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Twist-de-twist Method for Development of Soft Cotton Yarn

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ABSTRACT

In textile products, soft feel is an important characteristic in many end uses. This can be achieved by development of suitable yarn for knitting or chemical treatment at fabric stage. In this paper a method of producing soft yarn using twisting and de-twisting technique is investigated. Two types of cotton yarns, nominal and modified, are produced with same twist and count. The modified yarn was first produced at higher twist level. The excess twist was removed by de-twisting the yarn to nominal twist level. Yarn diameter, yarn compressibility, yarn stiffness, and yarn strength were measured and compared. 54.4% twist de-twist modification has shown 23.8 % increase in yarn diameter, 45.5 % decrease in bending rigidity and 47.1% improvement in yarn compressibility for 59 tex yarn. While 58.4% twist de-twist modification has shown 45.6% increase in yarn diameter, 35.0% decrease in bending rigidity and 15.0% improvement in yarn compressibility for 20 tex yarn. The experimental results indicate that the twist and de-twist process increases the yarn diameter; improves yarn softness and flexural rigidity without affecting the yarn strength. The production of modified yarn takes more energy and operation costs than the nominal yarn. However, the increase in yarn thickness increases fabric area and hence reduces cost of the yarn per unit area of the fabric.

Keywords: Modified yarn, yarn softness, twist-de-twist, yarn diameter, yarn stiffness, yarn compressibility

1. Introduction

Yarn softness depends on the nature and arrangement of fibers in the yarn. Finer and flexible fibers produce softer yarns. Fibers arranged with more free spaces in the yarn improve its compressibility. Better yarn flexibility and softness in turn improve fabric softness. Soft fabrics are highly demanded for children clothing, under garments, towels, hand kerchiefs, T-shirts etc… Soft clothes are very comfortable as it can absorb sweat on body and feel cool in hot conditions. Moreover, soft yarn being larger in diameter contributes to cost reduction [1]. This means if yarn is thicker, fabric produced from such yarns will have less stitch density. Therefore shorter length of yarn is used per unit area of the fabric and hence reduced cost of the yarn.

In idealized yarn geometry T = 1/h, where T is twist in the yarn and h is length of yarn in one turn of twist [2]. When the value of twist, T increases, h reduces while the radius of a cylinder containing the helical path of a particular fiber increases during twisting. As a result, length of fiber in one turn of twist at any radius, ($r \neq 0$) increases. This indicates that the contribution of fiber for yarn length reduces and contribution of fiber for yarn radius increases. When yarn is over twisted; and some amount of twist is reduced/de-twisted, those longer helix, especially at the surface, bulk outwards than extending and contributing to yarn length. To increase the yarn length by de-twisting all the fibers should be tensioned during de-twisting. But there is no tension force applied to each fiber during de-twisting.

Literature indicates that twist-less yarn improves the comfort properties of a garment as they are soft in nature [3]. Many attempts have been made to get softer yarn by manipulating fiber type and technologies. Use of fine fibers; manipulating twist (low twist); plying; spinning yarn at lesser tension and production of twist less yarns using PVA are the most commonly used ways to produce soft yarns [4]. First, third and the last alternatives are costly in nature. The fourth may lead to lower productivity or spinning instability. Hence “alternative 2” appears more practical. However, investigation of soft yarn development by such manipulation of twist is rather limited.

Two types of cotton yarns, nominal and modified, are produced with same twist and count. The modified yarn was first produced at higher twist level. The excess twist was removed by de-twisting the yarn to nominal twist level. Two-for-one twister machine was used to de-twist the yarns so that the net yarn twist remains equal to the nominal twist. Which means additional cost of energy and operation was used while over twisting in ring frame and de-twisting in two-for-one twister machine. Yarn diameter, yarn flexural rigidity, yarn compressibility and yarn strength were tested and compared. It was found that the modified yarn is softer, more flexible and has more diameter than the nominal yarn without affecting its strength.

2. Materials and methods

In this paper, 100% cotton roving of 422tex count was selected. Ring frame was used to produce 59 tex and 20tex yarn counts. As soft yarns are especially required for hosiery goods, the target nominal twist multiplier was set at 30.6 and 27.1 for 59tex and 20tex counts.

Two methods were followed to spin the yarns. In method I, the yarn was spun to the nominal twist value of 398tpm for 59tex yarn and 606 tpm for 20tex yarn. In method II, 59tex yarns were spun to 535tpm, 567tpm, 598tpm and 642tpm twist levels and 20tex yarns at 780tpm, 843tpm, 898tpm and 957tpm twist levels. Two-for-one yarn twister machine was used to de-twist the yarns to the nominal twists levels (twist values of method I) in both yarn types. This means additional cost of energy and operation is used during over twisting in the ring frame and de-twisting in the two-for-one yarn twister machine. The characteristics of yarns produced by the two methods were tested and compared.

Projectina microscope was used for measuring yarn diameter at 100magnification. Shirley twist tester was used to measure the twist in the yarns. Shirley weighted ring yarn stiffness tester with 5gm load and loop length (ring circumference) of 7.75cm was used to measure yarn flexural rigidity. Computer interfaced compression tester, KES was used to measure yarn compressibility. Instron digital tensile tester was used to measure the tensile strength of the yarns. The gauge length of 100mm, load cell of 1kg and the initial load of 0.5g were used during the tensile strength test.

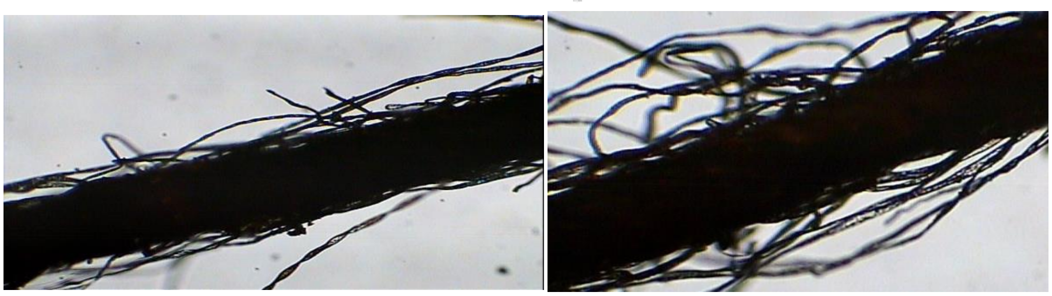
Table (1) Twist & de-twist values of the yarns

Yarn count (tex)	Initial twist (tpm)	Twist multiplier (√tex)*cm	De-twisted value (tpm)	Residual twist (tpm)	Residual Twist multiplier (√tex)*cm
59 (method I)	398	30.6	-	398	30.6
59 (method II)	535	41.1	138	398	30.6
	567	43.6	158	409	31.4
	598	45.9	177	421	32.3
	642	49.3	217	425	32.6
20 (method I)	606	27.1	-	606	27.1
20 (method II)	780	34.9	177	602	26.9
	843	37.7	217	626	28.0
	898	40.2	295	602	26.9
	957	42.8	354	602	26.9

3. Results and Discussion

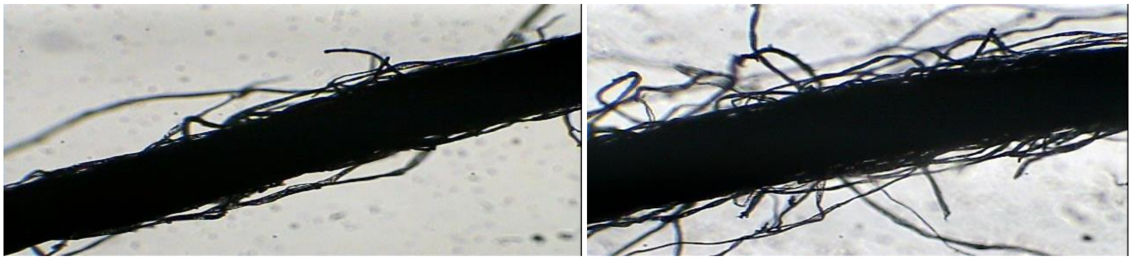
3.1. Yarn twist modification

In method I, 59tex yarns were produced at nominal twist level of 398tpm and 20tex yarns were produced at nominal twist level of 606tpm. In method II, 59tex and 20texyarns were produced at different twist levels as shown in the Table 1 bellow. 59tex yarns were produced at 535tpm, 567tpm, 598, and 642tpm twist levels. Twist values of all these yarns were reduced to be equal to 398tpm. The values after de-twisting were taken as residual twists. Twist multiplier was calculated for each type of yarn. Similarly, 20tex yarn types were produced at 780tpm, 843tpm, 898tpm and 957tpm values. Excess twist over 606tpm was reduced and residual twist values were obtained.



a. 59 tex nominal yarn **b. 59 tex yarn modified at 44.5% twist de-twist level**

Fig. (1) 59 tex yarn pictures at magnification power of 160



a. 20tex nominal yarn **b. 20tex yarn modified at 48.7% twist de-twist level**

Fig. (2) 20tex yarn pictures at magnification power of 160

3.2. Yarn pictures before and after de-twisting

In figure 1 and 2 above the modified yarns are bulkier and hairy on the surface than the nominal yarn. When yarn is over twisted and de-twisted to nominal level, the longer helix, especially at the surface, bulk outwards. This makes the modified yarns to have higher thickness than the nominal yarns. Observation through microscope could not clearly show spaces or pores created in modified yarns. Since yarn is three dimensional in nature the pores created are hidden inside the fibers.

3.3. Yarn diameter

The diameters of the nominal and the modified yarn types were measured. The differences in diameter of the modified yarns and the nominal yarns were analyzed. The significance difference, t-test, at 1% level was tested.

Table (2) Influence of twist-de-twist on yarn diameter

Yarn count (tex)	Initial twist (tpm)	De-twist value (tpm)	Residual twist (tpm)	Residual TM (√tex)* cm	Average yarn diameter (mm)		Difference in yarn diameter (mm)	Percentage Change in yarn diameter (%)	Significance difference t-test at 1% level
					Nominal yarn	De-twisted yarn			
59	398	-	398	30.6	0.404 (0.056)	0.404	-	-	-
	535	138	398	30.6	0.404 (0.055)	0.443	0.039	9.6%	Significant
	567	158	409	31.4	0.404 (0.059)	0.473	0.069	17.1%	Significant
	598	177	421	32.3	0.404 (0.074)	0.483	0.079	19.6%	Significant
	642	217	425	32.6	0.404 (0.081)	0.500	0.096	23.8%	Significant
20	606	-	606	27.1	0.237 (0.047)	0.237	-	-	-
	780	177	602	26.9	0.237 (0.047)	0.256	0.019	8.0%	Not significant
	843	217	626	28.0	0.237 (0.039)	0.300	0.063	26.6%	Significant
	898	295	602	26.9	0.237 (0.057)	0.313	0.076	32.1%	Significant
	957	354	602	26.9	0.237 (0.059)	0.345	0.108	45.6%	significant

(Figures within parenthesis indicate standard deviations)

Table 2 shows the diameter values of the modified and nominal yarns. Although the residual twist in the final yarn is same as the twist-de-twist percentage increases; there is a significant increase in yarn diameter in the modified yarns. In addition, 54.4% twist-de-twist modification led to 23.8 % increase in yarn diameter for 59tex count while 58.4% twist de-twist modification resulted in 45.6% increase in yarn diameter for 20tex count. The higher the twist de-twists percent the higher the increase in yarn diameter. For the same percent modification, finer yarn has shown more percent increment in yarn diameter. However, in 20tex count with 29.2% modification the yarn diameter increment is insignificant. This indicates that the increase in yarn diameter due to twist-de-twist depends on twist-de-twist percentage, nominal twist and twist-de-twist quantity.

Initially, as yarn is twisted the length of a fiber in a unit length of yarn becomes more and more. The de-twisting process reduces the number of turns in a unit length of the yarn. The longer length of the fiber with reduced number of turns has to be accommodated within the unit length of the yarn. This leads the fibers to migrate outwards which increases yarn diameter.

The length of fiber (q) in a unit length of yarn at a radius r is: [2]

$$q = z \sec\theta = z\,[1 + (4\pi^2 r^2)/h^2] = z\,[1 + 4\pi^2 r^2 T^2]$$

Where, z = unit axial length of yarn; θ = twist angle at radius r; h = length equal to one turn of twist and T = yarn twist.

The fiber length at the yarn surface is:

$$q = z \sec\alpha = z\,[1 + (4\pi^2 R^2)/h^2] = z\,[1 + 4\pi^2 R^2 T^2]\ [2]$$

α = twist angle at yarn surface

When twist is reduced from say T_0 to T_1, excess fiber length (q_o-q_1) becomes available per unit axial length of yarn which needs to be accommodated within the given yarn axial length. This is accomplished through increase in yarn diameter. The length availability becomes more; the more is the original yarn twist. Hence, high twisted yarns after de-twisting show more increase in diameter. The increase in yarn diameter creates pores between the fibers.

3.4 Yarn stiffness

Table 3 shows significant differences in yarn stiffness for 59tex and 20tex counts. The yarn stiffness of the nominal and modified yarn types with 59tex and 20tex counts were measured. The stiffness differences of the modified yarns with the nominal yarns were analyzed. The significance difference, t-test, at 1% level was tested.

Table (3) Influence of twist–de-twist process on yarn stiffness

Yarn count (tex)	Initial twist (tpm)	De-twist value (tpm)	Residual twist (tpm)	Residual twist multiplier (√tex)*cm	Average yarn stiffness (gcm^2)		Difference in yarn stiffness (gcm^2)	Percentage Change in yarn stiffness (%)	Significance of difference t-test at 1% level
					Nominal yarn	De-twisted yarn			
59	398	-	398	30.6	0.0066 (0.0010)	0.0066gcm²	-	-	-
	535	138	398	30.6	0.0066 (0.0011)	0.0059gcm²	-0.0007	-10.6	Not significant
	567	158	409	31.4	0.0066 (0.0009)	0.0049gcm²	-0.0017	-25.8	Significant
	598	177	421	32.3	0.0066 (0.0012)	0.0046gcm²	-0.002	-30.3	Significant
	642	217	425	32.6	0.0066 (0.0012)	0.0036gcm²	-0.003	-45.5	Significant

20	606	-	606	27.1	0.0020 (0.00051)	0.0020gcm^2	-	-	-
	780	177	602	26.9	0.0020 (0.00056)	0.0018gcm^2	-0.0002	-10	Not significant
	843	217	626	28.0	0.0020 (0.00057)	0.0017gcm^2	-0.0003	-15	Not significant
	898	295	602	26.9	0.0020 (0.00045)	0.0015gcm^2	-0.0005	-25	Significant
	957	354	602	26.9	0.0020 (0.0006)	0.0013gcm^2	-0.0007	-35	Significant

(Figures within parenthesis indicate standard deviations)

Yarn stiffness decreases as the de-twist value in the yarn increases. For 59tex yarn count, 54.4% twist-de-twist resulted in 45.5% reduction in yarn stiffness. At higher twist-de-twist percent coarser yarns showed more reduction in yarn stiffness for the same twist-de-twist percent. The stiffness quantity of 10Ne nominal yarn is 3.3 times the stiffness of 30Ne count. The higher the nominal stiffness the higher is reduction in stiffness by modification. This means the decrease in yarn stiffness depends on the nominal yarn stiffness, yarn count and twist-de-twist value.

For yarns of same count, twist and material but different diameter implies more pores or spaces are available for the yarn with higher diameter. As a yarn is bent the shearing action takes place between fibers in different layers in the yarn cross-section [7]. Frictional hindrance to shearing will be less the more open the structure is. As a result de-twisted yarns will easily bend in comparison to the similar yarn with lower diameter [8].

3.5 Yarn compressibility

The influence of twisting and de-twisting on yarn compressibility is shown in the table below. Yarn compressibility of various modified yarns is compared with the nominal yarn and significant levels were tested.

Table (4) Influence of twist-de-twist on yarn compressibility

Yarn count (tex)	Initial twist (tpm)	Untwist value (tpm)	Residual twist (tpm)	Residual twist multiplier (√tex)*cm	Average Yarn compression rate EMC (%)		Difference in yarn compression rate (%)	Percentage Change in yarn compression rate (%)	Significance of difference at 1% level
					Nominal yarn (%)	detwisted yarn (%)			
59	398	-	398	30.6	42.0	42.0 (2.9)	-	-	-
	535	138	398	30.6	42.0	45.4 (3.9)	3.4	8.1	Not significant
	567	158	409	31.4	42.0	46.3 (4.1)	4.3	10.2	Not significant
	598	177	421	32.3	42.0	54.6 (8.2)	12.4	29.5	Significant
	642	217	425	32.6	42.0	61.8 (3.3)	19.8	47.1	Significant
20	606	-	606	27.1	56.0	56.0 (3.1)	-	-	-
	780	177	602	26.9	56.0	58.6 (4.3)	2.6	4.6	Not significant
	843	217	626	28.0	56.0	60.0 (2.8)	4	7.1	Significant
	898	295	602	26.9	56.0	60.4 (2.9)	4.4	7.9	Significant
	957	354	602	26.9	56.0	64.4 (4.8)	8.4	15	significant

(Figures within parenthesis indicate standard deviations)

As de-twisting increases the yarn compressibility increases. The change in yarn compressibility due to twist de-twist is higher for finer yarn. Therefore the yarn will be softer if percentage de-twisting is increased. The reason can be due to the bulkiness of surface fibers during twisting and de-twisting.

Yarn compression behavior can be characterized by initial thickness, change in thickness, work of compression, and work of resilience for a given load. If we assume that initial thickness, and change in thickness is constant for a given load, the increase in work of compression justifies that the yarn takes higher loads between 0 load up to the ultimate (maximum) load [5]. Therefore the yarn will be softer if it has less work of compression. For the same count, twist and material, if the diameter of the yarn is higher, the yarn will obviously be compressed easily than the one with lower diameter. This happens due to empty spaces created between the fibers that reduce cohesive forces of the fibers.

3.6 Tensile strength

The breaking loads of the nominal and modified yarns in both 10Ne and 30Ne counts were measured and shown in table 4.The difference of the modified yarns with reference to the nominal yarn was made for both count types. The significance difference at 1% level was tested.

Table (5) Influence of twist –de-twist process on tensile strength

Yarn count (tex)	Initial twist (tpm)	Untwist value (tpm)	Residual twist (tpm)	Residual twist multiplier (√tex)*cm	Average Yarn Breaking load (g/tex)		Difference in yarn Breaking load (g/tex)	Percentage change in yarn Breaking load (%)	Difference at 1% level
					Nominal yarn	De-twisted yarn			
59	398	-	398	30.6	11.2	11.2 (1.3)	0	0	-
	535	138	398	30.6	11.2	10.8 (1.2)	-0.4	-3.5	Not significant
	567	158	409	31.4	11.2	10.7 (1.5)	-0.5	-4.5	Not significant
	598	177	421	32.3	11.2	10.7 (1.4)	-0.5	-4.5	Not significant
	642	217	425	32.6	11.2	11.4 (1.6)	+0.2	+1.5	Not significant
20	606	-	606	27.1	10.2	10.2 (1.1)	0	0	-
	780	177	602	26.9	10.2	10.5 (1.5)	+0.3	+2.9	Not significant
	843	217	626	28.0	10.2	9.8 (1.6)	-0.4	-3.9	Not significant
	898	295	602	26.9	10.2	10.6 (1.4)	+0.4	+3.9	Not significant
	957	354	602	26.9	10.2	9.7 (1.5)	-0.5	-4.9	Not significant t

(Figures within parenthesis indicate standard deviations)

Average breaking loads of nominal and modified yarns are very similar, as shown in table 5. The differences are less than 5%. The differences in strength values are not statistically significant too. Strength of yarns is mainly determined by the constituent fiber strength and their fineness, fiber arrangement in the yarn, and yarn twist [5]. While other things remain constant, twist plays the most critical role. As the net twist in the yarns does not change the strength therefore do not get affected. The insignificant reduction in some cases may be ascribed to the rearrangement of fibers due to fiber migration and rapid de-twisting process.

Conclusions

Although the net or residual twist in the nominal and modified yarns are same in a given count, as the twist de-twist value increases yarn diameter increases. The twisting process increases length of a fiber in one turn of the yarn that expands while de-twisting.

Twist-de-twist modification has increased yarn diameter, decreased bending rigidity and improved yarn compressibility. The higher the twist-de-twist percentage the higher is the increase in yarn diameter; the higher is the decrease in bending rigidity; and the better is yarn compressibility. For same twist-de-twist-percentage finer yarns has shown higher percentage increase in yarn diameter and higher percentage decrease in bending rigidity. The twist de-twist process does not make significant change on yarn strength. The twist-de-twist process takes additional energy and operation costs.

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