An overview of spinning technologies: Possibilities, applications and limitations

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The new spinning technologies such as rotor, air jet and friction spinning have tremendous potential for higher productivity. However, at present these technologies not only suffer from the problem of imparting some undesirable properties to the fabric but also have limited applicability due to the restricted choice of fibres and counts which can be successfully spun on them. Ring-spinning system, though having lower productivity, does not have these drawbacks. This system, therefore, with the incorporation of some recent improvements is likely to occupy the centre stage for the next few years.

Keywords: Air jet spinning, Fabric hand, Friction spinning, Jet spin-assembly wind, Open-end spinning, Ring spinning, Rotor spinning, Twin spinner, Wrap spinning, Yarn properties

1 Introduction

The ring-spinning system had remained unchallenged since its introduction in the middle of last century till the late 1960s. However, the spinners were becoming increasingly aware of the fact that low productivity was inherent to the basic principle of ring spinning. The system had reached a plateau in regard to maximum production speeds. The breaking of this barrier required a fundamental change in the system of fibre consolidation and winding of yarn. It was in 1967 that the breakthrough became a commercial possibility with the introduction of BD-200 Rotor Spinner which did away with the concept of spindle twisting. The event created tremendous interest all over the world and aroused great expectations from this break-away technology. Subsequently, many other spinning systems, which departed from the principle of ring spinning, kept on appearing from time to time. Systems such as twistless spinning, air vortex spinning and self-twist spinning made their entry in the late sixties. However, except for self-twist spinning the other systems could not progress beyond the stage of prototypes or manufacture of a few commercial machines. The main reason for their fading away appeared to be the poor quality of yarn and/or unacceptability of the resultant fabrics. The systems failed to provide certain desirable product attributes and flexibility. The twistless yarns produced fabrics with 'dead' and harsh hand. The self-twist yarns retained their undesirable twist non-uniformity and produced 'moire' effect in the fabric despite many modifications made to the original yarn. This situation was entirely different from the earlier developments from hand spinning to ring spinning when the product characteristics did not undergo any basic change in its structure. The systems such as hand wheel, flyer spinning, cap spinning, spinning jenny, mule spinning and finally ring spinning produced yarns having real unidirectional twist which did not cause any significant change in the yarn structure. These successive developments led to increase in productivity without adversely affecting the yarn quality and fabric characteristics.

Among the new spinning technologies introduced in late sixties and early seventies, only rotor spinning sustained its promise and in the years to follow, it established itself as a worthy alternative to ring spinning in the coarse and medium count range. The reasons for its phenomenal growth were very high productivity (around 5-8 times that of ring system) and amenability to automation and elimination of roving and winding processes. However, along with these positive aspects there was a growing realization that the system has sectorial applicability and that this yarn imparts a harsh feel to the fabric. The techno-economic considerations restricted rotor spinning to coarse and medium counts. The search, therefore, continued for other technologies for spinning finer yarns.

Wrap spinning, which was developed during this time, produced hybrid yarns in which a filament was
The production rate per position is 4-8 times that of ring spinning. The maximum rotor speed has reached an extremely high level of 1,25,000 rpm for a 32 mm rotor. 
(ii) The roving and winding processes have been dispensed with. Rewinding may be resorted to only for specific requirements.
(iii) The rotor yarns are extremely regular and have much lower levels of imperfections and faults as compared to ring yarns. Such aspects have made these yarns quite attractive for products where these aspects command a premium.
(iv) The system is extremely amenable to automation. Features like auto-feeding, auto-cleaning and auto-doffing have become standard features of modern rotor frames.

2.2 Fibre Specifications for Optimum Results
For best results on a rotor spinner, the fibre properties, in order of importance, are tenacity, fineness, length and cleanliness.
High tenacity fibres should normally be preferred so as to reduce the strength deficiency of rotor yarns.
Use of finer fibres for spinning rotor yarns provides several advantages such as increased spinning limit, more even yarn, higher yarn strength and lower optimum twist, all due to greater number of fibres in the yarn cross-section. The fabric hand also becomes softer. However, as fine fibres are prone to damage, the optimum denier seems to be 1.5 (4.0 µg/in).
The optimum fibre length has been found to be 32 mm for manmade fibres. Longer fibres not only restrict rotor speed due to larger rotor required, but also adversely affect yarn strength and evenness due to greater incidence of wrapper fibres and poor fibre orientation.
The effect of trash and other impurities on yarn quality and performance are well known. The feed sliver should be quite free from impurities.
In addition to the above mentioned characteristics, the fibre crimp should also be considered. A lower fibre crimp yields better results. The arcs/cm should lie between 3.5 and 5.0. The delustrant TiO₂ added to fibres meant for rotor spinning should be less than that normally used for ring system. As a compromise between fibre whiteness and wear of opening roller, etc. a value of 0.1% seems to be the optimum.

2.3 Drawbacks and Limitations
The rotor-spinning system has the following inherent drawbacks/limitations:
(i) The rotor yarns have 10-30% lower tenacity than the ring yarns. The strength loss is lower for cotton than for manmade fibre yarns. The lower yarn strength of rotor yarn is carried into the fabric which shows lower tensile and tear strengths.
(ii) The yarn twist required for optimum quality and performance has to be kept around 15% higher than that for ring yarns.

(iii) The minimum number of fibres required in the cross-section of rotor yarn is around 100-110 compared to 50 for ring yarns. Therefore, the quality of rotor yarns deteriorates when finer yarns are spun on this system. The techno-economics of the system also favours spinning of coarser yarns. In India, this limit is said to be around 24 tex for cotton yarns. In the West, the limit is around 18 tex.

(iv) Unlike in ring spinning, longer fibres (> 32 mm) offer no advantage in regard to yarn quality and/or productivity. On the other hand, very long fibres (> 38 mm) adversely affect the yarn quality.

(v) The biggest drawback of rotor yarns is the harsh feel of the fabrics made out of them. This could be overcome by selection of suitable weaves and use of certain chemical treatments such as bio-wash which has been successfully used for denims.

(vi) The limiting rotor speed appears to be 1,25,000 rpm. As the yarn quality and performance tend to deteriorate at very high speeds, the acceptable commercial speed generally lies around 80,000 rpm.

2.4 Application of Rotor Yarns

Rotor spinning can be employed to spin good quality yarns from cotton, polyester blends, viscose rayon and acrylic fibres. The count range in which it can be successfully used lies between 18-200 tex (3s to 32s Ne).

The products where rotor yarns are suitable include sheetings, furnishings, denims and jeans, dress materials, leisure wear, towels, warp knits and knitted goods.

3 Air-Jet Spinning

The technological improvements in rotor spinning resulted in phenomenal increase in spinning speeds, improved performance and extended spinning limit. However, towards the late seventies, it became quite clear that this system could not go much beyond the yarn count of 20 tex and rotor speed of 1,25,000 rpm. Therefore, a great interest arose in finding new systems which could facilitate extension of count and speed limits. Murata Jet Spinner (MJS) introduced around 1980 fulfilled these aspirations.

The wrap spinning principle of MJS system is shown in Fig. 2. The drafted strand coming out of the front rollers is subjected to ballooning and twisting action when it passes through the jets 1 and 2 rotating in opposite directions. Such an arrangement results in delayed wrapping of edge fibres by the twisting yarn near the front nip, causing longer and extensive wrappings. Systems using single jet fail to delay catching of edge fibres by the twisting yarn thus leaving large unwrapped yarn lengths which become weak spots in the yarn. Fig. 2 also shows the final yarn structure in which a core of parallel fibres is wrapped by the edge fibres, a typical fasciated structure.

On MJS, it is possible to feed in more than one sliver. Using specially designed feeding trumpets, it can be ascertained that a majority of wrappers originate from the designated sliver. In another development, a 4-roller drafting system allows feeding coarser sliver which makes the two-silver technique more practical to produce good quality sheath-core yarn.

![Fig. 2—Wrap-spinning principle of Murata Jet Spinner](image-url)
3.1 Possibilities and Merits

Some of the major merits/possibilities of air jet spinning are as follows:

(i) Synthetic fibres and their blends such as polyester-cotton and polyester-viscose spun on this system give yarns of rather good quality. Their strength is greater than that of rotor yarns but 10-15% lower than that of ring yarns. They are somewhat bulkier and have slightly higher breaking extension.

(ii) A wide range of medium and fine count yarns can be produced.

(iii) The yarn is more even than ring yarn as high speed drafting on MJS produces an evenly drafted strand due to low incidence of fibres moving out of turn because of the inertia effect.

(iv) Low spinning tension allows very high production speeds reaching up to 2,50,000 rpm, which is twice that of maximum rotor speed. The maximum linear production speed goes up to 300 m/min (MJS 802H).

(v) The system can produce sheath-core structures by feeding two slivers.

(vi) Automatic features such as auto-piecing and auto-doffing are available on these machines.

(vii) Like in rotor spinning, roving and winding processes are eliminated in this system too.

(viii) The air jet yarn fabrics are less prone to pilling than the corresponding ring yarn fabrics.

(ix) The loom shed efficiency, using air jet yarns, is much higher than that in case of ring yarns, especially when air jet looms are used.

3.2 Fibre Specifications for Optimum Results

The requirements of fibre specifications for air jet spinning are quite different from that of other spinning systems. The fibre specifications in order of importance are: fineness, length, tenacity, cleanliness and inter-fibre friction.

As the number of fibres in the cross-section of air jet yarn has to be greater than that for ring yarns, finer fibres should be preferred. Finer fibres also help in bringing down the bending rigidity of air jet yarns and increase the tightness of wrapping around the core. As very fine fibres result in increased nep level which can cause plugging of nozzles, the fibre denier should be around 1.3 dtex (1.2 den).

In general, longer fibres should be preferred which give longer and firm wrappings. Looking at the problems encountered in processing long fibres at card, such as nep, it is preferable to use fibres of 38 mm for polyester-cotton blends and 44 mm for polyester-viscose blends.

Yarn strength is significantly influenced by fibre strength in air jet yarns; hence, in general, stronger fibres should be preferred. However, this aspect should always be considered along with fibre elongation which should be high enough to generate enough wrapping-compression. In case of polyester, it has been observed that fibre tenacity beyond 7.0 gpd offers no additional advantage in yarn strength due to reduced fibre elongation in such super high tenacity fibres. Such fibres have high orientation and brittleness and such are easily damaged during mechanical operations at fibre producer's end and in opening and carding at the mills. The strength loss incurred in these operations is as high as 15%. A tougher fibre (high strength and high elongation) having a uniform coating with a more wettable finish can reduce the extent of such damage.

The sliver cleanliness is a crucial factor in air jet spinning. Any trash particle or fibrous aggregate like neps would hinder the rotation of yarn in the narrow yarn tube of air jets. This leads to short-term interruption in twist insertion, creating weak places and even end breaks. The machine life is also adversely affected by such abrasive trash particles.

In regard to inter-fibre friction, a higher value is generally desirable. The increased cohesion not only helps in producing stronger yarn but also in reducing end breaks.

In addition to the above mentioned fibre characteristics, it is helpful to use bright fibres as they cause less fibre dust during spinning and thus avoid choking of air jet nozzle.

3.3 Drawbacks and Limitations

The air jet spinning has the following drawbacks/limitations:

(i) The air jet yarns are stiffer than ring yarns and impart a crisp or harsh feel to the fabric.

(ii) The air jet yarns show a variable texture along the yarn length; some sections have a normal cylindrical structure while others show a corkscrew configuration.

(iii) The tenacity of MJS yarns span from polyester blends is 10-15% lower than that of the corresponding ring yarns but higher than that of rotor yarns. This system fails to produce strong yarns from short fibres, such as cotton, due to shorter and less intensive wrappings. Such yarns are also more irregular than ring yarns. The lower strength of these yarns is carried into the fabric.

(iv) The system is better suited to medium and fine counts i.e. 12 tex (50s Ne) to 25 tex (24s Ne). The end breakage rate goes up when one tries to spin finer
yarns due to the spinning triangle near the front roller nip growing longer with finer yarns.
(v) The drafting system sets a limit to the maximum possible production speed to around 300 m/min.

3.4 Two-ply Air Jet Yarns
A later concept in air jet spinning is the so-called "jet-spin-assembly wind" used in Plyfill (Suessen) and MJS (Murata Twin Spinner). In this system, two single air jet yarns are produced which have just enough wrappings to give tenacity of 3-5 cN/tex so that they can be easily wound as a pair and then unwound for twisting at the two-for-one twister. Such a twisted structure would have much lower rigidity and thus overcome one of the most serious drawbacks of air jet yarns. The production speed in this spinning system easily reaches 300 m/min. The system is well suited to production of 2-ply yarns.

3.5 Application of Air Jet Yarns
Due to the harsh feel imparted by air jet yarns (MJS) to the fabric, various ways have been devised to mitigate this problem. Choice of proper weaves such as twill or sateen, suitable fabric finish and use of fine count yarns are some of the ways to improve the fabric hand. The air jet yarns have also been used along with ring yarns, either as warp or weft, for the same purpose.

Some of the products where these yarns have been extensively used are bed linens, shirtings, overcoat fabrics, dress materials, home furnishings, towels and some industrial textiles. However, product development needs to be accelerated to exploit the unique features of these yarns.

4 Friction Spinning
Friction spinning is based on the principle of open-end spinning (DREF-2 and Master Spinner). The fibres are opened by an opening roller, as in rotor spinning, and collected in a suction area between two drums. The twist is imparted through friction between the yarn and the drums' surface. The twisted strand is drawn along the direction of the drum. An extremely high rate of twist insertion is achieved because each rotation of drums imparts about 100 turns to the yarn.

Recent studies by Stalder et al.3-5 have shown, with the help of high speed photography, that the yarn being formed is surrounded by a rotating sleeve formed by the fibres coming from the opening roller. The fibres are transferred from this sleeve to the yarn core inside. The rotation of sleeve imparts twist to the yarn while fibres are being peeled from it. The mechanism of yarns formation is shown in Fig. 3.

DREF-3 is a core type friction-spinning system which is a development over DREF-2 for improving yarn quality and productivity and extending count range to the finer end.

4.1 Possibilities and Merits
The friction-spinning system offers the following advantages/possibilities:
(i) It can spin at very high twist insertion rates of up to 3,00,000 rpm due to very low spinning tension which is only 20% of that in ring and 14% of that in rotor spinning. The production works out to 16 times that of rotor spinning and more than twice that of rotor spinning (per position).
(ii) Due to presence of twist in yarns and absence of wrappers, these yarns impart a soft hand to the fabric.
(iii) The yarns are bulkier than ring and rotor yarns.
(iv) The system is much more versatile, in terms of fibres used, than air jet and rotor spinning systems. It can handle various types of natural and manmade fibres. It can also process recycled textile wastes.
(v) Core-spun yarns can be easily produced on DREF-3.
(vi) Like rotor and air jet spinning, this system too has dispensed with the roving and winding processes.
(vii) The system is amenable to automation which include automatic piecing and doffing.
(viii) The yarn produced is cleaner as the drum's suction removes dust and trash particles.

4.2 Fibre Specifications for Optimum Results
The fibre properties for optimum yarn quality, in order of importance, are: fibre friction, strength, fineness, length and cleanliness.

The twisting rate in friction spinning is largely dependent upon friction between fibres and the drum surface. Therefore, a high friction between the fibres and the drum surface is desirable. The inter-fibre friction should also be higher as the parallel-fibre core need to be properly bound to resist slippage.

Fig. 3—Mechanism of yarn formation in friction spinning. F—Opened fibres; T—Yarn tail; S—Sleeve; Y—Twisted yarn; and D—Drum.
The inherent weakness of friction yarns can be partly overcome through use of high tenacity fibres. The minimum number of fibres required in friction yarn is higher. Therefore, fine denier fibres should be used for the finer range of counts.

The fibre length requirement in friction spinning is similar to that in rotor spinning. The optimum value lies between 32-38 mm. Longer fibres are more susceptible to damage and show tendency to lap around the opening roller. While DREF-2 is meant for long-staple material, DREF-3 can handle shorter fibres.

The cleanliness of feed material is the fourth important requirement. Of course, this aspect is relevant only for natural fibres like cotton. An unduly high trash content would lead to frequent clogging of drum perforations.

4.3 Drawbacks and Limitations

There are a number of drawbacks and limitations of friction spinning which are restricting its acceptance as a system for producing general purpose yarns. The main drawbacks/limitations are:

(i) The extremely poor fibre orientation renders the friction yarn very weak. The extent of disorientation and buckling is much longer and finer fibres. The yarns are weaker than rotor yarns.

(ii) The twist variation from surface to core is quite high. This is another reason for the low strength of this yarn.

(iii) Due to variations in friction condition from one position to the other, there is a high between-position twist variation.

(iv) The number of fibres in the sleeve reduces as the count becomes finer and the incidence of holes (no fibres) in the sleeve increases, thereby increasing the chances of yarn tail losing contact with the sleeve thus leading to higher end breakage rate. The instability in yarn formation with lower number of fibres in yarn cross-section restricts the applicability of friction spinning to coarse counts.

(v) The doubling of fibre layers taking place in the rotor groove is absent in this system. Periodic air stream variations due to spiral clothing of opening roller introduce mass variations which do not get evened out. This leads to periodic yarn strength variations.

(vi) The maximum production rate is limited by the fibre transport system and the drafting system. The maximum production rate is around 300 m/min. It is unlikely to go much beyond that if the above mentioned problems are not solved.

Due to all these drawbacks, friction spinning has still not established itself as a viable spinning technology.

4.4 Application of Friction Yarns

At present, three types of commercial friction spinning machines are available, viz. DREF-2, DREF-3 and Master Spinner. DREF-2 is meant for spinning coarse yarns of 100 tex (6s Ne) to 600 tex (18s Ne) at around 150 m/min from long-staple material. DREF-3, which is a development over DREF-2, can produce 33 tex (18s Ne) to 150 tex (4s Ne) yarn at 150-300 m/min from shorter fibres. Master Spinner is capable of spinning 25tex (24s Ne) to 60 tex (lOs Ne) yarn at 150-300 m/min depending upon the raw material.

In general, one can say that friction spinning can be used to spin yarns from cotton, polyester, acrylic, blends and even recycled fibres. The yarns can be used for knit goods, Terry towels, weft yarns, pile yarns, velvets and blankets. Some other applications include carpet backing, wrapping cloth, furnishings, filters and technical textiles. The core-spun yarns (DREF-3) are suitable for industrial textiles like feltings, tarpaulins, etc. Friction spinning can also be used to produce fancy yarns.

5 Ring Spinning

Since its inception, ring spinning had remained unchallenged for almost 150 years. However, its limitation in regard to production speeds was well realized which made its position quite vulnerable. The tremendous enthusiasm to introduction of BD 200 in 1967 was, therefore, well justified. However, in a few years time the inherent drawbacks of rotor yarns were well established. The sectorial applicability of rotor spinning became quite clear. This led to a cautious attitude on the part of spinners to any innovation which was introduced later on. They realized that any basic departure from ring spinning leads to changes in yarn structure which are generally unfavourable or unacceptable. These aspects have been discussed earlier. Subsequent to this realization, renewed attempts made by machinery manufacturers led to considerable upgrading of ring spinning system. The maximum production speed has increased to 25,000 rpm by extending the maximum traveller speed to 45 m/s through further developments and using smaller ring diameter and bobbin lift. The subsequent problem of excessive material handling has been solved by linking ring spinning frame to the winding machine. This has come to be known as linked ring spinning. The problem of excessive knots due to smaller ring
5.1 Merits of Ring-Spinning System

It would be worthwhile to briefly mention the well-known merits of ring spinning.

(i) Among all 100% staple-fibre spinning systems it produces the strongest yarn (Fig. 4) from various types of fibres and their blends.

(ii) This system can produce yarns with a large range of twist density, from very low (knitting yarns) to very high (voie yarns). No other system can match this unique capability.

(iii) The ring-yarn fabrics can be imparted the desired hand, crisp or soft, as per requirements.

(iv) It can be used for all types of fibres and can spin from very coarse to extremely fine yarns.

6 Present Status and Future Prospects

The high expectations aroused by the introduction of rotor spinning in late sixties and of air jet and friction spinning in late seventies and early eighties did not materialize to the full. Their sectorial applicability, in terms of type of fibres and yarn counts, is well established. Some undesirable characteristics of yarns spun on these systems have further detracted them from their promise. The virtues of ring spinning such as versatility and wide range of fabric hand are given greater respect now.

Rotor spinning which has been in existence for 25 years now has gone through a long trial in regard to usage of end product, modifications in design, use of special fibre and fabric finishes, and optimization of product specifications before it could establish itself as a worthy successor to ring spinning for spinning coarse yarns. It had to fight against another fact that there are already 200 million ring spindles in the world. Any new technology can be considered only for replacement of ring spindles or addition to existing production capacity.

The air jet spinning would also have to come with viable solutions to the twin problems of harsh fabric feel and spinning of poor quality 100% cotton yarns. The friction spinning has still greater technological deficiencies such as lower yarn strength and high twist variation. A viable commercial friction spinning machine to spin good quality fine yarns is yet to arrive. The count range which can be successfully spun on various spinning systems are given in Fig. 5. At the present juncture, ring spinning in its new form of linked ring spinning supported by automatic features such as transport of roving bobbins to ring frame, automatic piecing and doffing reigns supreme due to its unmatched versatility. The fact that more than 200 million ring spindles already exist in the textile mills is another factor in favour of ring spinning as far as the next 7-10 years are concerned.

It is expected that the next decade would see lot of developments in regard to quality of yarns spun on the new systems. The problem of harsh feel of air jet yarn fabric would also be solved by suitable design and process modifications. The new technologies would become attractive as time passes on and the techno-economic advantages are likely to go more and more in their favour.
References