Air-jet texturing of filament feed yarns of different shrinkage potential

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The possibility of feeding filament yarns with different shrinkage potential in air-jet texturing has been studied. Parallel-end air-jet texturing of filament yarns with different shrinkage potential results in decrease of bulk with the increase in shrinkage difference level initially, but then increases with further increase in shrinkage difference. Instability of air-jet textured yarns also first decreases and then increases with the increasing shrinkage difference. The study suggests that shrinkage difference in the feeder yarn is not an effective way to increase the bulk of air-jet textured yarns.

Keywords: Air-jet texturing, Filament feed yarn, Shrinkage potential, Textured yarn

1 Introduction

Techniques of using differential shrinkage for producing bulk in the final yarn and fabric had been used by several researchers and some of these techniques were exploited commercially. High bulk acrylic yarn could be cited as one of the examples. Use of different shrinkage yarns in air-jet texturing has been tried by a few workers. Piller used parallel-end air-jet texturing of different shrinkage potential yarns and reported higher loop frequency, greater cover, and warm and full hand in the resultant yarns after shrinkage. Piller has also reported that it is not only the shrinkage value of feed yarns which decides the shrinkage properties of resultant textured yarns but also the shrinkage force and the shrinkage work. He produced different shrinkage in the modified yarns by varying draw ratio and drawing temperature and obtained a direct relationship between physical bulk and shrinkage force multiplied by the amount of shrinkage. In the present work, a very low shrinkage yarn has been combined with high shrinkage yarns produced by changing the hot-pin temperature alone to study the effect of difference in yarn shrinkage on the resultant air-jet yarn properties.

2 Materials and Methods

2.1 Materials

Two semi-dull partially-oriented polyester yarns of circular cross-section of 125/100 and 126/34 deniers were used for the study. Draw ratios used were 1.564 and 1.632, resulting in drawn yarn deniers of 80/100 and 80/34 respectively. Different shrinkage level yarns for each POY (partially-oriented yarn) were produced by varying the hot-pin temperature on the Eltex AT/HS air texturing machine. Hot-pin temperature was varied from 60°C to 140°C in steps of 20°C to produce 5 yarns of different shrinkage levels. A low shrinkage yarn was produced by drawing POY at 140°C hot-pin temperature and post heat-stabilizing it at 200°C and 15% overfeed.

Parallel-end air-jet textured yarns were produced on Eltex AT/HS air texturing machine. Low shrinkage yarn was fed directly to the texturing zone feed roller, whereas the POY was fed to drawing feed roller where it was drawn at different hot-pin temperatures to induce different shrinkage potential in one of the ends of the two ends fed to the jet. Textured yarns were then post heat-stabilized sequentially on the machine. All textured yarns were heat-stabilized at constant tension. Following air-jet texturing parameters were kept at constant level:

- Overfeed to the air-jet: 25%
- Texturing nozzle type: HemaJet with T310 core
- Water application: 1 litre/h at 1 bar water pressure
- Winding underfeed: 0.7 %
- Air pressure: 9 bar
- Mechanical stretch: 4.7 %
- Stabilizing temperature: 200°C
- Winding tension: 4 cN
- Winding speed: 300 m/min

In case of both POYs, an assembled yarn package having low shrinkage and drawn yarn was also produced for measurement of bulk and % increase in linear density and is referred to as the parent yarn sample.
2.2 Yarn Shrinkage

All drawn yarn series and low-shrinkage yarns were tested for hot-air shrinkage of single yarn as per the ASTM Test Method D5104-90 (ref. 5). From the conditioned yarn package, a 120 yd skein was prepared on a hand driven wrap reel. From this, 5 yarns of approx. 70 cm length were cut at random. These cut lengths were clamped from the top of vertical measuring stand and a load of 0.1 gf/den was applied to the other end. Two marks (50 cm apart) were then made on the suspended yarn. All such five yarns were then grouped together by fixing a Teflon tape at their tips and were placed in a relaxed state in a hot-air oven maintained at 120 ± 2°C for 30 min. These were then allowed to cool down under laboratory atmospheric conditions. The distance between the two marked points was measured under the same load of 0.1 gf/den and recorded as L. Shrinkage in yarn was calculated as follows:

\[
\text{Shrinkage (\%)} = \frac{50 - L}{50} \times 100
\]

2.3 Tensile Properties

Tensile properties of all textured yarns were measured in accordance with the ASTM Test Method D2256-95a (ref. 6). Instron (Model 4301) tensile testing machine working on CRE principle and fitted with pneumatic jaws and a load cell of 1 kgf was used. All measurements were made in a straight configuration of the specimen at 250±3 mm gauge length with a pretension of 0.06 gf/den. Jaw speed of 300 mm/min was used. Ten readings per sample were used to obtain the averages of tensile properties.

2.4 Physical Bulk

Physical bulk of air-jet textured yarns was measured using the modified Du Pont method suggested by Sengupta et al.7. Cylindrical package was wound under a fixed tension level of 4 cN at a speed of 300 m/min for 30 min. Physical bulk of the textured yarn was calculated as follows:

\[
\text{Physical bulk (\%)} = \frac{\text{Density of parent yarn package}}{\text{Density of textured yarn package}} \times 100
\]

2.5 Instability

A method suggested by Du Pont8 was used for the instability measurement of air-jet textured yarns. A basic load of 0.01 gf/den was applied to the yarn and a mark was made at 100 cm distance from the clamp. Yarn was then subjected to a load of 0.5 gf/den for 30 s. The permanent extension in the length of the yarn, measured 30 s after the heavy load has been removed, was taken as a measure of instability. Ten readings were taken from a sample package to estimate instability and between each successive readings nearly 5 m yarn was unwound from the package and discarded.

2.6 Yarn Count

Skeins were prepared on a motorized wrap reel of 1 m girth. Five skeins of 100 m each were prepared from each package and weighed on an electronic balance capable of measuring to an accuracy of 1 mg. The yarn denier was calculated as follows:

\[
\text{Yarn denier} = \frac{\text{Weight of 100 m skein in grams}}{100} \times 9000
\]

3 Results and Discussion

3.1 Relationship between Hot-Pin Temperature and Shrinkage

Fig. 1 shows the effect of hot-pin temperature on the hot-air shrinkage of drawn POY yarns. Shrinkage decreases with the increase in drawing temperature in a non-linear fashion. As the drawing temperature is increased there is an increased mobility of molecular chains, helping them in orienting in the direction of draw. Increased orientation increases the crystallinity by better packing of molecular chains in their most thermally stable positions. Shrinkage, which is due to
the rearrangement of molecular chains into new thermodynamically favourable configurations when an external heat is applied, is prevented by the increased crystallinity at higher drawing temperatures. The only shrinkage is due to the relaxation of residual strain in the molecular chains where the thermally-induced crystallisation has failed to take place. Similar results were also obtained by Piller and Sengupta et al.

3.2 Relationship between Hot-Air Shrinkage and Properties of Air-Jet Textured Yarns

Table 1 shows the properties of parallel-end air-jet textured yarns produced from POY of 126/34 and 125/100 deniers at constant winding tension. It has been shown earlier that as the shrinkage increases (reducing drawing temperature), the flexural rigidity of filaments decreases due to the less compact molecular structure of filaments. This lowering of flexural rigidity should help in better loop formation due to easy bending of filaments as they emerge out of the nozzle. This is supported by the findings of other researchers which show a lower loop size, lower yarn core and overall diameter, higher loop frequency and higher physical bulk for yarns having filaments of lower flexural rigidity.

Increasing yarn shrinkage potential in feed yarns would have the following effects on air-jet textured yarn produced at constant winding tension:

- Decreasing the flexural rigidity of drawn feed yarn.
- Increasing the overfeed in the stabilizing zone to compensate for increased tension due to higher shrinkage.
- Decreasing the loop size and compacting the yarn structure due to shrinkage in individual filaments.
- Bulging out of low shrinkage potential filaments under the action of shrinkage forces in the shrinkable component.

The net effect on the yarn properties depends on the relative dominance of each of the above factors at a given shrinkage value. Since the overall effect on the properties of the resultant air-jet textured yarns depends on the interaction between the two components of the feed yarn, all the results would be discussed with respect to the shrinkage difference in the feed yarns entering the jet.

Fig. 2 shows the effect of shrinkage difference in the feed yarn on the physical bulk. It is observed that the physical bulk increases after a initial drop with the increase in shrinkage difference. Initially, as the shrinkage difference increases the compaction due to the shrinkage of one of the ends, it has more effect counteracting the effect of smaller loops due to lower flexural rigidity filaments of one of the ends and reduction in loop size due to its shrinkage. The net effect of these two factors is the decrease in physical bulk. This decrease in bulk continues till the increase in bulk due to smaller loops and greater disorienting effect in the yarn matrix, making the core open, and bulging out of low shrinkage yarns start to have over-riding effect over the factors causing a reduction in bulk. Thus, bulk increases after a certain shrinkage value, due to opening of the yarn structure and bulging out of the low shrinkage component. The way by

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<th>Table 1—Properties of air-jet differential shrinkage yarns produced from POY of 126/34 and 125/100 deniers</th>
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<td>Drawing temperature</td>
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<td><strong>Yarns made from 126/34 denier POY</strong></td>
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which the bulk increases after reaching a minimum is unable to yield higher physical bulk than the lowest shrinkage difference yarn in present range of shrinkage values.

Fig. 3 shows the effect of shrinkage difference in feed yarn on instability. Initially, the increase in shrinkage difference makes the yarn core compact, resulting in reduction in instability. But after a certain value of shrinkage difference, the internal disorientation of the yarn matrix and bulging out of the filaments of low shrinkage yarn start to contribute in instability through reduction in the compactness of the structure.

Linear density increases with the increasing shrinkage difference due to increasing overfeed in the heat-stabilizing zone in order to keep the yarn tension constant, as the yarn shrinkage increases. There is a drop in tenacity with increasing shrinkage difference. This is probably due to (i) increasing linear density, (ii) increasing disorientation in the yarn matrix, and (iii) decreasing tenacity of the drawn yarn of one of the ends. Elongation increases with shrinkage difference after the initial drop. This is due to more instable structure obtained at higher shrinkage difference levels. There is an initial drop, except for 125/100 denier POY, which is due to initial compacting of yarn structure on shrinkage, resulting in greater interlocking between the filaments.

The present study is confined to the effect of shrinkage difference between the feed yarns on the properties of resultant air-jet textured yarns. The shrinkage in filament sections forming the loops and that in the core would be different as they would be under different levels of tension and the microstructure of these sections would change differently depending on whether it is free shrinkage or shrinkage under tension. The level of tension developed in different sections in the core will vary considerably during the shrinkage process. These effects would be important in further understanding of the mechanical behaviour of air-jet textured yarns.

3.3 Effect of Number of Filaments on Yarn Properties

It may be seen from Figs 2 and 3 that the yarn made from 125/100 denier POY, though having a high number of low denier filaments which is advantageous in air-jet texturing, shows inferior results compared to yarn produced from 126/34 denier POY.

Yarn from 125/100 denier POY results in a large number of smaller size loops at greater frequency and a compact core. Lower flexural rigidity of finer filaments leads to lower bulk levels. Compact core structure also results in lower effect of increasing shrinkage difference of the two components of feed yarns.

At lower range of shrinkage difference, the yarn from POY of 125/100 denier shows a higher instability due to a greater disorientation in the filaments of
lower flexural rigidity. At higher shrinkage difference, the greater filament entanglement and higher inter-filament friction due to more specific surface leads to lower instability of finer denier air-jet textured filament yarns.

Tenacity is lower and elongation is higher in yarns made from 125/100 denier POY due to greater obliquity in the yarn structure as compared to the yarns made from 126/34 denier POY, as the finer filaments of lower flexural rigidity lead to greater filament disorientation and entanglement in the texturing process.

4 Conclusions

Shrinkage potential in drawn yarns decreases as the drawing temperature increases. Bulk and instability first decrease and then increase with the increase in shrinkage difference between the two ends of feed yarns to air-jet texturing machine.

References