Air Jet Spinning—A Critical Review

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Introduction

Japan is, of course, the Home of Air Jet spinning. Ever since M/S Murata machinery Limited, Kyoto, Japan exhibited its Air Jet spinning machine MJS 801 in OTEMAS at Osaka in 1982 it has generated considerable interest in the textile industry. This is naturally so as it is the only latest technology, commercially available, in medium and fine count staple fiber spinning sector. Rotor spinning which is well established is applicable only for counts upto 30 Ne. Other latest technologies namely Hollow spindle spinning and Friction spinning are applicable only for course counts. Air Jet can be used to spin yarn from a wide range of raw materials as well. With these and other usual advantages associated with latest technologies like high productivity, reduced labour, etc., it is expected to be a real competitor for conventional ring spinning in the years to come.

Before going into details a brief review of literature available would be in order. The basic principle of Murata Air Jet spinning is explained in the Technical information published by M/S Murata Machinery Ltd. It is illustrated Fig 1(a).

Fig. 1 (a) Principle of air jet spinning (Murata)

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The sliver is drafted by a 3-over-3 (or 4 over 4) drafting system. The drafted strand is then twisted by employing swirling air currents in mutually opposite directions. The yarn emerging from the nozzle will have a typical structure consisting of core strand held tightly by wrapper fibres.

Toray Machinery works employs a fleece separator and a single air jet to achieve the twisting effect. It is illustrated in Fig 1(b).

Looney investigated the engineering of polyester fibers for Air Jet spinning. Artzt studied the suitability of 3 line and 4 line drafting systems for Air Jet spinning. Nakayama discussed in detail about Toray Air Jet system. Wang and Jordan studied the relationship between the physical properties of Air Jet yarns and fabric properties and the methods of improving the harsh fabric handle. Grosberg et al. discussed the advantages of the Murata principle over two other air jet spinning systems in producing stronger yarns and the twist distribution in Air Jet spinning. Stalder compared the new spinning technologies for their range of applications and possibilities for further developments. Recently Rasess et al. explored the relationship between structure and properties of Air Jet yarns.

The major aspects that sets Air jet apart from conventional ring spinning are interesting to note. They are,

- A high draft ratio in the range of 150 to 250
- A low spinning tension due to the type of twisting employed
- Yarn structure consisting of a core flux held tightly by wrapper fibres.
- High delivery speeds in the range of 150 to 250 mpm.

As with most of the new spinning technologies, Air Jet, though appeared first in 1982 took some time to get acceptance in the industry. Recently many progressive mills are going in for this revolutionary technology. There is a need to explore Air Jet not only at the place of manufacturing, but at academic institutions, research and factories. This is needed to keep/make the Air Jet competitive in future. This paper tries to fulfill the above objective partly by presenting a critical review of some of the technological aspects based on literature available and rising pertinent questions for further exploration.

**Count Range**

Yarn from 10's to 80's Ne can be spun on Air Jet system. Table 1 gives the count range in general, for different materials on Air Jet spinning system. This is reproduced from Technical information on MJS 802, a commercially successful Air Jet spinning machine marketed by M/S Murata Machinery Ltd. As we understand these are based on practical feasibility in a Mill condition and not under standard laboratory conditions only. Obviously the comparative scale for yarn quality has been ring yarn. Stalder cites low spinning tension as a major factor in deciding the count range. Due to low spinning tension it is not possible to create sufficient friction between fibres resulting in low yarn strength. It is more so if the short fibre percentage is high as in case of some cotton varieties. Other factor is the high draft used in Air Jet spinning. As is well known the short fibres cause problems
in drafting, resulting in poor yarn evenness. These are the ones deciding the limits at the lower end of the count range.

The length of the spinning triangle (length between front roller nip and twisting zone) is important in deciding end breaks. In case of Air Jet it is longer due to low spinning tension. The length of the triangle increases as the count becomes finer. This means the length of the spinning triangle which is already long due to low spinning tension will become longer while spinning finer counts. In such a case there are more chances for the length of triangle to exceed the mean length of fibers causing end break. This is the one which sets the upper limit of the count range.

It is interesting to mention here that the technical information published by M/S Murata Machinery Ltd does not give emphasis on spinning tension. Instead the amount of twist and its flow upto the nip of rollers is considered as a major factor. This is depending on many factors like type of nozzle, air pressure in nozzles, draft between front roll and the delivery roll, delivery roll speed, degree of opening of strand emerging from front roll, etc. Further the spinning tension and the strength of the yarn are not linearly related; the strength increases upto a certain limit and then reduces as the spinning tension is increased. More over strength of the yarn in case of air jet is dependent to a large extent on wrapper fibers and their percentage in total fibres constituting the yarn. Therefore spinning tension can not be considered as a limiting factor for spinning course counts.

In order to extend the count range following areas need through exploration,

1. Twist insertion and twist flow inside the nozzle assembly
2. Relation between spinning tension and yarn quality parameters
3. Wrapper fibres: quantity, tightness of wrapping, constitution of wrapper fibre bunch

Spinnability of Different Materials

Mills reported successful spinning of various types of synthetic fibers and their blends with cotton on Air Jet system during the Otemas. Even 100% cotton yarn for special end uses have been spun on the system. The count range for different materials is given in Table 1.

However spinning 100% all purpose cotton yarn is less common due to poor spinning performance. This in turn is due to poor yarn

<table>
<thead>
<tr>
<th>SL Details</th>
<th>Count Range</th>
</tr>
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<tbody>
<tr>
<td>Polyester 100%</td>
<td>2 1.5 1.25</td>
</tr>
<tr>
<td>Denier 3</td>
<td>10-40 10-30 -</td>
</tr>
<tr>
<td>Denier 2</td>
<td>10-45 10-45 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-80 10-80 10-50</td>
</tr>
<tr>
<td>Denier 1.2</td>
<td>10-100 10-90 10-60</td>
</tr>
<tr>
<td>Polyester/Cotton Denier 3</td>
<td>10-25 -</td>
</tr>
<tr>
<td>Denier 2</td>
<td>10-35 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-45 -</td>
</tr>
<tr>
<td>Denier 1.2</td>
<td>10-50 -</td>
</tr>
<tr>
<td>Polyester/Rayon Denier 3</td>
<td>10-30 10-25 -</td>
</tr>
<tr>
<td>Denier 2</td>
<td>10-40 10-40 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-45 10-45 -</td>
</tr>
<tr>
<td>Denier 1.2</td>
<td>10-50 10-45 -</td>
</tr>
<tr>
<td>Acrylic 100% Denier 3</td>
<td>10-20 10-20 -</td>
</tr>
<tr>
<td>Denier 2</td>
<td>10-40 10-40 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-45 10-45 -</td>
</tr>
<tr>
<td>Denier 1.2</td>
<td>10-50 10-45 -</td>
</tr>
<tr>
<td>Acrylic/Cotton Denier 2</td>
<td>10-30 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-35 -</td>
</tr>
<tr>
<td>Denier 1.2</td>
<td>10-40 -</td>
</tr>
<tr>
<td>Rayon 100% Denier 2</td>
<td>10-35 10-30 -</td>
</tr>
<tr>
<td>Denier 1.5</td>
<td>10-60 10-45 -</td>
</tr>
<tr>
<td>Cotton 100% Combed</td>
<td>10-70 10-40</td>
</tr>
<tr>
<td>Carded</td>
<td>10-60 10-30</td>
</tr>
</tbody>
</table>

Note: 1. Spinnability is expressed in English count (Ne).
2. The fibre length is in inches and is given below the count.
3. For cotton 100%, fibre length range is 1 to 1.2 inches (last column).
strength. The reason for this is the low fiber strength utilization factor (ratio of the yarn strength to the sum of the strengths of the fibres in the yarn cross section) due to presence of short fibres (length < 12.5 mm) in the raw material. Short fibres can make only a very small contribution to yarn strength as only a part of its length can be utilised in wrapping the core when it is used as wrapping fiber. In case of ring yarn this problem does not arise as all the fibres including the short fibres are twisted together. The questions to be answered in this respect are,

1. What is the percentage of short fibres playing the role of wrapper fibres among the total wrapper fibres?
2. Is there a way to increase the fibre strength utilization factor by improving the twisting efficiency?

Adaptability to Automation And CIM

The new spinning technologies with very high production levels like Air Jet should be conveniently adoptable to automation and CIM because,

— to reduce manpower which will be expensive day by day
— to utilise the high capital investment to maximum
— to produce quality yarn consistently

So it is desirable to have built in doffing, end piecing, package transport, position cleaning and slub remover. Both the manufacturers from Japan, namely, M/S Torey Engineering Co Ltd and M/S Murata Machinery Co Ltd have incorporated the above features into their models plus an elaborate intelligence analyzer system to ensure a high quality yarn as well as reduced maintenance cost. As the speeds scale new heights automation and CIM becomes more and more crucial to the success of the technology. Air Jet has shown excellent adoptability to both these aspects.

Yarn Quality

Fig. 2 gives the yarn quality of Air Jet along with Ring, Open end and DREF spinning systems.

As we understand these are applicable for synthetic and synthetic cotton blends and hold good for the count range that can be spun on MJS. Of all the quality aspects it is the strength of the yarn which decides to a large extent success or failure of the yarn in the market. The strength of the Air Jet yarn is lower than ring yarn by 5 to 30 percent depending on the type of fibre used. To overcome this drawback further exploration is needed in the areas of

— Twisting phenomenon
— Yarn structure

Obviously these two will lead to understand other aspects of yarn quality as well.

Uniformity of Air Jet is in general better than other systems. This is so even when draft employed is 8–10 times that of ring system. However the problems arise when using the mixing with large quantity of short fibres. This is due to drafting problems associated with short fibres. The areas which require attention are

1. Improvements in drafting to ensure better fiber control specially the short fibres
2. Experimentation in preparatory processes to achieve better fiber orientation and so yarn uniformity
3. Quantity of wrapper fibres and its effect on uniformity

Imperfections, as measured by Uster Imperfection Indicator, is lower than ring yarn. This is so especially in case of weak places which
cause end breaks. The reasons for this is to be explored.

Hairiness of yarn is less than ring yarn. The number of fibres detached from the main strand just prior to twisting and the quantity of wrapping fibres are the major factors influencing hairiness. While the former increases hairiness, latter reduces it when each one of them is increased independently. It is equally important to study the role of short fibres in influencing hairiness of yarn.

Weavability of yarn is better than ring though strength is lower than that of ring yarn. This is due to lower number of thin or weak places in the yarn.

Air jet is harsher than ring yarn. Harshness of yarn normally increases with increase in the strength of the yarn. This aspect is important particularly from the end use point of view. But lack of any published work on harshness of air jet yarns and lack of availability of any objective/precise method of measuring yarn harshness have made this issue complicated. Nevertheless there is a need to reduce the harshness of jet yarns. One way has been to spin core spun yarns like synthetic fibre core covered by cotton. Other area is to develop special finishing techniques to reduce harshness in fabrics.

**Energy Consumption**

The energy consumed is more in case of air jet compared to ring on a spindle to spindle bases. However if the comparison is based on per kilogram of yarn produced then air jet consumes much less power than ring. So there are savings in energy cost with air jet. This holds good for the entire count range spun on air jet. The reasons are obvious like,

- high productivity of air jet
- elimination of stages of manufacturing like roving and winding
- lesser labour, maintenance, energy and other costs

So it remains competitive to ring in this aspect.

**General**

It is necessary to carry out systematic studies to understand the relation between the various fiber properties and the yarn properties. Presently no such details are available. The systematic studies will help in spinning yarns tailor made for specific end uses.

Another area that needs to be explored is yarn structure. Many aspects which are not clear can be understood by an indepth structural analyses of yarn.

**Conclusion**

Air Jet yarn has a special structure consisting of core flux held tightly by wrapper fibres compared to conventional helically twisted ring yarn. Though Air Jet yarn has a low strength, its other quality measures are better compared to ring yarn. It can substitute ring yarn in many end uses. Its special structure may open up a range of new applications as well. Air Jet technology with its excellent adoptability to automation and CIM fits in well with the emerging trend in the textile manufacturing.

Air Jet spinning, therefore, is a new technology that has large potential in staple fiber spinning. There is a need to explore this new technology in depth to reap its benefits. We hope this paper will be of some assistance in such an endeavour.

**Literature Cited**

1) Technical information presented in seminar on Air Jet spinning held in New Delhi, India (1987).
12) Otemas 1989 at Osaka, Japan, Technical reports from mills.
13) MJS and MTS Published by M/S. Murata Machinery works, Kyoto, Japan.