Measurement of hairiness of jute yarns by discrete and integral methods

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1 Introduction

The demand for various value-added diversified jute products, e.g. wall coverings, upholsteries, curtains, soft-luggage, shoe-upper, etc., has been increasing day by day. These products are made of jute and jute-blended yarns. Excessive hairiness of jute yarn adversely affects its subsequent processing. Moreover, due to the excessive hairiness of the yarns, jute products have poor handle and aesthetic value. Besides shedding of jute fibres, picking up of dust quickly by the protruded fibres is also due to the excessive hairiness of jute yarns which is to be reduced if modern high speed weaving and wet processing treatments are to be adopted to make high value diversified jute products. So long jute was enjoying the large and ensured market of woven flexible packaging material where hairiness of yarn and fabrics was of little consequence. But now the hair-free, smooth synthetic bags made out of HDPE or PP tapes and films are posing serious threat to jute bags used for packing foodstuffs and other commodities. Thus, hairiness of jute yarn is to be measured and reduced, if not totally eliminated, not only to explore the high value markets of diversified jute products but also to retain the traditional market of flexible packaging material.

Ghosh et al.\textsuperscript{1-5} not only developed an instrument to measure the hairiness of jute yarns but also extensively studied the various factors that affect hairiness of jute yarns when they are spun on jute spinning machinery. Bhattacharyya et al.\textsuperscript{6} used the instrument developed by Ghosh et al.\textsuperscript{1} and determined the hairiness of filament-wrapped jute yarns spun in the conventional two-legged flyertype jute spinning frame. They observed that the hairiness of spin-wrapped jute yarn made on conventional jute spinning frame was far lower than that of all-jute yarn conventionally spun on the same machine. The instrument developed by Ghosh et al.\textsuperscript{1} is based on 'discrete' exploration method for determining 'long hairiness' as explained by Coll-Tortosa and Marcelo\textsuperscript{7}. The Zweigle tester for yarn hairiness measurement is based on the principle of optoelectronics of counting the number of protruding fibres from yarn surface, as explained by ten Brink and Topf\textsuperscript{8}.

Chaudhuri et al.\textsuperscript{9} prepared wrap-spun jute and jute-vicose blended yarns in hollow spindle machine and measured their hairiness in Uster tester (UT-3) which
is based on 'integral' exploration method for determining 'total hairiness' as suggested by Coll-Tortosa and Marcelo. As explained by Barella, this instrument is based on the principle of electrically measuring the scattered light resulting from the reflection, refraction, defraction and bending of parallel infrared laser rays falling on the protruding fibres of the yarn body. It gives an overall dimensionless numerical value of hairiness in terms of hairiness index which is defined as the ratio of cumulative length of protruding fibres in a unit length of yarn as explained by ten Brink and Top).

In the present work, hairiness of conventionally-spun (both slip draft and apron draft) all-jute yarns and that of wrap-spun jute yarns (prepared in hollow-spindle spinning machine) has been measured using the two types of instruments mentioned above.

2 Materials and Methods

2.1 Materials

Jute fibres of commercial hessian warp batch, polypropylene mono- and multi-filaments and polyester multi-filament were used. The specifications of these filaments are given in Table 1.

2.2 Methods

Jute yarn samples of 276 tex were prepared in three different spinning machines, viz. Mackie slip-draft jute sliver spinning machine, Mackie apron-draft jute sliver spinning machine and Suessen Parafil-2000 wrap-spinning machine. Five types of wrap-spun yarns with mono- and multi-filament as wrapping element and two types of conventional spun yarns were prepared. The slip-draft all-jute yarn and wrap-spun jute yarns were prepared in New Central Jute Mills Ltd, West Bengal, using jute fibres of commercial hessian warp batch. The apron-draft all-jute yarn was spun in the laboratory from the third-drawn sliver of the same hessian warp batch. The drawn sliver was brought from jute mill to laboratory in the polyethylene bag so that too much loss of moisture did not occur. Hairiness of the yarns was measured using the JTIRL jute yarn hairiness meter at a yarn speed of 27 m/min. The time interval was 5 s. Hence, the number of protruding hairs in a yarn length of 225 cm was determined by counting. Three hair-length settings of 3 mm, 5 mm and 7 mm were selected and denoted as \( l_1 \), \( l_2 \) and \( l_3 \) respectively. The number of hairs protruding from the yarn surface at three hair-length settings were recorded separately. Fifty such readings for each yarn at each hair-length setting were taken and their average was computed. These were denoted as \( \bar{n}_1 \), \( \bar{n}_2 \) and \( \bar{n}_3 \) respectively. The number and length of hairs of each yarn at each hair-length setting were also computed. The number of hairs at each hair-length setting was computed as follows:

(i) number of hairs equal to or greater than 7 mm = \( \bar{n}_1 \),
(ii) number of hairs equal to or greater than 5 mm but less than 7 mm = \( \bar{n}_2 \), and
(iii) number of hairs equal to or greater than 3 mm but less than 5 mm = \( \bar{n}_3 \).

The length of hairs at each hair-length setting was computed as follows:

(i) total length of hairs equal to or greater than 7 mm = \( L_1 = L_1 \) (assuming \( l_1 = 7 \) mm),
(ii) total length of hairs equal to or greater than 5 mm but less than 7 mm = \( L_2 = L_2 \) (assuming \( l_2 = 5 \) mm), and
(iii) total length of hairs equal to or greater than 3 mm but less than 5 mm = \( L_3 = L_3 \) (assuming \( l_3 = 3 \) mm).

The computed values of the number of hairs and length of hairs at different hair-length settings are given in Table 1. The cumulative hair length for each yarn over all the three settings was also determined (Table 1). This was computed as \( L = L_1 + L_2 + L_3 \).

Measurement of hairiness indices of all the yarns was made on Uster Tester 3, fitted with the attachment to measure hairiness of yarns, at a yarn speed of 100 m/min or 2.5 mm.

The correlation coefficients between the results of two methods of tests and the standard error of \( Y \) estimation were determined and are given in Table 2. To establish a relationship between the results from the two testers, cumulative hair lengths were calculated from the results of discrete method and are given in Table 2. The \( t \) test for determining the significance of the correlation coefficient was also carried out. The line of best fit (F) for cumulative hair length of all the yarns was computed and it is shown in Fig. 1. Later, correlation coefficient, standard error of \( Y \) (cumulative hair length) estimation, the significance of correlation coefficient and line of best fit (F') were determined for wrap-spun jute yarns only (Table 2 and Fig. 1).
<table>
<thead>
<tr>
<th>Type</th>
<th>Linear density tex</th>
<th>No. of wraps</th>
<th>Type and colour of filament</th>
<th>User hairiness index (UHI)</th>
<th>No. of hairs at hair-length settings of 3 mm (L₁)</th>
<th>No. of hairs at hair-length settings of 5 mm (L₂)</th>
<th>No. of hairs at hair-length settings of 7 mm (L₃)</th>
<th>Length of hairs (non-cumulative) in mm at hair-length settings of 3 mm (L₁), 5 mm (L₂) and 7 mm (L₃)</th>
<th>Total length of hairs (cumulative) (L₁+L₂+L₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrap-spun</td>
<td>243</td>
<td>13.35</td>
<td>250</td>
<td>1.45</td>
<td>30.40</td>
<td>6.63</td>
<td>3.86</td>
<td>23.77</td>
<td>2.77</td>
</tr>
<tr>
<td>Wrap-spun</td>
<td>300</td>
<td>23.33</td>
<td>350</td>
<td>5.06</td>
<td>36.31</td>
<td>6.83</td>
<td>0.86</td>
<td>29.48</td>
<td>5.97</td>
</tr>
<tr>
<td>Wrap-spun</td>
<td>270</td>
<td>8.89</td>
<td>450</td>
<td>5.33</td>
<td>10.63</td>
<td>2.14</td>
<td>0.31</td>
<td>8.49</td>
<td>1.83</td>
</tr>
<tr>
<td>Wrap-spun</td>
<td>262</td>
<td>10.00</td>
<td>300</td>
<td>6.75</td>
<td>30.77</td>
<td>6.66</td>
<td>2.69</td>
<td>24.11</td>
<td>3.97</td>
</tr>
<tr>
<td>Conventional</td>
<td>293</td>
<td>-</td>
<td>145⁴</td>
<td>7.49</td>
<td>33.46</td>
<td>7.82</td>
<td>1.97</td>
<td>25.64</td>
<td>5.85</td>
</tr>
<tr>
<td>Conventional</td>
<td>290</td>
<td>-</td>
<td>145⁵</td>
<td>9.47</td>
<td>126.51</td>
<td>37.31</td>
<td>17.26</td>
<td>89.20</td>
<td>20.05</td>
</tr>
</tbody>
</table>

1. JTRL, jute yarn hairiness meter reading.
2. Apson-draft machine with Baxter flyer.
4. Twist per meter.
Table 2—Statistical parameters

<table>
<thead>
<tr>
<th></th>
<th>Hair-length setting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 mm</td>
</tr>
<tr>
<td>No. of hairs for all types of yarns</td>
<td>0.81</td>
</tr>
<tr>
<td>No. of hairs for wrap-spun yarns</td>
<td>0.04</td>
</tr>
<tr>
<td>No. of hairs for all types of yarns (non-cumulative)</td>
<td>0.81</td>
</tr>
<tr>
<td>No. of hairs for wrap-spun yarns (non-cumulative)</td>
<td>0.03</td>
</tr>
<tr>
<td>Length of hairs for all types of yarns</td>
<td>0.81</td>
</tr>
<tr>
<td>Length of hairs for wrap-spun yarns</td>
<td>0.03</td>
</tr>
<tr>
<td>Total length of hairs for all types of yarns</td>
<td>0.81</td>
</tr>
<tr>
<td>Total length of hairs for wrap-spun yarns</td>
<td>0.02</td>
</tr>
</tbody>
</table>

$R$—Correlation coefficient

3 Results and Discussion

Table 1 shows that the wrap-spun jute yarns are far less hairy than the conventional all-jute yarn. The reduction in the hairiness of the yarns is reflected in the parameters measured by both integral method (Uster hairiness index) and discrete method (number and length of protruding hairs). Similar reduction in hairiness was reported by Barella et al.\(^1\) with wool, acrylic fibre, polyamide/acrylic and wool/acrylic fibre blended wrap-spun yarns. The reduction in the hairiness of wrap-spun yarn is mainly due to its structure. The staple fibres of these yarns are laid parallel to yarn axis and instead of twisting the staple fibres a filament yarn is wrapped round these parallel-laid staple fibres. As a result, the staple fibres of wrap-spun yarns do not experience twisting and bending to that extent during yarn formation and consequently, generation of hairs in wrap-spun yarn is restricted. Bhattacharya et al.\(^1\) also reported that the spun-wrapped jute yarns made in conventional rove spinning machine exhibit marked reduction in hairiness though the structure of spun-wrapped yarn is different from that of wrap-spun yarn.
When the Uster hairiness indices of all the yarns are compared with the total (cumulative) length of protruding fibres from the yarns, the correlation coefficient is found to be 0.81 which as per the t-test carried out yielded $t_{0.05} > t_{0.05}$. Therefore, the degree of association is positively and significantly correlated. It is, therefore, inferred that the two methods of measuring hairiness of jute yarns are well-correlated, the straight line of best fit ($Y'$) with standard error of $Y$ estimations is shown in Fig. 1. Similar high degree of correlations (0.871 and 0.825) were reported by Barella for cotton and cotton-man-made fibre blended yarns respectively spun in a cotton ring spinning system. But when the hairiness of only wrap-spin jute yarns is compared, the correlation coefficient is only 0.02. In other words, no correlation exists as illustrated by the straight line of best fit ($Y''$) shown in Fig. 1. After testing a large number of yarns, ten Brink and Topr reported that the overall correlation between the hairiness parameters measured by the two types of instruments was not more than 0.6. They observed that the data from the two instruments were poorly correlated in the range of statistical certainty because the two methods were fundamentally different. Barella also corroborated that view, though for certain yarns he reported quite high degree of correlation. ten Brink and Topr also reported that the yarns having higher level of hairiness were more closely correlated. Later, Coll Tortosa and Marcelo compared the hairiness parameters measured by two methods and reported that for carded cotton yarns the correlation coefficient was only 0.458 while for combed cotton yarns it was 0.779. They also concluded that fuzz formation depended upon the material preparation. For close structures, there was no dependence of fuzziness on the hairiness index obtained whereas for open structures, a certain relation was found. In the present study, the wrap-spin jute yarn had close structure while the conventionally-spin jute yarns had open structure.

In the present study, it has also been observed that jute yarn spun in slip-draft spinning frame with two-legged flyer exhibits higher degree of hairiness than the yarn spun in apron-draft spinning frame with baxter flyer. However, Ghosh et al. reported otherwise. It therefore requires further study. Moreover, it may be noted that the values of Uster hairiness index of wrap-spin jute and blended jute yarns, as reported by Chaudhuri, are usually higher than those obtained in the present study. This may be due to the higher degree of wraps/m employed in the present study. It is, however, very interesting to note that in the present study the Uster hairiness index of wrap-spin jute yarn with PP monofilament as wrapping element and with 250 wraps/m is very low (1.45). Chaudhuri et al. also reported quite low value (1.78) of Uster hairiness index for the yarn with 260 wraps/m. For all other wrap-spin all-jute yarns they found that the Uster indices hovered around 10-11. Neither Chaudhuri et al. made any comment about it nor could we explain it from our study. But it has been observed in the present study that though the integral exploration method employed by Uster hairiness technique yields a low Uster hairiness index value (1.45), the discrete exploration technique adopted in the instrument developed by Ghosh et al. does not corroborate it. From Table 1 it may be observed that not only the total length of the protruding hairs of this yarn is almost the same as that of other three types of yarns whose Uster hairiness indices are much higher than 1.45, but the total length of longest protruding hairs (with hair length above 7 mm of this yarn) is also maximum among the five experimental wrap-spin jute yarns. In other words, with long protruding hairs, this yarn may visually appear to be quite hairy. Therefore, further studies in this direction are required.

4 Conclusions

4.1 Total and long hairiness of wrap-spin jute yarns is much lower than that of conventionally-spin jute yarns.
4.2 When the results of both conventional and wrap-spun yarns are taken together, the correlation coefficient between integral and discrete methods is positive and significant, but no relationship can be established when the results of only wrap-spun yarn are considered.

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References