Characteristics of rotor-spun composite yarns
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Various rotor-spun composite yarns have been produced by combining staple fibres with filament yarns under varying filament overfeed ratio on a modified open-end rotor spinning frame. The effects of filament overfeed ratio on the structure and properties of composite yarns have been studied. It is observed that the filament overfeed ratio has great influence on the filament geometric position and helix trajectory in composite yarns. As the filament tension increases with decreasing filament overfeed ratio, the filament moves from the surface into the center of the composite yarn. The tensile properties of composite yarns depend on the filament overfeed ratio, and the filament overfeed ratio alone does not explain the CVO/O and hairiness of composite yarns. Compared with the normal rotor-spun yarn, the appearance and properties of rotor-spun composite yarns are improved.

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Rotor spinning has been adopted worldwide at present. Its main advantages over ring spinning are high yarn output rates, reduced production costs, increased bulkiness and improved evenness of the yarns. However, the relatively low breaking strength and wrapper fibres of yarn surface are still matters of concern. These disadvantages may be improved by combining staple fibres with a continuous filament yarn in rotor spinning process. Some researchers have studied the spinning conditions and characteristics of rotor-spun composite yarns. Nield and Ali described a mechanism for producing open-end core-spun yarns.

Cheng and Murray reported a method of making core-spun yarns on an open-end rotor spinning frame. Pouresfandiar et al. and Matsumoto et al. reported their progress in producing different kinds of novel hybrid yarns on an experimental open-end spinning frame.

In the present work, different kinds of composite yarns have been produced under varying filament overfeed ratio on a modified open-end rotor spinning frame, and the effects of filament overfeed ratio on the structure and properties of rotor-spun composite yarns analyzed.

A cotton sliver (25.4mm mean fibre length, 1.5dtex fibre linear density, 3.43 fibre micronaire value and 4.32g/m sliver size) was used as the staple fibre, and a polyester filament (3.33tex, 30d/15f) was used as the filament yarn fed into the rotor.

Figure 1 shows the schematic diagram of modified open-end rotor spinning process. The filament yarn was fed from a supply bobbin by the suitable guides to the filament feed rollers, passed straight through the filament guide tube and then drawn into the rotor freely by suction, where the filament yarn was combined with the staple fibre strand to form the composite yarn. The composite yarn was then drawn through the doffing tube and finally on to the take-up roller. The filament guide tube was positioned along the axis of rotation of the hollow rotor shaft, which rotated freely about it. The filament feed rollers were able to feed the filament yarn positively with a wide range of constant feeding speeds. During the spinning process, the tensions of both the filament and the composite yarns were measured by Rothchild R046 Tension Meter. The filament tension was measured between the filament feed rollers and the filament guide tube (A in Fig. 1), and the composite yarn tension was measured between the filament feed rollers and the doffing tube (B in Fig. 1).
tension was measured between the doffing tube and the take-up roller (B in Fig. 1).

Spinning parameters for composite yarns were: 58 tex normal linear density, 617 tpm designed twist, 7000 rpm opening roller speed, 45000 rpm rotor speed (50 mm rotor diameter), 72.9 m/min take-up speed, and 80.8 draft ratio. The filament overfeed ratio (OFR) was 0.91, 0.94, 0.97, 1, 1.03, 1.06, 1.09 and 1.12 respectively. It was calculated by the following relationship:

\[ \text{OFR} = \frac{\text{Filament feed speed}}{\text{Composite yarn take-up speed}}. \]

For the comparison, a normal rotor-spun yarn was produced under the same spinning conditions and parameters.

A tracer fibre technique was used to observe the yarn structure and the geometric position of the filament in the composite yarn. A black-dyed polyester filament (3.33 tex, 30d/15f) was used as the tracer fibre. The longitudinal view of composite yarns and the spatial trajectory of the filament yarn can be observed and recorded by Questar Hi-Scope Video Microscope System. The filament radial position \( R_0 \) and half pitch were measured. The filament relative radial position \( r \) could be obtained from the following equation:

\[ r = \frac{R_0}{R} \quad R \text{ was composite yarn radius} \]

Breaking strength and extension were determined from the mean of 60 tests with a test length of 500mm, extension rate of 500mm/min and pretension of 29cN, and the load-extension curves were obtained at the same time. Irregularity was measured with the yarn speed of 400 m/min and the testing time of 1 min. Hairiness was tested with the testing speed of 30m/min and test length of 100 m, and the hairs above 2mm per meter were measured. All the tests were performed under a standard atmosphere of 20±2°C and 65±2% RH.

Figure 2 shows the relationship between the filament overfeed ratio and the yarn tension. The tensions of both the filament and the composite yarns increase with decreasing filament overfeed ratio, and the composite yarn tension is found to be higher than the filament tension. The filament overfeed ratio decreases, i.e. the filament feed speed decreases gradually under the constant take-up speed, so the filament tension increases. As the spinning tension of the composite yarn is composed of the filament tension, staple fibre strand tension and other factors, the composite yarn tension increases with the increase in filament tension. When the filament overfeed ratio is beyond 0.91, a high frequency of end breakage for the staple fibre strand may occur.

Figure 3 shows the typical appearance of the composite yarns and normal rotor-spun yarn. The appearance of the composite yarn is clearer than that of the normal rotor-spun yarn. Rotor-spun yarn is
known to have a skin-core structure, consisting of a central core that resembles ring-spun yarn, and an outer sheath containing a random disarray of fibres and wrappers. The morphology of wrapper fibres lying near the surface of the rotor-spun yarn is relatively loose. During the spinning process of composite yarns, the morphology of wrapper fibres on the cotton strand surface becomes tighter and clearer than that of the normal rotor-spun yarn because of the insertion and wrapping of the filament.

The filament overfeed ratio has great influence on the appearance of composite yarns as shown in Fig. 3. When the filament overfeed ratio decreases, the filament moves from the surface into the center of the composite yarn gradually. If filament overfeed ratio decrease to 0.91, the polyester filament is located near the center of the composite yarn and is almost completely covered by the cotton fibres. The yarn morphology is similar to a normal rotor-spun yarn, but there is less hairiness than that of the normal rotor-spun yarn. The polyester filament in the composite yarn is twisted with the cotton strand and follows a helical path. According to idealized helical yarn geometry, when a composite yarn is made from two components, it is necessary to have different component lengths in the yarn. If one component is a filament yarn, the length can be easily controlled by the tension. When the filament tension increases with decreasing filament overfeed ratio, the filament yarn tends to lie near the axis of the composite yarn and can be covered by the staple fibre strand.

Figure 4 shows three kinds of typical structures of composite yarns produced at different filament overfeed ratios. When OFR is 1.12, the filament tension is relatively low and hence the filament yarn wraps over the staple fibre strand and follows a helical path. When OFR is 1, i.e. the filament feed speed is equivalent to the take-up speed, the filament yarn also follows a helical path and tends to lie in the inner layer of composite yarns. When OFR is 0.91, the filament tension becomes relatively high and hence the filament yarn lies along the axis of the composite yarn near the center.

Figure 5 shows the relationship between the filament overfeed ratio and the filament relative radial position \( r \) and half pitch. As the filament tension increases with decreasing filament overfeed ratio, the filament yarn tends to lie near the axis of the composite yarn. Accordingly, the filament relative radial position \( r \) decreases and the pitch of the filament helix trajectory increases gradually.

Figure 6 shows the typical load-extension curves of the composite yarn, normal rotor-spun yarn and filament yarn. The breaking strength of the filament yarn (30d/15f) is lower and extension is higher than other yarns. The composite yarn shows a marked increase in breaking strength, initial modulus and extension as compared to the normal rotor-spun yarn. The morphology of wrapper fibres on the surface of the rotor-spun yarn is relatively loose and they have
little contribution to the yarn strength. During the formation of composite yarns, owing to the insertion and wrapping of the filament, the morphology of wrapper fibres becomes much tighter and the transverse pressure as well as cohesive forces among fibres increase and the breaking strength of the composite yarn increases.

Figure 7 shows the effects of filament overfeed ratio on the tensile properties of composite yarns. In the case of OFR＞1, while the filament overfeed ratio decreases, the breaking strength of composite yarns has a tendency to increase and the breaking extension has no significant change. As the filament tension increases with decreasing filament overfeed ratio, the wrapping of the filament yarn is greater and the yarn structure becomes tight and uniform and hence the inter-fibre cohesive forces and the breaking strength of composite yarns increase. In the case of OFR＜1, the filament is stretched effectively and the tensile characteristics of the filament itself is changed, so the breaking strength of composite yarns decreases. When the composite yarn is withdrawn from the take-up bobbin, the filament yarn recovers from its spring stretch, which makes the staple fibre strand component in the yarn slack and the breaking extension of the composite yarn increases accordingly.

Figures 8 and 9 show the effects of filament overfeed ratio on the yarn irregularity and hairiness respectively. It can be observed that the filament overfeed ratio alone does not explain the CV% and hairiness of composite yarns. Both the CV% and hairiness of composite yarns are less than that of the normal rotor-spun yarn. The evenness of the composite yarn is better and its surface is clearer, i.e. consistent with the results drawn from the yarn longitudinal photographs (Fig. 3). The improvement in hairiness on the surface of the composite yarn is high. This phenomenon can be explained by the wrapping of the filament yarn on the cotton fibre strand.
The results show that the changes in filament overfeed ratio can lead to the changes in filament tension and have great influence on the appearance, structure and properties of composite yarns. The polyester filament in the composite yarn is twisted with cotton strand and follows a helical path. As the filament tension increases with decreasing filament overfeed ratio, the filament moves from the surface into the center of the composite yarn gradually. At the same time, the breaking strength of composite yarns has a tendency to increase, and the breaking extension, CV% and hairiness have no significant changes. With the filament overfeed ratio less than 1, the breaking strength of composite yarns decreases and the breaking extension increases. In comparison with the normal rotor-spun yarn, the morphology of wrapper fibres near the composite yarn surface is tighter and clearer. The composite yarn shows a marked increase in breaking strength, initial modulus and extension. The CV% of composite yarns is low and the improvement in hairiness is high.

References