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Weavability of core-spun dref yarns

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A new method for evaluating weavability of heterogeneous core-spun dref yarns has been suggested. Among core-spun dref yarns, the weaving performance of cotton core dref yarn is found to be superior followed by that of dref yarns with textured core, Z-twist core and S-twist core. Under identical conditions, sizing causes deterioration in weaving performance of dref yarns, except in case of 100% cotton dref yarn.

Keywords : Core-spun yarn, Dref yarn, Sizing, Textured yarn, Weavability

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1 Introduction

Friction spinning is being recognized as an economical and a versatile alternative to ring and rotor spinning methods. It produces a highly uniform yarn from diverse stock including short or difficult-to-handle fibres at high production rates and low labour and energy expenses.[1,2] In comparison to conventional ring yarns, dref-2 yarns lack in certain qualities, such as tensile strength, which at present precludes their use as warp yarns. Attempts have been made by various researchers [3-7] to improve strength of friction-spun yarns by incorporating strong core. All of them used different core and studied the properties of core-spun dref yarn, but they did not investigate weaving potential of core-spun dref yarns. Since absolute strength of warp yarn is not a major criterion for producing better weavability, attempts have been made here to investigate weaving potential of core dref yarns by using different core materials. However, in this work to maintain the yarn surface characteristics, the same sheath material is used for all core-spun dref yarns. It has been earlier reported that dref-2 yarn shows significant improvement in weavability after sizing.[8] As sizing being inevitable process for single warp thread, it will be interesting to know how sizing affects weaving performance of these core yarns, which will be useful to exploit not only their high productivity but also versatility. Therefore, in this work, different core-spun dref yarns are sized under identical conditions to study their weavability.

2 Materials and Methods

2.1 Materials

Cotton mixing having the fibre properties 2.5% span length, 26.5 mm; uniformity ratio, 48.0%; micronaire value, 4.20; bundle strength, 21.0 cN/tex; and trash content , 4.41% was used as sheath.

Seven different yarn samples of 49 tex (12 Ne) dref yarn were used as core on dref-3 machine (Table 1). Modified maize starch and commercial mutton tallow were used for size mix.

2.2 Methods

2.2.1 Yarn Sample Peparation

Two passage drawn sliver of 2.56 ktex was produced from above cotton mixing with usual

Table 1—Yarn samples

Yarn code	Description of core	Tex of core	Core-sheath content, %
H1	Polyester, 34 filaments, 250 tpm, S-twist	16.67	34/66
H2	Polyester, 34 filaments, 110 tpm, Z-twist	16.67	34/66
H3	Polyester, 34 filaments, 200 tpm, Z-twist	16.67	34/66
H4	Polyester, 34 filaments, 350 tpm, Z-twist	16.67	34/66
H5	Polyester, 34 filaments, false twist textured	16.67	34/66
H6	Polyester, 34 filaments, air textured	16.67	34/66
H7	Cotton yarn, 715 tpm, Z-twist	29.53	60/40

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spinning practice to use as sheath along with above-mentioned different core materials to produce seven samples of core-spun dref yarns (Table 1). Other dref-3 machine parameters such as delivery speed, 100 m/min; drum speed, 5000 rpm; and friction ratio, 7.07 were kept constant. It should be noted that dref yarn with cotton core was spun with different core-sheath ratios than other yarns as it was not possible to spin satisfactorily the yarn below 34/66 core-sheath ratio due to machine limitations.

Further, these yarns were wound on mini warper's beam and subsequently sized with 5% size solution (97:3 starch:tallow) on laboratory sizing machine by using single pair of squeeze rollers, as suggested by Trauter[9], at delivery speed of 10 m/min, squeeze load of 90 daN on 180 mm wide warp sheet, sow box temperature of 85°C and drying cylinder temperature of 110°C.

2.2.2 Test Procedure

In order to know relative weaving potential, the yarns were tested on Reutlingen webtester (Fig. 1). This instrument simulates all major stresses occurring during weaving, such as cyclic extension, axial abrasion, flexing and bending, excluding beat-up and yarn entanglements. Like a loom, above-mentioned weaving stresses are applied simultaneously on a sheet of parallel 15 threads held at pre-selected constant tension. Instrument records cycles required to break first 10 threads. The average number of weavability cycles of each sample was observed by taking the average of number of cycles recorded for first 10 thread breaks on webtester. For every break, load is decreased by 1/15th of the initial preset load in order to maintain constant tension on each yarn throughout the completion of test. Criterion of deciding weavability has to be different for core-spun dref yarn due to its nature, where sheath slippage occurs during weaving quite early before breakage of yarn, which results in non-utility of yarn during weaving or from end-use point of view. In order to incorporate this concept on webtester, during testing as soon as sheath fibres were pushed aside and core filaments were exposed at abrading portion, the yarns were cut manually by scissors and simultaneously recorded as break on webtester. Thus, recording of weavability cycles is altogether different for core-spun yarns than for normal yarns, where break is recorded when yarn gets actually broken or slackens and ceases to take load.

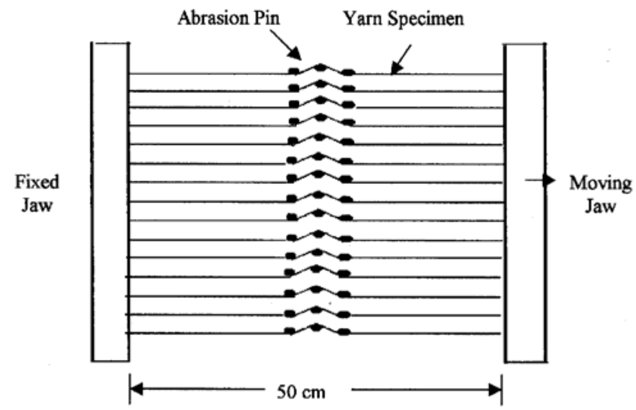

Fig. 1—Working principle of webtester

This method of evaluation was followed for all core-spun dref yarns where core was of heterogeneous type, i. e. having polyester filament in core. However, for dref yarn with cotton as a core, the normal method of evaluation was followed, as it was difficult to identify visually when core has been exposed during testing, core and sheath being from same homogenous material, i. e. cotton.

The instrument also displays yarn elongation resulting due to fatigue and abrasive actions while marinating constant tension per thread during testing. Moreover, it is provided with a facility to alter individually various test conditions such as yarn tension, intensity of yarn-to-metal abrasion, yarn cyclic extension and cyclic speed etc. Other necessary test details were as follows:

Specimen length	: 500 mm
Initial mounting tension/thread	: 0.5 cN/tex
Cyclic extension	: 0.5 %
Penetration of abrading pin	: 3.0 mm
Fatigue speed	: 300 cycles/min
Number of tests/sample	: 60
Tension/thread	: 1.5cN/tex

The yarns were also evaluated for the following properties using standard procedure: diameter on projectina microscope, tensile properties on Instron, dynamic properties on CTT, sonic modulus on PPM-5, and bending rigidity on Kawabata.

Size add-on was calculated by taking weights of oven dried sized and oven dried unsized yarn sample of around 10 g with 3 readings per sample. Except size add-on, all above-mentioned tests were carried out as per the standard testing conditions at a temperature of 25 ± 2°C and RH of 65 ± 2% .

Statistical analysis was carried out using SYSTAT 10 and EXCEL software for analysis of variance (ANOVA) and correlation coefficient.

3 Results and Discussion

3.1 Properties of Core Yarns

Table 2 shows the properties of yarns used as core in core-spun dref yarns. Except cotton yarn, all filament yarns are having tenacity in close range of 22-24.5 cN/tex. Breaking extension of twisted filament yarns is in the range of 26-31% except that of 200 tpm Z-twist yarn. Breaking extension of textured yarns is around 23-25%, while cotton yarn shows 5% breaking extension. However, in case of initial modulus, there is wide variation among yarns. Flat filament shows highest initial modulus, whereas false twist textured yarn shows lowest initial modulus. Remaining filaments and cotton yarns show intermediate values of initial modulus. The value of energy-to-break for Z-twist 350 tpm filament is highest and least for cotton yarn. Rest of the filament yarns show intermediate values.

3.2 Structure and Properties of Core-spun Dref Yarn

3.2.1 Packing Coefficient

It may be observed from Table 3 that the packing coefficient of core-spun dref yarn increases as twist of core filament changes from S to Z direction. This may be explained by the fact that the filament pre-twist in the same direction as sheath twist results in change over in filament twist direction at the point where first layer of sheath fibres gets deposited around filament. Thus, Z-twist core filament gives better anchoring to first layer of sheath fibres, which results in closer packing.

Packing coefficient of core-spun dref yarn increases after sizing (Table 4) as anticipated due to the compaction of yarn through squeeze rollers and increase in adhesion of fibres brought by size penetration and encapsulation. Sized textured core dref yarn has highest packing density followed by Z-twist filament core yarn. The yarn packing coefficient is least for S-twist core-spun yarn. This might be attributed to the fact that in case of dref yarns with Z-twist filament core, anchorage proportion being higher, the binding force with surface layer becomes stronger as compared to that of dref yarn with S-twist filament core, where anchorage with core is lesser. As the textured core gives more anchorage than Z-twist filament core, its yarn packing density is higher than that of Z-twist filament core-spun dref yarn.

3.2.2 Tensile Properties

It is revealed from Table 3 that the breaking load of twisted filament core dref yarn increases with the increase in Z-twist of the core filament, which might

Table 2—Properties of core yarns

Core yarn	Used in dref yarn (Code)	Tenacity cN/tex	Breaking load cN	Breaking extension %	Initial modulus cN/tex	Energy-to- break mJ
Polyester 250 tpm S	H1	23.71	378.5	28.97	303.2	191.1
Polyester 110 tpm Z	H2	23.13	385.6	26.17	615.7	199.1
Polyester 200 tpm Z	H3	23.42	390.4	38.01	383.2	236.5
Polyester 350 tpm Z	H4	24.52	408.7	30.90	567.3	311.1
Polyester false twist textured	H5	24.55	409.2	25.25	208.9	267.7
Polyester air textured	H6	22.67	377.9	23.59	398.1	212.9
Cotton 715 tpm Z	H7	12.54	370.3	5.01	347.3	25.9

Table 3—Properties of 49 tex (12 Ne) core-spun dref yarn

Yarn code	Packing coefficient		Breaking load cN	Tenacity		Breaking extension		Initial modulus	
	Value	CV%		cN/tex	CV%	%	CV%	cN/tex	CV%
H1	0.371	14.3	378.6	7.70	2.7	23.49	3.8	98.0	8.1
H2	0.378	13.1	386.2	7.85	9.2	33.42	9.9	100.4	12.0
H3	0.401	17.4	426.3	8.66	5.3	49.71	14.0	95.2	12.3
H4	0.412	13.8	450.7	9.16	7.7	32.25	10.1	81.2	12.2
H5	0.421	11.7	500.8	10.18	7.0	45.25	9.8	68.8	10.9
H6	0.411	11.3	450.9	9.16	8.4	40.20	14.1	53.7	13.0
H7	0.455	14.3	390.4	7.93	7.5	17.90	11.1	75.2	14.4

Table 4—Properties of sized, 49 tex (12 Ne) core dref yarn

Yarn code	Packing coefficient	Tenacity		Breaking extension		Initial modulus		Energy- to-break		Sonic modulus	Bending rigidity
		cN/tex	CV%	%	CV%	cN/tex	CV%	mJ	CV%	cN/tex	mN.mm^2
H1	0.531	8.36	2.3	17.37	4.9	148.4	17.7	21.8	36.7	276.9	39.29
H2	0.621	8.43	7.5	24.47	21.2	165.8	13.6	20.7	36.6	221.1	39.39
H3	0.630	9.73	14.6	38.11	16.7	144.3	10.4	21.4	50.2	230.8	42.23
H4	0.630	10.19	11.1	27.74	21.0	146.7	21.1	22.9	35.4	252.3	36.40
H5	0.661	11.4	9.0	38.12	9.7	120.0	14.3	17.9	41.8	223.9	30.12
H6	0.671	10.4	14.5	34.58	21.0	118.5	18.7	11.0	33.8	212.0	28.74
H7	0.619	10.6	13.1	10.54	28.1	131.5	30.5	60.1	45.3	526.1	31.24

be accounted for the better cohesion between core and sheath with increasing Z-twist in the core.

However, the tenacity of the yarn with highest twist in core (H4), is lower than that of false twist textured core-spun dref yarns (H5) due to the lesser cohesion between core and sheath. Figure 2 shows that the strength exploitation ratio is higher for textured core yarn than twisted filament core yarn. The increase in strength exploitation ratio (SER) of resultant dref yarn with textured filament core might be attributed to better cohesion between sheath and core due to the presence of loops and entanglements on surface of textured core yarn. The strength exploitation ratio of cotton core dref yarn is better than that of S-twist filament core dref yarns but it is lower than that of Z-twist or textured core dref yarns on account of low content of sheath, which might not be exerting lesser radial pressure on core.

It is revealed from Table 3 that 200 tpm Z-twist core-spun dref yarn shows highest breaking extension followed by textured core-spun dref yarn, other twisted core-spun dref yarns and cotton core dref yarns. This might be due to inherent large extension of 200 tpm polyester filament core compared to other polyester filament core yarns. The breaking extension exploitation ratio (EER), calculated on similar basis of strength exploitation ratio as explained above, is highest for cotton core dref yarn and lowest for S-twist core dref yarn. This might be due to more twist being imparted to cotton yarn in the core compared to filament yarn in the core, which facilitates better anchoring of first layer of sheath fibres with core. Textured core dref yarns show better extension exploitation ratio than twisted filament core yarns, which might be accounted for substantial anchorage provided to sheath fibres by loops and gaps between filaments

Figure 3 indicates that the initial modulus of twisted filament core dref yarn decreases with the increase in twist of core yarn. It is observed from

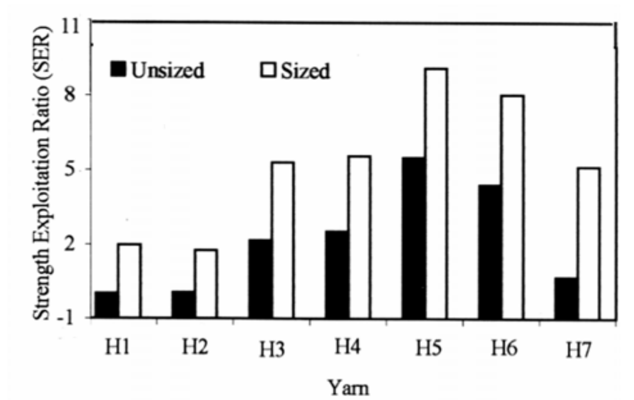

Fig. 2—Strength exploitation ratio of 49 tex core-spun dref yarns

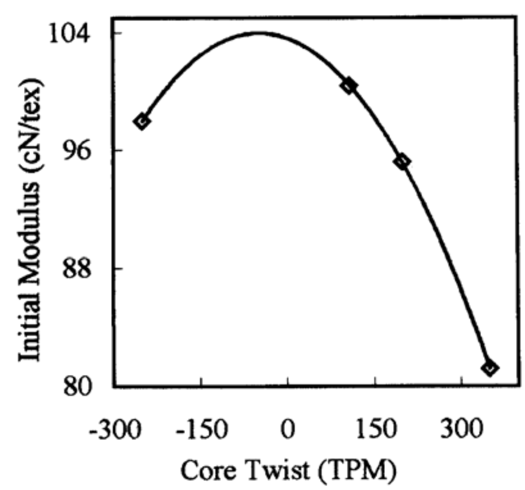

Fig. 3—Effect of core filament twist on initial modulus of 49 tex core dref yarns

Table 3 that the textured core dref yarn has lower initial modulus as compared to twisted filament core dref yarn, as the filaments in textured core are somewhat disoriented than filaments in twisted core. Cotton core dref yarn shows intermediate value of initial modulus, cotton being staple fibre and having substantial low extensibility than that of synthetic fibres.

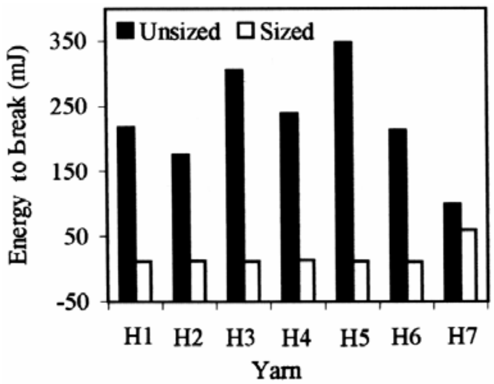

Fig. 4—Energy-to-break of 49 tex core dref yarns

It is observed from Fig. 4 that the cotton core dref yarn requires lowest energy-to-break as compared to that required for polyester filament core dref yarn, as filament core yarn itself has quite high extension than that of cotton yarn. Among the twisted filament core dref yarns, Z-twist core dref yarn requires higher energy-to-break than that required for flat or S-twist core dref yarn. This might be attributed to higher anchorage with surrounding sheath with the increase in filament twist in Z direction.

It is observed that sizing has little influence on nominal tenacity of core-spun dref yarn as the major contribution comes from core only, which is present in filament form and sustains higher breaking load. As the cohesion between cotton fibre and polyester filament is weaker, cotton sheath does not add much strength to core.

However, in case of dref yarn with cotton core, sheath and core being of same fibres, cohesion is stronger. Thus, the reinforcement of sheath due to sizing helps to add strength to yarn in addition to strength provided by cotton core to yarn. In addition, core content being higher and hydrophilic, probably it has provided better anchorage with size film, thereby enhancing the cohesion between core and sheath. It can be observed from Fig. 2 that the gain in SER is quite higher in case of dref yarn with cotton core than that observed in case of dref yarn with polyester filament core.

Tables 3 and 4 show that the loss in breaking extension after sizing is substantial. This loss might be attributed to yarn extension caused during preparatory processes, such as warping and sizing. Higher loss in case of dref yarn consisting of cotton in the core might be due to high size-fibre matrix formation as both core and sheath are cotton enabling more size penetration.

The initial modulus of core-spun dref yarn rises drastically on sizing, which might be attributed to the size-yarn interaction. It is revealed from the tables that there is quite substantial loss in energy-to-break required for sized core-spun dref yarn as compared to that required for unsized yarn. This loss might be ascribed to energy lost to overcome stresses and strains in preparatory processes.

3.2.3 Dynamic Properties

Table 3 shows that the dynamic strength is nearly 60-65% to that of breaking load for all twisted and textured filament core dref yarns, except S-twist core dref yarns where it is around 53%. Dynamic strength of cotton core dref yarn is around 76%, which might be attributed to the better cohesion between cotton fibres as compared to cohesion between polyester filament and cotton sheath. Dynamic strength of core-spun dref yarn increases as the filament twist in the core increases. This might be attributed to the increase in anchoring of first layer of sheath fibres with filament core as explained earlier for the increase in strength.

Considering dynamic extension of core-spun dref yarn, it is observed that the dynamic extension varies in the range of 60-70% to that of breaking extension as shown in Table 3. It is found that in case of twisted filament core dref yarn with increasing twist, the yarn sonic modulus decreases. This might be attributed to the increase in fibre path length with the increase in twist, resulting in decrease in sound velocity. Table 3 reveals that the cotton core dref yarn shows lower sonic modulus than that of filament core dref yarn on account of absence of continuity, which is present in filament core yarn.

3.2.4 Bending Rigidity

It can be observed from Table 3 that the bending rigidity of textured core dref yarn is lower than that of dref yarn having either twisted filament or cotton yarn in core. This lower bending rigidity might be attributed to the low initial modulus of these yarns. In case of twisted filament core-spun dref yarns, the yarn bending rigidity decreases as the twist in core increases, which might be ascribed to lowering of initial modulus with the increase in filament twist. Cotton core dref yarn shows higher bending rigidity than that of dref yarn having textured yarn as core. This might be attributed to majority of fibres being in core and they are in almost parallel form. Moreover, these yarns have higher packing density, resulting in higher stiffness than that of dref yarns consisting of textured yarn in core.

Tables 3 and 4 show that the sonic modulus of polyester core-spun dref yarn remains unaffected after sizing. This might be explained as follows. Sound wave passes through polyester core filament whose configuration is not changed after sizing, resulting in no effect on sonic modulus. However, in case of cotton core-spun dref yarn, as the material is in staple form, the sound wave is transmitted from one fibre to other fibre, and it gets delayed on account of discontinuity between these fibres. After sizing, the size-fibre matrix is formed, making a single united compact structure which facilitates transmission of sound wave in lesser time, thereby increasing the yarn sonic modulus.

It is also observed that the bending rigidity of core-spun dref yarn increases drastically after sizing (Tables 3 and 4). This might be attributed to the formation of size-fibre matrix with sheath fibres, which occurs on account of size penetration as well as film formation due to size encapsulation on yarn surface. However, the bending rigidity of sized dref yarns consisting of textured core is lesser than that of yarns consisting of twisted filament in the core. This might be due to the lesser orientation of filaments in textured core compared to that in twisted filament core.

3.3 Weavability of Unsized Core-spun Dref Yarns

The exposure of core at abrading zone after removal of loosely anchored sheath fibres due to abrasive action is taken as landmark for determination of relative weaving potential of core-spun dref yarn. Figure 5 indicates that the weaving performance of cotton core dref yarn is highest followed by that of dref yarns consisting of textured yarn, Z-twist yarn and S-twist yarn in core. This might be explained as follows. Cotton core has better cohesion with cotton sheath as both core and sheath are of same homogenous materials. Moreover, the cotton yarn consisting of staple fibres twisted in Z direction is getting some S-twist, while just entering before friction drum which creates sufficient gap among core fibres in which falling sheath fibres are getting anchored and then twisted in Z direction producing strong binding with core. Thus, the core does not allow sheath to slip over it easily and thereby enhances weaving performance.

On the other hand, polyester filament core lacks such cohesion with cotton fibres present in the sheath. Moreover, anchorage provided is lesser on account of

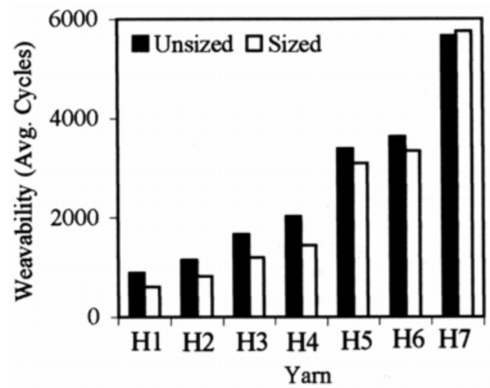

Fig. 5—Weavability of 49 tex unsized core dref yarns

filament being continuous and fibres slipping over filament due to smoother surface unlike that of cotton fibre. This results in poor weaving performance of dref yarns consisting of filament yarns compared to that consisting of cotton yarn as a core.

Nevertheless, dref yarns with textured core give better weaving performance than the dref yarns having twisted filament in core. This might be ascribed to more cohesion between sheath and core as compared to the yarns consisting of twisted core on account of the presence of loops and entanglements on its surface, and surface being rougher than twisted filament core.

Among dref yarns with twisted filament core, as the twist in core filament changes from S to Z direction, the weaving performance shows remarkable improvement. Plausible reason is that in spinning of dref yarn with Z twist filament core the filament pre-twist in same direction as that of sheath twist would result in change over in filament twist direction at point where first layer of sheath fibres deposits around filament. This might have contributed in providing better anchorage to the sheath fibres and thus better structural integrity to higher Z-twist core-spun dref yarns, subsequently providing greater sheath slippage resistance. It is observed that the introduction of core to the dref yarn does not help to achieve desired weaving performance comparable to ring and rotor yarns.

3.4 Weavability of Sized Core-spun Dref Yarn

Figure 5 also reveals that there is drop in weavability after sizing of polyester filament core-spun dref yarns. This might be explained as follows. During squeezing, size solution penetrates in yarn body and binds sheath fibres separately without interacting with core, since core is a separate entity.

This results in discontinuity in structural integrity from sheath to core. At the same time, the loss in flexibility of few layers of sheath fibres due to size-fibre adhesion results in more stress on anchored fibres during abrasive action. This may subsequently result in entire sheath slipping over core. Secondly, though encapsulation will try to improve yarn abrasion resistance, once the thin size film is broken by abrasion, further abrasion will cause size-fibre matrix to pluck anchored fibres from core which might have been loosened earlier due to stress experienced during preparatory processes, resulting in sheath slipping over filament core. Moreover, the core being hydrophobic and major content being of sheath, the size material will hardly reach up to core and thus any improvement in cohesion of core with sheath fibres is ruled out. Thus, cumulative result of above discussed phenomenon causes early slippage of sheath over core in case of sized dref yarns consisting of polyester filament as core. This indicates that the sizing does not help at all in the weaving performance of dref yarns consisting of filament in the core and cotton in the sheath. As against this, in cotton core dref yarn, the core content being higher and having affinity for starch material, it is expected that at certain places starch will enhance binding between core and sheath, and thus provides structural integrity between neighbouring annular layers of yarn cross-section, which delays the plucking of sheath fibres from core. This subsequently results in better weaving performance than that of unsized yarn.

4 Conclusions

Introduction of core to dref yarn does not help to achieve desired weavability comparable to ring and rotor yarns. Among core-spun dref yarns, weaving performance of cotton core dref yarn is superior followed by that of dref yarns with textured core, with Z-twist core and S-twist core. Under identical conditions, sizing does not help in all core-spun dref yarns in improving weaving performance, rather it causes deterioration in weaving performance, except in case of 100% cotton dref yarn.

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