INFLUENCE OF FIBRE PARAMETERS AND TWIST ON FRICTION YARN QUALITY AND SPINNING STABILITY

by

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Dedicated to

My Parents

CERTIFICATE

This is to certify that the thesis entitled "***Influence of Fibre Parameters and Twist on Friction Yarn Quality and Spinning Stability***", being submitted by Mr. Anup Kumar Chakrabarti to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him. Mr. Anup Kumar Chakrabarti has worked under my guidance and supervision and fulfilled the requirements for submission of the thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

New spinning technologies are being evolved and modified with the aim to substitute the use of conventional ring yarns. A very common characteristic of these technologies is the tremendous speed at which spinning takes place. Friction spinning is capable of producing at a speed of 300 m/min and is gradually establishing itself in the production of multicomponent core, technical and speciality yarns. But the volume of market in these areas being limited, its wider acceptance in traditional sector is desirable.

The technology of friction spinning has been the subject of study by many researchers who have reported about its poor tensile strength. The low strength of these yarns is ascribed to its peculiar structure (lack of binding between successive layers for OE yarns and ineffective and inconsistent wrapping of core by sheath fibres for Dref-3 yarns), highly deformed and buckled fibre configurations and inadequate packing of fibres due to insufficient spinning tension. The scope for improving fibre configuration and spinning tension is very limited. The possibilities to generate a self-interlocking structure as observed in ring yarns are also remote. Twist, in case of friction spinning can be manipulated by friction ratio i.e. the ratio of surface speed of friction drum to delivery speed. Twist, estimated by twist-to-break method has been found to increase with friction ratio. This ratio can be changed by varying drum speed at a constant delivery speed (mode A) or varying delivery speed at a constant drum speed (mode B). Since the drum rotates the yarn tail that rests on it to impart twist, the size of this portion can play an important role in deciding the level of twist in yarn. A simple relationship was established between yarn twist, the size of the yarn tail with machine and process parameter. The estimated diameter of the yarn tail was found to be much larger than actual yarn diameter.

As twist is the most important yarn parameter that affects strength, the response of yarn tenacity to change in friction ratio has been investigated. It has been found to depend upon mode of change of friction ratio. It had been seen that in general reduction in friction ratio through reduction in drum speed enhances yarn tenacity whereas the same through increase in delivery speed reduces tenacity. The reduction in friction ratio through mode A causes less interference to the fibre integration process in the spinning zone due to lower drum speed and reduced turbulence generated by the collisions of air currents associated with friction drum rotation and the incoming air flow through the transportation duct. Hence an improvement in strength is expected. On the other hand, reduction in friction ratio through mode B causes a drop in the residual time for fibres in the twisting zone. This results in inadequate integration of fibres in the yarn. Moreover, fibre opening gets negatively affected due to higher throughput rate. As a result yarn tenacity would reduce. Yarn tenacity has been found to increase with friction ratio up to a certain limit beyond which it declined thus resembling twist- strength relationship observed for classical ring yarns.

It is not only friction ratio but also the combination of friction drum and delivery speed used to attain it, affects yarn tenacity. A yarn spun at a friction ratio obtained at the combination of lower delivery and friction drum speed is stronger than the same obtained at the combinations of higher speeds. This can be ascribed to (i) the production of more stable structure because of higher residual time of fibres in the yarn formation zone facilitating proper integration of fibres into the yarn. (ii) to their better opening by the opening roller due to lower mass flow rate and (iii) stable spinning conditions.

The scope for enhancing strength substantially from a given fibre is limited during spinning operation unless a strong filament yarn is incorporated in the core. This may at times means a compromise on composition. The rupture behaviour of friction yarns has been found to be dominated by fibre slippage rather than breakage So, incorporation of additional twist, plying and mercerization (for cotton yarn) could be some of the alternatives at the post-spinning stage to improve structural integrity and thereby strength of these yarns.

Cotton and acrylic yarns were modified by incorporating twist on a ring twister. The yarns modified by additional twist have been observed to possess higher strength with respect to their respective parent yarns. For cotton this improvement was in the range of 66% to 139% whereas for acrylic it was up to 40%. Dref-3 finer yarns show higher tenacity rise compared to coarser yarns. The tenacity rise can be attributed to enhancement of frictional resistance to slippage due to addition of twist, which improves structural integrity of both the yarns. The initial rise in tenacity of Dref-3 finer (30 tex) yarn may be ascribed to positive effect of reinforcement by tighter sheath and twisted core. For coarser yarns the obliquity effect predominates right from the beginning as the twist multiplier corresponding to minimum added twist (2.8 and tex twist multiplier is 27.3) lies probably close to the optimum. Besides, structural flaws in coarse yarns are likely to be less due to more number of fibres in the yarn cross-section than finer yarns. Cotton yarns are likely to have more flaws since it contains lot of short fibres. Therefore, gain in strength for cotton would be more.

Z twisted cotton and acrylic yarns were plied on a ring doubling machine using a wide range of ply twist level. Dref-3 yarns have been found to derive maximum advantage out of plying. The improvement in tenacity was of the order of 25-51% for acrylic and 77-209% for cotton yarns. But the change in tenacity was found to be not so sensitive to the amount of change in ply twist level. The Z-ply direction produced stronger yarns than S-ply direction for both cotton and acrylic yarns.

However, the direction of plying appears to affect the tenacity in case of cotton yarns substantially whereas for acrylic the effect is marginal for both OE and Dref-3 structures. This difference can be attributed to the presence of short fibres in cotton. In case of acrylic most of the fibres being sufficiently long (i.e. close to 38 mm.), the fibres generate sufficient frictional resistance to slippage due to inter yarn wrapping even when individual structure gets loosened. The influence of opening up of the structure due to reverse ply twist direction therefore becomes more evident in the case of cotton than acrylic. Thus, cotton yarn gets more affected than acrylic. With Dref-3 structure a similar phenomenon also occurs with sheath fibres when plied in S direction i.e., they become loose. However, additional tightness is induced in wrapped sheath fibres when they are Z plied. The core, which is partially twisted, is expected to contribute equally towards strength irrespective of the direction of ply twist. Therefore, even though substantial improvement in tenacity occurs after S-plying, a dramatic rise in strength is observed when they are Z-plied.

In case of mercerization, it has been observed that in general mercerisation leads to tenacity rise to the extent of 28- 44% for OE-friction and 12- 84% for Dref-3 yarns respectively. But the extent of rise is significant for the later one and more specifically for coarser yarns. In mercerized yarns transverse swelling and longitudinal shrinkage of constituent fibres was found to significantly affect the internal packing of fibres. Interfibre void spaces are therefore, expected to decrease due to swelling and change in fibre cross-sectional shape and thereby enhancing the potential contact among the fibre surfaces. Removal of wax will lead to increase in fibre to fibre friction. Therefore, strength is expected to increase in mercerized yarns, more so for Dref-3 yarns due to the shrinkage of sheath fibres whose number being substantial will further reinforce the structure.

Strength being one of the most important criteria of quality, maximum attention is always paid to tenacity of yarns. The Dref-3 friction spinning technology enables definite predetermined placement of fibres across yarn cross- sections i.e. either in core or sheath. So, this type of structure leaves ample scope for correct selection of fibres to constitute either core or sheath so as to derive maximum advantage in terms of reinforcing effect of sheath and load bearing capacity of core. The role of fibre fineness and length, which are available commercially, was studied in this respect. The influence of fineness was studied using 38 mm polyester and acrylic fibres. The fineness chosen was 1.56, 2.33 and 3.33 dtex for polyester 1.33, 1.67 and 2.22 dtex for acrylic. Similarly to investigate the influence of fibre length polyester and acrylic tows consisting of 3.33 and 2.22 dtex filaments respectively were cut into 32, 38 and 44 mm. From three different fibre fineness values, nine 42 tex polyester and nine 74 tex acrylic yarns were produced and for both the yarns fibre fineness in core and sheath were made available. Similarly, from three different fibre lengths, nine 59 tex polyester yarns and six 74 tex acrylic yarns were spun changing fibre length in core and sheath.

It has been found that use of finer fibres either in core or sheath produces stronger yarns. It was seen that in case of polyester, for a given core fibre fineness, the yarn tenacity gradually diminished as the sheath fibres become coarser. But for acrylic fibres, the decline in strength was observed only when coarsest (i.e. 2.22 dtex) fibres was employed in sheath. The yarn strength was always higher with finer fibres in core irrespective of sheath fibre fineness employed. This phenomenon is more prominent with polyester than acrylic fibres. With increase in sheath fibre length, tenacity remained more or less constant except when core consisted of shorter fibres i.e. 32mm fibres. As the sheath fibres become coarser, the bending rigidity of fibres increases and as a result the wrapping of these fibres around core is not likely to be very tight. Besides, for a given yarn with core-sheath ratio maintained at a particular level, the number of fibres in the cross-section-forming sheath also reduces. Further, tenacity of sheath fibres are less as it becomes coarser. Hence a reduction in tenacity is expected when sheath fibres become too coarse.

As the sheath fibres are released from the opening roller, they travel through a transportation duct at high speed and land on a slowly rotating drum surface. This causes most of the sheath fibres to buckle. The buckling tendency is expected to be more for longer fibres than shorter ones. Proportional fibre extent values also supported this phenomenon. With 32 mm fibre the wrapping is not likely to be very effective because of short length. As length is increased more effective wrapping takes place. But the advantage of length diminishes due to possibilities of creation of more buckled fibres as length is further increased. Hence hardly any gain in tenacity was observed beyond 38 mm.

In any spinning system uninterrupted spinning of yarn is highly desirable. The more are the interruptions, the less stable is the spinning operation. The performance of the process and technology can be judged from spinning stability. The influence of fibre and yarn parameters on stability in friction spinning has been investigated in terms of 'minimum friction ratio' (f_{min}) needed to ensure stable spinning. After attaining a stable spinning condition, the friction ratio was deliberately reduced so as to create an adverse situation till torque available at yarn formation zone failed to bind fibres effectively at the yarn tail causing repeated disruptions. The friction ratio at which it occurred is 'minimum friction ratio'.

Fibre and yarn fineness was found to have a strong influence on spinning stability. Finer fibres required lower minimum friction ratio (f_{min}) value than coarser fibres. Again, for a given fibre fineness, the f_{min} value was lower for coarser yarns. Polyester fibres were seen to spin better than acrylic fibres. It was also found that Dref-3 yarns required higher friction ratio (f_{min}) than OE-friction yarns for a given fibre for uninterrupted processing. As far as length is concerned 38 mm was found to be optimum from spinning stability point of view.

In case of Dref-3 spinning the strength of the false twisted core in between drafting unit I to the exit end of the drums and the reinforcing effect of the sheath fibres beyond the exit point of drum are most important for spinning to continue. Finer fibres (for a given yarn count) because of their number in yarn cross-section being more would lead to more cohesion in core and more effective wrapping due to lesser bending rigidity and higher numbers. Therefore, it would be able to support the same spinning tension even at a lesser false twist level and thus, the minimum friction ratio is expected to decline. The same is also true with coarser yarn for a given fibre fineness.

For OE-friction yarns finer fibres because of their lower torsional and bending rigidities, get wrapped easily around the stationary (i.e. non-rotating) yarn tail. Besides, the number of fibres in yarn cross-section being more, the cohesion of the assembled fibres in this zone will also be more and thus will be able to support the spinning tension even at much lesser friction ratio. Thus finer fibres are expected to show lesser f_{min} value. Finer yarns can not withstand even mild disturbances in the spinning process because of low cohesion of assembled fibres and due to less number of fibres in yarn cross section. Hence coarser yarns made from any fibres show a better spinning stability i.e. lower f_{min} value in general.

Acrylic fibres because of its higher torsional and bending rigidities and inadequate cohesion requires a higher f_{min} value to ensure proper integration of the fibres into the yarn structure so that it can sustain yarn tension and continue spinning.

As stated earlier, the discontinuity of the spinning operation in Dref-3 process as friction ratio is reduced is either due to inadequate twist in the core fibre assembly or ineffective wrap of the sheath fibres. The core fibre assembly in between the front roller nip of the drafting unit I and the friction drum is highly vulnerable to break since it does not get any support from sheath fibres. However, such an assembly of fibres does not exist in OE-friction mode of spinning. Therefore, the strength of core fibre assembly, in this highly vulnerable zone for Def-3 spinning, is very critical for the continuation of spinning operation. Hence, the extent of reduction of friction ratio possible with OE-friction mode of spinning is much higher than that is achievable in Dref-3 spinning.

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CHAPTER 5:

INFLUENCE OF SHEATH-CORE FIBRE CHARACTERISTICS ON PROPERTIES OF DREF-3 FRICTION YARNS