Studies on Structure and Properties of Low Twist Wet Spun Cotton Yarns

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The structure and properties of low twist wet spun cotton yarns have been studied and compared with those of normal ring spun yarns. It is observed that even at a low twist level, wet spinning produces a much stronger yarn than ring spinning. The strength is further enhanced on dewaxing followed by swelling in sodium hydroxide. The packing and clustering of wet spun yarns are considerably higher and the yarns exhibit poorer migration. The rate of strength loss on abrasion is higher for wet spun yarns compared to normal yarns, signifying poorer abrasion resistance of wet spun yarns.

Low twist spinning is a technology developed by the Ahmedabad Textile Industry's Research Association in which a thoroughly wetted cotton roving is spun on a conventional ring frame. With this system, yarn strength considerably higher than that obtainable with normal spinning is achieved at much lower twist levels.

In the present investigation, the structure and properties of low twist yarns have been studied and compared with those of normal ring spun yarns.

Materials and Methods

A roving of 2.5 hank (236.2 tex) was prepared with 1.17 twist multiplier from 320 F (Indian) saw ginned cotton. The particulars of the cotton are: Staple length, 27/32 in; and fineness, 4.7 µ g/in (0.18 tex).

Production of normal and wet spun yarns - All yarns were spun to a nominal count of 24 cotton (24.6 tex) on a ring frame. For normal yarns, SKF-PK211 drafting system was used and the twist multiplier employed was 4.5. For wet spun yarns, the drafting system was modified to have only the front and back pairs of rollers with a setting of 76 mm between the nips. The roving, prewetted in water, was again passed through a trough of water before drafting. A twist multiplier of 2.88 was used for all wet spun yarns. ‘C’ shaped travellers of 8 and 2 numbers were used for wet spun and normal spun yarns respectively.

Treatment of roving prior to and during spinning - Several treatments were given to the roving to study their effects on yarn properties. The treatments may be summarized as follows:

1. The roving in loose form was prewetted in water for 72 hr and wet spun.
2. The roving in loose form was dewaxed for 4 hr in a soxhlet apparatus by extraction with petroleum ether, wetted in water for 72 hr and wet spun.
3. The dewaxed roving was soaked in 5% sodium hydroxide at room temperature for 48 hr, washed well with water, neutralized with 0.1% acetic acid, washed well with water again and wet spun.
4. The roving was wetted in methanol for 24 hr and spun by again passing it through methanol.

Yarn conditioning - Bobbins of wet spun yarns were first dried at 70°C for more than 4 hr in a hot air chamber and then conditioned for one week under standard atmosphere before testing. All the tests were performed at 65 ± 2% RH and 20 ± 2°C.

Results and Discussion

Data in respect of mechanical and geometrical properties of yarns are presented in Table 1.

Breaking strength - It is seen from Table 1 that wet spun yarns have considerably higher strength than the normal spun yarns. The strength increases with dewaxing, and swelling with sodium hydroxide following dewaxing enhances the strength still further.

Role of water in wet spinning - The increase in strength through wet spinning even at a considerably lower twist level suggests a key role for water in the structural regulation of these yarns. Swelling in sodium hydroxide and increasing the
Table 1 - Properties of Dry (Normal) and Wet Spun Yarns

<table>
<thead>
<tr>
<th>Processing conditions</th>
<th>Twist/in Tex of yarn</th>
<th>Uster single yarn strength g/tex</th>
<th>Uster elongation %</th>
<th>Packing coeff</th>
<th>Specific flexural rigidity (g cm²/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal spun</td>
<td>22.2</td>
<td>23.7</td>
<td>12.4</td>
<td>6.1</td>
<td>0.57</td>
</tr>
<tr>
<td>Grey wet spun</td>
<td>11.65</td>
<td>23.3</td>
<td>18.3</td>
<td>2.8</td>
<td>0.69</td>
</tr>
<tr>
<td>Dewaxed and wet spun</td>
<td>11.83</td>
<td>23.3</td>
<td>19.6</td>
<td>3.4</td>
<td>0.88</td>
</tr>
<tr>
<td>Dewaxed, NaOH treated and wet spun</td>
<td>11.03</td>
<td>24.4</td>
<td>22.4</td>
<td>3.3</td>
<td>0.88</td>
</tr>
</tbody>
</table>

frictional resistance between fibres by wax removal also contribute, but the contributions of these factors are relatively less compared to the part played by water. When methanol is used in place of water, the yarn strength drops considerably, resulting in a strength of 6.1 g/tex as against 18.3 g/tex for grey wet spun yarn. It is, thus, evident that water used during drafting and spinning is the most important factor contributing to such high strength for wet spun yarns.

A probable explanation for the high strength of wet spun yarns is as follows. The wet spun yarn is spun in a complete wet state of the fibres when they are more pliable and are under very high drafting and spinning tensions. The higher drafting tension is due to greater adhesion of fibres in the roving caused by swelling of fibres in the wet state and high tension at the fibre-water interface. This tension facilitates the straightening of fibres and offers a more positive control on fibres in the drafting zone. The drafted material is, therefore, brought to the point of yarn formation under high tension and in straightened condition. In the spinning zone, the tension in the yarn is further enhanced due to the use of the heavy traveller, which is necessary to restrict the ballooning of the heavy wet yarn. Due to these high tensions, the component fibres of the yarn come much closer to one another, consequently increasing the clustering and surface contact between fibres.

Packing coefficient and specific flexural rigidity - The packing coefficients of the yarns, as calculated from their diameters, provide evidence of better packing of the fibres in the wet spun yarns. Packing of the fibres is considerably enhanced in the case of dewaxed, sodium hydroxide-treated roving.

Indirect evidence of packing and clustering of fibres in a yarn is obtained from the data on specific flexural rigidity. Since an individual fibre cannot resist high bending stresses; high flexural rigidity generally signifies a high degree of clustering.

In the present study, the flexural rigidity of the yarn shows positive evidence of very high clustering of fibres in wet spun yarns. The specific flexural rigidity of wet spun yarn is observed to be 40-50 times higher than that of the normal yarn. Due to the favourable influence of water in wet spinning, the fibres adhere to one another to produce a high degree of clustering and consequently the strength as well as the flexural rigidity are both higher than for normal yarns.

Elongation at break - In the wet spun yarns, the elongation at break is approximately half of that for the normal yarn. Due to higher cohesion between fibres in wet spun yarns, the contribution of fibre slippage to yarn elongation is expected to be much lower than in the case of normal yarns. Moreover, due to higher tension in the processing of wet spun yarns, the fibres are already in a highly strained condition; hence, yarn elongation at break is greatly reduced.

Fibre migration in the yarns - The tracer fibre technique of Morton² was employed to determine the coefficient of migration for normal and grey wet spun yarns. These studies present an interesting feature of structural geometry for wet spun yarns. The value of the coefficient of migration obtained is 0.1781 for normal spun yarn and 0.1366 for wet spun yarn. It is, thus, observed that in the case of grey wet spun yarn, the migration is relatively inhibited and the fibres tend to follow the path of coaxial helices.

The effect of spinning tension on migration was studied by Hearle and Merchant³, who developed a theoretical value of tension which would be needed to stop migration. Experiments on staple fibre yarns conducted by Hearle and Gupta⁴ showed that the effect of twisting tension on the migration
Abrasion resistance of yarns- The abrasion resistance of the yarns was tested on a specially fabricated instrument similar in design to the one used by Faasen and Van Harten. This study was done with two objects in mind: (1) to study the effect of abrasion on yarn strength, and (2) to confirm the validity of the argument that wet spun yarn structure tends more towards the coaxial helix model. Considering the much higher levels of breaking stresses of wet spun yarns, if these were to behave in a similar fashion as conventional yarns in their resistance to abrasion during weaving, there appears to be a distinct possibility of their being used as warp yarns without sizing. On the other hand, if the surface fibres were to remain on the surface, as in a coaxial helix model, they would easily come off from the body of the yarn during abrasion because of inadequate anchorage of these fibres to the yarn matrix.

The values of residual strength obtained on Instron after a certain number of abrasion cycles show an interesting trend (Fig.1) and support the idea that the wet spun yarn tends towards a coaxial helix structure.

References