Control of Jute Yarn Tension during Preparatory Processes

P K BHATTACHARYYA & B L BANERJEE
Indian Jute Industries' Research Association, Calcutta 700088

Received 2 March 1984; accepted 3 May 1984

The nature and magnitude of tension variation during preparatory processes for jute yarn has been studied under actual production conditions with a view to minimizing the tension variation within a weaver's beam. It is found that the tension varies with the different diameters and locations of the spools during warping. Proper adjustments of the tensioning device at the creel during warping and of braking force on the warper's beam during sizing minimize tension variation, and as a result there are fewer warp breaks and an improvement of yarn and fabric properties.

To achieve the desired weaving performance and fabric quality, it is of utmost importance to have a good-quality weaver's beam. Among the factors which determine the quality of a beam, uniformity in yarn tension is perhaps the most important one. Hence, the warp sheet should be wound at a uniform tension throughout the building of weaver's beam, and the variation in tension among individual yarns should be as minimum as possible. During warping, i.e. pre-beaming process, the yarn tension varies because of the varying diameters and locations of spools at the creel, unequal angle of yarn deflection at the guide bars and dividing reeds, design and loading system of yarn tensioners, etc.1-5. During slashing, i.e. beaming process, the uniformity in yarn tension depends mainly on the braking moment applied on the head of the warper's beam, which has to be altered with the diminution in the yarn content of warper's beam6-12.

Although detailed studies on yarn tension variation during preparatory processes have been made with cotton and other yarns1-12, no systematic and quantitative study has been made so far with jute yarn, the processing technology of which is fairly old and involves subjective adjustments of machines for controlling the yarn tension.

The factors influencing the unwinding tension of jute yarns from spinning bobbin and spool have been investigated earlier by Bhattacharyya et al.13 on a prototype machine developed for the purpose. The relationships between yarn tension during unwinding and each of the variables like yarn speed, grist, balloon height, package position and dimension, and disc-tensioner have been established.

The aim of the present study was to estimate the nature and magnitude of tension variation during preparatory processes under the existing systems followed by jute mills and to determine its effect on the warp breakage rate, and yarn and fabric properties. Attempts have also been made to minimize the tension variation in each stage of the preparatory processes and hence improve the warp beam quality, warp breakage rate, and yarn and fabric properties.

Experimental Procedure

To control the yarn tension variation, it is essential to know the causes of such variation. Since during pre-beaming with jute yarn, the tension variations due to different locations and sizes of the packages on the creel were not known, we felt it necessary to study these aspects before starting the main experimental work.

Preliminary study during pre-beaming—A study on the above-mentioned aspects was carried out by mounting the spools of equal package density at two extreme heights (top and bottom) and three different depths (front, middle and back) on the creel. With each location, spools of three diameters, viz. full, half-full and almost empty, were considered. The yarn was withdrawn through one yarn guide, nearest to the spool. Fig. 1 shows the schematic diagram of the arrangements on the pre-beaming machine. For each condition of spool, yarn tension was measured on five spools successively at normal warping speed. The particulars of machines and materials are given in App.1.

![Schematic diagram of pre-beaming machine](image-url)
The results of the experiment (Table 1) show that the yarn tension increases both with the depletion of the spool and with increase in distance of the spool from the head-stock of the machine, which is in agreement with the finding of Klauer. The effect of distance is, however, more significant with the almost empty spool. The height of the spool on the creel has no significant effect on yarn tension. The standard deviation (σ) and CV% of yarn tension also show a similar trend of variation as for yarn tension.

Study conditions (general)—The entire study was conducted in a jute mill under actual manufacturing conditions on the same machines for a given quality of fabric. The mechanical conditions of all the machines were good and kept unaltered throughout the study. The tensions of 50 randomly selected warp ends were measured just after the measuring roller during pre-beaming and just before the size bath and the dividing reed during beaming. Care was taken to maintain identical size content of warp yarns for all the weaver’s beams under study. For assessing the extent of tension difference among the warp yarns in a weaver’s beam, an ink-line of 6 mm width and 120 mm length was drawn across the warp sheet at the delivery end during beaming with the help of an aluminium template. Fig. 2 shows the plan and front view of the template. It consists of two strips A and B, each 18 cm long, 2.5 cm wide and 0.5 cm thick, placed one above the other. The top one (A) has a rectangular slot (S) and its inner surface is pasted with a thin rubber sheet (R). To mark the warp yarns (W), the yarn sheet is placed and pressed between the two strips. The rubber sheet helps restrict the lateral movement of yarns while marking the yarns through the slot. If the variation in tension among the yarns is assumed to be nil, the ink-line appears as a well-defined straight line after being woven into the fabric. On the other hand, if there is a difference in tension, the line becomes diffused and scattered. The degree of scatteredness would, therefore, depend on the extent of tension difference. The distances of ink-marks on warp yarns were measured individually on 30 ends from a reference line and its standard deviation was estimated for each cloth sample at off-loom state after allowing them to relax at least for 48 hr. The warp breakage rate was measured at regular intervals for five machine-hours each for pre-beaming and beaming and ten machine-hours for weaving. During weaving, the static tension at three different places on warp sheet was measured of double yarns (of front and back heald passing through the same dent of reed) only at shed full open, and this was kept almost unaltered throughout the study by adjusting the let-off motion. Moisture regain(%) during beaming and weaving was noted at each interval. The yarn tension was measured and recorded on a Rothschild electronic tensiometer and a Helcoscripter recorder respectively, the speed of the recording chart being 10 mm/s.

Yarn and fabric samples were collected for physical testing. Since the weft yarn remained unaltered, only the warp-way fabric properties were studied. The tensile strength and elongation of yarns were measured on an Instron machine of 10 kg capacity. The grip

<table>
<thead>
<tr>
<th>Table 1 — Variation in Yarn Tension, with Different Diameters and Locations of Spool on the Creel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spool size</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Full</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Half</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Empty</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

SD—Standard deviation
length, breaking period, cross-head speed and chart speed were kept at 61 cm, 20±5 s, 5 cm/min and 10 cm/min respectively. In all, 150 yarn samples were tested. The tensile strength and elongation of fabrics were measured on an Instron machine of 100 kg capacity. The fabric strip dimension and breaking period were kept at 20×5 cm and 10±5 s respectively and both cross-head and chart speeds at 30 cm/min. The warp crimp of fabrics was measured on a Shirley crimp tester of 80 g load. In all, 20 fabric samples were tested.

Study conditions (special)—The study was carried out under the existing as well as modified conditions.

Under existing condition: At each stage of pre-beaming, beaming and weaving, the yarn tension was measured and the end breakage rate of warp yarn was noted with the normal processing system followed by the jute mills. This system has been referred to as conventional system in the discussion section.

Under modified condition: To minimize the tension variation, full spools were taken on the creel for making warper’s beams and the dead weights of the tensioning devices at the creel were adjusted on the basis of the experimental results reported under ‘Preliminary study during pre-beaming’ to suit the location and diameter of the spool. Yarn tension and end breakage rate were then noted during the operation of the machine.

In the next step, modified braking systems (Fig. 3) equipped with a spring balance and attached to a band, composed of leather and steel straps (former at the lower surface), were attached on the heads of the warper’s beams during beaming. The minimum single-yarn tension required to rotate a full warper’s beam on the creel of the beaming machine was calculated theoretically by selecting a certain amount of braking force on each side of the beam head. The braking force was just sufficient to control the inertial effect of the beam when stopped, so that it did not over-run. Since the unwinding tension from the warper’s beam during beaming should remain, as far as possible, minimum and constant to avoid undue strain on yarn and to minimize tension variation within a weaver’s beam, the varying braking force according to the decreasing radius of warper’s beam was also calculated theoretically. The method of calculating yarn tension during beaming is given in App.2. Based on the calculations of braking force, weaver’s beams were prepared from a group of three warper’s beams at the creel. Yarn tension and end breakage rate were noted at three decreasing radii of warper’s beam. Two weaver’s beams prepared in this manner were selected for warp breakage study at weaving. This processing system has been referred to as modified system in the discussion section.

Results and Discussion

The details of machines and fabric are given in App. 1. The calculated values of yarn tension at different decreasing radii of warper’s beam and the braking forces required to obtain the minimum and uniform tensions throughout are given in Table 2. Table 3 shows the different dead weights on the disc-type tensioning devices of the pre-beaming machine for controlling the variation in yarn tension. The dead weights were selected by trial and error, keeping in view the operational simplicity and the experimental results as reported under ‘Preliminary study during pre-beaming’. Table 4 shows the yarn tension during both the conventional and modified systems of pre-beaming and beaming at three decreasing sizes of
warper's beam. The average yarn tensions are the same for both the systems during pre-beaming, but with the modified system, the standard deviation and CV% of yarn tension have been reduced to 9.09 and 23.54% respectively as compared to 14.91 and 38.98% respectively with the conventional system. One of the reasons may be that in the conventional system, spools of different sizes have been used and there is no objective method of controlling the yarn tension. Beam size has no significant effect on tension. Table 4 further shows that as the braking force on beam-head is not properly adjusted during the conventional beaming system, the yarn tension and its standard deviation gradually increase with the depletion of warper's beam, which is detrimental to the yarn property, particularly in wet conditions. In the modified beaming system, on the other hand, the yarn tension remains almost constant with the gradual exhaustion of warper's beam and the tension values are very near to the calculated ones given in Table 2. The standard deviation and CV% of yarn tension have also been reduced accordingly.

Warp breaks in the post-spinning processes lead to productivity losses and consequent cost escalations, and owing to the break of one single yarn the whole warp sheet has to wait until the break is repaired. The reduced tension variation (Table 4) minimizes the warp breakage rate at weaving (Table 5). In each processing stage, the number of warp breaks per hour is less in the modified system than in the conventional system—a result which is expected to increase the productivity.

It is well known that the higher the tension difference in a weaver's beam the higher the variation in the yarn crimp of the fabric and the lower the fabric strength. Likewise, in respect of ink marking on the yarns, if there is a higher variation in the yarn crimp, the standard deviation of ink mark measurements will also be higher. The results in Table 6 and Figs 4-9 are in accord with this trend. For both the systems, the standard deviation has reduced slightly at half-size of weaver's beam and increased at empty size of the weaver's beam. The standard deviation in the modified system is, however, always less than that in the conventional system. The pulled standard deviation was calculated for each system and the variance test (F-ratio) result has been found to be statistically highly significant.

Jute yarn is relatively non-uniform in diameter and it has a low elongation at break. If it is subjected to higher tension or transient variation of tension, its extensibility will be affected. A critical analysis of the physical properties of yarn (Table 7) indicates an overall improvement in yarn properties in the case of the modified system, as expected. The physical properties of fabrics made at different sizes of weaver's beam (Table 8) show a higher tensile strength and lower strength CV%, elongation and crimp in the case of the modified system, the reason for which has been given earlier.

---

**Table 3—Dead Weights (in g) on the Tensioning Devices during Pre-beaming**

<table>
<thead>
<tr>
<th>Spool size</th>
<th>Location of spool on creel</th>
<th>Front</th>
<th>Middle</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td></td>
<td>48.5</td>
<td>36.1</td>
<td>36.1</td>
</tr>
<tr>
<td>Half</td>
<td></td>
<td>36.1</td>
<td>23.7</td>
<td>23.7</td>
</tr>
<tr>
<td>Empty</td>
<td></td>
<td>23.7</td>
<td>11.3</td>
<td>11.3</td>
</tr>
</tbody>
</table>

**Table 4—Yarn Tension during Conventional and Modified Systems of Pre-beaming and Beaming at Three Sizes of Warper's Beam**

<table>
<thead>
<tr>
<th>Processing stage</th>
<th>Warper's beam size</th>
<th>Full</th>
<th>Half</th>
<th>Empty</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conv.</td>
<td>Mod.</td>
<td>Conv.</td>
<td>Mod.</td>
</tr>
<tr>
<td>Pre-beaming</td>
<td>Tension, g</td>
<td>39.88</td>
<td>44.76</td>
<td>49.24</td>
<td>31.92</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>17.45</td>
<td>10.14</td>
<td>14.53</td>
<td>8.81</td>
</tr>
<tr>
<td></td>
<td>CV%</td>
<td>43.75</td>
<td>22.67</td>
<td>29.51</td>
<td>27.59</td>
</tr>
<tr>
<td>Beaming</td>
<td>Tension, g</td>
<td>88.0</td>
<td>101.7</td>
<td>171.84</td>
<td>99.88</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>34.78</td>
<td>17.96</td>
<td>44.35</td>
<td>22.92</td>
</tr>
<tr>
<td></td>
<td>CV%</td>
<td>39.52</td>
<td>17.66</td>
<td>25.81</td>
<td>22.95</td>
</tr>
</tbody>
</table>
BHATTACHARYYA & BANERJEE: CONTROL OF JUTE YARN TENSION

Table 6—Scatteredness of Ink-Mark on Fabric

<table>
<thead>
<tr>
<th>Processing system</th>
<th>Weaver’s beam size</th>
<th>Standard deviation</th>
<th>Pulled standard deviation</th>
<th>F ratio</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Full</td>
<td>4.4</td>
<td>4.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Half</td>
<td>3.76</td>
<td>4.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Empty</td>
<td>4.91</td>
<td>3.02</td>
<td>3.02</td>
<td>Statistically highly significant</td>
</tr>
<tr>
<td>Modified</td>
<td>Full</td>
<td>2.48</td>
<td>2.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Half</td>
<td>1.98</td>
<td>2.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Empty</td>
<td>2.87</td>
<td>3.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7—Physical Properties of Yarn

<table>
<thead>
<tr>
<th>Property</th>
<th>Yarn samples from</th>
<th>Spool</th>
<th>Pre-beaming</th>
<th>Beaming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Conv.</td>
<td>Mod.</td>
<td>Conv.</td>
</tr>
<tr>
<td>Count at 16% moisture regain, tex</td>
<td>320</td>
<td>292</td>
<td>296</td>
<td>303</td>
</tr>
<tr>
<td>Tensile strength, kg</td>
<td>3.32</td>
<td>2.74</td>
<td>3.0</td>
<td>3.28</td>
</tr>
<tr>
<td>Strength CV%</td>
<td>21.5</td>
<td>25.9</td>
<td>25.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Quality ratio, %</td>
<td>79</td>
<td>71</td>
<td>77</td>
<td>85</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>2.04</td>
<td>1.3</td>
<td>1.4</td>
<td>1.21</td>
</tr>
<tr>
<td>Elongation at 1 kg load, %</td>
<td>0.99</td>
<td>0.66</td>
<td>0.64</td>
<td>0.4</td>
</tr>
<tr>
<td>Toughness index, g/tex</td>
<td>$106 \times 10^{-3}$</td>
<td>$61 \times 10^{-3}$</td>
<td>$71 \times 10^{-3}$</td>
<td>$65 \times 10^{-3}$</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>508.6</td>
<td>721.8</td>
<td>723.9</td>
<td>894.6</td>
</tr>
<tr>
<td>Tenacity, g/tex</td>
<td>10.4</td>
<td>9.4</td>
<td>10.1</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Fig. 4—Ink-marks on cloth at full-size of weaver’s beam in conventional system

Fig. 5—Ink-marks on cloth at half-size of weaver’s beam in conventional system

Fig. 6—Ink-marks on cloth at almost empty size of weaver’s beam in conventional system

Fig. 7—Ink-marks on cloth at full-size of weaver’s beam in modified system

Fig. 8—Ink-marks on cloth at half-size of weaver’s beam in modified system

Fig. 9—Ink-marks on cloth at almost empty size of weaver’s beam in modified system
Table 8—Physical Properties of Fabric

<table>
<thead>
<tr>
<th>Property</th>
<th>Weaver's beam size</th>
<th>Full</th>
<th>Conv.</th>
<th>Mod.</th>
<th>Half</th>
<th>Conv.</th>
<th>Mod.</th>
<th>Empty</th>
<th>Conv.</th>
<th>Mod.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile strength, kg</td>
<td></td>
<td></td>
<td>59.0</td>
<td>62.0</td>
<td>58.0</td>
<td>63.0</td>
<td>39.0</td>
<td>54.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength CV%</td>
<td></td>
<td></td>
<td>12.4</td>
<td>9.0</td>
<td>11.6</td>
<td>7.0</td>
<td>16.5</td>
<td>12.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation, %</td>
<td></td>
<td></td>
<td>4.65</td>
<td>4.63</td>
<td>5.02</td>
<td>3.5</td>
<td>6.18</td>
<td>4.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crimp, %</td>
<td></td>
<td></td>
<td>4.78</td>
<td>5.0</td>
<td>4.83</td>
<td>3.73</td>
<td>6.83</td>
<td>4.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions
(1) The nature and magnitude of variation in yarn tension depend on the size and location of the spool at the creel during pre-beaming.

(2) The variation in tension among the yarns in a weaver's beam can be minimized by proper adjustments of the tensioning devices at the creel during pre-beaming and of braking force on the warper's beam during beaming.

(3) The reduction in tension variation among the warp yarns in a beam lowers the warp breaks during pre-beaming, beaming and weaving and improves the physical characteristics of yarns and fabrics.

Acknowledgement
The authors are thankful to Sarvashri S K Neogi, S K Bose and A Lahiri of IJIRA for help and valuable suggestions during the study and to Dr S R Ranganathan, Director, IJIRA, for permission to publish this paper.

References
5 Kaller L V, Tekhnologiya tekstil'noi promyshlennosti, (6) (1976) 64.
8 Makhover V L, Tekhnologiya tekstil'noi promyshlennosti, (2) (1973) 62.

Appendix 1: Particulars of Machines and Materials

Pre-beaming machine
Make: Mackie
Speed: 183 m/min
Length of yarn/beam: 6190 m
No. of ends: 182
Distance of tensioning-device/thread-guide from top of spool: 30 cm
Weight of disc of tensioning device: 11.3 g
Weight of each dead weight of tensioning device: 12.4 g

Pre-beaming machine for preliminary study
Distance from tension measuring head to front creel: 250.5 cm
... middle creel: 467.0 cm
..... back creel: 1312.0 cm
Height of creel: 133.0 cm

Spool
Yarn count: 292 tex (8.5 lb/spindle)
Average weight: 5.9 kg
Average length: 24.25 cm
Average diameter: 26.6 cm
Conicity of spool: 1.18

Beaming machine
Make: Chas Parker Sons & Co., Dundee
Speed: 22 m/min
No. of drying cylinder: 6
Laid length: 123 m
No. of ends: 546
Drive: Friction disc system
Size content in yarn: 5%
Moisture regain: 30%
Appendix 2: Theoretical Calculations of Yarn Tension during Beaming

A similar type of calculation for weaving has been given by Neogi and Roy. Fig. 10 shows the side elevation of a warper’s beam rotating on the creel of the beaming machine in the direction shown by the arrow. Let the tension of warp sheet at beam radius \((R + r)\), where \(R\) is the radius of yarn layers and \(r\), the radius of beam barrel. From the theory of coil friction, the frictional force \(F\) on the beam head equals \(T_r - T_s\), where \(T_r\) is the tension on the tight side of the brake band, i.e. the spring balance reading, and \(T_s\), the tension on the slack side of the brake band.

Again, when slip occurs

\[
T_i = T_s e^{e\theta}
\]

where \(e\) is the base of Napierian logarithm, i.e. 2.718; \(\mu\), the coefficient of friction between brake band and beam head; and \(\theta\), the angle of lap of brake band in radian.

So, \(T_s = T_i / e^{e\theta}\)

Moment about beam heads = \(F \times B \times 2\), where \(B\) is the radius of beam head and the factor 2 accounts for the two sides of beam.

Again, moment about bearing (i.e. moment about beam arbour)\(^1\)

\[
= W_1 \mu \tau A
\]

where \(W_1\) is the weight of beam with yarn; \(\mu\), the coefficient of friction between arbour and beam-stand; and \(A\), the radius of arbour.

Again when slip occurs

\[
T = 2FB + W_1 \mu \tau A
\]

\[
T = \frac{2FB + W_1 \mu \tau A}{(R + r)}
\]

\[
\frac{T}{\text{No. of runners}} = \text{tension of single yarn}
\]

Again, the volume of yarn at beam radius \((R + r)\) is

\[
\pi (R + r)^2 L - \pi r^2 L
\]

where \(L\) is the distance between the two flanges of the beam.

Let the weight of the yarn of afore-said volume be \(W_2\). Then \(W_2 = \) (weight of full beam – weight of empty beam).

Therefore, at any beam radius, say \((R + r)\), the weight of yarn in the beam may be worked out, which is necessary for calculating the changing moment about the beam arbour.