Structural and functional characteristics of yarns manufactured by different pneumatic spinning systems

A Riva*, L Coll & M Kasem
Instituto de Investigación Textil de Terrassa (INTEXTER), Universidad Politécnica de Cataluña, Spain

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The structural and functional properties of yarns manufactured by two pneumatic spinning systems, namely pneumatic wrapping spinning by false twist and pneumatic spinning by real wrapping twist, have been studied and compared to those of the yarns manufactured by conventional ring spinning. These properties are assessed by determining apparent diameter, yarn deformation, yarn evenness, hairiness, neps, average apparent twist, tenacity, elongation, twist vividity, elongation due to untwist-backtwisting and residual shrinkage. The real wrapping twist pneumatic spinning system produces yarns that have a less pronounced corkscrew structure than those produced by false twist pneumatic spinning. However, the yarns produced by real twist spinning show some characteristics of irregularity and dynamometric characteristics that situate them in an inferior position to yarns produced by conventional ring spinning.

Keywords: Cotton, Corkscrew structure, Pneumatic spinning, Polyester, Ring spinning, Wrapping fibre. Yarn
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1 Introduction

Of the various spinning systems utilized to manufacture yarns, pneumatic spinning allows one of the quickest speeds of production. Nevertheless, the yarns manufactured by pneumatic spinning are characterised by a particular structure, in which a core of parallel fibres is bound by wrapping fibres. This structure is peculiar and responsible for the difference between the physical properties of these yarns and those of the yarns manufactured by conventional ring spinning or open-end spinning (rotor) systems.

The yarns manufactured by pneumatic spinning have a corkscrew type structure that is more or less pronounced depending on the quantity of wrapping fibres and on their tension around the core fibres. The regularity and other structural characteristics of the pneumatic yarns depend on a number of variables in the spinning process.

In this paper, the structural and functional properties of yarns manufactured by two pneumatic spinning systems (pneumatic wrapping spinning by false twist and pneumatic spinning by real wrapping twist) have been studied and compared to those of the yarns manufactured by the conventional ring spinning.12 These properties are assessed by determining the parameters, such as apparent diameter, yarn deformation, yarn evenness, hairiness, neps, average apparent twist, tenacity, elongation, twist vividity, elongation due to untwist-backtwisting and residual shrinkage.

2 Materials and Methods

2.1 Materials

The yarns used in the study were of three types. Two types of yarns were manufactured using two different pneumatic spinning systems and the third type was obtained using the conventional ring spinning.

The two pneumatic spinning systems used were as follows:

(i) Pneumatic wrapping spinning by false twist, hereafter referred to as HZNTf.

(ii) Pneumatic spinning by real wrapping twist, hereafter referred to as HZNTrz.

The fundamental difference between the two systems is the manner in which they twist the wrapping fibres. The pneumatic wrapping spinning system (HZNTf) (Fig. 1) consists of a tandem twist-detwist air jet. The types of air jets which are now used to impart transient (false) twist in the pneumatic wrapping-spinning system have the disadvantage that the spun yarn takes the characteristic form of a
corkscrew and shows a rough touch which negatively influences the properties of the end product. This effect is particularly felt in the case of high quality woven and knitted fabrics. On trying to weigh out the low twisting power of the spinning air jets by air overpressure, the excess of flows degradates the quality of the yarns. This fact, together with high hairiness more considerable in 100% cotton spun yarns, negatively influences the properties of the end product and thus the application of these yarns is limited.

A Murata MJS 802 spinning frame was utilised to implement this spinning system. The yarn obtained using conventional ring spinning are referred to as RS.

Cotton/polyester blend yarns (15 tex) were spun on each of the spinning systems in the ratios 100:0, 75:25, 50:50, 25:75 and 0:100. The raw materials used were extra-long Egyptian cotton (CO) and 1.3/38 Br polyester (PES).

The spinning was done in an INTEXTER pilot plant. The slivers of all the compositions were made by three passes through a modified Ingolstadt (Shubert-Salzer) drawing frame. From the resulting slivers, the evenness of the sliver and the average fibre length were determined.

The average fibre length was determined as per the DIN Standard 53808 (ref. 22) using Afis (Uster) equipment. The evenness of the slivers was obtained using an Uster Evenness Tester III following the ASTM Standard D 1425 (ref. 24).

The characteristics of the resulting slivers are given in Table 1.

### Table 1—Average fibre length and evenness of the slivers

<table>
<thead>
<tr>
<th>Composition</th>
<th>Average fibre length, mm</th>
<th>Evenness Uster CV %</th>
<th>Neys nepes/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO PES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>27.5</td>
<td>3.84</td>
<td>11</td>
</tr>
<tr>
<td>75</td>
<td>25</td>
<td>28.5</td>
<td>4.46</td>
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<tr>
<td>50</td>
<td>50</td>
<td>30.0</td>
<td>4.49</td>
</tr>
<tr>
<td>25</td>
<td>75</td>
<td>31.7</td>
<td>3.57</td>
</tr>
<tr>
<td>-</td>
<td>100</td>
<td>34.8</td>
<td>2.95</td>
</tr>
</tbody>
</table>

2.2 Methods

2.2.1 Apparent Diameter and Yarn Deformation

To determine the apparent diameter and the yarn deformation of the wrapped yarns, a unique methodology was developed. The yarn was taken under constant tension over a glass slide to facilitate a continuous observation of its structure. The diameters $d_1$ and $d_2$ were measured in the tested yarns by means of optical and electronic microscopy, where the hairiness can be easily discarded optically (Fig. 3).

One hundred measurements were made for each type of yarn. The average apparent diameter,
necessary to study the yarn deformation, was measured in the areas of little deformation. The coefficient of yarn deformation was determined using the following relationship:

\[ D_v = \frac{d_i - d_r}{d} \]

where \( D_v \) is the coefficient of deformation (0 < \( D_v \) < 1); \( d_i \), the maximum diameter of the yarn (\( \mu \)); \( d_r \), the minimum diameter of the yarn (\( \mu \)); and \( d \), the average apparent diameter of the yarn in non-deformed areas (\( \mu \)).

The closer the value of \( D_v \) to one, the greater is the deformation of the resulting yarn, which will have a more pronounced "corkscrew" structure. On the other hand, as this value approaches zero, the yarn shows less deformation and is more cylindrical. Figure 4 illustrates the meaning of the parameters indicated above.

2.2.2 Yarn Evenness, Hairiness and Neps

The yarn evenness was determined with an Uster Evenness Tester III 23 as per the ASTM Standard D1425 (ref. 24). The hairiness and neps were analysed using the method incorporated in the evenness tester, which gives a value corresponding to the total hairiness and the number of neps.

2.2.3 Average Apparent Twist

The average apparent twist of the yarns was determined using the Zweigle D-312 S Automatic Digital Twist Counter, following the DIN Standard 53832 for twist-backtwisting 25.

2.2.4 Tenacity and Elongation

Uster Automatic Dynamometer was used to determine the tenacity and elongation of the yarns, following the ASTM Standard D2256 (ref. 26). Each yarn was tested 100 times and the average was taken.

2.2.5 Twist Vivacity

Twist vivacity is the tendency of a yarn to twist as a consequence of the twist caused by the spinning process. The method to determine the twist vivacity entails determining the twist produced in a thread after it is plied and hung with a small weight and left to twist until it stabilises. The backtwisting was determined following the ISO 2061 (ref. 27).

2.2.6 Elongation due to Untwist-Backtwisting Effect

This parameter was determined from the elongation curve that results from the untwist-backtwisting of the yarn. The method is based on the hypothesis that the lesser the degree to which the thread exhibits a corkscrew structure, the greater is the compensation for fibrillar twisting in the group of fibres that make up the nucleus of the wrapped yarn. For this reason, the elongation curve yields information on the structure of this type of yarn. The process followed to determine the elongation curve is as follows:

The average apparent twist was measured using an automatic twist counter and following the usual procedure. Subsequently, the elongation produced in the yarn at the following four different moments of backtwisting was measured:

- When half (50%) of the apparent twist of the yarn had unwound.
- When all (100%) of the apparent twist of the yarn had unwound.
- When half (50%) of the apparent twist of the yarn had backtwisted.
- When all (100%) of the apparent twist of the yarn had backtwisted and the yarn had reached its initial length.

\[ \text{Fig. 3—Structure of the HZNtrz yarn} \]

\[ \text{Fig. 4—Wrapped yarns (a) with little deformation and (b) with pronounced deformation} \]
The average apparent twist of the yarns along with the elongation curves was determined using a Zweigle D-312 S Automatic Digital Twist Counter following the untwist-backtwisting method as per the DIN Standard 53832 (ref. 25).

2.2.7 Residual Shrinkage
This parameter was observed by determining the contraction undergone by the yarns after being boiled in distilled water. The testing method was based on determining the length of a 2620 tex hank, prior to and following hydrothermal treatment, by suspending a 497 g weight from it for 30 s. The procedure used was as follows:
- Acclimate the hanks to a standard relative temperature and humidity for a minimum of 24 h prior to the test.
- Determine the initial length of the hanks while they sustain a weight of 479 g for 30 s.
- Carry out the aforementioned shrinkage test. To avoid the hanks becoming tangled during the boiling process, they were introduced longitudinally into individual pouches made of Marquisette fabric. The boiling time was 30 min. The hanks were subsequently allowed to cool till they reached an approximate temperature of 50°C.
- Centrifuge the hanks for 3 min, dry them at 30-40°C and then suspend them for 2 h under forced ventilation.
- Re-acclimate the hanks.
- Re-measure the length of the hanks in the same conditions indicated before.
- Calculate the shrinkage using the following formula:

\[
\text{Shrinkage (\%)} = \frac{\text{Initial length} - \text{Final length}}{\text{Initial length}} \times 100
\]

3 Results and Discussion
3.1 Apparent Diameter and Yarn Deformation
The results obtained for these parameters are shown in Table 2. While in all the cotton/polyester blends the apparent diameters of the HZNtrz yarns are smaller than the HZNtf yarns, the significant differences do not exist among the different blends.

It can be clearly observed that for all the cotton/polyester blends the deformation produced by the HZNtrz system is less than that of the HZNtf yarns. This reflects the difference that exists between the two spinning systems; in the HZNtrz system, as a consequence of not generating false twist, the wrapping fibres are submitted to less tension than in the HZNtf which subsequently diminishes the corkscrew effect and, therefore, yarn deformation. Consequently, the structure of the HZNtrz yarns is closer to that of the yarns produced by conventional ring spinning.

The yarns with 50:50 CO/PES blend ratio show a slightly higher degree of deformation for both the spinning systems. For the HZNtf system, the 100% polyester thread shows the lowest degree of deformation, while in the HZNtrz system the 75:25 CO/PES yarns show the lowest degree of deformation.

The differences in deformation between samples of different cotton/polyester blends can be attributed to slight, inherent variations in tension during the spinning process that stem from spinning different compositions of materials.

3.2 Yarn Evenness, Hairiness and Neps
Table 3 shows the results for yarn evenness and Table 4 the results for hairiness and the number of neps for 5 different cotton/polyester blends studied.

The yarns produced by the three spinning systems show CV Uster values within the 25th percentile of the Uster Standard. The HZNtf yarns yield lower values, i.e. they have a lower percentage of
irregularity. It is also these yarns that have a smaller incidence of thin and thick parts.

The HZNtrz yarns have the highest Uster coefficients of variation, and are thus less even. They also have the highest number of thin and thick parts. So, the HZNtrz yarns have less corkscrew structure but simultaneously are more irregular because along the yarn length more thin and thick places exist (Fig. 5).

The yarns obtained by pneumatic spinning show higher numbers of neps than the conventional yarns; the values for the HZNtrz yarns are slightly higher than those for the HZNtf yarns.

Though the values for hairiness are generally around 25% limit of the Uster Standard, a few samples slightly exceeded it. Differences between the spinning systems were not observed.

Table 3—Yarn evenness properties

<table>
<thead>
<tr>
<th>Composition</th>
<th>Uster Thin places (%50)</th>
<th>Thick places (%50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CV %</td>
<td>1/1000 m</td>
</tr>
<tr>
<td>CO</td>
<td>HZNtrz</td>
<td>HZNtf</td>
</tr>
<tr>
<td>100</td>
<td>14.6</td>
<td>12.55</td>
</tr>
<tr>
<td>75</td>
<td>25</td>
<td>15.17</td>
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<td>50</td>
<td>50</td>
<td>15.89</td>
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<td>25</td>
<td>75</td>
<td>15.92</td>
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<tr>
<td>-</td>
<td>100</td>
<td>17.64</td>
</tr>
</tbody>
</table>

Table 4—Neps and hairiness of the yarns

<table>
<thead>
<tr>
<th>Composition</th>
<th>Neps (+200%)</th>
<th>Hairs (h)</th>
<th>σ Hairiness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/1000 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>HZNtrz</td>
<td>HZNtf</td>
<td>RS</td>
</tr>
<tr>
<td>100</td>
<td>29</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>75</td>
<td>50</td>
<td>33</td>
<td>9</td>
</tr>
<tr>
<td>50</td>
<td>42</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>25</td>
<td>75</td>
<td>17</td>
<td>40</td>
</tr>
<tr>
<td>-</td>
<td>100</td>
<td>13</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 5—Average apparent twist and dynamometric properties of the yarns

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Average apparent twist</th>
<th>Tenacity</th>
<th>Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>twists/m</td>
<td>cN/tex</td>
<td>%</td>
</tr>
<tr>
<td>CO</td>
<td>HZNtrz</td>
<td>HZNtf</td>
<td>RS</td>
</tr>
<tr>
<td>100</td>
<td>374.2</td>
<td>472.9</td>
<td>15.04</td>
</tr>
<tr>
<td>75</td>
<td>192.4</td>
<td>392.0</td>
<td>14.94</td>
</tr>
<tr>
<td>50</td>
<td>183.4</td>
<td>414.7</td>
<td>16.38</td>
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<tr>
<td>25</td>
<td>177.8</td>
<td>408.4</td>
<td>22.51</td>
</tr>
<tr>
<td>-</td>
<td>112.3</td>
<td>464.5</td>
<td>24.84</td>
</tr>
</tbody>
</table>

Values in parentheses are CV%.

3.3 Average Apparent Twist, Tenacity and Elongation

The results obtained are shown in Table 5. The HZNtf yarns uniformly show higher twist values than the HZNtrz yarns. The yarns obtained by pneumatic spinning have lower tenacity values than the yarns.
produced by conventional ring spinning, as expected. The inferior tenacity of pneumatic yarns with respect to conventional yarns is a well-known fact and represents one of the main disadvantages of this type of yarn. There were no differences worthy of mention between the two pneumatic spinning systems.

The increase in polyester fibre percentage increases the tenacity of the yarns produced on pneumatic spinning systems. There is a slight loss in tenacity of conventional yarn as the polyester percentage is increased to 50%; the tenacity however increases on further increase in polyester content.

For the yarns obtained by pneumatic spinning, the elongation values are lower than those obtained by conventional yarns; the HZNtf yarns have the lowest values. This behaviour can be explained by their yarn structure; in the case of the HZNtf yarns, there exists a smaller chance of sliding of fibres in the nucleus of the yarn.

3.4 Twist Vivacity of Threads

The values of twist vivacity (Table 6), somewhat higher in the HZNtf yarns, indicate that these yarns have a greater tendency to backtwist than the HZNtrz yarns. Once again, the values for this parameter indicate that the structure of the HZNtf yarns has areas where the wrapping is very pronounced.

3.5 Elongation due to Untwist-Backtwisting Effect

Table 7 shows that the values obtained for elongation due to the untwist-backtwisting effect are greater in the HZNtf yarns for all the cotton/polyester blends, which indicates that these kind of yarns have a more pronounced corkscrew structure than the HZNtrz yarns.

Coherent elongation values were obtained for the 100% polyester and 25:75 cotton/polyester yarns. The values increase when the yarn approach the total unwound and then decrease to zero once the yarn had completely backtwisted. In other cases, the behaviour was somewhat anomalous. One should take note that as the yarns did not show a uniform twist, the moment at which the yarn was completely untwisted cannot be determined with exactitude (even if the apparent twist had been determined previously). Thus, it is possible for the yarns to begin to twist again without reaching zero twist, and for this reason they have a smaller length at the end of the test than at the beginning; this explains why in some cases negative elongation values are obtained.

3.6 Residual Shrinkage

The values for residual shrinkage are shown in Table 8. It can be observed that the HZNtrz yarns show less shrinkage than the conventional yarns and that the HZNtf yarns exhibit more shrinkage. The reason behind this behaviour is again the HZNtf yarns’ thread composition, which is characterised by a strong wrapping configuration.

This behaviour is explained by the fact that inside a hank the areas of HZNtf yarns that have a corkscrew structure are more likely to be compacted. The HZNtrz yarns have a higher apparent diameter than the HZNtf yarns, though they have an identical count (number of fibres per section). Thus, the porosity of the HZNtrz yarns is greater than that of the HZNtf yarns.

Furthermore, there is a greater incidence of yarn deformation in the HZNtf yarns than in the HZNtrz yarns, which causes the former to be more liable to suffer shrinkage.

The 100% cotton yarns had the least shrinkage throughout. Bearing in mind the fact that the polyester

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Twist vivacity, twists/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO 100</td>
<td>HZNtrz 20.7, HZNtf 30.6</td>
</tr>
<tr>
<td>75</td>
<td>HZNtrz 25.0, HZNtf 39.6</td>
</tr>
<tr>
<td>50</td>
<td>HZNtrz 19.1, HZNtf 49.8</td>
</tr>
<tr>
<td>25</td>
<td>HZNtrz 18.2, HZNtf 49.9</td>
</tr>
<tr>
<td>100</td>
<td>HZNtrz 29.4, HZNtf 49.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Untwist-backtwisting %</th>
<th>100% CO</th>
<th>75:25 CO/PES</th>
<th>50:50 CO/PES</th>
<th>25:75 CO/PES</th>
<th>100% PES</th>
</tr>
</thead>
<tbody>
<tr>
<td>HZNtrz</td>
<td>HZNtf</td>
<td>HZNtrz</td>
<td>HZNtf</td>
<td>HZNtrz</td>
<td>HZNtf</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-50</td>
<td>0.24</td>
<td>0.27</td>
<td>0.08</td>
<td>0.21</td>
<td>0.08</td>
</tr>
<tr>
<td>-100</td>
<td>0.36</td>
<td>0.39</td>
<td>0.10</td>
<td>0.32</td>
<td>0.08</td>
</tr>
<tr>
<td>50</td>
<td>0.21</td>
<td>0.36</td>
<td>-0.02</td>
<td>0.11</td>
<td>-0.07</td>
</tr>
<tr>
<td>100</td>
<td>-0.50</td>
<td>0.02</td>
<td>-0.48</td>
<td>-0.39</td>
<td>-0.44</td>
</tr>
</tbody>
</table>
yarns had not been thermofixed beforehand, it stands to reason that the polyester and the cotton/polyester blend yarns should exhibit a greater degree of shrinkage.

4 Conclusions

4.1 The real wrapping twist pneumatic spinning system gives rise to yarns that exhibit less yarn deformation and have a slightly greater apparent diameter than the yarns produced by the false twist spinning system.

4.2 The yarns obtained by the real twist pneumatic system (HZNtrz) exhibit less evenness although have a greater number of thin and thick places which exceed in both measures the corresponding values for the HZNtf yarns. The HZNtrz yarns also have a higher number of neps.

4.3 The average apparent twist is greater in the HZNtf yarns than in the HZNtrz yarns for all the blends studied.

4.4 The dynamometric behaviour of the yarns produced by both pneumatic spinning systems is very similar and logically worse than that of the yarns produced by conventional ring spinning.

4.5 The HZNtrz yarns have less twist viscosity than the HZNtf yarns.

4.6 The elongation due to untwist-backtwisting is greater in HZNtf yarns than that in HZNtrz yarns.

4.7 The shrinkage produced by hydrothermal treatment is less in HZNtrz yarns than in HZNtf yarns.

It can be concluded that the real wrapping twist pneumatic spinning system produces yarns that have a less pronounced corkscrew structure than those produced by false twist pneumatic spinning. However, the yarns produced by real twist spinning show some characteristics of irregularity and dynamometric characteristics that situate them in an inferior position to yarns produced by conventional ring spinning.

References

3 Coll-Tortosa L, Chemiefasern Text Ind, 27 (1977) 422.
6 Mori S, U S Pat 5,211,001 (to Murata Kikai Kabushiki Kaisha, Kyoto, Japan), 18 May 1993.
8 Mori S, U S Pat 5,193,335 (to Murata Kikai Kabushiki Kaisha, Kyoto, Japan), 16 March 1993.
15 Coll L & Garcia E, Bol Intester, 96(1989) 86.
18 Coll L, García E & Galván F, Melland Textilber, 73(3) (1992) 220.
22 DIN Standards DIN 53808 (Deutshes Institut für Normung e.V., Berlin), 2003.
25 DIN Standards DIN 53832 (Deutshes Institut für Normung e.V., Berlin).