Fibre quality and yarn strength relationships

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Received 12 October 1989; accepted 18 December 1989

A simple empirical relationship between the fibre properties of cottons currently in use and the CSP of the yarns spun on modern machinery has been worked out in view of the changes both in technology and indigenous cottons. A higher degree of correlation of the order of 0.99 is obtained between the actual and predicted values of CSP in the modified relationship.

Keywords: Fibre quality index, Span length, Twist multiplier, Yarn strength

1 Introduction
Evolving workable prediction formulae to relate fibre properties to yarn quality has been an interesting field of work for several research workers for more than three decades. Lord developed an integrated index using basic fibre properties to predict the spinning performance. Subramaniam et al. put forward a fibre quality index by which Bogdan's intrinsic strength parameter of a cotton can be predicted. In addition to this, they also identified two constants, which, once evaluated for a given spinning set-up, would enable the lea strength to be predicted by estimating first the intrinsic strength parameter and then the lea strength from Bogdan's equation. This procedure was modified by Dhawan and Subramaniam to further improve the accuracy of prediction. Two other papers dealing with this subject have been published by Iyer and Iyer.

Recently, Hunter has related the properties of fibres measured by HVI and the conventional systems to the processing waste and yarn properties using multiple regression technique. SITRA developed an empirical relationship between important fibre properties and yarn CSP in 1968.

However, in the last decade there has been a spectacular improvement in the technological performance of spinning machinery. This resulted from a number of factors such as improved opening and effective separation of heavy particles in modern blow room lines, better carding and efficient fibre control during drafting in modern preparatory and spinning machinery. Apart from the technological improvements, indigenous cottons have also undergone significant qualitative changes during the same period. Fibre tended to become finer and longer but less mature. There has also been higher incidence of seed coats, trash content and foreign matter.

In view of the above changes both in technology and indigenous cottons, it was considered worthwhile to take a fresh look at the relationship between yarn quality and fibre properties. This paper reports a simple empirical relationship between fibre properties of cottons currently in use and the CSP of yarns spun on modern machinery.

2 Materials and Methods
Nine cottons, viz. J-34, Jayadhar, Jyoti, LRA, MCU-7, H-4, Shankar-4, Varalakshmi and Suvin, were selected for this study. The important quality characteristics of these cottons are given in Table 1. Each cotton was spun to 3-6 counts and each count at 4 different twist multipliers. In all, about 150 spinnings were made. The yarn samples were tested for lea CSP taking 40 readings per test.

2.1 Analysis of Data
The data were analyzed keeping in view the simple relationship developed earlier at SITRA. First, the relationship between fibre properties and maximum strength of yarn spun to a given count was studied. Then the optimum TM for maximum strength was determined for each cotton and its relationship with fibre properties was examined. Finally, the extent to which the yarn strength at a given TM decreases from the maximum strength at optimum TM was related to the...
Table 1 – Fibre properties

<table>
<thead>
<tr>
<th>Property</th>
<th>J-34</th>
<th>Jayadhar</th>
<th>Jyoti</th>
<th>MCU-7</th>
<th>H-4</th>
<th>LRA</th>
<th>Shankar-4</th>
<th>Varalakshmi</th>
<th>Suvin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective length, mm</td>
<td>24.8</td>
<td>26.4</td>
<td>26.9</td>
<td>29.7</td>
<td>30.5</td>
<td>31.0</td>
<td>32.8</td>
<td>36.1</td>
<td>39.4</td>
</tr>
<tr>
<td>Short fibres, %</td>
<td>17.8</td>
<td>15.1</td>
<td>18.2</td>
<td>14.9</td>
<td>13.5</td>
<td>14.4</td>
<td>14.9</td>
<td>15.6</td>
<td>15.6</td>
</tr>
<tr>
<td>2.5% Span length, mm</td>
<td>22.1</td>
<td>22.3</td>
<td>24.2</td>
<td>27.9</td>
<td>28.4</td>
<td>27.6</td>
<td>29.8</td>
<td>33.3</td>
<td>37.8</td>
</tr>
<tr>
<td>50% Span length, mm</td>
<td>10.9</td>
<td>11.5</td>
<td>12.0</td>
<td>13.6</td>
<td>14.0</td>
<td>13.8</td>
<td>14.8</td>
<td>15.6</td>
<td>17.7</td>
</tr>
<tr>
<td>Steio strength at 3 mm gauge, g/tex</td>
<td>17.1</td>
<td>17.2</td>
<td>19.6</td>
<td>23.9</td>
<td>20.3</td>
<td>20.6</td>
<td>20.9</td>
<td>24.3</td>
<td>30.3</td>
</tr>
<tr>
<td>µg/in</td>
<td>3.80</td>
<td>4.75</td>
<td>4.70</td>
<td>4.40</td>
<td>3.80</td>
<td>4.00</td>
<td>3.65</td>
<td>3.20</td>
<td>2.90</td>
</tr>
<tr>
<td>Maturity coefficient (Caustic soda method)</td>
<td>0.788</td>
<td>0.792</td>
<td>0.770</td>
<td>0.830</td>
<td>0.788</td>
<td>0.844</td>
<td>0.784</td>
<td>0.800</td>
<td>0.758</td>
</tr>
</tbody>
</table>

deviation of the actual TM from the optimum TM.

3 Results and Discussion

3.1 Fibre Quality and Yarn CSP

It is well known that when a given cotton is spun to different counts using the same twist multipliers for all the yarns, cottons giving strong yarns not only tend to fall off in strength less rapidly but also show high initial values, i.e. high intercept on the Y-axis. Weak yarns have relatively high fall in strength with low intercept values. The analysis of data in the study showed that in long- and extra long-staple cottons (> 28 mm), the drop in CSP for a unit increase in count is 0.5%, whereas in short- and medium-staple cottons the fall in strength is 0.8%.

The slope of the regression line relating count and CSP was, however, practically the same for all the cottons studied (Fig. 1). It was 16 for the best fit. For establishing a relationship between yarn strength and fibre properties, the slope has been assumed to be equal to this best value.

Thus, the yarn CSP (Y) is given by:

\[ Y = 320 \left( \frac{FQI + 1}{S} \right) - 16n \]  

where FQI = \( \frac{LSm}{F} \), and n is the count.
L = 50% span length (mm).
S = Fibre strength (g/tex) measured by stelometer at 3 mm gauge.
F = Fineness (micronaire value in mg/in) measured using airflow method.

To examine the closeness of fit, the actual maximum CSP values were compared with those predicted from Eq. (1). A high correlation of 0.99 was obtained between the actual and expected values (Fig. 2). The standard error of estimate was about 100 units of CSP, which works out to 4.3% on average values.

In the spinning made in this study, the yarn strength values relating to 14s count were found to be highly inconsistent. In fact, in six cottons, the CSP values for the same twist multiplier were lower by 4-8% compared to those for 20s count.
spun from the same cottons. The average CSP for all the nine cottons was 4% less in 14s. In view of this, 14s count was not included in the above fit. However, the analysis of data including 14s count also gave a high correlation of 0.98 between the actual and expected CSP values (Eq. 2).

\[ Y = 293 + 320 \sqrt{\text{FQI}} - 16 \n \]  

Eq. (2) is the same as Eq. (1) except for a lower value for constant term (by 27 units). This is because generally low values of CSP are observed for 14s. Consequently, by the inclusion of 14s count, the standard error of estimate of CSP was significantly greater at 120 units.

The ratio between the actual and predicted values of yarn CSP for various cottons and counts is given in Table 2, which shows a good agreement between the predicted and actual values in all the nine cottons and counts, the overall mean deviation being only about 3.5%.

A multiple linear regression analysis of the data (Eq. 3) also gave a fairly high correlation of 0.98.

\[ Y = 66L + 72S - 374F + 314M - 16n + 1588 \]  

where \( Y \) is the lea CSP and \( n \), the yarn count. The units and measurements for other variables were the same as for Eq. (1).

However, Eq. (1) derived from FQI is of a simpler form with ease of application at mill level apart from being able to characterize by a single value (FQI) the overall cotton quality from the point of view of yarn strength.

### 3.2 Effect of Various Fibre Properties

The expression relating fibre properties to CSP without taking maturity into account is given by:

\[ \text{CSP} = 393 + 270 \sqrt{L/S/F} - 15n \]  

The correlation coefficient between the actual CSP values and those predicted using Eq. (4) was found to be 0.98. The corresponding standard error of estimate was about 5%.

Considering the separate contribution of fibre length, fibre strength and fibre fineness, all of

<table>
<thead>
<tr>
<th>Cotton</th>
<th>20s</th>
<th>30s</th>
<th>40s</th>
<th>60s</th>
<th>80s</th>
<th>100s</th>
<th>Average</th>
<th>Mean deviation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jayadhar</td>
<td>0.95</td>
<td>0.95</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.95</td>
<td>5.4</td>
</tr>
<tr>
<td>Jyoti</td>
<td>1.05</td>
<td>0.97</td>
<td>0.98</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.00</td>
<td>3.4</td>
</tr>
<tr>
<td>J-34</td>
<td>1.03</td>
<td>1.05</td>
<td>1.03</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>1.04</td>
<td>3.4</td>
</tr>
<tr>
<td>MCU-7</td>
<td>0.98</td>
<td>0.95</td>
<td>0.97</td>
<td>1.02</td>
<td>—</td>
<td>—</td>
<td>0.98</td>
<td>3.1</td>
</tr>
<tr>
<td>H-4</td>
<td>1.04</td>
<td>1.00</td>
<td>0.99</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>1.01</td>
<td>1.8</td>
</tr>
<tr>
<td>LRA</td>
<td>1.03</td>
<td>—</td>
<td>1.00</td>
<td>1.05</td>
<td>—</td>
<td>—</td>
<td>1.03</td>
<td>2.7</td>
</tr>
<tr>
<td>Shankar-4</td>
<td>0.93</td>
<td>0.97</td>
<td>1.04</td>
<td>1.01</td>
<td>1.06</td>
<td>—</td>
<td>1.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Varaalakshmi</td>
<td>0.98</td>
<td>1.03</td>
<td>1.04</td>
<td>0.87</td>
<td>0.95</td>
<td>0.98</td>
<td>0.98</td>
<td>5.0</td>
</tr>
<tr>
<td>Suvin</td>
<td>0.98</td>
<td>1.04</td>
<td>1.05</td>
<td>0.98</td>
<td>0.93</td>
<td>1.03</td>
<td>1.00</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>1.00</td>
<td>0.99</td>
<td>1.01</td>
<td>0.99</td>
<td>0.98</td>
<td>1.01</td>
<td>1.00</td>
<td>—</td>
</tr>
</tbody>
</table>

**Mean deviation, %**  
3.1 3.7 2.7 4.0 6.1 2.8 — 3.6
which have about equal effect on yarn CSP, each property taken along with the count individually explains about 75-85% of the total variation, the correlation coefficient being in the range of 0.85-0.90. Also, any two of these three fibre properties taken together along with the count gave a very good fit, the correlation coefficients between the actual and predicted values being in the range of 0.96-0.98.

For a given cotton, the CSP values obtained in this study were about 13% more in coarse counts and 7% more in fine counts as compared to the values obtained earlier at SITRA.

The improved opening, carding and fibre control on modern machines explain the better quality of yams obtained in the present study.

3.3 Twist for Maximum Strength

It is well known that the twist multiplier for maximum strength is a function of cotton quality. Longer, more uniform and finer cottons have, in general, lower optimum twist multipliers. Optimum TM for maximum strength was found to be linearly related to 50% span length and fibre fineness of cottons studied. It is given by the following equation:

\[ \text{Optimum TM} = \frac{(50 - L + F)}{9} \]  \hspace{1cm} (5)

The optimum TM for maximum strength was about 5% lower than that observed in an earlier study. Improvement in the fibre cohesion achieved in modern machinery, perhaps, explains the attainment of maximum strength at lower levels of TM.

A very close fit was found between the predicted and the actual values of TM, the correlation coefficient being 0.95 (Fig. 3) and the mean deviation, 0.07.

3.4 Effect of TM on Strength

Eqs (1) to (4) are all based on the maximum strength of yams at optimum TM. Analysis of the data showed that the fall in strength (S%) is fairly uniform at different levels of twist (Fig. 4). It is represented by the following relationship:

\[ S = 0.53i - 0.40 \]  \hspace{1cm} (6)

where \( i \) is the % difference in twist multiplier from the optimum.

4 Limitations

The various relationships given in this paper are empirical and as such can be applied only for the range of cottons and counts studied. They will nevertheless help mills in evaluating, with a high degree of accuracy, their process proficiency in terms of yarn CSP with reference to modern machinery. The standard error of the predicted values is about 5%, and this fact should not be overlooked while interpreting data. Also, the relationships are applicable only to the maximum yarn strength. How closely the process proficiency attained by the mills approaches the one worked out from these relationships is being investigated.

5 Conclusions

A simple relationship has been established between yarn CSP at optimum TM and the square root of the fibre properties, viz. 50% span length, strength, fineness and maturity. The correlation coefficient between the actual and predicted va-
values has been found to be 0.99, the standard error of estimate being about 5%.

The CSP at optimum twist decreases at the rate of 0.8% for every unit increase in count in the case of short- and medium-staple cottons and 0.5% for long- and extra-long staple cottons. The slope of the regression line is, however, almost same for all the cottons.

Fibre length, strength and fineness have about the same effect on yarn CSP. Taken along with the count, they account for 75-85% variation individually and 97% variation collectively. The effect of maturity on yarn strength is marginal.

Yarn strength values are about 13% higher in coarse counts and 7% in fine counts than those found earlier at SITRA in 1968. The improved technological efficiency of modern machinery perhaps explains the better quality.

The optimum TM for maximum strength has a linear relationship with 50% span length and fineness. A very close fit is observed between the predicted and actual values of optimum TM ($r = 0.95$) with a mean deviation of only 0.07 TM.

The optimum TM for maximum strength is about 5% lower than that observed in an earlier study.

The fall in strength from the level at optimum TM is fairly uniform at different levels of twist.

**Acknowledgement**

The authors would like to express their grateful thanks to M/s Lakshmi Machine Works Limited and, in particular, to Shri K.B. Krishnan, Assistant General Manager and Shri K P R Pillay, Consultant, for their cooperation and help in processing the samples at their spinning laboratory. They are also thankful to Shri R. Rajamanickam for analyzing statistical data in computer and to the staff of Physics Division for testing the samples.

**References**