Physical properties and weavability of different types of knot with jute yarns

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The tensile properties, thickness and weavability (in terms of beat-up tension at weaving) of seven different knots with jute yarns of three different counts have been studied. It is observed that dog knot is the poorest in all respect, although it is extensively used at various stages prior to jute weaving. The overall performance of weaver's knot, used invariably in weaving, is fairly good. Barrel and Fisherman's knots, the latter of SZ and SS variants, are better than dog knot but inferior to weaver's knot. Both the SS and SZ variants of double-harness bend, a new knot yet to be used in textile processing, have been found to have the minimum thickness and very high breaking strength and show superior weavability compared to others. As such, the double-harness bend can be considered to be the most suitable for joining the yarns. No slippage or loss in tail length of any knot has been observed at any stage.

Keywords: Barrel knot, Dog knot, Double-harness bend, Fisherman's knot, Jute yarn, Knot strength, Knot thickness, Knot weavability, Weaver's knot

1 Introduction
In weaving and its various preparatory processes, occurrence of yarn breakage is inevitable. The most common means of joining the two ends of a broken thread is by inserting a knot of suitable shape and size. Although the methods for producing knot-free yarn joints have been devised recently, knots are still used in many cases, particularly in the jute industry. Varieties of knots, each with distinctly different characteristics, have been reported by many workers. Most of the reports, however, deal mainly with the mode and chances of failure of different types of knot with varying tail length and only a few reports have considered the tensile properties and rise in tension of knotted yarns while passing through the reed or against the capstan-like guides. The effect of sizing on the slippage of different knots has also been studied. While in many of these studies, passage of knots has been studied under the simulated or stationary condition of the reed, in some others, where the Fisherman's knot has been considered, no mention of the exact nature of the knot has been made. It has been reported that there are three distinct structures of Fisherman's knot and each performs differently.

Garnsworthy and Plate have made some studies on a new type of knot, the double-harness bend, and observed its superiority over the other knots in weaving performance. But here too, no information on the physical properties of the knots is given. View of the above, a study to investigate the tensile properties, thickness and weavability (in terms of tension of the knotted yarns used as warp) under the actual weaving condition has been undertaken for different types of knot with jute yarns of different counts. Efforts have also been made to critically evaluate the suitability of double-harness bend over the other knots commonly used.

2 Materials and Methods

2.1 Yarns
Unsized jute yarns of 214, 286 and 451 tex with twists/m of 187, 199 and 144 respectively were used. Each yarn was spun on a flyer spinning system with Z twist. Load-elongation properties of these yarns are given in Table I. For each yarn, seven different types of knot (Fig. 1) were studied, thus making the total number of knotted samples as 21.

2.2 Knots
In the processing of jute yarns, dog knot (Fig. 1a) is used at all the winding stages while the weaver's knot (Fig. 1b) is used in weaving only. Barrel knot (Fig. 1c), although fairly bulky, can perform well in weaving. Fisherman's (FM) knot (Figs 1d and 1e) and double-harness bend (DHB) (Figs 1f and 1g) can be tied with three variants SS, SZ and ZZ. In torque-unbalanced yarn, SZ variant of FM knots performs most poorly and SS variant on Z-twisted or ZZ variant on S-twisted yarn performs better. But in the case of DHB, the variant SZ performs even better.
Table I—Load-elongation properties of knotted and normal yarns

<table>
<thead>
<tr>
<th>Yarn count (tex)</th>
<th>Normal yarn (without knot)</th>
<th>Knotted yarn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BS BE BS BE BS BE BS BE</td>
<td>BS BE BS BE BS BE BS BE</td>
</tr>
<tr>
<td></td>
<td>kg % kg % kg % kg %</td>
<td>kg % kg % kg % kg %</td>
</tr>
<tr>
<td>214</td>
<td>1.86 1.48 1.6 1.91 1.83 1.62 1.87 1.81</td>
<td>1.74 1.51 1.76 1.41 1.77 1.72 1.78 1.51</td>
</tr>
<tr>
<td></td>
<td>(22.9) (12.9) (19.7) (21.6) (21.6) (14.4) (22.2) (16.6)</td>
<td>(25.3) (16.8) (20.8) (15.2) (20.8) (17.5) (20.9) (16.3)</td>
</tr>
<tr>
<td>286</td>
<td>3.15 1.48 2.67 1.91 3.3 2.13 2.90 1.65</td>
<td>3.13 1.79 2.57 1.51 2.98 1.72 2.97 1.92</td>
</tr>
<tr>
<td></td>
<td>(18.1) (14.9) (21.4) (15.0) (15.5) (11.4) (18.1) (14.9)</td>
<td>(15.1) (12.3) (20.4) (16.0) (19.5) (18.7) (19.8) (16.5)</td>
</tr>
<tr>
<td>451</td>
<td>5.65 2.44 3.64 2.34 4.27 2.04 4.98 2.46</td>
<td>4.66 2.26 5.24 2.46 5.21 2.51 5.1 2.3</td>
</tr>
<tr>
<td></td>
<td>(14.6) (13.8) (15.6) (13.7) (18.7) (14.2) (17.4) (16.4)</td>
<td>(17.7) (15.0) (15.9) (13.8) (15.4) (13.3) (19.0) (15.2)</td>
</tr>
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</table>

Figures in parantheses indicate CV%; BS—Breaking strength; BE—Breaking elongation.

2.3 Tensile Testing
The load-elongation properties of the knotted and normal yarns were measured using Instron tensile tester at a gauge length of 50 cm and a crosshead speed of 2 cm/min. For each type of sample, 50 yarns were tested.

2.4 Measurement of Knot Thickness
The thickness of knots and the diameter of normal yarns were measured with the help of a Projectina microscope at magnification × 10. For each sample, 20 yarns were tested.

2.5 Weavability Test
To study the weavability of different knots, the yarns with knots were used as warps at four different places across the warp sheet and yarn tension (of both knotted and normal yarns) was recorded during weaving with the help of Rothschild electronic tensiometer and Helcoscriptor recorder with chart speed of 5 cm/s. Initially, it was planned to weave all the yarn samples in a pneumatic rapier loom with one end per dent in the reed of 45 dents/dm and reed wire-to-air gap ratio of 25.5:74.5. While the yarns of 214 and 286 tex could be woven without any problem, it was not possible to weave the coarsest yarn (i.e. 451 tex) under these conditions. Study with this yarn was, therefore, made with two ends per dent in the reed of 22.5 dents/dm and reed wire-to-air gap ratio of 33.3:66.7. The speed of the loom was 300 picks/m.

3 Results and Discussion
3.1 Load-Elongation Properties of Knots
The load-elongation properties of the knotted and normal yarns are given in Table 1. As expected, the
breaking strength and elongation of the normal yarns increase with yarn tex. Similar results have been obtained with knotted yarns also for a given type of knot. The breaking strength of the knotted yarns is, in general, slightly lower than that of the respective normal yarns. Among the various types of knot, the strength of dog knot is minimum in all cases except one and that of DHB is fairly high; in case of Fisherman's knot of SS variant only, the strength of the knot with 286 tex is little lower than the corresponding strength of the dog knot. While the strength retention values of dog knot vary from 64 to 86%, those of DHB (SZ and SS) are above 90% and in many cases, slightly higher than those of other types. No significant difference in breaking strength has been observed between SZ and SS variants of DHB. The strength of barrel, weaver's and FM knots is also high and more or less similar to that of DHB. There are, however, noticeable differences in strength between FM(SZ) and FM(SS) knots with the coarser yarn counts but they do not follow any trend with the variants. Table 1 also reveals that breaking elongation of the knotted yarns is, in most cases, higher than that of the respective normal yarns. The strength retention values and elongation of the knotted yarns are generally minimum for the coarsest yarn.

Strength CV generally decreases with the increase in yarn tex for both the normal and knotted yarns but the elongation CV does not follow any definite trend. The effects of type of knot on the strength and elongation CV are also not clear.

During the study of the load-elongation properties of knotted yarns, the exact place of break of each sample, that is whether at the knot or at the yarn, has also been noted separately and the results are given in Table 2. It is observed that for a given type of knot, the number of break at the knot increases significantly with the increase in yarn tex, because of corresponding increase in yarn strength. In the case of coarsest yarn, % break at knot is always much higher than that at yarn. Further, the maximum number of break occurs at the dog knot and the minimum at DHB(SS) for all the three yarn counts. For both the variants of FM knots, the number of break at knot is generally low compared to that at barrel or weaver's knot. The reason for yarn breakage at knot possibly is that when two ends of a yarn are knotted, the portion of the yarn that constitutes the knot (indicated by X in Fig. 1) remains at right angle to the yarn axis. As a result, when a load is applied on the yarn in its longitudinal direction, the component fibres in the innermost and outermost yarn segments, in this area, are stressed differently and this produces a potential weak place. If the places are located at the threshold of a knot, as in case of dog knot for example, the flow of load would be restricted at these points and the chances of breakage at knot would increase. If, on the other hand, the weak places are so located that the load in the yarns can pass inside the knot structure, as in case of other knots, the knot can share the load to a greater extent to reduce the possibility of knot failure.

### 3.2 Thickness of Knots

The thickness of various knots are given in Table 3. Each value is the mean of two measurements, one along the transverse direction and the other along the vertical direction of the knot. It is observed that regardless of the type of knot, the thickness of a knot increases with yarn tex but there is no clear relationship between the magnitude of increase in thickness and yarn count. Compared to the diameter of normal yarns, the thickness of knot increases by 2.7-3.8 times. For all the yarn counts, the thickness of dog knot is maximum, closely followed by that of FM(SZ). The thickness of barrel knot comes next and that of FM(SS) is lower than that of FM(SZ). The thickness of DHB(SS and SZ) is generally the lowest while that of weaver's knot is slightly higher than that of DHB. It is also observed from Table 3 that there is

<table>
<thead>
<tr>
<th>Yarn count tex</th>
<th>Dog K/Y</th>
<th>Weaver's K/Y</th>
<th>Barrel K/Y</th>
<th>Fisherman's K/Y</th>
<th>Double-harness bend K/Y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SZ</td>
<td>SS</td>
<td>SZ</td>
<td>SS</td>
<td>SZ</td>
</tr>
<tr>
<td>214</td>
<td>66/34</td>
<td>38/62</td>
<td>24/76</td>
<td>16/84</td>
<td>10/90</td>
</tr>
<tr>
<td>286</td>
<td>70/30</td>
<td>52/48</td>
<td>34/66</td>
<td>38/62</td>
<td>22/78</td>
</tr>
<tr>
<td>451</td>
<td>84/16</td>
<td>66/34</td>
<td>74/26</td>
<td>66/34</td>
<td>60/40</td>
</tr>
<tr>
<td>Mean</td>
<td>73.3/26.7</td>
<td>52/48</td>
<td>44/56</td>
<td>40/60</td>
<td>30.7/69.3</td>
</tr>
</tbody>
</table>

K/Y—Knot/Yarn.
no significant difference in knot thickness between the two variants of DHB. DHB is 12-29% smaller in thickness than dog knot.

It has been reported\(^5\) that when a torque-unbalanced yarn is tied by FM(SZ) knot, the overhand knot, whose twist direction in the folded part resembles the twist angle of the parent yarn, shows greater tendency to loosen. Possibly for this reason, the thickness of FM(SZ) knot has been found to be higher than that of FM(SS) for all the yarn counts studied (Table 3). To verify this point, the thickness of S and Z overhand knots of FM have been measured separately and the results are given in Table 4. For this study, each yarn of the three counts was tied with FM(SZ) knot, but the two overhand knots were not drawn together. In tying the knots, care was taken so that both the overhand knots are tensioned, as far as possible, equally. Thickness of these knots was measured after about 1 h of preparation of the samples. From Table 4, it is evident that the Z overhand knot is always higher in thickness than the S overhand and the difference in thickness increases with yarn tex. This clearly indicates that not only the Z overhand knot on Z-twisted yarn tends to loosen but this tendency also increases as the yarn becomes coarser. This is equally true for S overhand knot on S-twisted yarn.

### 3.3 Weavability of Knots

During weaving, warp breaks occur mainly because of obstructions experienced by the thick places on the yarns while passing through the heald eyes and reed dents. These obstructions cause excessively high tension in the yarns.\(^9\) To assess the performance of a knot on the loom, the tension of knotted yarn was measured after the knot traversed into the sweep of the reed. Fig. 2 shows the percentage rise in yarn tension at beat-up of the knotted yarns over that of the respective normal yarns. The figure shows the mean value of three yarn counts. Since the action of the reed on a knot is more severe than that of heald, the results of beat-up tension only have been considered here. For all types of knot and yarn count, the yarn tension at beat-up rises appreciably. While the rise in beat-up tension is maximum with dog knot, it is minimum with DHB(SS). A few yarn breakages at the knot also occurred for dog knot. There is no significant difference in rise in tension between the two variants of DHB, as observed in their thickness also (Table 3), and their tension values are much
lower than those obtained with barrel and FM knots for all the three yarn counts. Weaver's knots also register low rise in beat-up tension and their results are close to those of DHB. Because of high bulk, barrel knots cause fairly high rise in tension. Although the thickness values of FM(SZ) are higher than those of FM(SS) and very close to the maximum values obtained with dog knots (Table 3), their effects have not been reflected accordingly in the results of yarn tension (Fig. 2). Tension values of both FM(SZ) and FM(SS) are much higher than those of DHB and weaver's knots. No slippage or loss in tail length of any knot was observed during tensile testing or weaving.

While studying the warp tension it has often been observed, particularly with dog knot, that after the knot has reached the fell of the cloth and the pick laid behind it is pushed forward by the reed during the process of beat-up, the knot creates obstructions to the movement of the pick, as shown in Fig. 3. This also contributes much to the rise in beat-up tension of the knotted yarns. This situation continues for a few more succeeding picks, but with gradually decreasing magnitude, until the knot passes well inside the cloth. Similar behaviours have also been observed with other knots, but their effects are far less severe.

Compared to others, the thickness of dog knot in the vertical direction is very high and this causes greater hindrance to the movement of the picks during beat-up.

3.4 Performance Rating of Knots

On the basis of the retained strength and increase in thickness and beat-up tension of the knotted yarns over those of the normal yarns, ratings have been given to the seven knots (Table 5). Figures in increasing order indicate corresponding increase in strength and decrease in thickness and beat-up tension. As can be observed, dog knot is the poorest in all respects. DHB(SZ), rated very high in every respect, is the best among the various knots studied. DHB(SS) is not as good as DHB(SZ) in all respects, but much superior to others. Barrel knot is second best in respect of strength but its performance at weaving is very poor owing to its high bulk. FM knots of both variants are superior to dog knot but inferior to DHB and weaver's knots. Between the two variants of FM knot, FM(SZ) is slightly lower in respect of thickness. The overall performance of weaver's knot is a little worse than that of DHB but better than those of others.

4 Conclusions

Yarn joints by knots slightly decrease the breaking strength of jute yarns. Decrease in strength is greater for dog knots than for weaver's, barrel and two variants (SZ and SS) of double-harness bend (DHB) and Fisherman's (FM) knots with three yarn counts studied. Dog knots show the greatest tendency of breakage at the knots and DHB(SZ), the least. The breaking elongation of yarns generally increases after knotting. Dog knot is the largest in size and, therefore, causes maximum rise in warp tension during beat-up. Both the variants of DHB are the smallest in thickness and can pass through the reeds with minimum resistance. Their breaking strength are also very high. Weaver's and Fisherman's knots have high strength retention values but the former performs comparatively much better in weaving because of its lower thickness. Barrel knot also registers high breaking strength but its large dimension poses problems at weaving. Between the two variants of FM knot, SZ variant is larger in size, as the Z overhand knot loosens on the Z-twisted yarns, but this has not been reflected on their weavability. The loosening tendency of Z overhand knot increases with the increase in yarn tex. No significant difference in thickness has been observed between the two variants of DHB. No slippage or loss in tail length has been observed for any knot. Considering the overall performance, DHB(SZ) is the best and is closely
followed by DHB(SS). The weaver’s knot is the third best while the dog knot is the poorest in all. FM of SZ and SS variants and barrel knots are superior to dog knot but inferior to DHB and weaver’s knots.

References