Yarn quality improvement with an air-jet attachment in cone winding

K P Chellaman, D Chattopadhyay & K Kumarasamy
The South India Textile Research Association, Coimbatore 641 014, India

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An air-jet nozzle for cone winding machine was designed and fabricated to decrease the hairiness of yarn and, thereby, to control the deterioration in yarn quality. Yarn quality improvement in five different counts (two carded and three combed) was studied using air-jet nozzles of three different orifice angles (30°, 45° and 60°) and three different air pressures (0.5 kg/cm², 1.0 kg/cm² and 1.5 kg/cm²). It has been observed that the best results are achieved with air-jet nozzle of 60° orifice angle and 1.0 kg/cm² air pressure. Using this nozzle during winding, the hairs in ring yarn decrease by 50 - 75%. Hence, the use of air-jet nozzle in cone winder helps to maintain the quality of wound yarns at par with that of ring yarns.

Keywords: Air-jet nozzle, Hairiness, Imperfections, Jet orifice angle, Unevenness, Winding

1 Introduction

During winding, the imperfections in ring yarn increase to some extent due to the abrasion of yarn with the metallic parts of the winder. Due to abrasion, the surface hairs in the ring yarn get rolled up together and tend to form fibre clusters and nep like defects. Hence, the appearance of the fabrics made out of ring yarns gets degraded in addition to higher breaks during weaving. Therefore, any method to bring down the extent of increase in yarn imperfections by decreasing yarn hairiness during winding is highly useful to the industry from the point of view of producing quality fabrics and to obtain higher machine efficiencies.

In spite of the several process control measures adopted during spinning, the total elimination of hairs in ring yarns is not possible. Due to the mechanism of yarn formation in ring spinning, a certain level of hairiness will always be there in ring yarn and these hairs get curled and form imperfections during winding. Hence, studies to decrease the yarn hairiness either at the spinning stage or at the winding stage are required with a view to contain imperfection increase during winding.

Substantial decrease in yarn hairiness was observed while using jet ring spinning system where an air-jet was employed below the spinning triangle in the conventional ring spinning system. This produced an upward swirling air flow against the yarn movement and twist, which facilitated the tucking of protruding fibre ends into the body of yarn by loosening the tightening up of the fibre strand. However, in this study the deterioration in yarn quality in terms of evenness and imperfections was observed due to the disturbance caused to the spinning triangle. Kalyanaraman showed that by inserting a pressure column between the front roller and the lappet in a ring frame and by allowing the twisting yarn to pass through this column, the hairiness in ring yarn could be considerably decreased. However, he did not mention about the effects on other yarn quality parameters. It could be deduced from the above studies that the yarn hairiness decrease in ring spinning is not a workable proposition due to the deterioration in other quality attributes.

Miao and Wang examined the cause of hairiness decrease with an air-jet during winding and found that yarn hairiness can be decreased if the gyrating air current produced by the air-jet lowers the twist level in the ring yarn before it enters the air-jet in the winding machine. Hence, a study was carried out with the following objectives:

- To design and fabricate an air-jet nozzle which can be fitted in a winding machine,
- To optimize the design features of the nozzle, and
- To evaluate the attainable hairiness decrease in yarns while using the air-jet nozzle in winding.

The present paper deals with yarn hairiness reduction while using air-jet nozzle in conventional cone winder.
2 Materials and Methods

2.1 Materials
Two carded counts (20s and 40s) and three combed counts (40s, 80s & 100s) spun from 100% cotton were considered for the study. These yarns were wound on a manual cone winder with and without using SITRA’s air-jet attachment. The process parameters employed during winding were: winding speed, 600 mpm; air pressure, 0.5, 1.0 & 1.5 kg/cm²; and jet orifice angle, 30, 45 & 60 deg.

2.2 Design and Fabrication of Air-jet Nozzle
An air-jet nozzle for cone winding machine has been designed and fabricated in the laboratory. The basic geometry of the air-jet nozzle is shown in Fig. 1. It consists of two components, i.e. vortex assembly (dotted portion) and outer assembly (shaded portion). The main parts of vortex assembly are (i) an air vortex chamber and (ii) a jet orifice. The specifications of vortex assembly used in the present study are: vortex chamber diam., 2.0 mm; jet orifice diam., 0.5 mm; and jet orifice angle, 30, 45 & 60 deg. The outer assembly consists of an air reservoir and a compressed air supply unit.

2.2.1 Mechanism of Vortex Formation in Nozzle
Air is supplied from compressor to reservoir of the air-jet nozzle through regulator. The pressurized air enters the vortex chamber through jet orifice which was fabricated in an angular offset position with respect to the nozzle axis. Hence, a swirling air current is generated inside the vortex chamber.

2.2.2 False Untwisting of Ring Yarn by Air-jet Nozzle
The air-jet attachment was fitted about 2 cm in front of the electronic yarn clearer between the yarn tensioners on a cone winder. A schematic diagram of the winding process is shown in Fig. 2. When the yarn passes through the air-jet nozzle, a swirling air current is generated inside the vortex chamber opposite to the direction of yarn twist and traverse. This helps to decrease the twist level of yarn inside the vortex chamber by false untwisting action. After emerging from the nozzle, twist in the yarn is resorted to the original level before the yarn is wound on the cone. Due to this loosening and tightening of the yarn structure, some protruding hairs are expected to get
themselves tucked in and some other hairs are expected to be removed as fly. As a result, some decrease in yarn hairiness could be anticipated.

The various yarns wound with and without using air-jet attachment were tested for the hairiness and its distribution, unevenness and imperfections, and twist and its variation.

3 Results and Discussion
3.1 Mechanism of Hairiness Decrease while using Air-jet Nozzle

The ring yarn passes through yarn tensioner, electronic yarn clearer, air-jet nozzle and another yarn tensioner before it is wound on the cone. A gyrating air current is created constantly inside the air-jet nozzle by supplying regulated pressurized air through a compressor. The nozzle can be designed in such a way that the gyrating air current moves in a direction opposite to that of ring yarn traverse and twist as shown in Fig. 3. Due to this, the structure of the yarn inside the nozzle gets loosened.

In spun yarns, three types of hairs, viz. leading hairs, trailing hairs and loops are present. As per the studies by Pillay, ring yarns during formation have about 60% of the hairs as loops, 25% as trailing and the remaining 15% as leading. When these yarns are fed to the winding machine, due to the change in direction, the proportion of the trailing and leading hairs become 15% and 25% respectively while that of loops remains unchanged.

As the yarn structure gets loosened in the air-jet nozzle and then tightened on exit from the nozzle, some decrease in trailing and leading hairs could be anticipated due to the following reasons:

- Trailing hairs may get tucked inside the yarn body,
- Leading hairs may get converted into loops,
- Loops, which are firmly anchored with the yarn structure, may remain unchanged, and
- Loosely attached protruding hairs (leading, trailing or loops) may get lost as a fly.

3.2 Optimization of Orifice Angle and Air Pressure

Air-jet nozzles with three different orifice angles (30°, 45° and 60°), pressure levels of 0.5, 1.0 and 1.5 kg/cm² in the air-jet nozzle, and 40s carded and 100s combed yarns were considered for the optimization study. A total of 20 trials (18 with air-jet nozzle and 2 without air-jet nozzle in the winding machine) were conducted.

The total number of protruding hairs (≥ 3 mm) in the yarns wound in all the 20 trials are shown in Fig. 4. Air pressures higher than 1.5 kg/cm² could not be tried due to the higher incidence of yarn breaks. Similarly, orifice angles higher than 60° were not tried due to the obstruction caused to the yarn passage.

It is observed that an orifice angle of 60° yields the maximum decrease in protruding hairs in both the counts. The average level of hairs with 60° orifice angle is lower by 40-45% and 25-35% as compared to that with 30° and 45° orifice angles respectively. In
both the cases, the decrease in hairs is significant at 95% level. Among the three pressure levels tried, 1.0 kg/cm² and 1.5 kg/cm² yield more or less similar results. Hence, 60° orifice angle and 1.0 kg/cm² air pressure were selected for further exploratory studies. Protruding hairs in cone yarns wound with air-jet nozzle (orifice angle 60°, air pressure 1.0 kg/cm²) are significantly lower by 30-60% than that in yarns wound without nozzle. The decrease is significant at 95% level. It is more in 40s carded yarn, probably due to the presence of more hairs in the basic yarn.

3.3 Pattern of Hairiness Decrease while using Air-jet Nozzle in Winding

To estimate how far the air-jet nozzle influences ring yarn hairiness, the yarns of three different counts were wound with and without the nozzle in the cone winder. Hairs in ring and cone yarns are shown in Fig. 5. It is observed that the hairs in cone yarn (without air-jet) are lower by about 30% than that in ring yarns for all the three counts. This confirms the earlier findings of Krishnaswamy et al. While winding hairy ring yarns, the hairiness decreases after winding due to the substantial decrease in short length hairs of 3 mm and 4 mm. The short length hairs contribute roughly 65% of the total protruding hairs in yarn. Due to the decrease in these hairs during winding, the overall hairiness in wound yarn is lower as compared to that in ring yarns.

With an air-jet nozzle in cone winder, ring yarn hairiness further decreases significantly, the decrease being very steep (about 70-75%) in 20s and 40s yarns and slightly lower (50%) in 80s count. In both the cases, the decrease in hairs is significant at 99% level. As the 20s and 40s ring yarns have higher number of fibres in yarn cross-section and hence higher protruding fibres, they offer more scope for hairiness decrease by the air-jet.

To understand the pattern of hairiness decrease, the hairs in different length groups in ring and cone yarns were estimated and are shown in Fig. 6. It is observed that while using air-jet in winding machine, the hairs of all the length groups decrease, but the quantum of decrease varies. Hairs of 6 - 8 mm and 8 - 10 mm
length decrease by over 90%. The extent of decrease comes down with the decrease in the length of protruding hairs, the decrease being 60-80% for 4 - 6 mm and 35 - 60% for 3 - 4 mm hairs. Long hairs facilitate easy tucking-in of the protruding fibres and that could be the reason for the higher quantum decrease in the long hairs.

3.3.1 Effect of Air-jet in Winding and Rewinding on Yarn Hairiness

To find out whether the hairiness decreases further by applying rewinding process (one more winding after the normal winding process) with air-jet, three counts were wound and rewound with air-jet in both the processes. Protruding hairs in all these yarns are shown in Fig. 7. No significant decrease in protruding hairs is observed while using a rewinding process with air-jet. This shows that shorter length hairs in cone yarn could not be decreased below a certain level, irrespective of the number of winding processes used, and the threshold value seems to be in the region of 9 - 101 m.

3.3.2 Effect of Air-jet in Winding and Rewinding on Yarn Unevenness and Imperfections

The effect of using air-jet nozzle in winding on yarn unevenness and imperfections is shown in Fig. 8. It is observed that while unevenness remains same in ring and cone yarns, the imperfections in wound yarn (without air-jet) are higher by 20 - 35% as compared to that in ring yarns, which agrees with the findings of Kathirvel et al.6. However, in wound yarns with air-jet, imperfections remain at the same level as that in ring yarn.

During winding, the increase in imperfections may be due to (i) pulling tension on the yarn, (ii) abrasion of the yarn with metallic surfaces, and (iii) protruding fibres in the yarn which get curled and thereby form clusters and nep-like defects. In conventional cone winders, the effect of pulling tension and abrasion could be expected to be less and it is primarily the protruding hairs, which determine the extent of im-

![Fig. 8—Unevenness and imperfections in ring and cone yarns](image-url)
Table 2—Twist and twist variation in ring and cone yarns

<table>
<thead>
<tr>
<th>Count</th>
<th>Yarn type</th>
<th>Twist</th>
<th>CV% of twist</th>
</tr>
</thead>
<tbody>
<tr>
<td>20s Carded</td>
<td>Ring yarn</td>
<td>710</td>
<td>5.86</td>
</tr>
<tr>
<td></td>
<td>Cone yarn</td>
<td>698</td>
<td>5.06</td>
</tr>
<tr>
<td></td>
<td>Cone yarn with air-jet</td>
<td>929</td>
<td>5.88</td>
</tr>
<tr>
<td>40s Combed</td>
<td>Ring yarn</td>
<td>988</td>
<td>5.49</td>
</tr>
<tr>
<td></td>
<td>Cone yarn</td>
<td>949</td>
<td>5.08</td>
</tr>
<tr>
<td></td>
<td>Cone yarn with air-jet</td>
<td>1286</td>
<td>5.66</td>
</tr>
<tr>
<td>80s Combed</td>
<td>Ring yarn</td>
<td>1324</td>
<td>6.08</td>
</tr>
<tr>
<td></td>
<td>Cone yarn</td>
<td>1239</td>
<td>5.96</td>
</tr>
</tbody>
</table>

perfection increase. Ring yarns with higher level of hairiness cause higher % increase in imperfections and vice versa. In cone yarns produced using air-jet, there is a substantial decrease (50 - 75%) in yarn hairiness as compared to that in basic yarns, and this could be ascribed to be the factor for maintaining the cone yarn imperfections at the same level as that in ring yarns.

The fact that hairiness in basic yarn is the major cause for imperfection increase in cone yarn is also clear from the observation that the imperfections in rewound yarn with air-jet are more or less equal to that in wound yarn with air-jet (Table 1). While using air-jet in winding and rewinding process, there is no significant change in small imperfections like thick places (+35%) and neps (+140%). This is due to the substantial decrease in hairs during winding using air-jet attachment. While using air-jet in winding machine, hairs of all the length decrease significantly. The decrease is highly significant (99% level) for 6 - 8 mm and 8 - 10 mm hairs and significant (95% level) for 4 - 6 mm and 3 - 4 mm hairs (Fig. 6). Hairiness level in ring yarn, cone yarn with air-jet and rewound yarn with air-jet is shown in Fig. 7.

While using air-jet during winding, the ring yarn in its passage to the drum gets untwisted and on exit from the nozzle gets retwisted. Due to this, some change in twist and its variation between fed yarn and delivered yarn from the nozzle may occur. To verify this, twist and CV of twist were measured for ring and wound yarns and are given in Table 2. It is discernible from the table that use of air-jet in winding does not affect the average yarn twist and its variation.

4 Conclusions

4.1 An air-jet nozzle has been designed and fabricated for containing the imperfection increase during winding.

4.2 During winding, the yarn imperfections increased by 20 - 35% and unevenness by 0.7% (absolute value) for all the yarn counts studied.

4.3 The use of air-jet nozzle in cone winder helps to maintain evenness and imperfections in wound yarns at par with that of ring yarns.

4.4 With air-jet nozzle, hairs in ring yarns decrease by 50 - 75%, the extent of decrease being more for longer hairs.

4.5 Air-jet nozzle in winding does not affect the average level of twist and its variation in ring yarns.

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References