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Effect of single yarn twist, ply-to-singles twist ratio and tightness factor on spirality of single jersey cotton knitted fabrics

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The effect of single yarn twist, ply-to-singles twist ratio and tightness factor on spirality of single jersey cotton knitted fabrics has been studied. The results show that the single jersey fabrics knitted from two-ply yarn with 1/2 of single yarn twist do not show spirality, whereas the fabrics produced using two-ply yarn with 1/3 and 3/4 of single yarn twist show spirality in Z and S directions respectively and the magnitude of spirality increases on wet relaxation. As the cotton two-ply yarn with 1/2 of single twist does not snarl in water, it can be considered as a balanced two-ply yarn. As the tightness of the fabric construction increases, the spirality of the fabric decreases.

**Keywords**: Cotton, Ply twist, Single jersey knitted fabric, Single yarn twist, Tightness factor, Twist liveliness

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**1 Introduction**

The fibrous strand is twisted in the spinning machine to hold the constituent fibres together, thus giving strength to the yarn. As the twist increases the yarn strength increases up to a certain level, beyond which the increase in twist decreases the strength of staple yarn. During the conversion of cotton fibres into yarn through the short staple spinning system, the fibres are stressed at all stages of the process. As the fibres are loosely held in lap, sliver and roving, they can slowly release all the stresses imposed on them, whereas the fibres in the yarn are not allowed to move freely to release all the torsional stresses. Hence, the spun yarn is twist lively, i.e. the fibres try to come back to the original unstressed state. As the twist in the yarn increases, the amount of torsional stress in the fibres increases, i.e. the increase in twist increases the twist liveliness of the yarn.

The lively twist present in the yarn creates skewness in the woven fabrics and spirality in the knitted fabrics. The wale line of single jersey fabric produced using twist lively yarn will not be parallel to the course line. Spirality affects both aesthetic and functional performance of knitted fabrics. The direction of spirality is determined by the direction of twist. Z and S directions of twist in the yarn generate spirality in the Z and S directions respectively. For the fabrics with a given tightness factor, the spirality increases linearly with increasing yarn twist liveliness. The magnitude of spirality depends on the type of fibre, fibre diameter, linear density of yarn, fabric structure, number of feeders, direction of rotation of knitting machine and the state of fabric (relaxed, unrelaxed and resin finished). The increase in proportion of polyester component in the polyester/cotton blend increases the spirality. The yarn twist factor and fabric tightness factor are the most predominant factors which determine the magnitude of spirality1. The increase in yarn twist factor increases the spirality. As different spinning systems produce yarn with different structure, the angle of spirality induced by them in the fabrics also varies2. Closer construction of fabric reduces the spirality to a greater extent1,3,4. Multi-feed circular knitting machines rotating counter clockwise will produce wales inclined to the right, and the machines rotating clockwise will produce wales inclined to the left5. Washing of fabrics increases relaxation of fabrics and angle of spirality. Partial detwisting of steamed high twisted ring-spun, rotor-spun and friction-spun (DREF–III) yarns eliminates or minimises spirality of weft knitted fabrics produced from them6-8.

The lively twists in the synthetic and cotton spun yarns are set by the process of heat setting and steaming respectively. The twist setting of cotton spun yarn by steaming is a temporary twist stabilization process. When the steamed yarn is entered into water, the yarn will start snarling. The most suitable method to remove the torque in the cotton yarn is by ply twisting the single yarn in the direction opposite to single yarn twist. The ply twist should remove all the torque present in the single yarn. Hence, it is essential to determine the amount of ply twist required to produce balanced ply yarn. The ratio of ply-to-single yarn twist required to produce balanced two-ply cotton yarn was determined in our earlier study9. Self-plying technique was used to predict the amount of ply twist required to produce balance yarn. However, self-plying of yarn at dry state will not release all the torque in the single yarn. But self-plying of yarn in water will release the torque in the yarn and it would be in the balanced state.

The yarn, which does not snarl in water, is considered as balanced yarn. The amount of ply twist required to produce two-ply cotton balanced yarn is half of the single yarn twist9. The two-ply cotton yarn with 1/3 of single yarn twist does not snarl at dry state but snarls in water, whereas two-ply yarn with 1/2 of single yarn twist snarls at dry state but does not snarl in water. Hence, the knitted fabrics produced using yarn with 1/3 of single yarn twist should not produce spirality in the dry state but should generate spirality during wet relaxation. Similarly, the knitted fabrics produced using yarn with 1/2 of single yarn twist should show spirality in dry state but should not have spirality after wet relaxation. Since the change of angle of spirality in the knitted fabrics during wet relaxation depends on tightness of the fabrics, the above predictions have to be verified experimentally. Hence, the present work is aimed at studying the effect of single yarn twist, ply-to-singles twist ratio and tightness factor on spirality of single jersey cotton knitted fabrics.

**2 Materials and Methods**

Combed cotton yarn 11.81 tex (50s Ne) was spun using Lakshmi G 5/1 ring frame from the roving of 0.28 ktex (2.1Ne). The yarn was spun at four different twist levels, i.e. the standard twist level normally applied on the combed cotton yarn, and 15%, 30% and 45% higher than the normal level. Each of these yarns was doubled at three different ply twist levels, i.e. 1/3, 1/2 and 3/4 of the single yarn twist. The twist liveliness of yarn was tested in dry and wet states as explained earlier9.

These yarns were knitted at three different tightness levels (10.63, 12.87 and 15.37 tex1/2cm-1) using single jersey knitting machine with single feeder. The fabrics produced were conditioned at 65% RH and 27oC for 24 h. The spirality of fabrics was tested at 10 different places at random by drawing lines along the courses and wales and degree of spirality [θ= tan-1 (d/L)] was calculated (Fig. 1). The spirality of fabrics was tested both after dry and wet relaxations. For wet relaxation, the fabrics were immersed in 0.05% soap solution for 24 h, washed, flat dried and conditioned at standard testing atmosphere. The fabric samples were knitted using different yarn samples and marked to identify the same. The knitted fabrics were tested for spirality after dry relaxation and then they were washed. Since all yarn samples were knitted continuously, the knitted fabrics made from them may have alternate Z and S directions spirality and vice versa in adjacent along its length, resulting in improper relaxation during first wash. Hence, the second and third washes were carried out after cutting each and every sample separately.

**3 Results and Discussion**

**3.1 Effect of Single Yarn Twist and Ply-to-singles Twist Ratio on Twist Liveliness**

Fig. 1Method  of measuring spirality of fabrics

Tables 1 and 2 show twist liveliness of 2/50s yarn tested at dry state immediately after the production of yarn and after one month of storage. The yarn with 1/3 of single yarn twist initially does not show snarling but on storage it starts snarling in the direction of ply twist. But when the same yarn is tested for twist liveliness in water (Table 3), it shows significant amount of snarling in the direction of ply twist. When the yarn is in dry state, most of the bending, torsional and tensional strains in the yarn are locked in by fibre-to-fibre frictional forces10. But when the same yarn is immersed in water, it penetrates between the fibres, reduces the friction between them and releases all the stresses. Similar phenomenon would happen when the dry yarn is exposed to atmospheric condition for a long period of time. Hence, the yarn with 1/3 of single yarn twist starts snarling on storage. The yarn with 1/2 and 3/4 of single yarn twist shows snarling in the direction opposite to the direction of ply twist (Z direction). Twist liveliness of the yarn with 1/2 and 3/4 of single yarn twist decreases on storage. The reduction of twist liveliness is due to the temporary set in the yarn on storage. The yarn with 3/4 of single yarn twist has high lively twist than the yarn with 1/2 of single yarn twist.

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The twist liveliness of 2/50s yarn in water is given in Table 3. It is observed that the yarn with 1/3 and 3/4 of single yarn twist exhibits snarling in S and Z directions respectively. The yarn with 1/2 of single yarn twist shows negligible amount of snarling. This shows that the ply twist of 1/2 of single yarn twist produces balanced two-ply yarn. The ply twist less than this does not fully remove the torque present in the single yarn and the ply twist higher than this generates torque in the direction of ply twist. This result is inline with the results of earlier investigations10,11carried out on wool yarn. As the single yarn twist before plying increases, the twist liveliness of yarn with 1/3 and 3/4 of single yarn twist increases.

**3.2  Effect of Single Yarn Twist, Ply-to-singles Twist Ratio and Tightness Factor on Spirality of Fabric**

Table 4 shows the spirality of single jersey knitted fabrics after dry and wet relaxations. In the dry relaxed state, the fabrics produced using two-ply yarns with 1/3 and 3/4 of single yarn twist show spirality in Z and S directions respectively, whereas the fabrics produced using two-ply yarn with 1/2 of single yarn twist show negligible amount of spirality. There is no clear trend on the effect of single yarn twist and tightness factor on spirality of knitted fabrics. Based on the twist liveliness values of the yarns at dry condition, it can be said that the fabrics produced from yarn with 1/3 of single yarn twist will not have spirality whereas the fabrics produced from yarn with 1/2 and 3/4 of single yarn twist will have spirality. But actual results of spirality differ from the trend assumed from the results of yarn twist liveliness. Since the yarn from the cop is measured for twist liveliness, it would have not been allowed to undergo relaxation. As the yarn in the knitted fabric is not held as tightly as in the cop and also the yarn in the fabrics is fully exposed to atmospheric condition, it can relax to a greater extent. However, the complete relaxation of yarn would occur only by wet relaxation.

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| Table 1Twist liveliness of 2/50s yarn tested at dry state immediately after the production  of yarn | | | | | | | | | | | | | | | | | | | |
| Single yarn  twist before plying, tpi | | Two-ply yarn with 1/3  of single yarn twist | | | | | Two-ply yarn with 1/2 of  single yarn twist | | | | | | Two-ply yarn with 3/4 of  single yarn twist | | | | | |  |
| Length at which snarl starts, cm | | No. of turns of  snarl twist | | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) | | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) | | |  |
| 27.74 | | - | | 0 | | | 3.23 | | | 5.8 | | | 4.42 | | | 10.8 | | |  |
| 31.51 | | - | | 0 | | | 3.15 | | | 5.0 | | | 4.58 | | | 11.5 | | |  |
| 35.79 | | - | | 0 | | | 2.76 | | | 2.8 | | | 4.53 | | | 10.4 | | |  |
| 39.43 | | - | | 0 | | | 2.14 | | | 2.4 | | | 6.05 | | | 17.1 | | |  |
| Table 2****Twist liveliness of 2/50s yarn tested at dry state after one month of storage | | | | | | | | | | | | | | | | | | | |
| Single yarn twist before plying, tpi | Two-ply yarn with 1/3 of  single yarn twist | | | | | | | | Two-ply yarn with 1/2 of  single yarn twist | | | | | | Two-ply yarn with 3/4 of  single yarn twist | | | |  |
| Length at  which snarl starts, cm | | | | No. of turns of snarl twist (S direction) | | | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) | | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) |  |
| 27.74 | 0.30 | | | | 0.2 | | | | 1.88 | | | 3.3 | | | 3.59 | | | 8.9 |  |
| 31.51 | 1.89 | | | | 3.0 | | | | 1.66 | | | 2.1 | | | 3.78 | | | 8.9 |  |
| 35.79 | 1.34 | | | | 1.4 | | | | 1.70 | | | 2.2 | | | 4.01 | | | 8.3 |  |
| 39.43 | 0.46 | | | | 0.8 | | | | 0.98 | | | 2.2 | | | 5.80 | | | 14.4 |  |
| Table 3Twist liveliness of 2/50s yarn in water | | | | | | | | | | | | | | | | | | | |
| Single yarn twist before plying, tpi | | | Two-ply yarn with 1/3 of  single yarn twist | | | | | Two-ply yarn with 1/2 of  single yarn twist | | | | | | Two-ply yarn with 3/4 of  single yarn twist | | | | |  |
| Length at which snarl starts, cm | | | No. of turns of snarl twist (S direction) | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) | | | Length at which snarl starts, cm | | | No. of turns of snarl twist (Z direction) | |  |
| 27.74 | | | 3.75 | | | 8.67 | | - | | | 0 | | | 3.31 | | | 14.67 | |  |
| 31.51 | | | 4.69 | | | 14.73 | | - | | | 0 | | | 4.68 | | | 17.93 | |  |
| 35.79 | | | 4.83 | | | 18.33 | | 1.02 | | | 1.67 | | | 4.77 | | | 19.07 | |  |
| 39.43 | | | 5.57 | | | 20.07 | | 0.57 | | | 1.0 | | | 6.38 | | | 25.60 | |  |
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The spirality of the fabrics, produced using two-ply yarn with 1/3 and 3/4 of single yarn twist, increases after the wet relaxation of the fabrics. This phenomenon is similar to twist liveliness of yarn before and after wet relaxations. The relaxation treatment relieves the residual torque present in the yarn as a result of change in the fibre molecular structure and the increasing yarn mobility3,4. Twist liveliness of two-ply yarn with 1/3 and 3/4 of single yarn twist increases after wetting the yarn. There is a significant change in spirality of fabrics produced using the yarn with 1/3 and 3/4 of single yarn twist after first and second washes. But between second and third washes, the spirality of fabrics is not changed much. There is no significant change in spirality of fabrics produced using two-ply yarn with 1/2 of single yarn twist before and after wet relaxations. The fabrics produced using two-ply yarn with 1/2 of single yarn twist show nearly zero spirality. This shows that the yarn that does not snarl in water will not produce spirality in the fabrics. The results also show that as the tightness of the fabric increases, the spirality of the fabric decreases. This finding is consistent with the results of earlier investigations on fabrics produced using single yarns1,3,4. In a more tightly knitted fabric, the movement of a knitted loop is restricted and thus spirality is reduced.

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| Table 4Spirality (degree) of single jersey knitted fabrics after dry and wet relaxations | | | | | | | | | | | | |
| Tightness factor tex1/2cm-1 | 27.74a | | | 31.51a | | | 35.79a | | | 39.43a | | |
| 1/3 (Z) | 1/2 (Z) | 3/4 (S) | 1/3 (Z) | 1/2 (Z) | 3/4 (S) | 1/3 (Z) | 1/2 (Z) | 3/4 (S) | 1/3 (Z) | 1/2 (Z) | 3/4 (S) |
| **After dry relaxation** | | | | | | | | | | | | |
| 10.63 | 3.07 | 0.14 | 6.35 | 7.24 | 0.48 | 5.02 | 11.82 | 2.67 | 7.69 | 3.8 | - 0.9 | 17.42 |
| 12.87 | 1.48 | 0.17 | 3.23 | 9.40 | 2.48 | 4.41 | 11.91 | 1.63 | 8.19 | 6.15 | 2.92 | 12.17 |
| 15.37 | 3.79 | 2.34 | 5.00 | 9.14 | 1.64 | 9.81 | 10.15 | 1.67 | 11.09 | 7.64 | 2.87 | 20.33 |
| **After I wash** | | | | | | | | | | | | |
| 10.63 | 8.53 | 0.99 | 10.72 | 14.52 | 1.09 | 10.83 | 18.90 | 2.59 | 12.93 | 3.24 | 5.05 | 31.43 |
| 12.87 | 7.97 | 2.20 | 7.52 | 11.53 | 3.33 | 8.71 | 11.32 | 2.07 | 12.03 | 3.01 | 0.15 | 14.88 |
| 15.37 | 4.25 | 0.60 | 6.70 | 8.73 | 2.75 | 10.96 | 8.72 | 0.67 | 13.39 | 10.15 | 0.38 | 15.49 |
| **After II wash** | | | | | | | | | | | | |
| 10.63 | 17.32 | -1.80 | 14.39 | 12.52 | 0.92 | 12.52 | 30.0 | 3.6 | 25.23 | 19.26 | -0.11 | 38.64 |
| 12.87 | 9.00 | -0.17 | 9.96 | 13.38 | 2.06 | 10.14 | 16.85 | 3.49 | 16.22 | 7.92 | 0.31 | 18.07 |
| 15.37 | 6.26 | -0.90 | 7.65 | 7.56 | 3.37 | 10.21 | 8.43 | 0.97 | 12.23 | 8.66 | 0.76 | 15.87 |
| **After III wash** | | | | | | | | | | | | |
| 10.63 | 15.56 | -1.00 | 13.30 | 14.94 | 0.56 | 13.57 | 26.72 | 3.25 | 27.38 | 18.56 | -0.33 | 36.84 |
| 12.87 | 13.61 | 2.73 | 11.16 | 12.52 | 2.56 | 13.28 | 14.60 | 4.74 | 15.23 | 11.24 | 0.15 | 19.02 |
| 15.37 | 5.93 | 1.49 | 7.84 | 10.95 | 1.87 | 9.91 | 8.43 | 1.09 | 12.93 | 8.60 | 1.08 | 16.15 |
| aSingle yarn twist before plying (tpi)  1/3 , 1/2 and 3/4 are the spirality  of fabrics knitted using two-ply cotton yarn with 1/3, 1/2 and 3/4 of single yarn twist respectively.  Z and S are the directions of spirality of knitted fabrics | | | | | | | | | | | | |

**4 Conclusions**

**4.1** The yarn with 1/3 of single yarn twist initially does not show snarling but on storage, it starts snarling in the direction of ply twist. This is due to the release of stress that has been locked in the yarn due to fibre-to-fibre friction on storage.

**4.2** The yarn with 1/2 of single yarn twist shows negligible amount of snarling in water. Hence, ply twist of 1/2 of single yarn twist would produce balanced two-ply cotton yarn.

**4.3** The fabrics produced using two-ply yarns with 1/3 and 3/4 of single yarn twist show spirality in Z and S directions respectively. The magnitude of spirality increases on wet relaxation.

**4.4** The fabrics produced from yarn with 1/2 of single yarn twist show nearly zero spirality and the magnitude of spirality is not changed significantly on wet relaxation.

**4.5** To produce zero spirality single jersey fabrics, the yarn that does not snarl in water should be used. However, if the yarn that does not snarl at dry state is used for making the fabric, it will have spirality.

**4.6** Tighter the fabric construction, lower will be the angle of spirality.

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