Balanced two-ply cotton yarn

N K Palaniswamy and A Peer Mohamed
Department of Textile Technology, A C College of Technology, Anna University, Chennai 600 025, India

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The twist set in the cotton single yarn and amount of doubling twist required to produce balanced two-ply yarn have been determined by wet relaxing the yarn from torsional stress and strain. Irrespective of the amount of single yarn twist, the amount of twist set in the single yarn is about 45% of the original twist. Balanced two-ply yarn can be produced by giving half of single yarn twist as ply twist in the direction opposite to that of the single yarn twist.

Keywords: Cotton yarn, Lively twist, Ply twist, Torque-free yarn, Torsional stress relaxation

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1 Introduction

Staple fibres are twisted together in the spinning frame to get enough cohesion between the fibres and continuity in the yarn. Torque is developed in the strand when it is twisted. The amount of torque developed mainly depends upon the amount of twist given, torsional rigidity of the fibres and yarn diameter. The torque generated during twisting of yarn is considered to have three components, namely fibre torsion, fibre bending and internal fibre tensile and compressive stresses within the yarn. Of these three components, the sum of the first two is small in comparison with the torque due to fibre tension.

Tandon et al. have developed a theory to predict the torsional behaviour of single yarns, which may be bulky and have non-uniform initial fibre packing density across their cross-sections. The theory is based on discrete fibre-modelling assumption, an energy method and a shortest path hypothesis.

The presence of lively twist in the yarn causes yarn snarling and buckling, spirality in single jersey knitted fabric and skewness in the woven fabric. Heat setting, steaming and doubling processes can reduce or eliminate the torque in the yarn. Heat setting and steaming are mostly used to stabilise synthetic and natural fibres respectively. The theory of bending and twisting of thin elastic rods of uniform circular cross-section and inextensible axis has been used to derive equations for the pretwist that must be inserted into the single yarn to create a balanced ply of specified ply twist.

When staple fibre yarn is twisted, the shear stress developed in the fibres exceeds the proportionality limit and hence if the yarn is allowed to relax freely, the yarn will not come back to its original position. There would be some amount of twist set in the yarn. Hence, the ply twist required to produce a torque-free two-ply yarn can be predicted.
from the amount of twist set. The ply twist required would be equal to the lively twist present in the single yarn. However, in practice, irrespective of the type of fibre and the amount of twist set in the yarn, two-third of single yarn twist is given as doubling twist in the direction opposite to the single yarn twist.

In the present work, the amount of twist set in the single yarn and the amount of doubling twist required to produce torque-free two-ply yarn have been studied after fully relaxing the yarn in water.

2 Materials and Methods

Combed cotton yarn of 14.8 tex (40Ne) was spun using Lakshmi G 5/1 ring frame from the roving of 0.37 ctex (1.6Ne). The yarn was spun at six different twist levels. These were the standard twist levels normally applied on the combed cotton yarn and 10%, 20%, 30%, 40% and 50% higher than the normal level. Each of these yarns was doubled at three different doubling twist levels (1/3, 1/2 and 3/4 of single yarn twist).

2.1 Determination of Twist Set in Single Yarns

2.1.1 Determination of Twist Set in Dry Condition

The yarn was cut to a length of 12-15 inch. One end of the yarn was held by hand and the other end was left free and vice versa. Since one end of the yarn was free, the untwisting of yarn takes place. After untwisting of yarn, the amount of twist in the single yarn was measured using single yarn twist tester based on twist contraction method. This would be the amount of twist set in dry condition.

2.1.2 Determination of Twist Set after Relaxing Single Yarn in Water

The yarn was cut to a length of 12-15 inch and was put in a water tray containing soapy water (Soap 0.1 g/L) at room temperature. The water tray length was selected in such a way that the yarn would be straight when wet in the water. Since both ends of the yarn were left free, instantly as the yarn entered into water, it started untwisting due to the removal of torsional stress in the yarn. The yarn was kept in the water bath for 15 min, so that it would come to equilibrium after removal of twist. The yarn was taken out from the water bath and dried in the atmospheric condition. Both the ends of the yarns were held firmly, not allowing the yarn to twist or untwist during drying.

Dried yarn does not have enough strength due to removal of most of the twist in the yarn and hence the twist in the dried yarn could not be measured in usual test method. In the usual test method, the samples are clamped between fixed and rotatable jaws with a pretension in the yarn so that the pointer in the non-rotatable jaw will coincide with the reference line. The fibre slips in this wet-relaxed yarn upon pretensioning. Hence, the specimen was clamped between the jaws with very small amount of tension to keep the specimen under taut condition but the pointer was kept vertical. Initially, the jaw was rotated in the same direction as that of twist present in the dry yarn until the pointer coincides with the reference line. The amount of twist given was observed (say X) and the twist counter was reset to zero. Now as usual, the single yarn twist was measured (say Y). The twist set, i.e. the amount of twist present in the yarn, would be Y-X. The lively twist present in the spun yarn is the difference between the original twist and the twist set.

2.2 Determination of Twist Liveliness

The twist liveliness of the double yarns was measured by using the principle similar to ISO standard 03343-1984 (ref. 7). The fabric crimp tester was used as a residual torque tester, consisting of fixed clamp and movable clamp on the scale. At the beginning, the clamps were located at a distance of 50 cm; the yarn was clamped between the jaws without disturbing twist in the yarn with a pretension of 1 cN/tex.

Soap of 0.1 g/L was added in water bath to assist wetting of the yarn. The residual torque tester was placed over the water bath and a weight of 0.02 cN/tex was added on the middle of the yarn. Then, the movable clamp was moved towards the fixed clamp slowly and the yarn was allowed to enter into water simultaneously. The distance where the specimen starts snarling was observed. Then, the movable clamp was moved up to the fixed clamp so that all the 50cm length of yarn would be in the water. The snarled yarn was kept in the water bath until it did not snarl further with respect to time. The amount of snarl twist was measured manually by removing the snarls. Fifteen tests were carried out for each specimen. In a similar way, the amount of snarl twists and length at which snarling starts were measured without entering the yarn into the water bath.

2.3 Determination of Torsional Stabilisation of Doubled Yarn in Water

The double yarn was cut to a length of 12-15 inch. The yarn was put in the soapy water similar to the test method for twist set. As soon as it entered in the
water, the yarn started untwisting or twisting in the direction of doubling twist, depending upon the direction and level of torque present in the double yarn. This yarn was kept in the water bath until there was no change in twist with respect to time. Then the yarn was taken out and dried. After drying, the amount of doubling twist present in the yarn was measured. This is the actual amount of doubling twist that should have been given to remove the single yarn torque.

3 Results and Discussion

3.1 Set Twist and Lively Twist

Tables 1 and 2 show that the amount of untwisting is very low in the dry state (15-20% of the single yarn twist) when compared with untwisting of yarn in water. In the dry state, there would be more friction between the fibres and this friction might have not allowed the yarn to relax fully from the torsional stress and strain. When the yarn enters in the soapy water, the water molecules penetrate between the fibres and acts as lubricant. Hence, it reduces the friction between the fibres and allows the yarn to relax almost fully from the torsional stress and strain. The effect of swelling of yarn in water on the amount of untwisting was also verified. The yarn was relaxed in 15% NaOH solution as maximum swelling of cotton takes place at this concentration. The amount of twist set was measured after relaxing the yarn in NaOH solution. There is no significant difference between the amounts of twist set in water and NaOH.

Table 1 shows the amount of twist set and lively twist present in the single yarn at different levels of twist in the dry condition. The amount of twist set is about 80-85% of the original twist, irrespective of the amount of single yarn twist. In order to produce a balanced two-ply yarn, it is required to measure the amount of twist set after wet relaxing the single yarn.

Table 2 shows the set twist and lively twist for the single yarn at different levels of twist in the wet condition. Irrespective of the level of single yarn twist, the amount of twist set for all the yarns is 45% of the original twist that was inserted during spinning. Therefore, only 55% of the twist in the yarn is lively twist. Hence, the balanced yarn can be produced by inserting 55% of the single yarn twist as doubling twist in the direction opposite to single yarn twist. Table 2 also shows that as the single yarn twist increases, the amount of twist set in the yarn also increases.

3.2 Amount of Snarl Twist and Length at which Snarl Starts

The snarl twist measured in the dry state shows different results from the snarl twist measured in water. In the dry state, the double yarn with 1/3 of single yarn twist does not show snarling whereas both double yarns with 1/2 and 3/4 of single yarn twist show snarling (Figs 1 and 2). As the single yarn twist increases, the snarling twist and the length at which snarling starts first increase and then decrease for both the double yarns. Both the double yarns with 1/2 and 3/4 of single yarn twist snarl in Z direction. This shows that the amount of doubling twist given is more than that required to achieve a balanced yarn in dry state.
In water, double yarn with 1/2 of single yarn twist does not show snarling but the other two yarns show snarling (Figs 3 and 4). If the fabrics are produced from these yarns, the fabric produced from the double yarn with 1/3 of single yarn twist will not show skewness or spirality in the dry state whereas the other two fabrics will show skewness and spirality. On the other hand, after wet relaxation of these fabrics, the fabric made of double yarn with 1/2 of single yarn twist will not show skewness and spirality. However, the extent of wet relaxation also depends upon the structure of fabric.

Figs 3 and 4 show snarling twist and the length at which snarling starts for the double yarn in water. The double yarn with 1/3 of the single yarn twist snarls in S direction whereas double yarn with 3/4 of single yarn twist snarls in Z direction. This shows that 1/3 of the single yarn twist does not remove all the torque in the single yarn and in the case of 3/4 of the single yarn twist, all the torque originally present in the single yarns is removed and extra torque is created in the opposite direction. The double yarn with 1/2 of the single yarn twist does not snarl. Figs 3 and 4 show that as the single yarn twist increases the amount of snarl twist and length at which snarling starts increase.

### 3.3 Doubling Twist after Wet Relaxation in Water

Table 3 shows the amount of ply twist present in the double yarn before and after wet relaxation. It shows that the difference between twist in the double yarn before and after wet relaxation is higher for both the double yarns with 1/3 and 3/4 of single yarn twist.

<table>
<thead>
<tr>
<th>Single yarn twist (turns/inch)</th>
<th>1/3 of single yarn twist</th>
<th>1/2 of single yarn twist</th>
<th>3/4 of single yarn twist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrelaxed Ply twist in double yarn, turns/inch</td>
<td>Relaxed % of single twist after wet relaxation</td>
<td>Unrelaxed Ply twist in double yarn, turns/inch</td>
<td>Relaxed % of single twist after wet relaxation</td>
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<td>-------------------------------</td>
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<tr>
<td>24.74</td>
<td>7.29</td>
<td>10.41</td>
<td>42.15</td>
</tr>
<tr>
<td>27.24</td>
<td>8.54</td>
<td>11.67</td>
<td>42.84</td>
</tr>
<tr>
<td>29.3</td>
<td>9.18</td>
<td>12.67</td>
<td>43.24</td>
</tr>
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<td>32.29</td>
<td>10.32</td>
<td>13.25</td>
<td>41.03</td>
</tr>
<tr>
<td>34.09</td>
<td>10.27</td>
<td>14.84</td>
<td>43.53</td>
</tr>
<tr>
<td>36.67</td>
<td>11.51</td>
<td>15.43</td>
<td>42.08</td>
</tr>
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</table>
This difference is negligible in the case of yarn doubled with 1/2 of single yarn twist. This shows that the yarn with 1/2 of single yarn twist is torque free. But double yarn with 1/3 of single yarn twist gets more amount of doubling twist than the original by untwisting the single yarn twist in the doubling twist direction. This shows that the amount of doubling given is insufficient to remove torque in the single yarn. However, the double yarn with 3/4 of single yarn twist starts untwisting some of the doubling twist which was inserted during plying. It reveals that the amount of doubling twist given is more than required amount.

As the amount of twist set in the single yarn is about 45% of the original twist, the doubling twist present in the double yarn after wet relaxation should have been 55% of single yarn twist, irrespective of amount of doubling twist given to the yarn. However, the double yarns with 1/3 and 3/4 of single yarn twist have the doubling twist of about 42% and 55% respectively. This shows that the yarn itself cannot release complete torsional stress and strain in water. In order to untwist the yarn in water, it requires some energy. Initially, the yarn has high torsional energy and hence it untwists. Once most of the energy is released by untwisting, there may be a small amount of torsional energy still present in the yarn. But this energy may not be sufficient to untwist the yarn further.

4 Conclusions

4.1 When the single yarn is allowed to untwist freely in the dry state, only about 15-20% of the original twist is removed. Even though there is torsional stress and strain in the yarn, the yarn could not untwist fully due to higher fibre-to-fibre cohesive force.

4.2 When the same yarn is kept in water it untwists further until all the stress and strain are released. The amount of twist set measured after wet relaxation is around 45% of original twist for all the single yarns with different twist levels.

4.3 In dry state, the double yarns with doubling twist of 1/3 of single yarn twist show no snarling but the other two double yarns with 1/2 and 3/4 of single yarn twist show snarling. However, the yarn with doubling twist of 1/2 of the single yarn twist does not show snarling in a water bath.

4.4 Balanced double yarn can be produced by giving 1/2 of single yarn twist as ply twist in the direction opposite to single yarn twist.

References