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Twist structure of friction-spun yarns: Part II — Core-spun DREF-III yarns

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The twist structure of DREF-III friction-spun yarns has been studied by optical method. It is observed that the different layers of sheath fibres exhibit more or less the same average twist as observed in the fibre layers of DREF-II structures. However, under the identical spinning conditions this twist is lower than the twist in DREF-II yarn structures and the use of coarser fibres further reduces it. The twist also shows a decreasing trend with the increase in fibre length from 25 mm to 44 mm followed by a slight increase thereafter. Core fibres, instead of being straight and parallel to the yarn axis as generally expected, are seen to be twisted. Both the core and the sheath fibres twist values have been found to increase with the increase in suction pressure. A decrease in core content increases the core twist while the sheath twist drops after an initial increase.

Keywords: Core-spun yarn, DREF-III yarn, Friction-spun yarn, Tracer fibre technique, Yarn twist, Yarn structure

1 Introduction

DREF-III is an improvement over DREF-II friction spinning system but does not have an open-end like it. DREF-III system, classified as core-sheath type, is capable of producing stronger and multicomponent yarns for special fields of application[1-12]. The distinguishing feature of the DREF-III spinning machine is an additional apron drafting system beside the set of opening roller(s) used on DREF-II spinning machine. A single sliver is fed to this drafting system and drafted to form the yarn core of parallel fibres. This arrangement creates two independently controlled fibre-feeding streams. The one, from the opening roller(s), is made to wrap over the other delivered by apron drafting system, thus producing yarn of core-sheath structure. It is believed that the core is false twisted by the rotation of friction drums before being wrapped by the sheath fibres[2, 13-15]. According to Lord *et al.*[14], this false twist is removed upon emerging from the nip of friction drums and the sheath fibres are reverse twisted so that a complex twisting pattern is achieved in the yarn structure. It has been reported by them that the yarn consists of an almost twistless core with the sheath fibres helically wound over it at differing helix angles and twist levels. For such a structure, it is not possible to measure yarn twist by the traditional methods of detwist or detwist-retwist since untwisting would mean twisting the yarn core of parallel fibres.

Lord *et al.*[14] have photographically studied the twist distributions in these yarns. They also measured the helix angle in different layers by progressively singeing the yarns and found that the outer layers have lower values than those nearer the core. Manich *et al.*[16] have described a method to record apparent twist by untwisting the yarn and measuring its residual strength till a minimum value of strength is reached. However, the optical method described earlier[17] for measuring twist in DREF-II yarns seems to be the only reliable and accurate method for studying the twist densities in DREF-III structures. This technique has the additional advantage that the core and sheath fibres can be simultaneously observed for twist measurement.

The importance of twist structure of friction-spun yarns has already been emphasized[17] in the sense that it influences the physical and mechanical properties of

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yarns and fabrics. The present study was, therefore, aimed at investigating the twist structure of DREF-III friction-spun yarns in relation to some fibre and process parameters.

2 Materials and Methods

2.1 Fibres

Two types of acrylic tows were used for the study. One tow having individual filaments of 1.67 dtex was passed through a tow cutter to obtain fibres of five different lengths (25, 32, 38, 44 and 51 mm) while the other having individual filaments of 3.33 dtex was cut into fibres of 51 mm length only. The same fibres had also been used for studying the twist structure of DREF-II spun yarns[17].

2.2 Preparation of Yarn Samples

Each type of fibres was processed through an MMC card and a Lakshmi Rieter's DO/2S drawframe to produce a set of drawn slivers. Three drawing passages were given to the carded slivers. The linear density of the drawn slivers was adjusted to 3.5 ktex. Wherever required, a small amount of dyed tracer fibres (less than 1%) was mixed with grey fibres before processing; the colour of the dyed fibres was kept different for different slivers in a set. The type and level of spin finish added to the stock of grey fibres before processing was kept constant (0.4% LV40 owf) for all the cases.

The set of slivers from 1.67 dtex fibres was friction spun into 70:30 core-sheath yarns of three different linear densities (39.4, 59.0 and 118.1 tex) on a DREF-III spinning machine. To avoid any difference arising due to change in core component, the sliver made of 51 mm fibres was used as core for all the yarns. Maintaining the same level of suction pressure (-12 mbar) through the friction drums, the delivery rate and the drum speed were kept constant at 150 m/min and 4500 rpm respectively (a constant friction ratio of 4.24), the same as used earlier[17] for the production of DREF-II yarns.

In a similar way, the finest possible yarns of 59.0 tex were produced from the slivers of 3.33 dtex fibres using DREF-III mode of yarn spinning. All other conditions were kept constant as given above, except that the core-sheath ratio was varied from 70:30 to 50:50 at three different levels of suction pressures, viz. -12, -15 and -20 mbar. In these yarns, the core sliver has tracer fibres of the colour different from that of tracers used for sheath slivers so that both core as well as sheath fibres could be observed for twist measurement. The list of yarn samples produced and the corresponding variables are given in Table 1.

2.3 Measurement of Yarn Twist

The yarns were optically dissolved in a liquid (carbon tetrachloride) of similar refractive index as that of the grey fibres so that the coloured tracer fibres could be readily observed through a projection microscope (Projectina). The yarn twist at a particular point along the length of the yarn was calculated from the measured values of helix angle and helix diameter for different coloured fibres by the optical method as described earlier[17].

3 Results and Discussion

Initially, the core fibres were assumed to be twistless as reported by other authors[13-15] and only the twist in the sheath fibres was measured.

Table 1 — List of yarn samples and corresponding variables

Yarn ref. no.	Fibre length[a] mm	Fibre fineness dtex	Yarn linear density tex	Core/sheath ratio	Suction pressure mbar
Y_1	25	1.67	39.4	70:30	-12
Y_2	25	1.67	59.0	70:30	-12
Y_3	25	1.67	118.1	70:30	-12
Y_4	32	1.67	39.4	70:30	-12
Y_5	32	1.67	59.0	70:30	-12
Y_6	32	1.67	118.1	70:30	-12
Y_7	38	1.67	39.4	70:30	-12
Y_8	38	1.67	59.0	70:30	-12
Y_9	38	1.67	118.1	70:30	-12
Y_{10}	44	1.67	39.4	70:30	-12
Y_{11}	44	1.67	59.0	70:30	-12
Y_{12}	44	1.67	118.1	70:30	-12
Y_{13}	51	1.67	39.4	70:30	-12
Y_{14}	51	1.67	59.0	70:30	-12
Y_{15}	51	1.67	118.1	70:30	-12
Y_{16}	51	3.33	59.0	70:30	-12
Y_{17}	51	3.33	59.0	60:40	-12
Y_{18}	51	3.33	59.0	50:50	-12
Y_{19}	51	3.33	59.0	70:30	-15
Y_{20}	51	3.33	59.0	60:40	-15
Y_{21}	51	3.33	59.0	50:50	-15
Y_{22}	51	3.33	59.0	70:30	-20
Y_{23}	51	3.33	59.0	60:40	-20
Y_{24}	51	3.33	59.0	50:50	-20

[a] Fibres of 51 mm length were used in core for all the yarn samples.

3.1 Sheath Twist

3.1.1 Influence of Feed Position of Sheath Fibres

The average twist values of sheath fibres, calculated from the values of helix angle and helix diameter measured at different points along the length of the yarn for all the five different sliver positions, are shown in Table 2. The data for a particular yarn count reveal more or less the same average twist (turns/m) for the sheath fibres arriving at different positions in the fibre assembly zone along the nip of the friction drums. The differences in twist are found to be insignificant at 1% level of significance as shown in Table 3. It is similar to that observed in DREF-II yarns while studying their twist structure[17].

Since most of the twist influencing parameters are maintained constant, the amount of twist will only be governed by the ratio of the fibre sleeve rotational speed and the yarn withdrawal rate. As both of these are not affected by the position of the arriving fibres, the ratio and thus the amount of twist inserted in the fibre assembly remains constant.

Table 2— Average twist for the sheath fibres fed at different positions along the length of fibre assembling zone in DREF-III mode of spinning
[Core/sheath ratio, 70:30]

Yarn ref. no.	Twist, tpm					
	Sliver position from the delivery side of the friction drums					Mean[a]
	First	Second	Third	Fourth	Fifth	
Y_1	628 (27.54)	600 (27.47)	611 (25.46)	602 (23.49)	614 (27.76)	611 (26.58)
Y_2	563 (21.68)	579 (24.69)	581 (29.10)	575 (29.39)	575 (29.76)	575 (27.87)
Y_3	440 (32.05)	461 (35.40)	453 (27.81)	486 (28.76)	423 (33.06)	453 (32.24)
Y_4	615 (30.37)	591 (26.77)	608 (25.41)	589 (25.79)	619 (24.83)	604 (27.59)
Y_5	539 (34.40)	560 (31.05)	583 (35.22)	565 (29.77)	555 (27.06)	560 (32.31)
Y_6	444 (37.11)	450 (32.98)	425 (25.54)	409 (22.99)	421 (30.71)	430 (31.49)
Y_7	590 (31.19)	579 (27.03)	593 (24.15)	573 (27.41)	608 (25.41)	589 (27.36)
Y_8	513 (28.04)	523 (33.31)	490 (28.28)	525 (29.43)	507 (28.31)	512 (30.04)
Y_9	418 (26.29)	421 (27.65)	400 (26.30)	438 (28.54)	446 (25.68)	425 (27.30)
Y_{10}	572 (25.05)	578 (24.16)	569 (23.12)	579 (25.21)	556 (22.31)	571 (24.22)
Y_{11}	472 (24.90)	531 (28.06)	495 (28.87)	535 (27.25)	528 (26.57)	506 (27.67)
Y_{12}	413 (22.09)	379 (30.69)	409 (22.29)	398 (27.28)	421 (24.22)	404 (26.33)
Y_{13}	552 (27.55)	588 (26.51)	567 (27.73)	599 (25.76)	556 (25.17)	572 (26.74)
Y_{14}	527 (27.53)	526 (26.31)	519 (25.09)	538 (21.69)	569 (23.97)	536 (24.82)
Y_{15}	451 (24.65)	436 (24.41)	428 (28.87)	440 (25.42)	443 (25.01)	440 (25.89)
Y_{16}	517 (29.59)	453 (24.77)	497 (30.07)	467 (24.22)	509 (33.31)	489 (29.47)

[a] Mean of all the five positions of the sliver.
The values in the parentheses indicate CV%.

3.1.2 Influence of Fibre Length

The analysis of variance (ANOVA) as applied to the results given in Table 2 indicates significant effect of fibre length on sheath fibre twist in DREF-III yarns (Table 3). From Table 2 and Fig. 1, it may be observed that the changes in sheath fibre twist with fibre length are also similar to those observed for twist in DREF-II yarns[17]. The twist level initially decreases with the increase in fibre length from 25 mm to 44 mm followed by an increase thereafter with further increase in fibre length. These changes, as

Table 3 – ANOVA test results showing effect of variables on sheath fibre twist in DREF-III yarns

Variable(s)	Effect
A	S
B	NS
C	S
A*B	NS
A*C	NS
B*C	NS
A*B*C	NS

A – Fibre length; B – Sliver position from the delivery side of the friction drums; and C – Yarn linear density.
S – Significant at 1% level of significance; and
NS – Not significant at 1% level of significance.

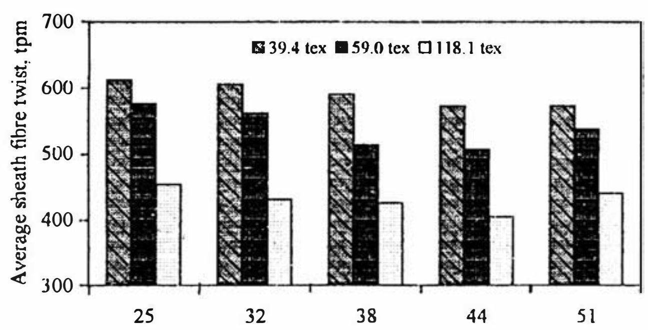

Fig. 1 – Variation in average sheath fibre twist in DREF-III yarns in relation to fibre length

discussed for DREF-II yarns[17], may also be explained on the basis of changes in sleeve diameter caused by fibre individualization and number of fibre extremities.

3.1.3 Influence of Fibre Linear Density

A comparison of the twist values (Table 2) for the yarns spun from the two different fibre linear densities (1.67 and 3.33 dtex) reveals that the yarn twist is lower in case of coarser fibres. This can be attributed to a possibly larger sleeve size when coarser fibres are spun due to their higher bending rigidity.

3.1.4 Influence of Yarn Linear Density

Table 2 shows that the sheath fibre twist in DREF-III yarns is significantly affected by the yarn linear density. Coarser yarns are found to have considerably lower twist (turns/m) than the finer ones (Fig. 1). This may be attributed to the increased yarn diameter and a larger fibre sleeve caused by the higher stiffness of fibrous assembly as a result of higher sheath fibre density and lower degree of fibre separation at higher input speeds[18].

3.1.5 Comparison with Twist in DREF-II Spun Yarns

To compare the data, a part of the twist results for DREF-II yarns published earlier[17] is reproduced here in Table 4. The spinning conditions for the production of DREF-II yarns were kept the same as used for the production of DREF-III yarns (Table 1) so that a direct comparison can be made between the two. Contrary to the expectations, for the same yarn count the sheath fibres in case of DREF-III yarns are found to have less twist as compared to their counterparts in DREF-II system (Tables 2 and 4).

Since the overall twist generated by the twisting torque developed by the friction drums is expected to be the same for both the modes [open-end (DREF-II) and core type (DREF-III)] when the yarns of the same size are spun under similar conditions, there would be no difference between the twist values of DREF-II yarns and sheath fibres in DREF-III yarns. The core component fed through the apron drafting system in case of DREF-III spinning is false twisted by the rotation of friction drums before being wrapped by the sheath fibres and is expected as well as reported to be almost twistless[13-15]. A lower twist in the sheath fibres of the DREF-III yarns suggests either a twist loss or the presence of twist in the core fibres.

3.2 Core Twist

To measure twist in core fibres and different radial zones, the tracer fibres of the colour different from that of the tracers used for the sheath component were mixed in the core slivers for producing yarn samples of varying core-sheath ratios as described in section 2.2. Both core as well as sheath fibres were then observed for twist measurement as described earlier.

Contrary to expectations, the tracer fibres blended in the core sliver were observed to follow a spiral path like that of sheath fibres. Consequently, their helix angle and helix diameter were measured in the same way as for the sheath fibres. Fig. 2 depicts the changes in average values of helix angle and helix diameter in DREF-III yarns (spun at constant suction pressure of -12 mbar) with respect to their arriving position at the nip of friction drums. Both these parameters assume higher values for the surface fibres assembled towards yarn delivery. These parameters go on reducing as one moves away from the delivery end, i. e. from position 1 towards position 5. Core fibres fed through the apron drafting system (position 6) show lowest values of helix diameter and helix angle (Fig. 2). Table 5 shows the average twist of all

Table 4 — Average twist for the fibres fed at different positions along the length of fibre assembling zone in DREF-II mode of spinning

[Fibre length, 51 mm; and Fibre linear density, 1.67 dtex]

Suction pressure mbar	Yarn linear density, tex	Twist, tpm					
		Sliver position from the delivery side of the friction drums					Mean[a]
		First	Second	Third	Fourth	Fifth	
-12	39.4	788 (32.83)	795 (34.05)	842 (31.16)	775 (33.93)	856 (28.13)	811 (32.48)
-12	59.0	672 (25.62)	635 (34.01)	665 (29.19)	695 (28.28)	634 (29.24)	660 (29.45)
-12	118.1	568 (26.91)	630 (26.25)	620 (31.42)	631 (23.69)	634 (23.73)	617 (26.32)

[a] Mean of all the five positions of the sliver.
The values in the parentheses indicate CV%.

the yarn samples calculated from these parameters at different points along the length of the yarn. Interestingly, the fibres used in the core are found to have slightly higher twist as compared to that of sheath fibres.

As mentioned earlier, the core type friction spinning (DREF-III system) involves wrapping of individual sheath fibres supplied by the opening roller on a false-twisted core component fed through a separate apron drafting system. It is possible that the sheath fibre wrappings entrap a part of the false twist in the core. An equilibrium is reached in the yarn structure when the twisting torque in the wrapping fibres (sheath) is balanced by the untwisting torque in the core. This balancing may reduce the twist in the sheath fibres and entrap a part of the false twist of the core. The torque balance between core and sheath fibres depends on the amount of twist and the weight ratio between the two. This probably explains for a lower twist in the sheath fibres of DREF-III yarns (70:30 core/sheath ratio) in comparison to that of DREF-II yarns.

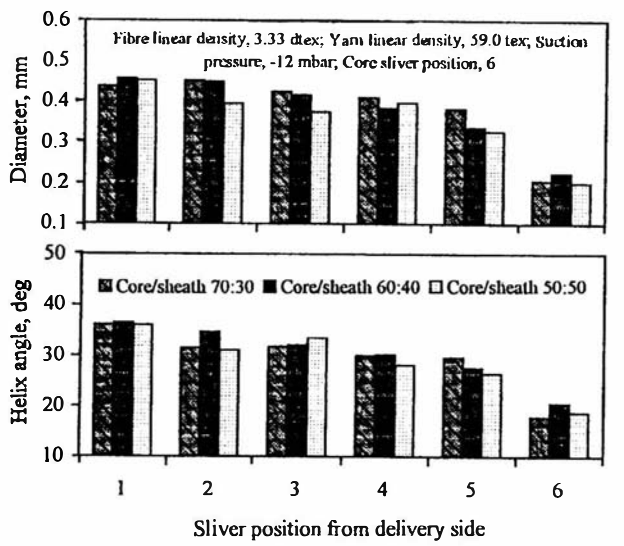

Fig. 2 — Variation in helix diameter and helix angle in DREF-III yarns

It is important to mention here that the tracer fibre technique used is not able to distinguish between S and Z twist. It is therefore presumed that though the core has twist, it would be present equally in Z and S directions so that the net twist is zero.

3.3 Influence of Core-Sheath Ratio on Core and Sheath Fibres Twist

Analysis of the twist results (Table 5) shows insignificant effect of core-sheath ratio on both core and sheath fibres twist (1% level of significance).

Table 5 – Average twist for the fibres fed at different positions in DREF-III mode of spinning
[Fibre length, 51 mm; Fibre linear density, 3.33 dtex; and Yarn linear density, 59.0 tex]

Yarn ref. no.	Suction pressure mbar	Core/ sheath ratio	Twist, tpm						
			Sheath						Core
			Sliver position from the delivery side of the friction drums						
			First	Second	Third	Fourth	Fifth	Mean[a]	
Y_{16}	-12	70:30	517 (29.59)	453 (24.77)	497 (30.07)	467 (24.22)	509 (33.31)	489 (29.47)	535 (30.35)
Y_{17}	-12	60:40	536 (28.75)	525 (34.80)	510 (27.38)	494 (23.08)	516 (25.56)	516 (28.90)	552 (28.81)
Y_{18}	-12	50:50	546 (26.63)	505 (29.03)	453 (28.14)	453 (28.14)	492 (29.42)	490 (28.26)	572 (28.13)
Y_{19}	-15	70:30	500 (25.55)	560 (32.62)	534 (24.24)	517 (29.96)	519 (19.33)	526 (27.63)	565 (28.90)
Y_{20}	-15	60:40	562 (25.51)	539 (29.86)	609 (27.04)	544 (18.63)	567 (26.76)	564 (26.17)	601 (29.93)
Y_{21}	-15	50:50	582 (23.54)	477 (28.64)	552 (27.18)	586 (27.21)	565 (24.68)	552 (26.06)	615 (26.28)
Y_{22}	-20	70:30	558 (22.70)	611 (30.94)	556 (27.73)	579 (30.15)	524 (22.67)	566 (28.80)	568 (29.26)
Y_{23}	-20	60:40	611 (25.98)	602 (22.19)	618 (21.44)	565 (27.32)	600 (27.62)	599 (24.97)	613 (29.27)
Y_{24}	-20	50:50	643 (23.36)	525 (25.20)	639 (22.04)	520 (21.95)	583 (23.34)	582 (23.33)	626 (32.47)

[a] Mean of all the five positions of the sliver.
The values in the parentheses indicate CV%.

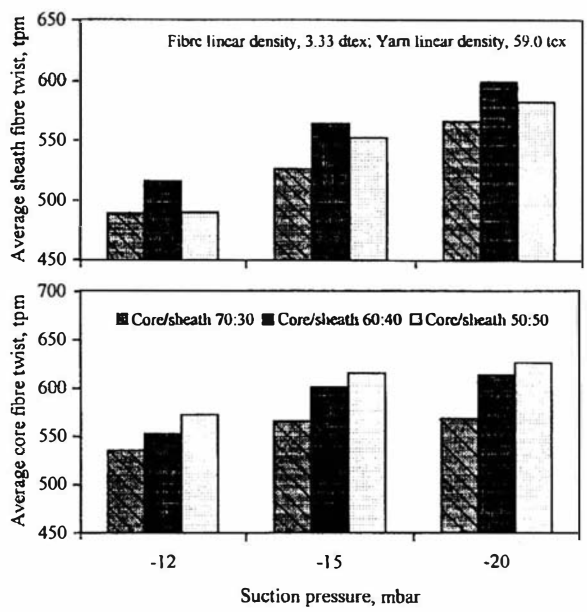

Fig. 3 – Variation in twist of sheath and core fibres in DREF-III yarns in relation to suction pressure

However, it can be observed from Fig. 3 that the twist in the core slightly increases with decreasing core size while sheath fibres twist decreases marginally after an initial increase.

As mentioned earlier, the torque balance between core and sheath fibres depends on the weight ratio of the two. The increase in core twist with an increase in sheath content may be ascribed to the early balance of low untwisting torque of the thinner core and higher twisting torque of the thicker sheath. This increases the sheath twist but is counteracted by the fact that a thicker sheath will have larger sleeve size due to less opening of fibres. This argument is similar to that applicable to coarser yarns spun on DREF-II system[17]. The same statements may probably explain the trend in sheath fibre twist.

3.4 Influence of Suction Pressure on Core and Sheath Fibres Twist

Fig. 3 shows that an increase in suction pressure increases both the core as well as the sheath fibres twist. However, the increase is significant only for sheath fibres twist. This is obviously due to the increased friction between the fibrous assembly and the surface of friction drums at high suction pressure[19-21].

4 Conclusions

4.1 Different layers of sheath fibres in DREF-III yarns exhibit the same average twist as observed in the fibre layers of DREF-II yarns.

4.2 The twist received by the sheath fibres in DREF-III yarns decreases as the fibre length increases from 25 mm to 44 mm. However, beyond 44 mm fibre length it shows a slight increase.

4.3 Under the identical spinning conditions, the sheath fibre twist in DREF-III yarn structures is less than the twist in DREF-II yarn structures; the use of coarser fibres further reduces it.

4.4 Coarser yarns exhibit lower sheath fibre twist than the finer ones.

4.5 Core fibres in DREF-III yarn are found to have twist, presumably entrapped false twist; the lower core content leads to more twist in it.

4.6 The helical configurations of the fibres in DREF-III yarns is such that the average helix angle and the helix diameter reduce progressively as one moves from the surface towards the core. Though the helix angle and helix diameter of core fibres are always less than those of the sheath fibres, the core twist is slightly more than that of sheath twist.

4.7 The sheath fibre twist initially increases and then decreases marginally with the increase in sheath content.

4.8 The twist of both the core and the sheath fibres increases with the increase in suction pressure.

4.9 Sheath fibres are seen to be Z-twisted (visualised from the yarn surface and the way of twist insertion). However, it is difficult to observe the direction of twist in core fibres. Since the core component is only false twisted by the friction drums and no real twist is inserted, one can presume that twist in Z- and S-directions present in core fibres is equal which means that the net twist is zero.

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