PHYSICAL CHARACTERISTICS OF COTTON/POLYESTER CORE SPUN YARN MADE USING RING AND AIR-JET SYSTEMS

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Abstract:
The manufacture of core yarn from polyester-cotton is one of the most important developments in the textile industry. The use of core yarns is mainly aimed at improving the strength, comfort, durability, aesthetics, and other functional properties of the final yarn. This article reports the results of investigation of core spun yarns made from polyester filament as core and cotton as sheath material manufactured using both ring and air-jet spinning systems. Polyester filaments with different proportions were chosen for the core component and cotton was used as the sheath. A total of twelve different core yarns were made on different spinning systems (i.e. six on air-jet and six on ring frame systems) and the yarn properties were compared with those of 100% cotton ring-spun yarn. It was observed that core yarns had improved physical properties compared to 100% cotton ring-spun yarn in many respects such as yarn strength, elongation, energy to break, and yarn imperfections. Only air-jet core yarn showed lower yarn strength than 100% cotton yarn but the same yarn excelled in other properties compared to 100% cotton yarn.

Key words:
Air-jet, cotton, polyester, ring frame, SEM, yarn

1. Introduction
Core yarn structure consists of two components: one forms the central axis or core of the yarn and the other is the covering part, better known as the sheath. Continuous multifilament yarn is generally used as a core while cotton staple fibres are used to cover the filaments.

Core spun yarn shows some improved characteristics over 100% cotton yarn or 100% filament yarns. Core spun yarn was preferred to blended staple spun yarn in terms of strength and comfort [1,2]. Phenomenal improvements in durability and aesthetic properties were observed in core spun yarn [3,4] compared to cotton spun yarn. As the cotton was wrapped over polyester filament, improvements were observed in yarn properties like moisture absorption, heat resistance, air permeability, and depth of shade in dyeing [5] compared to synthetic yarns. The tensile strength of yarn was increased by the presence of polyester filament at the core, which was the main load carrier when we compared it with cotton yarn.

It was also observed that 100% cotton yarn showed lower strength after application of chemical finishes. Research was therefore planned to develop and produce strong, predominately cotton covered yarn which may be combined with different chemical finishes without any difficulties [6,7] as and when required. The research is therefore devoted to developing a cotton rich, high strength filament core yarn with sufficient cotton on the outer surface [8,9].

2. Material and methods
The raw materials selected for the core are described below.

2.1. Filaments used at the core
i) 30 den./24 filaments drawn polyester
ii) 30 den./24 filaments crimped polyester
iii) 44 den./36 filaments drawn polyester
iv) 44 den./36 filaments crimped polyester
v) 70 den./36 filaments drawn polyester
vi) 70 den./36 filaments crimped polyester

The properties of synthetic core polyester yarns are shown in Table 1.

2.2. Cotton fibre covering
The cotton fibre used for covering the core synthetic had the following properties:
a) 2.5% span length 33.5 mm
b) Strength 28 gram/tex
c) UR% 48
d) Mic. 4.2

Table 1. The properties of filaments.

<table>
<thead>
<tr>
<th>Description</th>
<th>30/24D</th>
<th>44/36D</th>
<th>70/36D</th>
<th>30/24CR</th>
<th>44/36CR</th>
<th>70/36CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenacity (gpd)</td>
<td>3.25</td>
<td>3.31</td>
<td>3.34</td>
<td>3.30</td>
<td>3.32</td>
<td>3.35</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>21.69</td>
<td>22.9</td>
<td>33.57</td>
<td>23.50</td>
<td>27.64</td>
<td>34.57</td>
</tr>
<tr>
<td>Energy to break</td>
<td>276.70</td>
<td>547.10</td>
<td>957.00</td>
<td>383.70</td>
<td>550.10</td>
<td>1185.00</td>
</tr>
<tr>
<td>Initial Modulus (gf/cm)</td>
<td>21.73</td>
<td>30.08</td>
<td>10.50</td>
<td>22.83</td>
<td>33.05</td>
<td>12.20</td>
</tr>
</tbody>
</table>
### 2.3. Preparation of yarn

Using a conventional ring spinning process, core yarns were prepared on a ring frame by passing polyester filament yarn through the front roller nip of a ring frame [10,11] and roving through the drafting zone of the ring frame as shown in Fig. 1. The roving was prepared by passing the fibres through the modern blow room, carding machine, modern combers, draw frame, and speed frame. A total of six different types of core yarns were prepared on the ring frame under ideal conditions by varying the core–sheath ratio. Using the same core–sheath ratio, six core yarns were also prepared [12] on a Murata Air-Jet Spinner MJS802 as shown in Fig. 2. Using the same cotton sliver at the back of the main drafting zone and polyester filament passing through the front drafting roller, 30sNe core yarns were prepared. Parameters such as drafts and denier of polyester core yarns were varied. The twist multiplier and other spinning process parameters were kept unchanged throughout all the yarn manufacturing processes.

### 2.4. Yarn quality evaluation

#### 2.4.1. Breaking strength and extension

The breaking strength and extension of the yarn samples were measured on an Instron tensile tester using the standard procedures in accordance with ASTM D 2256.

#### 2.4.2. Unevenness and imperfections

Measurements of yarn unevenness and imperfections were taken using an Uster-4. The yarn irregularity in terms of U% and the imperfections in terms of thick places, thin places, and nepes were evaluated.

#### 2.4.3. Yarn count and count strength product

Yarn count was measured with the help of wrap reel and count strength product by using a good brand of lea strength tester. Twenty (20) readings per sample were taken to get the average value.

#### 2.4.4. Core yarn initial modulus and core yarn energy to break

The core yarn initial modulus and core yarn energy to break of different core yarns were tested on an Instron machine.

#### 2.4.5. Scanning electron microscopy (SEM) photographs

Cross-sectional views of 2/30 Ne yarns were observed under a scanning electron microscope (SEM) and photographs were taken. The photographs were evaluated using computer aided software. The perimeters of photographs covered by cotton as well as covered by polyester were measured. Then percentage perimeters covered by cotton were calculated and compared.

### 3. Results and discussion

#### 3.1. Count strength product

The lea strengths of different core yarns were tested on an electronic lea strength testing machine. From the results it was observed that introducing a very minor amount of filament (15%, 30 den.) at the core reduced the CSP value of the ring yarn by about 15-17% compared to 100% cotton yarn. Thereafter it was seen that a further increase in filaments at the core by about 25-40% caused the CSP values to increase significantly, compared to 100% cotton yarn, by about 29-31% when 44 den. was used and 31-36% when 70 den. yarn was used at the core. This was because of simple elongation of filament yarn at the initial state of loading of the yarn, and the complete load was shared by the cotton at the sheath, which was broken very fast, and therefore made the yarn weak. With the further increase in filament denier at the core and fewer cotton fibres at the sheath, the maximum load was shared by the straight synthetic filaments which were stronger than the cotton, and therefore the strength was increased compared to the cotton yarn.

If we compare the CSP values of drawn and crimped core yarn, no significant difference was observed.

It was also observed that the CSP values of air-jet core yarns made from polyester core yarns were all weaker than those of 100% cotton yarn. This was because of low binding forces between the fibres due to false twisting, generally used in the spinning process. In air-jet yarns it was seen that when we increased the denier of drawn yarns from 30 den. to 70 den. the core yarn showed between 29 and 14% lower strength than 100% cotton yarn. With crimped core filaments, the strength was between 25 and 11% lower when we changed the denier from 30 den. to 70 den.
3.2 Single yarn strength

From the results it was observed that when 15% (30 den.) filaments were introduced at the core, yarn strength was reduced by about 15 to 17% for ring core yarn in both drawn and crimped yarns compared to 100% cotton yarn strength. When the percentage of filament was 25% (44 den.) there was absolutely no gain or loss in strength for both drawn and crimped yarns compared to 100% cotton yarn. When the percentage of filaments was nearly 40% (using 70 den.) then the strength of core yarn was increased for both drawn and crimped yarns by about 43% compared to 100% cotton yarn, which is clearly seen from Fig. 4.

It was observed that ring-core yarns always showed 15–33% greater single yarn strength than air-jet core yarn. It was also clear that as the percentage of polyester was increased at the core, whether by crimped or drawn filaments, the strength increased in proportion to the increase in denier at the core.

It was observed that in the case of 30 den. air-jet core yarn, the strength fell to 50% compared to 100% cotton ring-spun yarn strength, which was considered a major setback for the introduction of only 15% filament at the core compared to 100% cotton ring-spun yarn. When we increased the filament percentage at the core, the difference was gradually reduced: with 25% filament at the core the strength difference was about 25% and with 40% filament at the core the strength difference was reduced to 7%, which may not be considered significant.

3.4. Core yarn energy to break

Energy to break of different core yarns was tested on an Instron machine. From the results shown in Fig. 6 it was observed that when the percentage of filaments (polyester) was only 15% at the core no significant differences were observed in energy to break compared to 100% spun cotton yarn. When the percentage of filaments at the core was increased by 25%, (44 den.) there was a drastic increase in the energy to break, which was observed to be 107–125% for ring core yarn, and when the filament percentage was increased by 40% at the core the value was increased by 10–11 times the value for 100% cotton yarn.

Air-jet core yarn with up to 25% filament at the core did not show any change in energy to break compared to 100% spun cotton yarn, but when the percentage reached 40% at the core there was a drastic increase in the energy to break observed for the air-jet core yarn, which was nearly 6-8 times more than that for 100% cotton yarn.

Generally, a lower percentage of filament at the core may not contribute more to the strength of the yarn, but a greater elongation of the yarn jointly provided energy to break at per with 100% cotton yarn. When the percentage of filament was increased substantially at the core, both strength and elongation jointly led to higher energy to break.

Crimped yarns always showed higher values of energy to break than drawn yarns at higher percentages of filaments at the core: when the percentage of filament at the core was 40%, the core yarn energy to break increased by 33% and 15% for ring core and air-jet core yarns respectively.
3.5. Core yarn initial modulus

The initial modulus of different core yarns was tested on an Instron machine. From the results it was observed that the core yarn initial modulus was mostly influenced by the initial modulus of the filament yarns at the core, the yarn characteristics, and characteristics of the spinning systems. It was seen that a high initial modulus filament at the core provided a higher initial modulus of the core yarn. For example, 44 den. yarn had a high modulus, which directly shows the higher modulus of the core yarn. The low modulus of yarn like 70 den. polyester yarn was also influenced by the low modulus of the final core yarn. Because there were more straight fibres at the core of air-jet yarns (70 den.), the initial loads were immediately shared by the filaments and therefore the initial moduli of those yarns showed higher values.

3.6. U%

The U% of different core yarns were tested on a UT4 evenness testing machine. From the results it was observed that there were no significant differences in U% values among the different core spun yarns made on the ring frame. It is clear from Table 6 that air-jet yarns have lower U% values than ring core yarns because they have more parallel fibres at the core than ring core yarns. It was also observed that crimped or drawn yarns at the core do not contribute to yarn uniformity.

3.7. Total imperfection

The total imperfection of different core yarns was tested on a UT4 evenness testing machine. From the results it was observed that there were no clear trends in total imperfection values within the ring frame and air-jet yarns. But air-jet core yarns showed minimal imperfection values compared to ring-spun core yarns. When the percentage of filaments was increased at the core it was observed that imperfection values were reduced in ring-spun core yarns, which was not observed in air-jet core yarns.

3.8. Evaluation of percentage coverage of core yarn by scanning electron microscope (SEM)

Cross-sectional views of the final double yarns were observed by scanning microscope to estimate the extent of cover of core filament yarns by the sheath cotton fibres. In this study, drawn core yarns and crimped core yarns showed similar types of properties. Moreover the chance of filaments coming out at the surface is greater in crimped core yarns than in drawn core yarns. However, because of resource constraints, only cross-sectional views of crimped core yarns were observed.

The results are shown in Table 2 and the respective photographs are shown in Figs. 10–16.

Table 2. Evaluation of percentage coverage of core yarn.

<table>
<thead>
<tr>
<th>Description</th>
<th>30/CR/A</th>
<th>44/CR/A</th>
<th>70/CR/A</th>
<th>30/CR/R</th>
<th>44/CR/R</th>
<th>70/CR/R</th>
<th>100%C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual cover by cotton</td>
<td>100%</td>
<td>100%</td>
<td>98%</td>
<td>100%</td>
<td>100%</td>
<td>98%</td>
<td>100%</td>
</tr>
</tbody>
</table>

It was observed that polyester core filaments were placed exactly at the centre with 30 den. and 44 den. yarns in ring and air-jet systems. It was observed that in the case of 70 den. polyester yarns at the core of air-jet and ring core yarns, there was 98% cover of the filament by the cotton. It can be concluded that when finer denier yarn was inserted at the core and represented only a 15–25% proportion, it was well covered by the cotton sheath fibres. When the core percentage was 40%, the sheath cotton could not give 100% coverage of the core, but the cover was reasonably good.
4. Conclusion

It was concluded that when using filament yarn at the core, the CSP value fell by about 15% in 30 den. polyester core yarns. With 44 den. and 70 den. cores, the CSP values increased by about 31% and 36% respectively. CSP values for air-jet core yarns were less than for 100% ring-spun cotton yarn. The air-jet yarns were observed to have about 30% to 11% lower CSP values than 100% cotton ring spun yarn.

Similar results were observed in respect of single yarn strength: when introducing 30 den. filament at the core the fall in strength was 15 % to 17% and when introducing 44 den. and 70 den. filament at the core, the strength was...
improved by about 43%. In the case of air-jet spun core yarns, the trend was from 50% lower strength with 30 den. core to 7% lower strength with 70 den. core compared to 100% cotton-ring spun yarn.

The elongation at break was observed to increase by 20% to 500% with the increase in the filament percentage at the core from 15 to 40%.

With 30 den. core the energy to break was not significantly different than that for 100% cotton ring-spun yarn. With 44 den. and 70 den. the values were 25% and 1100% higher respectively. In the case of air-jet spun core yarns, 30 den. and 44 den. cores did not require any significant difference in energy to break compared to 100% cotton ring-spun yarn, but with a 70 den. core, the energy required was 600% to 800% higher.

Air-jet core yarns had low U% and lower imperfections compared to both ring-spun core yarns and ring-spun cotton yarns.

With 30 den. and 44 den. filament at the core, the sheath cover was 100%, whereas with 70 den. core it was about 98% in both air-jet and ring-spun core yarns.

Therefore, it can be concluded that ring-spun and air-jet spun yarns show better performance in all respects compare to 100% cotton ring-spun yarn. Ring-spun core yarn is superior to air-jet in tensile properties whereas in terms of U% and imperfection, air-jet spun yarn is superior to ring-spun yarn.

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