Air-jet texturing of twisted filament yarns using new jets: Part I—Influence of twist levels and direction of twist on the properties of air-jet textured yarns

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Studies conducted on the effectiveness of new air texturing jets (HemaJet T100 and Taslan XX) in opening up and bulking twisted filament yarns show that these jets are able to texture continuous filament yarns twisted in both Z and S directions. While the physical bulk of the textured yarn made from pre-twisted feeder yarn is lower than that of the textured yarn made from zero twist feeder yarn, the former has a more stable structure. An increase in twist density in the feeder yarn reduces bulk but enhances stability and tenacity of the textured yarns. The direction of twist in the feeder yarn has no effect on texturability.

Keywords: Air-jet texturing, Textured yarn properties, Twist direction, Twist level

1 Introduction
Air-jet texturing is a pneumo-mechanical bulking process in which a bundle of multifilament yarn is overfed into a nozzle and subjected to an air stream, entering the nozzle at high pressure, to form loops in the individual filaments comprising the yarn as well as to criss-cross and entangle the filaments so that a structurally stable bulked yarn with spun-like aesthetics is obtained. Pre-twisted supply yarns were used with the earlier versions of jet designs to impart the stability needed for these textured structures. However, with the evolution of improved jet designs, the process became suitable for zero twist supply yarns. Thus, the earlier attempts to texture pre-twisted supply yarns were mainly restricted to Taslan type IX and type X jets. Wray and coworkers1-7 and Sen8 made use of a Taslan type IX jet in their investigations. Wray and Entwistle3 suggested that the positioning of the feed needle should depend on the direction of twist in the supply yarn for the satisfactory texturing of pre-twisted yarns. They further suggested4 a modification of the Taslan type IX jet in which either one of the two halves of a good fit moulded plug was used for processing a particular direction of parent yarn twist. Rozmarynowska and Godek9 used a device fitted to winding machines and an air-jet of their own design to study the effect of processing variables on Z and S twisted supply yarns. Sivakumar10 used a type X jet while investigating the mechanism of air-jet texturing using pre-twisted multifilament yarns. However, since then no attempt has been made to process pre-twisted feeder yarns in the later versions of different jets. Attempts to bulk spun yarns in air-jet texturing by the present authors revealed that the new jets have an untwisting action on the yarn11-13 and this rekindled the interest for investigating the behaviour of pre-twisted feeder yarns using the newer versions of both the conically convergent-divergent and cylindrical types of air-jet texturing nozzles. In the present work, Z twisted, S twisted and zero twist filament feeder yarns have been textured using new air-jet texturing nozzles and the properties of resultant textured yarns have been compared.

2 Materials and Methods
Polyester multifilament yarn of 53 den/27 fil. was used. Twisted samples were prepared from this yarn on a ring frame with twist levels of 5, 10, 15, 20 and 25 tpi in both Z and S directions. Z twisted yarns, S twisted yarns and yarns with no twist, hereafter referred to as ZT, ST and NT yarns respectively, were textured on Eltex AT/HS air-jet texturing machine using the following texturing conditions:

- Overfeed to jet: 33.3%
- Air pressure: 9 kg/cm²
- Texturing speed: 300 m/min
- Amount of water per jet: 1 litre/h
- Water pressure: 2 kg/cm²
- Stabilization stretch: 4.7%
- Stabilization heater temperature: 200°C
- Winding underfeed: 0.7%
HemaJet type LB-02 with T100 core and Du Pont's Taslan XX jet were used in this study. They represent new types of texturing jets in the two basic classes, viz. the radial cylindrical and the coaxial conically convergent-divergent texturing jets used in the industry.

Yarn tension in the delivery and stabilizing zones of texturing were measured with Rothschild tensiometer. The probes were fixed on the machine frame in the delivery and stabilizing zones of texturing. Tension levels were measured for 2 min in each zone and the measured signals were fed into a computing multimeter to get the average tension values.

Textured yarn instability and physical bulk were measured using the Du Pont's test methods. Tensile properties were tested on an Instron tensile tester using 100 mm gauge length and 50 mm/min cross-head speed. The structural parameters of air-jet textured yarns, such as frequency of loops and their configurations were measured using the method suggested by us earlier. Instability of air-jet textured yarns was also measured by the method suggested by us earlier which is based on cyclic load testing on an Instron tensile tester and instability in this method is referred to as percentage decay.

Creep and delayed recovery studies were made on 1 m long samples using a load of 0.33 gf/den, the load used for the instability measurements of air-jet textured yarns in the Du Pont's method. The samples were mechanically conditioned before these measurements by applying a load of 0.33 gf/den for 3 h followed by a recovery period of 21 h and repeating this loading/unloading cycle till the recovery was complete and reproducible extension was obtained. This mechanical conditioning treatment has two important effects on the creep and recovery behaviour of the yarn samples: (i) the subsequent creep and recovery responses under a given load are identical after mechanical conditioning, i.e. the sample loses its long-term memory and remembers only the loads applied in its immediate past history, and (ii) after conditioning, the deformation induced by any loading programme is completely recoverable during the recovery cycle.

The creep strain was recorded by subjecting the samples to the load of 0.33 gf/den for 3 h and the samples were allowed to recover for 21 h to record the recovered strain. The relative delayed extension after 3 h was taken as the total extension after 3 h minus the value of the total extension corresponding to a time of 1 min. The delayed recovery after 21 h was also calculated by taking the total recovery after 21 h minus the value of the total recovery corresponding to a time of 1 min. Fig. 1 illustrates the creep and creep recovery studies schematically. Referring to Fig. 1, the calculations for arriving at these properties are as given below:

| Specimen length | = 'ab' measured under a load of 0.01 gf/den |
| Load applied | = 0.33 gf/den |
| Elongation after 1 min | = 'bc' |
| Elongation after 3 h | = 'bd' |
| Creep strain after 3 h | = cd/ab x 100% |
| Recovery under a load of 0.01 gf/den | |
| Recovery after 1 min | = 'de' |
| Recovery after 21 h | = 'df' |
| Delayed recovery after 21 h | = ef/ab x 100% |

An apparatus used for the instability measurements of air-jet textured yarns was used for creep and creep recovery studies. This apparatus consists of a 5 ft tall wooden board fixed in an upright position on a wall and has spring clamps on the top to mount the specimens. A marking notch is fixed at 1 m interval from the top clamp and loads are applied to the free end of the yarn samples by a hook tied to it. The sample deformation is measured using a travelling microscope having a least count of 0.01 mm.

3 Results and Discussion

Table 1 shows the parent yarn tenacity and breaking extension at various twist levels. Table 2 shows the tension levels observed in the delivery and stabilizing zones for both pre-twisted and zero twist yarns textured using HemaJet T100 and Taslan XX nozzles in both wet and dry conditions. Tension levels at the delivery zone of the air-jet texturing nozzles provide a good idea about the extent of texturing and the tensions at the stabilizing zone indicate the
effectiveness of texturing in terms of the stability of the yarn produced. It is observed from Table 2 that the tension levels in the wet state are higher than those in the dry state. This is because of the reduced inter-filament friction and better filament separation by the lubricating effect of water. In comparison to the zero twist yarn, the twisted yarns show reduced tension levels in the delivery zone and increased tension levels in the stabilizing zone of the jets. This implies that the pre-twisted yarns are not as responsive as the zero twist yarns in loop formation but produce textured yarns with higher structural integrity. Thus, it may be concluded that the twist in the multifilament yarn aids in the stability of the structure at the expense of the frequency of loop formation to some extent.

Table 3 shows a comparison of physical bulk, instability, mechanical properties and structural properties of ZT, ST and NT yarns textured with HemaJet T100 core and Taslan XX jet nozzles. As compared to the NT yarns, the ZT and ST yarns give lower physical bulk levels which can be attributed to the distribution of texturing time in the jet nozzle for opening up of the twist and separation of filaments in the twisted yarns as compared to only separation of filaments in zero twist yarns. With the increasing level of twist, the physical bulk of the twisted textured yarns is reduced. Increased twist level in the multifilament yarn has a somewhat similar effect to that of increased speed during texturing as more is the time needed for opening up of the twist, the less is the time available for loop formation in individual filaments. The twisted textured yarns give lesser instability than the zero twist textured yarns and higher twist in the yarn results in further lowering of instability. This can be ascertained from the fact that both the method of instability measurement, viz. Du Pont's method and % Decay method, give reduced instability with increased twist levels, confirming the role played by the twist in imparting higher structural integrity to the textured yarn structure.

It is observed from Table 3 that the reduced physical bulk of twisted yarns at higher twist levels is accompanied with increased tenacity and breaking elongation. The attractive features of the twisted textured yarns are that the tenacity and breaking elongation.
### Table 3—Influence of twist level on air-jet textured yarn properties

<table>
<thead>
<tr>
<th>Jet type</th>
<th>Twist level</th>
<th>Physical bulk, %</th>
<th>Instability, %</th>
<th>Mechanical properties</th>
<th>Structural properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tpi</td>
<td>ZT</td>
<td>NT</td>
<td>ST</td>
<td>ZT</td>
</tr>
<tr>
<td>HemaJet</td>
<td>T100</td>
<td>0</td>
<td>190</td>
<td>2.70</td>
<td>37.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>154</td>
<td>155</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>146</td>
<td>147</td>
<td>1.40</td>
</tr>
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<td></td>
<td></td>
<td>15</td>
<td>139</td>
<td>140</td>
<td>1.30</td>
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<td></td>
<td></td>
<td>20</td>
<td>132</td>
<td>132</td>
<td>1.15</td>
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<td></td>
<td></td>
<td>25</td>
<td>126</td>
<td>126</td>
<td>1.00</td>
</tr>
<tr>
<td>Taslan</td>
<td>XX</td>
<td>0</td>
<td>189</td>
<td>2.80</td>
<td>38.2</td>
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<tr>
<td></td>
<td></td>
<td>5</td>
<td>154</td>
<td>153</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>139</td>
<td>139</td>
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<td>20</td>
<td>131</td>
<td>132</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>125</td>
<td>126</td>
<td>1.00</td>
</tr>
</tbody>
</table>

ZT—Z twisted yarn; ST—S twisted yarn; and NT—Zero twist yarn.
elongation of these yarns are higher than those of the zero twist textured yarns. These yarns, hence, may be of particular value for applications where moderate bulk but high strength and stability are required.

The creep and delayed recovery test results show that the twisted textured yarns show lesser creep strain and higher recovered strain than the zero twist textured yarns obtained from both wet and dry texturing conditions. Increase in twist in the yarn results in reduced creep strain and higher recovered strain and at high twist level, the yarns tend to complete recovery of the overall creep strain in wet texturing conditions. These results indicate that the twist in the textured yarns improves their structural integrity and aids in attaining a stable loop structure.

The structural properties of the twisted yarns show that these yarns have reduced core diameter, loop size and loop frequency after texturing in both wet and dry conditions. Increased twist level results in reduction of these structural parameters. Thus, the twist in the multifilament yarn helps in attaining a more compact textured yarn structure with reduced ‘velcro’ effect though the number of loops formed is reduced in comparison to the zero twist yarns.

4 Conclusions
The new air texturing jets are effective in bulking pre-twisted continuous filament yarns. Pre-twisting of filament yarns results in lower tension levels in the delivery zone but higher tension levels in the stabilizing zone than what is observed with zero twist filament yarns during air-jet texturing. This signifies that though the extent of texturing is less for twisted yarns, yarns produced have higher structural stability. The twisted textured filament yarns result in higher tenacity and stability of the textured configuration at the expense of some reduction in the extent of bulking. Lower creep strain and higher recovered strain are observed in the case of twisted textured filament yarns as compared to zero twist textured filament yarns. The twisted filament yarns give rise to a more compact textured yarn structure with reduced core diameter, loop size and loop frequency which will result in reduced ‘velcro’ effect for these yarns. The twist in the textured yarn, in general, enhances stability and tenacity and improves creep behaviour at the cost of a moderate reduction in bulk.

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References
1 Wray G R, Bulk, stretch and texture, edited by P W Harrison (The Textile Institute, Manchester, UK) 1966, 18.
9 Rozmarynowska K & Godek J, Bulk, stretch and texture, edited by P W Harrison (The Textile Institute, Manchester, UK) 1966, 39.