Study on drafting force of roving: Part II – Effect of material variables

A Das\textsuperscript{a}, S M Ishtiaque & Rajesh Kumar

Department of Textile Technology, Indian Institute of Technology, New Delhi 110 016, India

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The effect of some material variables, namely fibre-to-fibre friction, roving hank and roving twist, on drafting force of roving has been studied. A very good correlation ($R^2 = 0.903$) between material variables and drafting force has been obtained. The drafting force increases sharply with the increase in fibre friction and roving twist multiplier due to the rapid increase in mutual coherence among the fibres. The drafting force is less influenced by the change in roving hank, but it decreases initially and then increases as the roving hank becomes finer.

Keywords: Cotton, Drafting force, Fibre friction, Roving hank, Twist multiplier

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1 Introduction

The effect of process variables, namely draft, drafting speed and roller setting, on drafting force, keeping the material variables constant, has been studied earlier\textsuperscript{1}. Apart from process variables, the material variables, namely fibre and roving parameters, also affect the drafting force of roving significantly. The frictional force acting on fibre assembly during drafting can be determined experimentally by measuring the total resistance of fibre assembly. The frictional force depends on relative fibre velocities and density distribution\textsuperscript{2}. It is very difficult to predict the relative velocities of short fibres as their velocities are highly variable. In addition, the material density distribution is also not constant along the drafting line. Due to these, the fibre movement during drafting becomes irregular and causes generation of drafting waves. Therefore, drafting force becomes highly variable and results in variability in the output material.

In roller drafting, the significance of drafting force is necessary to overcome inter-fibre frictional forces, which generate due to inter-fibre contacts and also to counteract fibre bending\textsuperscript{3}. Thus, fibre bending or flexural rigidity of a fibre is also an important factor which affects the drafting force. Deluca and Thibodeaux\textsuperscript{4} found that in cotton card sliver the fibre torsional and bending rigidities are more important to sliver cohesive forces than fibre-to-fibre frictional forces. On the other hand, in roving the twist and improved fibre orientation cause fibre-to-fibre frictional forces to be more important to roving cohesive forces than fibre torsional and bending rigidities.

Fibre crimp and fibre-to-fibre friction determine the surface properties of a fibre. Fibre crimp\textsuperscript{3,5} plays a dominant role in drafting by affecting the motion of fibre in drafting zone, bulk properties of roving and drafting force. The more highly crimped fibres exhibit a larger drafting force because the fibre has more opportunity to interlock spatially, entangle and mesh with neighboring fibres. The role of friction in textile processing, though not quantified, is well recognized. In traditional textile processing, fibres are converted into yarn through a series of opening and drafting processes involving between different groups of fibres and other materials. These interactions determine relative fibre position and fibre movement during processing. The main mechanism governing these interactions is friction\textsuperscript{6}. The knowledge of the frictional values of individual fibres is very important to predict whether the processing will be satisfactory or not, when other physical properties are satisfactory.

Audivert and DeCastellar\textsuperscript{7} found that the fibre length is significantly more correlated with the drafting force as compared to the fibre fineness. Graham and Bragg\textsuperscript{8} experimentally found that 1\% change in fibre length changes the drafting force by about 5\%. It has also been studied\textsuperscript{8} that the increase in roving twist causes increase in drafting force.

In the present study, attempts have been made to correlate the material variables, namely fibre-to-fibre frictional
friction, roving hank and roving twist multiplier, with drafting force and also to investigate the combined influence of these parameters on drafting force of cotton rovings.

2 Material and Methods

2.1 Materials
Medium grade cotton (J-34) was dyed in different shades with natural dyes to get different levels of frictional coefficient. The reason for using natural dyes is that they are mainly surface deposition type, resulting in significant change in frictional properties of fibre. The tensile properties of cotton are least affected by these dyes. The properties of grey and dyed cottons are given in Table 1.

No significant change in the properties of cotton, except the frictional coefficient, has been observed after dyeing.

2.2 Fibre Friction Testing
The fibre samples, in the form of fringes of 30mm width, were prepared with the help of fibre sampler used in Zellweger Uster HVI. The straight end of the fringe was then fixed carefully with the adhesive tape so that no fibre distortion takes place. Proper care was taken while preparing the fibre samples so that the distribution of fibres along with the width of the fringe remains almost uniform and also the fibres should be parallel to each other in the fringe. The frictional coefficients of all the dyed cotton samples were measured with the help of a friction tester and the three samples, whose frictional coefficients are found to be at constant intervals, were selected for the study. The selected samples were grey, linen colour dyed and royal colour dyed cottons with static frictional coefficients of 0.3, 0.4 and 0.5 respectively.

2.3 Roving Preparation
The selected grey and dyed cotton fibres were processed in blow room, carded and then given two passages of draw frame. The finisher draw frame slivers with three different friction levels were then processed with different combinations of roving hank and roving twist multiplier (Table 2) in roving frame to get 15 different combinations of roving samples (Table 3).

2.4 Drafting Force Measurement
The drafting force of all the 15 rovings was measured on a draftometer having constant settings (draft, 1.5; roller setting, 40 mm; and drafting speed, 12 m/min). The details of drafting force values are given in Table 3.

2.5 Experimental Design
As studied earlier, a three-variable factorial design proposed by Box & Behnken was used to investigate the combined influence of material variables, namely fibre friction, roving hank and roving twist multiplier, on drafting force of roving. The actual values of three variables corresponding to coded levels are given in Table 2.

3 Results and Discussion
From the results of drafting force (Table 3) and response surface equation (Table 4), it is clear that the
drafting is well correlated with combined material variables ($R^2 = 0.903$). Also, it can be derived from the response surface equation that the maximum drafting force can be achieved at 0.5 static frictional coefficient and 1.3 roving twist multiplier. But in case of roving hank, the minimum drafting force is achieved at mid coded value, i.e. at roving hank of 1.1, and the drafting force increases when the roving hank is either coarser or finer.

The contour plots (Figs 1-3) show the influence of fibre friction, roving hank and twist multiplier on drafting force of roving. From the response surface equation and contour plots, it is clear that with the increase in fibre friction and roving twist multiplier the drafting force of roving always increases. It is also evident that the mid coded value of roving hank (roving hank, 1.1) for certain fibre friction and roving twist multiplier value results in lowest drafting force and it increases with either increase or decrease in roving hank.

Keeping the roving twist multiplier constant at its minimum coded level (0.9), when the fibre friction increases it has been observed that the drafting force value always increases because of the increase in inter-fibre cohesive force. When the roving hank increases, keeping the roving twist multiplier constant, the drafting force value initially decreases up to mid coded value and then increases. Initially, the reduction in number of fibres in the strand is predominating over the increase in roving twists per inch, i.e. for a constant roving twist multiplier as the hank becomes finer the twists per inch will be more. Therefore, the cohesion among the fibres reduces and after a certain value of the roving hank again the drafting force value starts increasing as the increase in roving twists per inch predominates the reduction in number of fibres. The increase in roving twists per inch results in the increase in transverse pressure on the fibre strand and thus the binding of fibres increases, which requires higher force during drafting. When roving twist multiplier is increased from its mid value (1.1) to maximum value (1.3), the effect of fibre friction and roving hank on drafting force becomes more prominent.

Table 4 — Response surface equation for drafting force

<table>
<thead>
<tr>
<th>Variable</th>
<th>Response surface equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drafting force</td>
<td>$1.351+0.985X_1+1.114X_2+0.781X_2^2$</td>
<td>0.903</td>
</tr>
<tr>
<td></td>
<td>$+0.443X_1X_2$</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1 — Effect of fibre friction and roving hank on drafting force [roving TM: (a) 0.9, (b) 1.1, and (c) 1.3]
Fig. 2—Effect of fibre friction and roving TM on drafting force
[roving hank: (a) 0.9, (b) 1.1, and (c) 1.3]

Fig. 3—Effect of roving hank and roving TM on drafting force
[fibre friction: (a) 0.3, (b) 0.4, and (c) 0.5]
In case of a constant roving hank (0.9), the increase in fibre friction and roving TM results in the increase in drafting force due to the same reason as mentioned above (Fig. 2a). From the contour plot, it is clear that the effect of roving TM is more in comparison to the fibre friction as more lines are cutting Y-axis. Similar trend is also observed in case of other level of roving hank (Figs 2b and 2c).

3.1 Effect of Fibre Friction

From the response surface equation (Table 4) and contour plots (Figs 1-3), it is clearly seen that the drafting force increases sharply as the fibre friction is increased, keeping the other material variables constant. The increase in drafting force is mainly due to the increase in mutual coherence among the fibres and hence the cohesive forces increase sharply. Due to the increased cohesives forces, the drafting force of roving increases.

3.2 Effect of Roving Hank

Figs 1-3 also show that the drafting force reduces as the roving hank is increased due to the reduction in number of fibres in the cross-section but it again increases with the increase in roving hank for a certain roving TM due to the better binding of fibres, as discussed earlier.

3.3 Effect of Roving Twist Multiplier

The drafting force increases sharply with the increase in roving twist multiplier (Figs 1-3). The increase in drafting force is again due to the increased fibre-to-fibre cohesion as the roving twist multiplier is increased. The details have been discussed earlier.

4 Conclusions

4.1 The correlation between drafting force and material variables is good ($R^2 = 0.903$).

4.2 The drafting force increases with the increase in fibre-to-fibre friction.

4.3 The drafting force initially reduces with the increased roving hank but increases as the roving hank increases further.

4.4 The drafting force value always increases with the increase in roving twist multiplier.

References