Spirality of weft-knitted fabrics: Part II—Methods for the reduction of the effect

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The effect of yarn steam setting and fabric washing on spirality has been studied and a brief description of a yarn treatment, based on the false twisting process, worked out towards the solution of this problem is given. The results indicate that a possible method for the reduction of the spirality effect should include a real reduction in the twist liveliness or torque existing in the yarns.

Keywords: Knitted fabric, Spirality, Steam setting

1 Introduction
Several techniques dealing with yarn and fabric processing have been adopted to overcome spirality. The most suitable method for producing spirality-free single jersey fabrics is by knitting two-folded yarns, where the opposing torsional forces in the singles yarns and the resulted folded yarn are counterbalanced. Although the use of folded yarns, instead of singles yarns, improves the fabric characteristics, due to the problems regarding the appropriate relation between their twist levels, fabrics may exhibit spirality that would be in the direction of the residual twist. Garments such as T-shirts, knitted from folded yarns, become heavier than those produced by using singles yarns. The two-folded yarns require the production of finer or lower linear density singles yarns to produce lighter fabrics, resulting in a dramatic increase in their production cost.

When two singles yarns of equal twist level, equivalent twist liveliness and opposite twist directions are fed to a feeder of a knitting machine, their tendency to distort the knitted loops towards the one or the other direction (S or Z) is neutralized and a straight fabric appears (Fig. 1a). The production of yarns of similar twist liveliness is rather difficult and any exhibited spirality of the resultant fabric assumes the twist direction of the yarn with the highest twist liveliness. This method, similar to plating, is an effective technique for keeping the spirality to a minimum level. Furthermore, knitting alternate ends of S- and Z-twisted yarns with equivalent twist liveliness will produce an overall spirality-free fabric with an irregular and uneven texture, presenting a cockling or a herring-bone effect on the fabric surface (Fig. 1b). Although this method is not suitable for the production of cotton or wool plain weft knitted fabrics, it is commonly used in the manufacturing of stockings from fine nylon yarns, where the herring-bone effect gives the fabric a greater potential for length-wise stretch. The last two afore-mentioned techniques are labour intensive since it is necessary to mark clearly the yarn twist direction on every yarn package and to inspect them in order to avoid the mixing of the yarn types during the fabric production.

Probably the first attempt for chemical correction of spirality was made on fabrics produced from crossbred worsted yarns. This detrimental effect disappeared as such cloths were cold crabbing treated using cold sodium sulphide solution, which caused partial decomposition of the wool fibres, resulting in the weakening of the fabric.

Research involving mercerization treatment of cotton yarns showed 45% reduction in yarn twist liveliness and 10-13% reduction in the spirality of dry-relaxed fabrics. On the other hand, a tremendous reduction of 20-30% in spirality was observed when mercerization took place in the fabric state, where a
larger reduction in loop asymmetry occurred\textsuperscript{16}. Although mercerization is an efficient wet-relaxation process, giving the best results compared to others\textsuperscript{17,18}, it is not a complete solution for the spirality of single knitted fabrics.

The blending of a small percentage of low-melt polyester fibres with cotton\textsuperscript{4} and the heat treatment of the produced yarn resulted in a reduced spiral distorted fabric with an unpleasant texture since the yarn and fabric became rather stiff. Although a resin treatment\textsuperscript{5} of knitted fabrics reduced their spirality and improved their dimensional stability, appearance and handle, it caused the weakening of cotton fabrics.

Twist setting or relaxation improves the mechanical stability of yarns\textsuperscript{1,4,13,19,20} as it relieves the stresses set up in textile fibres by twisting and ensures the standstill of the twist liveliness of even highly twisted yarns while retaining their twist level. The twist setting methods involve storage of yarn packages at adequately high temperature and relative humidity for a proper period of time\textsuperscript{21,22} or placement of the yarn packages in a perfectly enclosed chamber where the regulated humid air (heated air and moisture) is forced into the chamber for a given period of time\textsuperscript{23}. Steaming at 100 °C and normal atmospheric pressure is practically equivalent to boiling in water without the disadvantages of the latter (e.g. the motion of boiling water gives a felting effect in the case of wool yarns). The proper and even steam penetration to all parts of a yarn package is the main advantage of the modern sophisticated vacuum autoclave steamers. Although the steaming process seems to be simple, great care must be exercised to avoid possible damage such as yellowing of the white mixture yarns and colour bleeding and staining in dyed yarns\textsuperscript{22,24}. The yarn steam setting process does not entirely eliminate the untwisting torque of the set yarns and its effectiveness lasts up to the time that the yarns and the knitted fabrics are processed with a wet treatment\textsuperscript{17,10,13,25}. Especially for wool yarns\textsuperscript{17}, the yarn water setting, which involves the placing of the yarn packages in a vessel with boiling water and plunging the packages into cold water and drying, is more effective as it causes less discoloration of the dyed yarns\textsuperscript{1,18}. This method is not suitable for the treatment of cotton yarns\textsuperscript{26}.

The spirality of single-jersey knitted fabrics may be temporarily corrected by low levels of fabric strain, achieved by using a former during steam processing or pressing\textsuperscript{13,7,18}. For worsted fabrics, high temperature steaming of the fabric reduces spirality often after scouring but not after dyeing\textsuperscript{27}. Boarding or calendering of the fabric under ordinary finishing conditions are only transient methods because as soon as the fabric is wet, during subsequent washing or scouring, it regains its spirality, resulting in a consequent loss in appearance and discomfort in wear. In many cases, the fabric returns to the distorted shape, it might have had, if it was produced from the same but unset yarns\textsuperscript{13}.

2 Materials and Methods

Experiments were carried out to investigate the effect of the yarn steaming process on yarn properties and to confirm the effect of the steaming process on the temporary reduction of the spirality angle of fabrics produced from steamed yarns.

Z-twisted yarn samples of various twist factors, produced for a series of experiments\textsuperscript{28}, were split up into two groups. The yarn quantities of the first group were wound on perforated cones providing a means for easier penetration of the steam in the yarn.
package. These bobbins were placed in a Sanderson steam vacuum autoclave for the setting process. The yarns were steamed at 105 °C under a pressure of approximately 69 kN.m⁻² (kPa) for 60 min. After this, the set yarn samples of the first group and the unset yarns of the second group were left to relax in room conditions for 48 h. Finally, all the yarn samples were stored in standard atmospheric conditions (20±2 °C and 65±2% RH) for four days.

The yarn properties such as linear density, tenacity, snarliness, hairiness, evenness and friction of both the set and unset samples were tested on relative testing devices. The means of the readings are given in Table 1.

A WILD T one-feeder weft knitting machine with a gauge E14 was used for the production of the knitted fabric samples. The tightness factors were $K_1 = 1.115$ tex⁻¹.mm⁻¹ and $K_2 = 1.293$ tex⁻².mm⁻¹ for the yarns with linear densities of 29 tex and 39 tex respectively. The fabric samples were washed on a domestic washing machine running once a full washing cycle. A transparent sheet and a protractor were used for the direct measurement of the spirality angle of relaxed fabrics before and after the washing treatment. The results obtained are presented in Fig. 2.

3 Results and Discussion

3.1 Effect of Yarn Steaming on Yarn Properties and Fabric Spirality

As it can be seen from Table 1, it is clear that the steaming process did not affect the linear density of both 29 tex and 39 tex yarn samples. The linear density of 29 tex set yarn samples with low twist factors (32.4 and 34.9) was marginally higher than that of the unset yarns. Their differences were not significant.

Considering the differences shown by set and unset yarns in terms of tenacity, it could be said that the steaming process weakened the yarn and that the reduction in strength was probably due to the water absorption that occurred during steaming. When the fibres absorb water they change in dimensions, swelling transversely and axially, and become more rounded and the fibre slippage is more likely to occur, resulting in quicker yarn breakage. Another possible reason for this fall in tenacity is consistent with the idea caused by the breakage of the strong hydrogen bonds formed between chain molecules in the non-crystalline regions as well the weak hydrogen bonds formed between the fibres\(^\text{29}\). Moreover, as Behr\(^\text{27}\) has stated, the setting of textile fibre structures is understood to be the loosening of cross and auxiliary valency bonds between fibre molecules and the

<table>
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<tr>
<th>Actual linear density, tex</th>
<th>Twist factor, turns cm⁻¹TEX⁻¹</th>
<th>Steam setting</th>
<th>Tenacity, cNTEX⁻¹</th>
<th>Snarliness, cm</th>
<th>Hairiness, hairs cm⁻¹</th>
<th>Regularity CV %</th>
<th>Coefficient of friction (µ)</th>
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N—Unset yarn; and Y—Set yarn.

![Fig. 2—Effect of yarn steaming and fabric washing on spirality angle (BW—Before washing and AW—After washing)](image-url)
reorientation of these chain molecules followed by a new, tensionless arrangement of same at a higher degree of orientation. Despite 16% reduction in tenacity exhibited by one of the yarn samples (TF 34.9, 29 tex), in practical terms it was considered as not of great importance.

In the case of snarliness, the theory claiming the very significant effect of the steaming on yarn twist liveliness seems to be confirmed. The set yarns showed a substantial reduction in their twist liveliness.

Comparing the hairiness of the set and unset yarns, it could be stated that the steaming process resulted in a less hairy yarn appearance. This was probably due to hydrogen bond formation, bringing the protruding fibres (hairs) closer to the main body of the yarn. Furthermore, for both the yarn linear densities, as the twist factor increased, the hairiness decreased, a trend that was shown by both the set and unset yarns.

As the yarn evenness is concerned, the exhibited differences shown between set and unset yarns seemed to be irrelevant to the effect of steaming.

The set yarns exhibited higher coefficient of friction. This may be due to the removal of wax, applied in the yarn during winding, by the steaming process. Another possible explanation could be that the steaming process made the yarns stiffer. Thus, as the yarns were passing around the metal surface of the yarn abrasion-friction testing device, from the Amonton’s law \( T_2 = T_1 \times e^{\mu d} \), the tension \( T_2 \) increased due to the extra tension that might applied to the yarn to overcome its bending stiffness. The above reasoning comes in sharp contrast to the statement of Araujo and Smith who claimed that steam set yarns exhibit an improved knitability as the instability created by yarn bending during knitting is reduced.

From Fig. 2, it is clear that the yarn steaming in all yarn cases resulted in less spiral fabrics. The spirality reduction was very significant for the fabrics produced from the set yarns prior to washing and less significant after washing. It must be pointed out that a great reduction can only be achieved by the optimum yarn steaming conditions.

3.2 Application of False Twisting Process on Short-staple Yarns

The results of the previous experiment\(^2\) confirmed that a less twist-lively or lower torque yarn produces less distorted knitted fabric as the spirality is concerned. Therefore, it was decided to find another way to reduce or disturb the torque of short-staple yarns to determine whether this could affect the spirality. This torque disturbance could be achieved by applying the principle of false twisting process. In this process, although there is no twist alteration since the inserted twist in the upstream part of the yarn is removed as this yarn part passes through the false twisting device, a change in the yarn torque may occur. A specially designed hollow spindle with two apertures (Fig. 3) was used for the purposes of this experiment\(^2\). The spindle was rotating by means of a motor at a constant speed of 2000 revolutions per minute. The whole assembly was mounted on the WILDT circular knitting machine that was used for the previous experimental work. After a series of tests, the yarn passage through the spindle’s apertures in the manner shown in Fig. 4 was applied.

From the principle of the false twisting process it is known that as a yarn passes through the rotating device, the inserted twist in the upstream yarn part is cancelled by the twist in the downstream yarn part due to their opposite directions. To entrap the very fast changes of the yarn torque due to this twisting-detwisting process, the feeding end of the experimental spindle was located very close to the knitting zone. Many possible combinations of the speed ratio spindle/knitting machine and the spindle position in regards to the knitting zone were tried. In some cases, the yarn breaks occurred as the yarn was almost fully detwisted in its downstream part,
whereas in some other cases the formation of numerous snarls in the upstream yarn part took place and an irregular loop distortion in the fabric appeared. In the rest of the trials, no particular effect on the spirality of the fabrics was detected.

The false twisting method for torque disturbance or alteration of short-staple yarns proved insufficient in spite of the fact that this process, used and reported by Ngor\textsuperscript{30}, had an effect on cotton/polyester (67/33) blend where there was a balance of torque in the yarn and the fabric showed zero spirality. A possible explanation to this result is that the heat of the heater on a FTT machine could affect the polyester, a thermoplastic material.

4 Conclusions

Many methods have been developed to overcome the spirality of weft knitted fabrics. The most commonly applied, but expensive one, method is the use of two-folded yarns. The widely used yarn steam-set process merely reduces the spirality rather than preventing its appearance. Moreover, the washing of the fabrics produced from steam-set yarns increases their small spirality angle appeared before washing. Attempts to adopt the false twisting process for torque disturbance or twist alteration of short-staple yarns proved unsuccessful. A possible method for the reduction of the spirality effect should include a real reduction of the twist liveliness or torque existing in the short-staple ring-spun yarns.

References