A comparative study of the wrap-spun, flyer-spun covered and conventional all-jute yarns

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Jute yarns of 276 tex nominal count have been spun using polypropylene filaments as wrapping element on apron draft jute spinning frame with 240 tpm and the properties of these yarns compared with those of the conventional all-jute yarns of equivalent nominal count spun on the same apron draft jute spinning frame using the optimum twist of 160 tpm and higher twist of 240 tpm. The wrap-spun jute/polypropylene yarns of equivalent nominal tex have also been produced using hollow spindle spinning frame with 250, 300 and 350 wraps/m and their properties compared with those of the all-jute and covered yarns. It is observed that the tenacity of all the covered and wrap-spun yarns is lower than that of the all-jute yarn. However, the breaking extension and work of rupture of the covered and wrap-spun yarns are much higher than those of all-jute yarns. Yarn mass irregularity is found to be higher in all-jute yarn compared to other yarns. Hairiness of wrap-spun yarn is much lower than that of the all-jute and covered yarns.

Keywords: Covered yarn, Hairiness, Jute, Polypropylene multifilament, Tensile properties, Wrap-spun yarn, Yarn irregularities

1 Introduction

In an effort to develop yarns with improved properties from that of the conventional staple fibre yarn, Audivert1,2 tried to spin yarn using filament-staple fibre combination on standard ring spinning frame. The covered yarn so produced showed considerable improvement in properties and better process performance in weaving and knitting. It was possible to spin successfully covered3,5 jute yarn on existing jute spinning machine using wide range of covering material and jute as core component. Sengupta et al.3 showed that the optimum twist factor for the covered yarn was similar to that for all-jute yarn. Further, it was reported4 that the covered yarn prepared from high density polyethylene mono-filament showed improved tensile behaviour than the conventional all-jute yarn.

One of the latest spun yarn manufacturing technologies involves wrapping of a continuous filament yarn around a staple fibre bundle by adopting hollow spindle technology.6,9 Since the structure of these yarns is composed of untwisted parallel staple fibres held together by wrapping filament yarn, the yarn is called parallel yarn. The continuous filament yarn exerts a radial pressure, providing the necessary frictional force between the individual staple fibres. This frictional force increases as the wrapped yarn is subjected to tension, and this provides strength to wrapped yarn. Xie et al.6 proposed a general model which can be used to predict the relationship between the yarn strength and the structural parameters of wrap-spun yarn. The experimental work done by Xie et al.7,8 was found to be in reasonable agreement with the theoretical approach. Behery and Nunes9 studied the effect of the linear density of the wrapper filament and the wrapping density on the yarn structure and tensile properties. The morphology of yarn failure during tensile testing was also studied.

Jute is a bast fibre and its spinning involves age-long conventional flyer-spun technology with a low production rate of 18-25 m/min. In an effort to study the feasibility of spinning jute applying hollow spindle technology, Princz10 made a detailed comparative study of manufacturing cost, labour cost, power cost and the total cost for conversion per kg of yarn while spinning jute yarn on conventional jute spinning system and wrap-spun yarn on Suessen Parafil 2000 machine, highlighting the savings made in spinning wrap-spun yarn as compared to conven-
tional all-jute yarn. Some researchers\textsuperscript{11-15} have reported the physical properties of wrap-spun yarn made from jute and its blend using various types of synthetic filaments as wrapping element. Basu et al.\textsuperscript{14} reported some properties of fabrics made from wrap-spun jute yarn and compared with those of the fabric made from conventional all-jute yarn. An effort was also made to find out yarn-fabric relationship.

In the present work, a comparative study of the mechanical and physical properties of all-jute yarn spun on conventional jute spinning system, covered jute yarn spun on existing spinning machine and wrap-spun jute yarn spun using hollow spindle technology with varying twist level and wrap density has been made. The effect of filament linear density and filament type on the properties of wrap-spun yarn has also been studied.

2 Materials and Methods

2.1 Materials

Jute fibre of standard hessian warp batch was used. Two different types of polypropylene multifilament yarn (4.4tex/12 filament and 9.0tex/24 filament) and 13.3tex polypropylene monofilament were used.

2.2 Methods

Jute finisher card sliver was processed through hybrid draw frame developed in NIRJAF laboratory. The linear density of drawing sliver was adjusted accordingly to spin yarn on existing jute apron draft spinning frame and Suessen Parafil 2000 wrap spinning machine. The drawing sliver thus produced was used to prepare the following yarn samples:

- conventional all-jute yarns spun on Mackie’s apron draft jute spinning frame at a spindle speed of 4200 rpm and twist levels of 160 and 240 tpm, keeping the draft level at around 12.
- covered jute yarn spun on Mackie’s apron draft jute spinning frame at a twist level of 240 tpm, keeping the spindle speed and draft as above. The covering material was fed just in front of the front roller nip without any tension by adopting the processing technique developed by Sengupta et al.\textsuperscript{3}.
- wrap-spun yarn spun on Suessen Parafil 2000 wrap spinning machine with a draft of 32 and a delivery speed of 80 m/min. The wrap density was increased from 250 wpm to 350 wpm in steps of 50 wpm and the mono- and multi-filaments were used as wrapping elements.

In all, 13 different yarn samples were prepared with nominal linear density of 276 tex. All the yarn samples were tested for tensile properties on Instron Tensile Tester at 65% RH and 22-25° C. The gauge length and cross-head speed were maintained at 500 mm and 500 mm/min respectively. The yarn mass irregularity (Um%), yarn imperfections and hairiness index were evaluated using Uster Tester-3.

3 Results and Discussion

3.1 Tensile Properties

Table 1 shows that in case of conventional all-jute yarn, an increase in twist from the normal value of 160 tpm to 240 tpm results in decrease in tenacity, initial modulus and increase in breaking elongation. This is due to the obliquity effect of the fibres in the yarn owing to high twist. But, due to the increase in breaking elongation, the work of rupture of the yarn improves. In case of covered yarns made of jute and polypropylene multifilament, there is an overall improvement in tensile properties when compared with the conventional all-jute yarn. Though the tenacity of covered yarn is lower than that of all-jute yarn, the improvement in breaking extension, which is due to the higher twist and incorporation of filament, improves the work of rupture remarkably. The covered yarn shows lower initial modulus and higher CV% of breaking load compared to all-jute yarn. It is also observed that the wrap-spun jute yarn of 250 wpm with any kind of filament does not show any improvement in yarn tensile properties, except the initial modulus which decreases. Beyond 250 wpm, due to high extensibility of wrap-spun yarn, the work of rupture of all the wrap-spun yarn increases and initial modulus further decreases. The stress-strain curves of conventional all-jute yarn, covered yarn and wrap-spun yarn of 300 wpm (Fig. 1) show the comparative features of tensile properties. The increase in extensibility and decrease in initial modulus of wrap-spun yarns are mainly due to the removal of waviness of the yarn profile or yarn crimp which developed when the wrap-spun yarns were prepared in hollow spindle machine. The tenacity of wrapped jute yarn, where the yarn strength was achieved due to the radial pressure exerted by the wrapping filament on the parallel fibre core, is found to be lower than that of conventional all-jute yarn. The reason may be that the radial pressure exerted by the wrapping filament on the parallel fibre core is not sufficient to bring in the required cohesive force as
<table>
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<tr>
<th>Sample</th>
<th>Filament linear density tex</th>
<th>Wrap density wpm</th>
<th>Tenacity cN/tex</th>
<th>Breaking load CV%</th>
<th>Breaking elongation %</th>
<th>Initial modulus cN/tex</th>
<th>Specific work of rupture mJ/tex-m</th>
<th>( U_m ) %</th>
<th>( CV_m ) ( % )</th>
<th>Imperfections/km Thin places (-50%)</th>
<th>Imperfections/km Thick places (+50%)</th>
<th>Neps (+200%)</th>
<th>Hairiness index</th>
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*pPolypropylene monofilaments
*bTwists per metre
Fig. 1—Stress-strain curves of yarns: (a) all-jute yarn with 160 tpm, (b) all-jute yarn with 240 tpm, (c) 14.4tex monofilament wrap-spun jute/polypropylene yarn, (d) 10tex multifilament covered jute/polypropylene yarn, (e) 4.4tex multifilament covered jute/polypropylene yarn, (f) 4.4tex multifilament wrap-spun jute/polypropylene yarn, and (g) 10tex multifilament wrap-spun jute/polypropylene yarn.

has been done by the twist in ordinary yarn. It is also observed from Table 1 that with the increase in wrap density, the wrap-spun yarn tenacity first increases up to an optimum level and then it decreases, except in the case of wrap-spun yarn with 4.4 tex filament as wrapping element where a continuous increase in tenacity is observed up to 350 wpm. The reason is that the wrap-spun yarn strength is achieved from the strength of wrapping component and the strength of the fibrous core resulting from the cohesive or frictional force between the fibres. With the increase in wrap density, the radial compressive force exerted by the continuous filament yarn increases, making the fibrous core more compact and resulting in higher wrapped yarn strength. But after a certain wrap density, where the maximum compactness of core fibres is achieved, the increase in wrap density only increases the helix angle or the angle of coiling of the wrapping filament, and the yarn strength decreases. In case of wrap-spun yarn with 4.4 tex filament as wrapping element, it may be observed that the maximum compactness of the core fibres is not attained even up to a wrap density of 350 wpm. The wrap-spun yarn extensibility increases throughout with the increase in wrap density.

3.2 Yarn Irregularities

Table 1 shows that the irregularities of covered and wrap yarns in terms of $U_m$ % and $CV_m (10m) $ % are higher than that of the conventional all-jute yarn. The introduction of a filament in front of the front roller nip in case of covered yarn causes an instability in the delta zone, thereby increasing irregularity. The higher irregularity of wrap yarn might be due to very high draft of 32 against 13 used in normal apron draft spinning machine. It is interesting to observe that the thin places in the conventional all-jute yarns and covered yarns are much lower than the thick places while in the case of wrap-spun yarns it is quite opposite. Detailed investigation is required to find out the reasons for opposite behaviour of thick and thin places in the yarns spun in different spinning systems. Further, it is observed that except the wrap-spun yarn with 4.4tex multifilaments as wrapping element and the wrap spun yarns with 300 and 350 wpm and 10tex multifilaments as wrapping element, all the covered and wrap-spun yarns show much lower number of neps than that of the conventional all-jute yarn.

3.3 Yarn Hairiness

The hairiness index of wrap-spun yarn is found to be lower than those of conventional all-jute yarn and covered yarn. Since the staple fibres in wrap-spun yarn are laid parallel to the yarn axis and instead of twisting the staple fibres a filament yarn is wrapped round the parallel-laid staple fibres, the wrap-spun does not experience the centrifugal force to that extent as in flyer spinning during yarn formation. Therefore, generation of hairs in wrap-spun yarn is restricted.

4 Conclusions

4.1 Breaking strength of all the covered and wrap-spun yarns is lower than that of the conventional all-jute yarn. Breaking strength of wrap-spun jute yarn increases with the increase in wrap density up to a certain level and then it decreases with the further increase in wrap density.

4.2 Breaking extension and work of rupture of all the covered and wrap-spun yarns are higher than that of the conventional all-jute yarn.

4.3 Hairiness of wrap-spun yarns is lower than those of conventional all-jute and covered yarns.

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References
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