TORQUE MODIFICATION OF FALSE-TWIST TEXTURED YARN BY AIR TWISTER

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Abstract

There have been a few methods to modify or to reduce the torque of false-twist textured yarn, but they are too complicated in operation or machine set-up and are somewhat imperfect in performance. In this paper a new method is attempted in which an air twister was equipped at the exit of the 2nd heater of a tandem type false-twisting machine to twist a textured yarn again in a direction reverse to the initial twist direction. The effects of various treating conditions including the construction of the air twister on the yarn properties are described. The snarling tendency of the obtained yarn is reduced remarkably by an increase of twist added by the air twister, while the other properties are varied insignificantly. It is possible to choose the proper modifying conditions to attain the non-torque yarn, when the treating conditions in the subsequent processes are given. When an air twister is used in which an air conduit of air flow is inclined at 60 degrees to the yarn passage, it gives results superior to the other conditions except the inferior twisting efficiency.

1. Introduction

False-twist textured yarn has many conspicuous properties such as high extensibility, high bulk, high torque, rather high residual shrinkage and stable dyeability. These properties are generally useful for textiles, but in some cases some of them are also obstructive. Particularly, torque, which is a kind of torsional yarn property and makes the yarn apt to snarl, is troublesome in treating the yarn in the subsequent processes, e.g., in spiralling the wale of plain knitted fabrics, and high shrinkage makes fabric dimensions unstable. Some methods have been developed to rectify these obstructive properties, one of them is to twist the yarn again reverse to the initial false-twisting direction mechanically under extended state at post heat setting stage. This method, capable of controlling the torsional tendency of the yarn at an arbitrary level, is somewhat unable to decrease its residual shrinkage and requires a specially arranged machine and great skill in threading-up such a machine.

In this paper, some pneumatic twisting elements were adopted instead of mechanical one. The elements can be easily attached at the exit of the 2nd heater of the conventional tandem type false-twist texturing machine to twist a yarn in relaxed state as shown in Fig. 1. The effects of testing conditions, such as structure of air twister, air pressure, relaxing ratio, heating temperature, etc., on the yarn torque are described.

2. Experimental

2.1 Testing apparatus

An air twister was attached at 395 mm below the 2nd heater of a false-twist testing machine type
Fig. 1 Schematic view of testing machine.

A combination of twist directions shown in this figure is an example of exhausted air flow direction coinciding with that of the yarn proceeding.

SLT-2 made by Mitsubishi Heavy Industries, Ltd. The main characteristics of this machine are a direction of running yarn (top to bottom), and a second straight tubular heater which has a slit with a cover to facilitate the thread-up. Other items are briefly shown in Table 1.

### 2.2 Air twisters

Two types of air twister, denoted by R and W, were tested. Each of them has a yarn passage of 2.5 mmØ with a thin slit to insert the yarn with facility and with an air conduit which is tangentially opened into an inner surface of the yarn passage and inclined $\alpha$ degrees to the axis of the yarn passage. As shown in Fig. 2, $\alpha$ is 90 degrees in type R and 60 degrees in type W. The relative position of the air conduit and the slit is devised not to spout out the passing yarn through the slit by jetted air. In type R, the diameter of the yarn passage is squeezed at the half length to exhaust the air mainly through the other end of the passage. In type W, the inclined air conduit works likewise. When the directions of exhaust air and the yarn are the same, it is called forward flow, and when reversed, it is called backward flow.

### Table 1 Features of testing machine.

<table>
<thead>
<tr>
<th>Item</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine construction</td>
<td>Constructed from ST-5 (1 stage heating system) and LS-2 (2 stage heating system) on each other side</td>
</tr>
<tr>
<td>Yarn path</td>
<td>Top to down</td>
</tr>
<tr>
<td>Spindle</td>
<td>Pin type mechanical spindle maximum 300,000 r.p.m.</td>
</tr>
<tr>
<td>1st stage heater</td>
<td>1,000 mm long, contact type curved plate with cover indirect heating by vapourized Dowtherm</td>
</tr>
<tr>
<td>2nd stage heater</td>
<td>600 mm long non-contact type straight tube heater with slit and its cover indirect heating system</td>
</tr>
</tbody>
</table>

Fig. 2 Cross-sectional side and plane views of air twisters (Type W and R).
as illustrated in Fig. 3. (Abbreviated, when necessary, as F.F. and B.F. respectively, hereafter.)

These two modes of air flow were accomplished by turning the air twister upside-down. According to the turn of the air twister, the twist direction of the first heating stage was reversed mechanically.

2.3 Testing materials

Poly(ethylene terephthalate) (PET) multifilament yarns, such as 150D-30F and 50D-24F were mainly used. All of the samples were for the use of texturing and had relatively low specific densities.

2.4 Testing condition

In all of the experiments, the twisting directions at two heat setting zones were opposite to decrease the torque of treated yarn. Air pressure delivered to the air twister ranged from 0 to 1 kg/cm² G, but 0.4 kg/cm² G was found to enough to give the yarn torque opposite to the false-twisting direction of the 1st stage. Other testing conditions are tabulated in Table 2. Figures for the standard testing condition underlined in the table were adopted without any comments.

2.5 Estimation of yarn properties

2.5.1 Torsional property

The torque of obtained yarn was estimated by its snarling tendency and spirality in knitted fabrics. The measuring method of the snarling tendency (Abbreviated as S.T., hereafter) was introduced in part 14), but here, two estimating conditions were adopted to evaluate thermal behavior by keeping a loop of the yarn in a standard condition (20°C, 60% R.H.) and in autoclave at 105°C for 15 min. Thus measured values are denoted by S.T.(1) and S.T.(2), respectively.

2.5.2 Crimp capacity

Two items, crimp contraction (C.C.) and crimp rigidity (C.R.) (2), were measured to evaluate the crimp capacity of the obtained yarn. Both of them were measured according to the procedure developed by Heberlein and Company AG except that the treating time of the skein in boiling water was 10 min instead of 30 sec for the former, C.C., and except for hanging a small weight of 5 mg/den from the skein during treatment in boiling water for the latter, C.R. (2). The last condition was selected in order to estimate the durability of crimp capacity against heat treatment with stress which would be suffered in dyeing and drying processes.

<table>
<thead>
<tr>
<th>Material (den-fil)</th>
<th>Sp. rev. (r/m)</th>
<th>Yarn vel. (m/min.)</th>
<th>H. temp. (°C)</th>
<th>1st stage Feed r.</th>
<th>Twist (t/m)</th>
<th>H. temp. (°C)</th>
<th>2nd stage Feed r.</th>
<th>Air pres. (kg/cm² G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150-30</td>
<td>224000</td>
<td>92.6</td>
<td>210</td>
<td>0.97</td>
<td>2420</td>
<td>200</td>
<td>0.909</td>
<td>0.870</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.833</td>
</tr>
<tr>
<td>75-36</td>
<td>300000</td>
<td>90.9</td>
<td>210</td>
<td>0.97</td>
<td>3300</td>
<td>200</td>
<td>0.870</td>
<td>0.6</td>
</tr>
<tr>
<td>24</td>
<td>300000</td>
<td>78.7</td>
<td>210</td>
<td>0.97</td>
<td>3810</td>
<td>185</td>
<td>0.870</td>
<td>0.4</td>
</tr>
<tr>
<td>50-36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>48</td>
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</table>
2.5.3 Residual shrinkage

Residual shrinkage of textured yarn was estimated by the ordinary method of measuring the difference in the lengths of the skein under 100 mg/den weight before and after the boiling treatment in the free state.

3. Results and observations

3.1 Air flow and twisting function of air twister

Air flow was increased exponentially according to increasing air pressure up to 0.6 kg/cm² G as shown in Fig. 4. The value of air flow at 1 kg/cm² G, which was not shown in the figure, agreed well with that of the ejector, simply dependent upon the area of the air conduit as shown in Fig. 5. So the air flow in these normal pneumatic apparatuses was inferred to conform the theoretical pneumatic calculation and to increase proportionally to the air pressure over 0.6 kg/cm² G.

Twisting function of the air twister was evaluated by twist added to freshly textured yarn at post heating zone under forward flow at a feed ratio 0.87. The twist of the yarn was calculated by dividing the twist of the yarn which had been picked by nipping at both ends of the second heater by the length of de-twisted yarn at 0.1 g/den. As is well known, twist added to a running yarn has some inclined distribution along the yarn length and so does the twist in the post heating zone added by air twister. In this paper, the twist was defined as the mean value in the second heater, because such a distribution seemed to have little effect on the property of the yarn. As shown in Fig. 4, the twist added to the yarn increased sigmoidally with the air pressure supplied. The reason why the twist does not increase proportionally to the air pressure is inferred that the yarn crimped and bulked in the 1st stage is disturbed during the rotation by the frictional force given by the contact with the yarn passage wall of the twister. This inclination is also observed in the experimental results of Shimizu et al., where raw filament yarn was twisted by an air twister of different construction from that shown in Fig. 2, and rather high pressure was necessary to add the same level of twist in comparison with the present results shown in Fig. 4. This difference in twisting efficiency was thought to be dependent upon the apparent yarn diameter and yarn tension applied in the twisting zone. Naturally the twist level was varied by other factors, viz., exhausting air direction, feed ratio, mono filament denier, yarn velocity and so on.

3.2 Torsional property

3.2.1 Snarling tendency

Both types of air twister, W and R, were attached in two modes of air stream, forward and backward flow. S.T.(1) and S.T.(2) of the obtained...
yarn decreased with increasing air pressure as shown in Fig. 6 and 7 respectively. S.T. was represented to be positive in accordance with the first stage texturing direction regardless of the snarling direction. From Fig. 6, it was observed that S.T.(1) under backward flow was smaller than that under forward flow with type W twister. These trends were thought to be affected by the difference of S.T. of the yarn post treated without twist, as shown by the points at zero air pressure. The reason why S.T. at zero air pressure differs slightly according to the false-twisting direction may be related to the fact that the number of the tight spots of the yarn is increased clearly by the directional coincidence of the false-twist with the original twist added to the raw multifilament yarn. However, the variation of S.T. according to the air flow direction or the air twister type was clear in even considering twisting direction, and their trends were closely related to the yarn twist added in post treating zone as will be shown later.

When S.T.(1) becomes nearly zero, the yarn becomes very convenient to handle in the subsequent processes. However it should be noted that the yarn is not always free from torque because the snarling tendency of false-twist textured yarn is variable depending upon the subsequent mechanical or thermal conditions. In Fig. 7, S.T.(2) show a similar trend to S.T.(1) except the differences in their values incorporated by the difference in the estimating conditions which differentiate the releasing effect of the temporary set given at the texturing process.

**3.2.2 Wale spirality**

Fig. 8 shows that the wale spirality of plain tubular knitted fabric relaxed in boiling water has a high correlation with S.T.(2). The wale spirality changes depending upon stitch density, relaxation and dyeing conditions of the knitted fabric, because the yarn in the fabric suffers different mechanical or thermal affection from these conditions. Namely, the wale spirality increased slightly with increasing density or relaxing temperature as shown in Fig. 9 or 10 respectively.
Fig. 10 Relationship between relaxing temperature of fabric and wale spirality of the fabric.

These were thought to be the reasons why the correlation line in Fig. 8 did not pass the origin of the co-ordinate. It is impossible to select modifying conditions that produce no wale spirality under various conditions. Consequently it is impossible to obtain non-torque yarn that satisfies both the handling and the wale spirality in the subsequent processes at the same time. But, if the requirement, at what condition the yarn is necessary to be free from torque, is pointed out, it is possible to select the proper modifying conditions for the non-torque yarn to meet the requirement.

3.2.3 Twist added by air twister

As shown in Fig. 11, the number of twists added in post treating zone tended to change against the air pressure just in reverse of the inclination of both S.T.(1) and S.T.(2) shown in Fig. 6 and 7. So it was suggested that the higher the twist, the lower the S.T. Relationships between the number of twists and S.T.(1) and S.T.(2) were shown in Fig. 12 and 13 respectively, and high correlations were found between them in both cases as expected. From these figures the decrease in S.T. was seen to be not proportional to the increase in twist. Generally speaking, S.T. of false-twist textured yarn without post treatment has a tendency to increase steeply, reaches a maximum point and then decreases gradually with the increase in twist. The relationships between S.T. and twist of the obtained yarn shown in Fig. 12 and 13 are so similar to that of the simple textured yarn in low twist range that the general tendency in S.T. vs. twist is kept essentially in the yarn post treated with the air twister. The twist added by type R air twister with forward flow was particularly lower than those under the other conditions. The reason was presumed to be the disturbed transference of twist on the yarn running in the second heater from the air twister with the thin yarn passage. In Fig. 11, it is seen that the backward flow gave higher degree of twist than the forward flow because the backward flow would overfeed the yarn substantially more than the settled feed ratio. It is also seen that larger inclined angle α would have higher rotating efficiency except type R with forward flow, which was an unusual case as mentioned above.
3.3 Crimp capacity (C.C.)

Fig. 14 shows that C.C. of the yarn treated with the air twister is a little higher than that of the yarn treated without it. The filament alignment of the obtained yarn looked rather opened or separated in contrast to the conventionally textured yarn. This configuration seemed to give the former a higher value in C.C. than the latter through the free behaviour of the yarn in boiling water by decreased frictional disturbance among filaments. In the case of backward flow, C.C. increased with increasing the air pressure which accompanied a substantial overfeed. In the case of forward flow, C.C. increased with increasing the air pressure on account of the decreasing interfilament friction in the low air pressure range, and decreased on account of the decreasing substantial overfeed by increasing air flow with pulling force in high air pressure range. C.R.(2) decreased monotonically in all cases with increasing the air pressure as shown in Fig. 14, but the trend was much slighter than the trend found in S.T. It was inferred that the twist added by an air twister superimposed torsional deformation in reverse of the initial one effectively with keeping the initial bending deformation because the yarn was twisted loosely in relaxed state by overfeed in the second stage. Forward flow gave a lower value of C.R.(2) than backward flow because of the decreasing substantial overfeed mentioned above.

3.4 Residual shrinkage and tensile properties

As shown in Fig. 14, residual shrinkage of the obtained yarn did not show any clear tendency, but was scattered in the range of ca. 2 ~ 3%, which was the same level as that of simply modified yarn without air twister. Some variation of residual shrinkage found in the high air pressure zone might have been affected by the high value of C.C. On the other hand, residual shrinkage of the yarn textured experimentally by a conventional method...
of mechanical twice false-twisting was $5 \sim 6\%$, which was higher than those shown in Fig. 14.

Breaking strength and elongation of the yarn obtained in the present experiments were not shown in this paper, but were little affected by air pressure including zero, and the former was about 30% higher than that of the yarn treated twice by a mechanical spindle according to the conventional method.1)

Through these evaluations of the yarn properties, it was found that the modification with an air twister decreases yarn torque remarkably with keeping other properties unchanged.

3.5 Fabric appearance
Concerning experimental conditions, both the air twister type and the air flow direction had no essential difference on the yarn properties. Considered from the viewpoint of air consumption, backward flow is superior to forward flow and so is type R to type W in twisting function except the unusual case of type R. On the contrary, in fabric appearance of these yarns, backward flow was inferior to forward flow, and so is type R to type W; many strange defects were found on the fabrics except type W with forward flow. There was no clear reason to explain these effects, but both backward flow and forward flow with type R air twister were presumed to disturb fluent yarn proceeding and cause to outbreak irregular parts on the yarn. Therefore only the W type air twister with forward flow was judged useful and this combination was adopted in the following experiments.

3.6 2nd feed ratio
Yarn properties of the obtained yarn were also affected by the feed ratio in the post treating zone. The representative properties were shown in Fig. 15. All of them increased more or less with decreasing feed ratio (increasing overfeed), following the tendency of simply modified yarn which was shown by the points at zero air pressure. But the difference of C.R.(2) between yarns treated with and without air twister became clear at low feed ratio. This trend seemed to be dependent upon the substantial difference in feed ratio produced by the exhaust air flow.

3.7 2nd heater temperature
PET 50D-24F was used to find the effect of the 2nd heater temperature on yarn properties. As shown in Fig. 16, S.T.(1) and S.T.(2) decreased with increasing the air pressure, similarly to the results obtained by PET 150D-30F. The raise of the heater temperature reduced both S.T.(1) and S.T.(2). The difference in S.T. at different heater temperatures widened gradually with increased air pressure for S.T.(1) but was kept almost constant for S.T.(2). Relationship between S.T.(2) and the wale spirality of the tubular fabric knitted from these yarns, evaluated by boiling and 120°C relaxation temperature, was shown in Fig. 17. As seen in the figure, the wale spirality slightly increased with the increase in the relaxation temperature, similarly to Fig. 10. Including this variation, the wale spirality had high correlation to S.T.(2) but the inclination of correlation lines became large as the increase of the 2nd heater temperature. This tendency means that the low mechanical deformation in the post treating zone is enough to reduce the wale spirality at elevated heater temperature.

3.8 Denier of monofilament
Three kinds of PET 50D, constructed from 24, 36 and 48 monofilaments, were used to observe the effects of monofilament denier on S.T.(1) and S.T.(2). As shown in Fig. 18, both S.T.(1) and S.T.(2) had slightly increasing tendency according
to reduction of monofilament denier. In this case also, S.T. decreased according to the twist added in post treating zone as shown in Fig. 19. The figure shows that the finer the monofilament of the yarn, the higher the twist added at the same air pressure. Consequently, the difference of S.T. found among the yarns of various monofilament deniers came from that of facility of twisting. But the effects of monofilament denier on S.T. were so small as to be almost negligible.

3.9 Treating conditions to attain non-torque

As was described above, when the treating conditions in the subsequent processes are given, it is possible to select proper modifying conditions to attain the non-torque yarn. Some of these conditions were given in Fig. 20 i.e. combinations of twist and total yarn denier corresponding to non-torque at S.T.(1), S.T.(2) and wale spirality under ordinary texturing and knitting conditions. When a yarn is fine in total denier or thermal conditions of subsequent processes are severe, a large number of twists is required to make it non-torque. But the twist to be added in post treating zone is far lower in comparison with the twist inserted in the initial false-twisting zone, and is easily attainable by an air twister with low air consumption.
select proper modifying conditions to attain the non-torque yarn.

5) Judging from the appearance of knitted fabric, type W air twister, having an air conduit inclined to the yarn with forward flow of exhaust air, is superior to the other conditions, in spite of the inferior twisting efficiency.

5. Acknowledgement

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エアー加燃装置による仮燃加工系のトルク改良

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仮燃加工系のトルクを低減する方法の一つとして，仮燃機の2段ヒータの出口に空気仮燃子を設け，1段目仮燃方向とは逆方向の仮燃加工を施すことを試みた。得られた加工系のトルクは，空気仮燃子によって加えたトルクと良く対応し，通常の2段加工系に比べて著しく低減された。その他の特性は，巻縮圧縮度の若干の減少を除いてほぼ同等であった。加工系のトルクは，製織，染色工程などにおける取扱条件によって発現状態が変化する。従って汎用性をもったノントルク加工系を得る条件はあり得ないと，取扱条件が明確になればノントルクにすることは可能である。空気仮燃子の構造としては，空気噴入孔が系路に対して直角の場合，あるいは系路から排気が系の走行と逆方向の場合には加減効果は高いが，縫地の外観から見て，噴入孔が傾斜角（60°）をもち，排気が系と同方向の場合が好適であった。