

## Effect of yarn twisting and de-twisting on comfort characteristics of fabrics

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*Received 2 December 2013; revised received and accepted 22 April 2014*

Effect of yarn twisting and de-twisting on fabric comfort has been studied. Cotton yarns of 23 tex with 669 turns/m and 15 tex with 827 turns/m have been produced as nominal yarns. Another 23 tex yarn has been produced with 866 turns/m and 945 turns/m along with 15 tex yarns with twist of 1024 turns/m and 1103 turns/m, with excess twist of 197 turns/m and 276 turns/m than the nominal yarn. The excess twists in the 23 tex and 15 tex yarns are then removed by de-twisting process which results in yarns with twists of 669 turns/m and 827 turns/m respectively, called modified yarns. Plain knitted fabrics are produced from both modified and nominal yarns and then bleached. The dimensional properties, air permeability, water vapor permeability, wicking and fabric compressibility are measured for nominal and modified fabrics. Finally, comparison of comfort characteristics is made between the nominal and the modified materials. The twisting and de-twisting process made the modified yarns to have higher yarn diameter, softness and less flexural rigidity without any change in yarn strength as compared to nominal yarns. Modification increases fabric thickness, tightness factor, wicking height and compressibility. However, stitch density, air permeability and water vapor permeability of the modified fabrics are found to be reduced.

**Keywords:** Air permeability, Comfort property, Cotton, De-twisting, Fabric compressibility, Water vapor permeability

### 1 Introduction

Comfort is an important quality characteristic of apparel products. Fabric comfort along with fabric feel (hand feel and wearer's feel) and functional attributes such as insulation, moisture permeability, wicking, water uptake, and drying time become vital for the selection of fabrics. Comfort has been an inherent feature of knitted textiles. The major factors responsible for creating comfort are softness, ability to absorb moisture, air permeability, dissipation of heat and insulating properties<sup>1</sup>.

Literature indicates that twist-less yarn improves the comfort properties of a garment as they are basically soft in nature<sup>2</sup>. Many attempts have been made to get softer yarn by manipulating fibre type and technologies. There are several ways to produce soft yarns, such as (i) to use fine fibres, (ii) to manipulate twist (low twist), (iii) to ply yarn, (iv) to spin yarn at lesser tension, and (v) to produce twist less yarns using PVA. First, third and the last alternatives are costly in nature. The fourth alternative may lead to lower productivity or spinning instability. Hence, alternative (ii) appears more practical. However, investigation of soft yarn development by such manipulation of twist is rather limited.

Yarns produced by using various spinning technologies not only differ from one another in respect of their structure, but also in their bulk, mechanical and surface properties. The properties of the fabrics produced from these yarns are affected by such yarn properties, as well as by their fabric construction parameters. Efforts are being made to make a knitted fabric more comfortable by changing yarn parameters like twist, bulk, count and finishing treatments, knitting parameters like stitch length, courses per meter, wales per meter and fabric weight and post knitting finishes.

In this study, 100% cotton roving of 422 tex was selected. Ring frame was used to produce 23 tex and 15 tex yarns. As soft yarns are especially required for hosiery goods, the target nominal twist multiplier was set at  $3200 \text{ turns/m} * \sqrt{\text{tex}}$ . Two methods were followed to spin the yarns. In Method I, the yarn was spun to the nominal twist level of 669 turns/m for 23 tex yarn and 827 turns/m for 15 tex yarn. In Method II, 23 tex yarns were spun to 866 turns/m and 945 turns/m and 15 tex yarns to 1024 turns/m and 1103 turns/m. Subsequently doubling machine was used to reduce 866 turns/m and 945 turns/m to 669 turns/m for 23 tex yarn and 1024 turns/m and 1103 turns/m to 827 turns/m for 15 tex yarn. Yarns produced by Method I were taken as nominal yarns

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and Method II were taken as modified yarns. The characteristics of nominal and modified yarns were tested and compared. Plain knitted fabrics were produced from modified and nominal yarns and then bleached. Comfort properties of fabrics were measured. Finally, comparison of comfort characteristics was made between the nominal and the modified materials.

The twisting and de-twisting process made the modified yarns to have higher yarn diameter, softness and less flexural rigidity without any change in yarn strength as compared to nominal yarns. Modification has increased fabric thickness, tightness factor, wicking height and compressibility. However, stitch density, air permeability and water vapor permeability of the modified fabric were reduced.

**2 Materials and Methods**

**2.1 Materials**

In this study, 100% cotton roving of 422 tex was selected. Ring frame was used to produce 23 tex and 15 tex yarns. As soft yarns are especially required for hosiery goods, the target nominal twist multiplier was set at  $3200 \text{ turns/m} * \sqrt{\text{tex}}$ .

**2.2 Methods**

Two methods were followed to spin the yarns. In Method I, the yarns were spun to the nominal twist value of 669 turns/m for 23 tex and 827 turns/m for 15 tex yarns. In Method II, the 23 tex yarns were spun to 866 turns/m and 945 turns/m which subsequently reduced to keep the twist at 669 turns/m as in Method I. Similarly 15 tex yarns were spun to 1024 turns/m and

1103 turns/m and reduced to keep the twist at 827 turns/m as in Method I. Doubling machine was used to de-twist the yarns. The characteristics of yarns produced by the two methods were tested and compared based on ASTM standards.

Larger diameter single jersey knitting machine was used to produce nominal and modified fabrics. The samples were bleached using hydrogen peroxide, and their properties were measured and then compared.

All the test procedures were made based on ASTM standards. Projectina microscope was used for measuring yarn diameter with magnification of  $\times 100$ . Shirley twist tester was used to measure the twist in the yarns. Loop length, wales per inch, courses per inch and arial density were measured. The weight of the pieces was measured using digital balance. Essdiel thickness gauge was used to measure the compressibility as well as the thickness of the fabrics. In compressibility test, fabrics were loaded by eight different weights from smallest to the biggest sequentially. TEXTest air permeability tester with test pressure of 100 Pa was used to measure the air permeability of fabrics.

Vertical wicking measurement was carried out by fixing a scale vertically and filling water in beaker. Computer interfaced PERMETEST water vapour permeability tester with permeability calibrate coefficient of 0.14 and air temperature of 19.44 °C was used to record absolute water vapour permeability<sup>3</sup>.

**3 Results and Discussion**

**3.1 Yarn Characteristics**

Table 1 shows that 29.4% modification in the twist of 23 tex yarn gives 25% increase in yarn diameter,

Table 1—Effect of twist modification on yarn properties

Parameter	At 23 tex		At 15 tex			
	Method I	Method II	Method I	Method II		
Initial twist, turns/m	669	866	827	1024	1103	
Untwist value, turns/m	0	197	0	197	276	
Net twist, turns/m	669	669	827	827	827	
Net twist multiplier, $\text{turns/m} * \sqrt{\text{tex}}$	3200	3200	3200	3200	3200	
Average yarn diam., mm	0.255	0.319	0.331	0.150	0.197	0.201
Increase in yarn diam., %	-	25	30	-	31.5	34
Average yarn stiffness, $\text{gcm}^2$	0.0024	0.0017	0.0014	0.0015	0.0013	0.0012
Decrease in yarn stiffness, %	-	-29	-42	-	-13	-20
Average yarn compression rate, EMC %	49.0	53.1	55.2	61.0	64.4	66.0
Increase in yarn compression rate, %	-	8.4	12.6	-	5.6	8.2
Average yarn breaking load, g/tex	10.5	10.4	10.5	9.2	9.3	9.1
Change in yarn breaking load, %	-	-1.0	+0	-	+1	-1

-29% decrease in yarn stiffness, 8.4% increase in yarn compression rate and insignificant change in yarn breaching load. On the other hand, 23.8% modification in the twist of 15 tex yarn shows 31.5% increase in yarn diameter, -13% decrease in yarn stiffness, 5.6% increase in yarn compression rate and insignificant change in yarn breaking load.

Initially, as yarn is twisted the length of a fibre 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 fibre with reduced number of turns has to be accommodated within the unit length of the yarn. This leads the fibres to migrate outwards and as a result the diameter of the yarn increases. The length of fibre ( $q$ ) at a radius  $r$  is given by

$$q = z \sec \theta = z (1 + (4 \pi^2 r^2)/h^2)^{0.5} \text{ but } T=1/h \quad \dots (1)$$

$$= z (1 + 4 \pi^2 r^2 T^2)^{0.5} \quad \dots (2)$$

where  $z$  is the length along the yarn;  $\theta$ , the twist angle at radius  $r$ ;  $h$ , the length equal to one turn of twist; and  $T$ , the yarn twist.

The fibre length at the yarn surface<sup>4</sup> is;

$$q = z \sec \alpha = z (1 + (4 \pi^2 R^2)/h^2)^{0.5} = z (1 + 4 \pi^2 R^2 T^2)^{0.5} \quad \dots (3)$$

where  $\alpha$  is the twist angle at yarn surface,

When twist is reduced from  $T_0$  to  $T_1$ , excess fibre length ( $q_0 - q_1$ ) 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 higher the initial twist, the higher is the de-twist value and therefore the higher is the fibre length availability to increase yarn diameter. Hence, high twisted yarns show more increase in diameter of the yarn. The increase in yarn diameter creates pores between the fibres. The increase in diameter with increased pore sizes in the yarn decreases yarn stiffness and increases yarn compressibility significantly, as it is tested at a significance level of 1%  $t$ -test. When fibres are closely spun, they cannot slip over each other as cohesion among fibers is higher. But when fibres are distantly spun, they can easily slip over each other so the yarn can easily bend due to the yarn weight.

### 3.2 Fabric Properties

#### 3.2.1 Comparison of Fabric Structures

The nominal fabrics have high pores than the modified fabrics (Fig. 1). This can happen due to the bulking of fibres in the yarn of modified fabrics. As

the yarn diameter increases without any change in number of fibres, the bulkiness of the fibres fills up the inter yarn pores.

#### 3.2.2 Effect of Twisting and De-twisting on Fabric Dimensional Properties

Fabrics were made from the nominal and modified yarns of both 25Ne and 40Ne counts. The fabrics were bleached and their dimensional properties were measured (Table 2).

Modification decreases stitch density and increases thickness. Even though there is no difference in calculated tightness factor between the modified and the nominal fabrics, modified fabrics show higher tightness factor than the nominal fabrics in the actual fabrics. The reason is that while calculating the

tightness factor in knitting  $\left[ k = \frac{\sqrt{\text{tex}}}{l_{mm}} \right]$ , only loop

length and yarn count in tex is considered to calculate the extent to which the fabric area is covered with yarn. But without any change in loop length and yarn count, the bulking nature of fibres in the yarn can

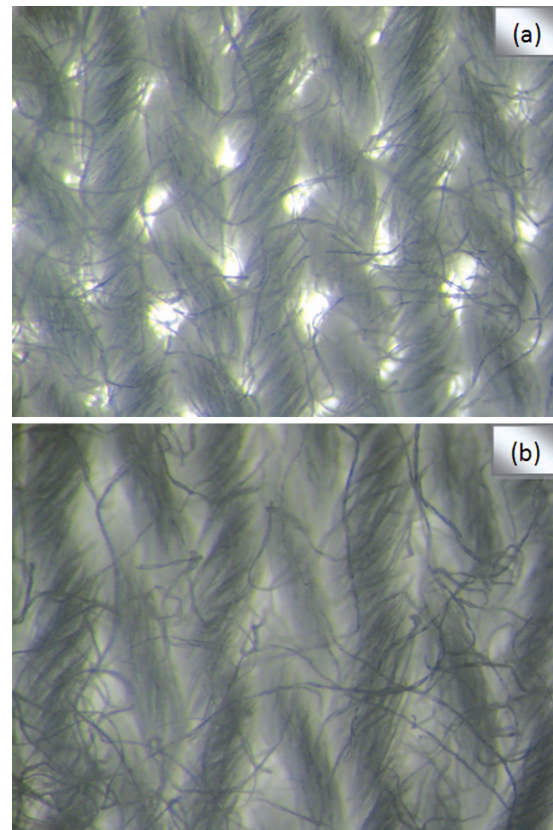


Fig. 1—Microscopic view of fabrics made of 23 tex yarn (a) nominal fabric, and (b) 29.4% twist modified fabric

Table 2—Result of fabric dimensional properties

Property	25Ne bleached fabrics			40Ne bleached fabrics		
	Twist modified		Normal	Twist modified		Normal
	29.4%	41.2%		23.8%	33.4%	
Loop length, mm	4.4	4.3	4.2	2.8	2.9	2.8
Courses per inch, cpi	18.6	18.9	20.3	38.1	37.6	39.0
Wales per inch, wpi	16.2	16.2	15.1	25.5	25.2	27.2
Stitch density, inch <sup>-2</sup>	301.32	301.10	306.53	971.55	964.51	1060.80
Arial density, g/m <sup>2</sup>	210	209	228	126	124	138
Tightness factor	1.10	1.12	1.16	1.37	1.36	1.37
Thickness, mm	1.54	1.55	1.50	0.50	0.51	0.48

increase the extent of covering of yarn in a given fabric area. Wales per inch and courses per inch of the fabrics have shown statistically insignificant difference when tested at 1% T-test.

**3.2.3 Air Permeability of Fabrics**

The air permeability (AP) of modified fabrics with yarn modification of 80turns/m reduces to 3cm/s for 23tex yarn and to 4cm/s for 15tex yarn. On the other hand, AP of the modified fabrics with modification of 276 turns/m reduces to 8cm/s for 23tex yarn and to 10cm/s for 15tex yarn. As the modification percentage increases air permeability decreases for the same yarn count.

As tightness factor increases the inter-yarn pores decrease. The passage of air inter-yarn pores is relatively higher than in inter-fibre pores, as the size of inter yarn pores are higher than inter-fibre pores<sup>5</sup>. Moreover, in the yarn, pores are distributed within the fibres which can disturb the uniform flow of air in the yarn. Even though bulkiness of fibres in the yarn is increased by increasing inter-fibre pores, inter-yarn pores significantly decrease in the fabric. This leads to decrease in air permeability in modified fabrics.

**3.2.4 Water Vapour Permeability**

The resistance to water vapour permeability of modified samples is more than that of nominal samples in both types of fabrics made of 15 tex and 23 tex yarn counts. As modification increases, the resistant to water vapor permeability decreases for a given yarn count. The larger inter-yarn pores of the normal fabric can hold moisture inside and increase water-vapor permeability<sup>6</sup>. But the higher space creation between fibres in the twisted yarn may not result in more vapor particles to pass through. When the inter-fibre pores become higher it may result in more vapour to diffuse, in yarn level.

**3.2.5 Wicking**

The wicking behavior of the two nominal fabrics and two fabrics modified with 197 turns/m is shown in (Fig. 2). The vertical dimension indicates the wicking height in centimeters and the horizontal axis indicate the time it takes for wicking. M-course is wicking of modified fabrics in course direction; N-course is wicking of nominal fabrics in course direction; M-wale is wicking of modified fabrics in wale direction and N-wale is wicking of nominal fabrics in wale direction.

The modified yarn has relatively uniform channel or capillary for the water to pass through as compared to nominal yarn. The more number of fibre contacts in the yarn leads to reduce the uniformity of the channels in nominal fabrics<sup>7</sup>. This leads the nominal samples to have lower wicking height. The difference in transmission of water through wales and courses is found to be less in fabrics made of 15 tex yarn count than in fabrics of 23 tex count. In fabrics made of 15 tex yarn, a course has shorter loop length so that the water can move faster in course direction, zigzag form. But in fabrics made of 23 tex yarns, having longer loop length, water has to move longer distances to reach the end of the yarn. In this case the movement of water in wale direction will be higher than in course direction.

**3.2.6 Fabric Compression**

The rate of compression of modified samples is higher than nominal fabrics as can be seen in Fig. 3. This is due to the improvement in yarn softness and stiffness. But, the rate of recovery of the nominal fabrics is higher. In nominal fabrics the force applied on a single fibre in the yarn due to the contact of other fibres is expected to be more. In modified yarn more space is created between fibres which reduces the number of contact points. Therefore, more internal strain energy is expected to be stored in the nominal fabrics which can increase recover energy.

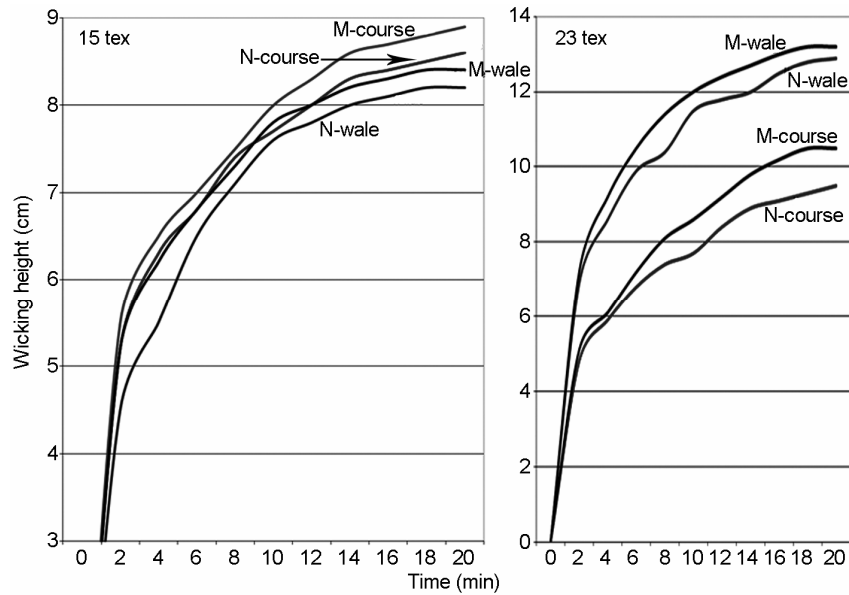


Fig. 2—Graph showing wicking height of both nominal and modified (197turns/m) fabrics [M- modified, N-Nominal, Wales-Wales direction, Course-Course direction]

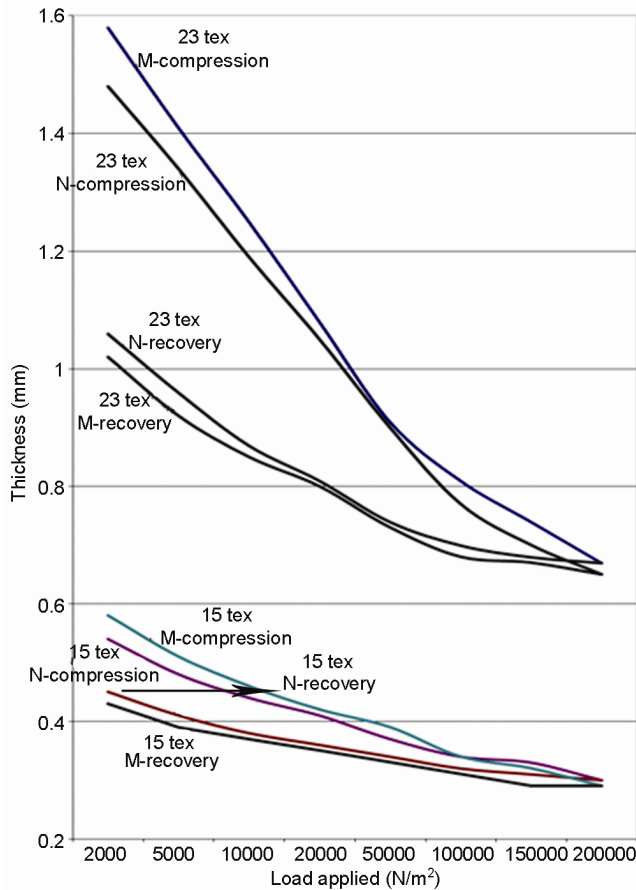


Fig 3—Compression and recovery of fabrics made of 23 tex and 15 tex (M – fabrics made of yarns modified by 197turns/m, and N – Nominal)

**4 Conclusion**

Study shows that 29.4% modification in the twist of 23 tex yarn results in 25% increase in yarn diameter, -29% decrease in yarn stiffness, 8.4% increase in yarn compression rate and insignificant change in yarn breaking load. Further, 23.8% modification in the twist of 15 tex yarn has shown 31.5% increase in yarn diameter, -13% decrease in yarn stiffness, and 5.6% increase in yarn compression rate without any change on yarn breaking load.

The inter-fibre pore sizes increase while the inter-yarn pore sizes decrease by the yarn modification. Modification has increased fabric thickness, tightness factor, wicking height and compressibility. However, stitch density, air permeability and water vapor permeability of the modified fabric are reduced.

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