% RH through sorption alone. Strength tests were carried out on the Schopper tester. The tuft was mounted on the jaws of the machine such that the nip at each end coincided with the edge of the adhesive tape. The traverse rate was 12 in/min. After the break, the fibres were cut close to the edges of the adhesive tapes and the weight of the broken fibre bits was determined on a torsion balance.

Results and Discussion

The results of measurements on 10 different wool samples at 0, 5, 10, 20 and 40 mm test lengths are given in Table 1. In the case of four samples, however, test at 40 mm was not possible, as the fibres were too short. Each tenacity value is the average for 10 bundles; the CV% values for these 10 tenacity values are given within parentheses (Table 1).

The CV% of tenacity ranges from 4 to 11%, which is notably lower than the figures reported earlier for wool fibre bundles. The comparatively lower values in the present tests show that better fibre alignment in the specimen is achieved in the modified procedure for bundle preparation.

Tenacity decreases with increase in gauge length, as in the case of other natural fibres like cotton or flax. This result is consistent with the well-known weak link theory. Since there are large variations among different samples of wool in the extent of this fall in tenacity, the average values have been calculated and plotted against gauge length in Fig. 2(a). The relationship, which is curvilinear, appears to be qualitatively similar to that obtained for cotton, inasmuch as the slope is reduced at higher gauge lengths. The log-log plot of the same quantities is nearly a straight line [Fig. 2(b)], indicating that the relationship between tenacity \( S \) and test length \( L \) could be represented by the formula

\[
S = A(L + 1)^B
\]

where \( A \) is the intrinsic strength at nominal zero gauge length; and \( B \), the degree of imperfection is a measure of the rate at which the strength falls with increase in gauge length. The value of \( B \) as given by the slope of the line in Fig 2(b) is 0.256, which is small compared to the values (0.3 - 0.6) reported for cotton. Qualitatively, therefore, wool could be described as a more uniform fibre as compared to cotton.

The values of the degree of imperfection calculated for each sample are given in Table 1. It varies from 0.25 to 0.44, suggesting that the extent of fall in tenacity with increasing test length is a varietal characteristic, as in the case of cotton. From the scatter of \( B \) values among the 10 samples studied, it would appear that this quantity does not depend on whether the wool is of Indian or exotic origin. An attempt was also made to examine the extent of association between the degree of imperfection with other fibre characteristics such as fibre length, fibre fineness and strength at nominal zero gauge length. Simple correlation analysis showed that the relationships are non-significant.

Table 1—Results of Bundle Tests on Ten Wool Samples

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Variety</th>
<th>Tenacity (g/tex) at gauge length (in cm)</th>
<th>Degree of imperfection ( B )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>1</td>
<td>USDA 36s</td>
<td>13.1</td>
<td>11.7</td>
</tr>
<tr>
<td>2</td>
<td>CORRIEDEALE</td>
<td>12.1</td>
<td>11.4</td>
</tr>
<tr>
<td>3</td>
<td>CHOKLA</td>
<td>11.8</td>
<td>8.9</td>
</tr>
<tr>
<td>4</td>
<td>RAMPUR BUSHIER</td>
<td>11.6</td>
<td>9.2</td>
</tr>
<tr>
<td>5</td>
<td>RUSSIAN MERINO</td>
<td>11.0</td>
<td>9.4</td>
</tr>
<tr>
<td>6</td>
<td>USDA 58s</td>
<td>10.5</td>
<td>7.9</td>
</tr>
<tr>
<td>7</td>
<td>NILGIRI</td>
<td>10.5</td>
<td>7.4</td>
</tr>
<tr>
<td>8</td>
<td>USDA 80s</td>
<td>10.1</td>
<td>8.3</td>
</tr>
<tr>
<td>9</td>
<td>COIMBATORE</td>
<td>9.8</td>
<td>8.3</td>
</tr>
<tr>
<td>10</td>
<td>MARWARI</td>
<td>9.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>11.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Values within parentheses indicate coefficient of variation (%)

Fig. 2—Plots showing (a) the curvilinear relationship between mean bundle tenacity \( S \) of 10 wool samples and the gauge length \( L \), and (b) the linear relationship between log \( S \) and log \( L + 1 \)
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References