

COMPARATIVE STUDY ON RING, ROTOR AND AIR-JET SPUN YARN

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Abstract

Although ring spinning is the universal spinning system but main limitation of this system is its limited spindle speed which causes lower production rate. Now-a-days spinners are trying to finding out various alternative spinning systems among which only rotor and air-jet has established market value. So it is very important for spinners to find out a suitable one according to end use and others economic aspects. Ring, Rotor and Air-jet spinning systems provide yarn with different structures and properties. Each system has its advantages and limitations in terms of technical feasibility and economic viability. We have produced 20's Ne, 100% cotton yarn from the above systems and their properties are tested by UT5 and lea strength tester. The main object of the project is to study the yarn properties (Um%, CVm%, Imperfection, Hairiness etc) of ring, rotor and air-jet spun yarn and compare among them. We observed how yarn properties are changed with the change of process. We analyzed the various yarn properties by the graphical representation.

Keywords: Yarn, Textile, Ring Spinning, Rotor spinning and Air-Jet Spinning

Introduction:

Spinning is an ancient textile art in which plant, animal or synthetic fibers are drawn out and twisted together to form yarn. For thousands of years, fiber was spun by hand using simple tools, the spindle and distaff. Only in the High Middle Ages did the spinning wheel increase the output of individual spinners, and mass-production only arose in the 18th century with the beginnings of the Industrial Revolution (Barber & Elizabeth, 1995). Now yarn are producing by different methods. Among them ring, rotor and air-jet spinning are mostly used. The title of our project is “**Comparative study on ring, rotor and air-jet spun yarn**”. It is a special type of project work as it is an observing and analytical work. It is very much important in this time because although ring spinning machine produces best quality yarn but some limitations specially limited productivity bounds the spinners to choose alternative spinning system. From the multitude of spinning processes developed in recent decades, only ring, rotor spinning and with reservations air-jet spinning have established themselves successfully on the market.

In our project work we observed the various yarn properties like U%., CV%, Imperfection Index (thick/km, thin/km, neps/km), hairiness and strength (CSP) of ring, rotor and air-jet yarn.

Research Objectives:

Main objectives of this study are as follows-

- ❖ To study different types of spinning methods.
- ❖ To explore the comparison among these spinning methods.
- ❖ To produce yarn using these methods.
- ❖ To test the yarn quality by testing machine.
- ❖ To compare the tested result and finally to find out-which spun yarn is the best.

Defining Different terms:

Spinning: Spinning is the process of producing yarn from fiber by twisting.

Ring, Rotor and air-jet: These are the main three spinning techniques to produce yarn from fiber in the spinning mills.

U% and CV%: These are the mass variation calculations along yarn length. Testing machine measures the mass of each centimeter of yarn and U% and CV% values are calculated using following formula and these are worldly used to determine how uniform or even the yarn is.

$$U = \frac{1}{x} \frac{\sum |x_i - \bar{x}|}{n} \times 100\%$$

$$CV\% = \frac{1}{x} \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}} \times 100\%$$

Thick/km, thin/km, neps/km: These are the number of faults within one kilometer length, where mass values are taken from each centimeter of length. We considered (+50%) thick place, (-50%) thin place -50% and neps +200% where these values mean ‘average value of mass + mentioned percentage of that mass’. These three faults are commonly called **Imperfection Index**.

CSP (Count Strength product): Count in English system (Ne) × Strength in pound.

Uster Tester 5: A testing machine to perform the tests and to find out the results in printed form.

Carded yarn and combed yarn: Ring spun yarn can be categorized into carded and combed yarn. Combed yarn is better quality yarn where to produce yarn short fibers are removed.

TM (Twist multiplier): A constant value on which yarn twist depends.

Sliver: Continuous fiber strand without twist, an intermediate stage between fiber and yarn.

Roving: Slightly twisted fiber strand, the stage immediate before yarn forming.

Ne (English count): It a numbering system which indicate how much the yarn is finer or coarser. Ne is the number of hank of 840 yards per pound.

Methodology:

We have divided our working methodology for this study into three major steps-

1. Literature review has been conducted to find out the comparison among different types of spun yarn. And articles that are related with spinning methods especially ring, rotor and air-jet spinning are reviewed to find out this comparison.
2. 20Ne yarns are produced by Ring, Rotor and Air-jet machines from same raw materials. Produced yarns are then tested by Uster Tester 5 machine. All the production and experiment are done in Square Spinning Mills Ltd., a leading Textile mill in Bangladesh.
3. And finally showed a clear comparison among different parameters like U%., CV%, Imperfection Index (thick/km, thin/km, neps/km), hairiness and strength (CSP) of ring, rotor and air-jet yarn.

Development of Spinning:

Seven thousand years ago spinning was already well established as a domestic craft. At that time and until the early Middle Ages spinning was an incredibly slow and tedious task. Throughout this period the spinning of one pound of cotton into a yarn suitable for the weaving of what we would now regard as a fairly heavy apparel fabric would keep a spinner busy for several weeks.

A revolutionary change had come in spinning when ring spinning machine was invented by an American named Thorp in 1828, and Jenk – another American – added the traveler rotating around the ring in 1830. In the intervening period of more than 170 years the ring spinning machine has undergone considerable modification in detail, but the basic concept has remained the same (Melissa, 2012). For many years any noteworthy further development hardly seemed possible, yet a significant process of evolution took place during this time. The productivity of the ring spinning machine has increased by 40% since the late nineteen-seventies. This has been achieved by using smaller ring and cop formats introducing piecing in the winding department substantial improvements in rings and travelers.

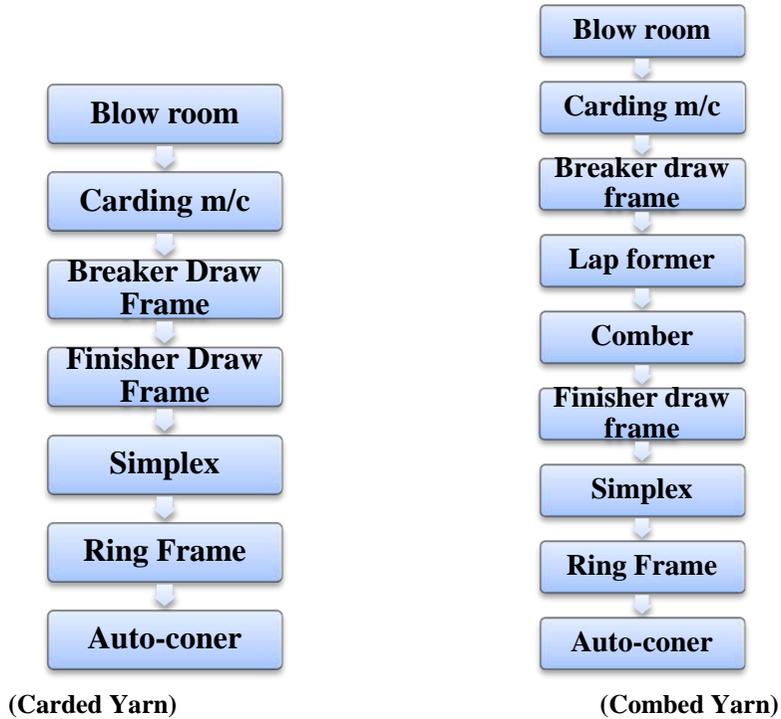
Commercial rotor spinning began in 1967 in Czechoslovakia. Rotor spinning has been characterized from the outset by incomparably higher production potential than ring spinning this potential has been steadily increased by the continuous rise in rotor and winding speeds. Rotor-spun yarns have therefore always been successful where they could be manufactured more cheaply than ring-spun yarns and proved suitable for the range of application in question.

The first industrial pneumatic spinning frame, called PF-1, was manufactured at the beginning of the 1970s in Poland in the WIFAMA Textile Machinery Factory. The yarn formation in this spinning frame was based on the open-end (OE) method with the product continuity being broken during the yarn formation. The swirled air jet that formed the yarn was generated by the suction of the air from the chamber (a sub-atmospheric pressure chamber). The yarn was characterized by a specific structure and a true twist. An invention by the Japanese company Murata was the next step in the progress of air-jet spinning methods. At the beginning of the 1980s, this company manufactured (and still manufactures) an air-jet spinning frame in which the yarn is formed by means of the false-twist MJS (Murata Jet Spinning) method and the product continuity is maintained during the whole spinning process. The yarn obtained with this method has a carrier almost without twist, which is braided on the yarn surface.

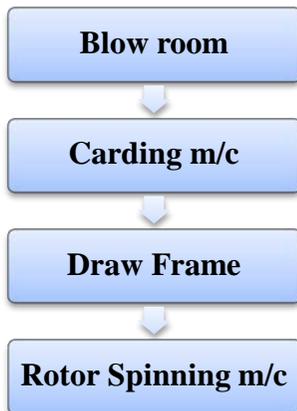
These two systems i.e. rotor and air-jet are very much popular and economic among all other new spinning process. But as their spinning

principle and product quality differ from each other so comparative discussion often arises to choose a suitable one for a definite purpose.

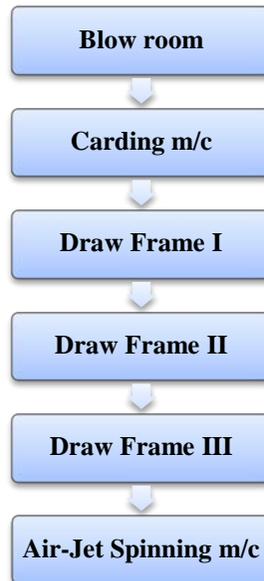
Process Flow chart of Ring Spinning:



Process Flow chart of Rotor Spinning:



Process Flow chart of Air-jet Spinning:



Basic Principle of Ring Spinning

The roving bobbins (1) are inserted in holders (3) on the creel (Fig. 01). Guide bars (4) guide the roving's (2) into the drafting system (5), where they are drawn to their final count. The drafting system is at an angle of 45-60° and is one of the most important units on the machine, since it exerts a very considerable influence on the uniformity of the yarn in particular.

After the resulting thin ribbon of fibers (6) leaves the delivery roller, the twist necessary for imparting strength is provided by spindle (8) rotating at high speed. In the process each rotation of the traveler on the spinning ring (10) produces a twist in the yarn. Ring traveler (9) is also necessary for taking up this yarn onto a tube mounted on the spindle. This traveler - a remnant of the flyer on the roving frame - moves on a guide rail around the spindle, the so-called ring (10). The ring traveler has no drive of its own; it is dragged with spindle (8) via the yarn attached to it. The rotation of the ring traveler lags somewhat behind that of the spindle due to the relatively high friction of the ring traveler on the ring and the atmospheric resistance of the traveler and the thread balloon between yarn guide eyelet (7) and traveler (9).

This difference in speed between the spindle and the traveler results in the thread being wound onto the tube. In contrast to the roving frame, the ring spinning machine spindle operates with at higher speed than the traveler (9). The yarn is wound up into a cylindrical cop form by rising and lowering of the rings, which are mounted on a continuous ring rail.

The layer traverse of the ring rail is also less than the full winding height of the tube. The ring rail therefore has to be raised slightly (shift traverse) after each layer has been wound. For a time, machines were also built featuring shift traverse produced by lowering the spindle bearing plate rather than raising the ring rail. These machines are no longer available today.

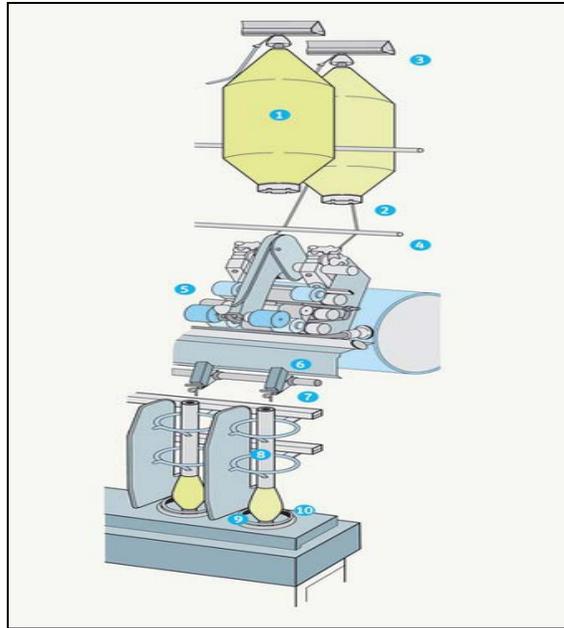


Fig. 01: Principle of ring spinning (Operating principle, Ring spinning)

Basic Principle of Rotor Spinning

The rotor spinning machine is unlike any other machine in the short staple spinning mill in the range of tasks it has to perform, namely all the basic operations (Fig. 02):

- **Sliver feed:** A card or draw frame sliver is fed through a sliver guide via a feed roller and feed table to a rapidly rotating opening roller.
- **Sliver opening:** The rotating teeth of the opening roller comb out the individual fibers from the sliver clamped between feed table and feed roller. After leaving the rotating opening roller, the fibers are fed to the fiber channel.

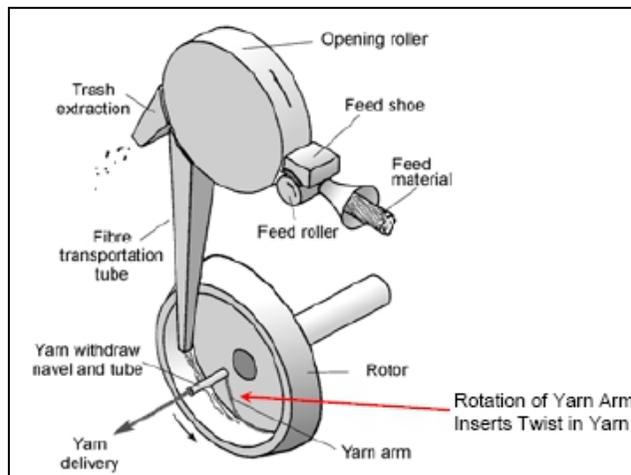


Fig. 02: Principle of Rotor spinning (Sheikh & Emeritus, 2013)

- **Fiber transport to the rotor:** Centrifugal forces and a vacuum in the rotor housing causes the fibers to disengage at a certain point from the opening roller and to move via the fiber channel to the inside wall of the rotor.
- **Fiber collection in the rotor groove:** The centrifugal forces in the rapidly rotating rotor cause the fibers to move from the conical rotor wall toward the rotor groove and be collected there to form a fiber ring.
- **Yarn formation:** When a spun yarn end emerges from the draw-off nozzle into the rotor groove, it receives twist from the rotation of the rotor outside the nozzle, which then continues in the yarn into the interior of the rotor. The yarn end rotates around its axis and continuously twists-in the fibers deposited in the rotor groove, assisted by the nozzle, which acts as a twist retaining element.
- **Yarn take-off, winding:** The yarn formed in the rotor is continuously taken off by the delivery shaft and the pressure roller through the nozzle and the draw-off tube and wound onto a cross-wound package. Between takeoff and package, several sensors control yarn movement as well as the quality of the yarn and initiate yarn clearing if any pre-selected values are exceeded.

Basic Principle of Air-Jet Spinning

Sliver is fed into the machine and is further drawn out to the final count and twist is inserted by means of a rotating vortex of high pressured air. By the action of the vortex, the fiber ends eventually whirl around the spindle tip and are thus twisted around the twist less yarn core and transformed into a twisted yarn surface or cover fibers. This occurs at the spindle tip.

Once inside the spindle tip, the yarn formation process is finished, and the yarn can be taken off and wound onto a package.

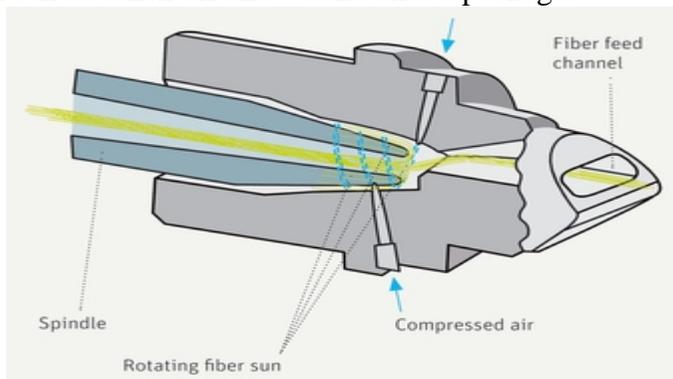


Fig. 03: Air-jet yarn formation (Vortex Spinning, Muratec)

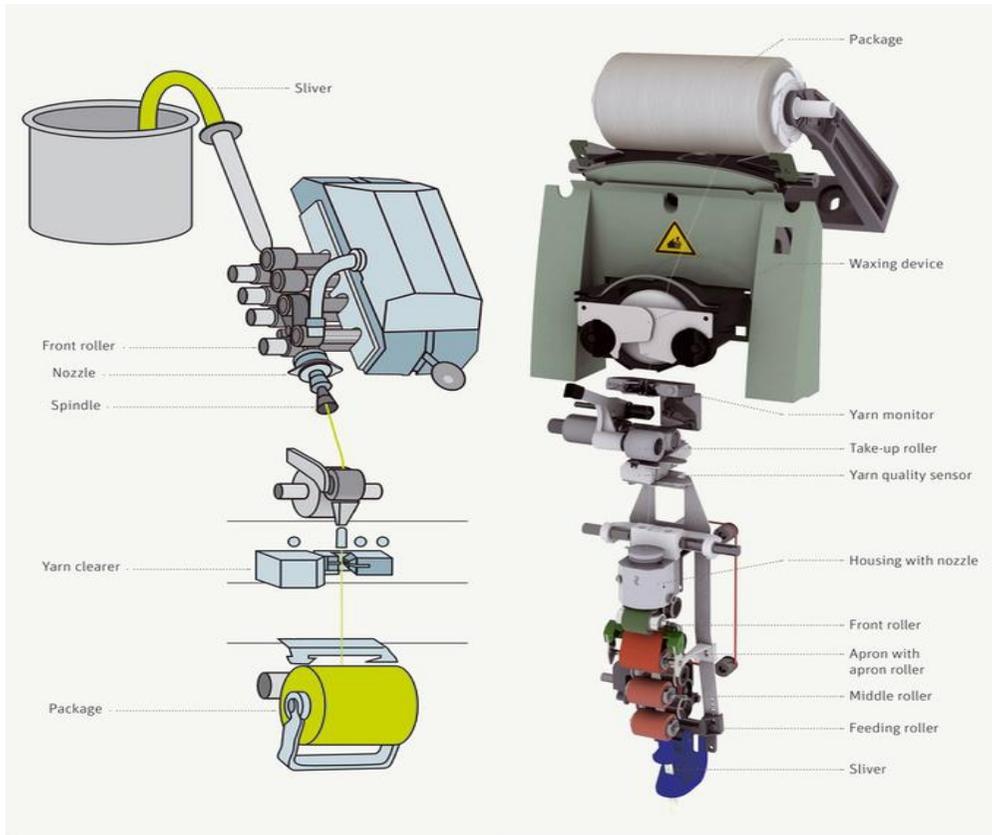


Fig 04: Air-jet spinning principle by Murata (MVS) (left) & by Rieter (J 10) (right)

Table-1: **Process parameters for 20 Ne ring (carded), rotor and air-jet spun yarn:**

Parameters	Ring spinning	Rotor spinning	Air-jet spinning
Fiber type	100% cotton (CIS Uzbekistan)	100% cotton (CIS Uzbekistan)	100% cotton (CIS Uzbekistan)
Staple length	28 mm	21mm*	28mm
Fiber fineness	4.1 Mic	4.1 Mic	4.1
Drawn Sliver Hank	70 grain/yard	70 grain/yard	70 grain/yard
Roving Hank	0.78 Ne	-	-
T.M.	4.7	4.7	4.7
Yarn Count	20 Ne	20 Ne	20Ne

*We selected 21mm fiber for producing rotor yarn due to the process limitation of higher length fiber in rotor machine.

Machines Description

a) Machineries for yarn production

Ring Spinning Machine

Manufacturer: Zhangjiagang Jinqiao Light Machinery Co. Ltd
 Model: FA507
 Origin: China
 Number of Spindle: 1008
 Spindle speed: 14,500

Rotor Spinning Machine

Manufacturer: Schlafhorst
 Model: SE12
 Origin: Germany
 Number of Head: 312
 Rotor R.P.M.: 1, 25,000

Air-Jet Spinning Machine

Manufacturer: Muratec
 Origin: Japan
 Number of Head: 16
 Delivery speed: 120-300 m/min

b) Machineries for yarn testing:

- ✓ Uster Tester 5
- ✓ Wrap reel
- ✓ Wrap block
- ✓ Lea strength tester
- ✓ Electrical balance

Test Result

Table-2: **Experimental value of various parameters.**

Properties		Ring spun yarn(Carded)	Rotor spun yarn	Air-jet spun yarn
Mass variation	U%	11.03	10.17	9.68
	CV _m %	13.81	12.68	12.51
Imperfection	Thin(-50%)/km	3.0	6.3	5.1
	Thick(+50%)/km	98.0	32.8	22.0
	Neps(+200%)/km(Ring); (+280%)/km(Rotor)	135.2	24.7	44.5
	IPI	236.2	63.8	71.6
Hairiness	H	5.37	4.75	4.24
	Sh	1.15	1.19	1.13
Strength (CSP)		2300	1750	1800

Discussion

Comparison of mass variation

Evenness of air jet yarn is the highest. Rotor spun yarn shows higher evenness than ring spun yarn.

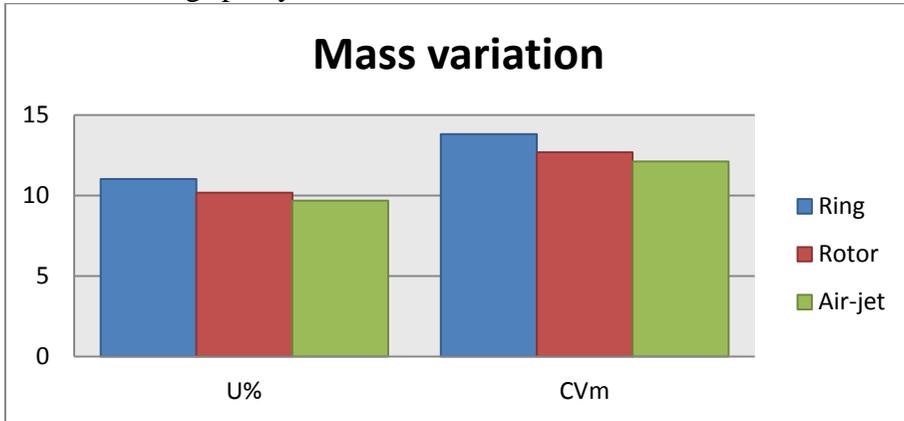


Fig 5: Comparison of mass variation among ring, rotor and air jet yarn (From table 2)

Roller drafting system is liable to produce more uneven yarn in ring spinning and less irregularity in rotor spun yarn is the result of positive influence of back doubling.^[6]

Comparison of imperfection

Imperfection of rotor spun yarn is very much lower than ring spun yarn but rotor spun yarn contains more thin places. IPI of air jet yarn lies between ring and rotor yarn.

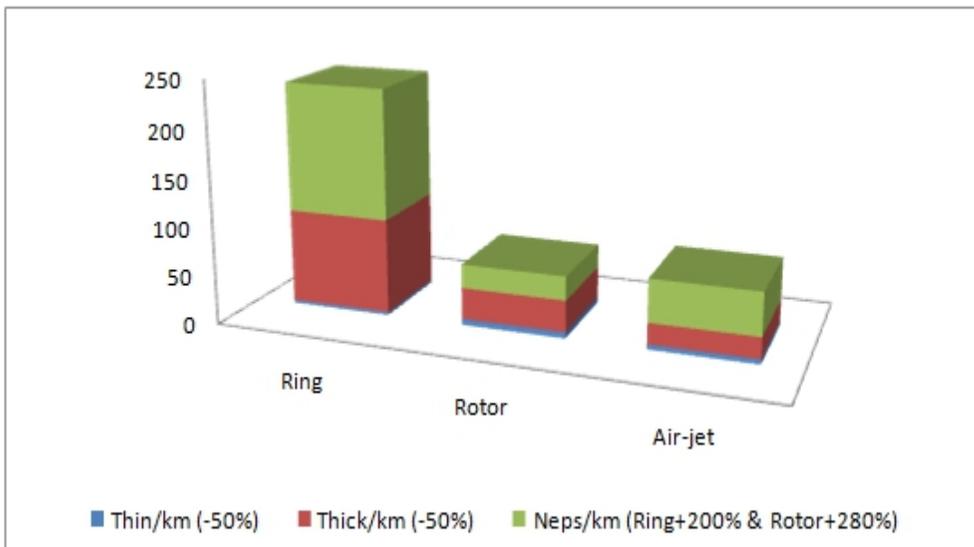


Fig 6: Comparison of IPI mass variation among ring, rotor and air jet yarn (From table 2)

Comparison of hairiness

Air jet yarn shows least hairiness whereas hairiness of rotor spun yarn is lower than ring spun yarn.

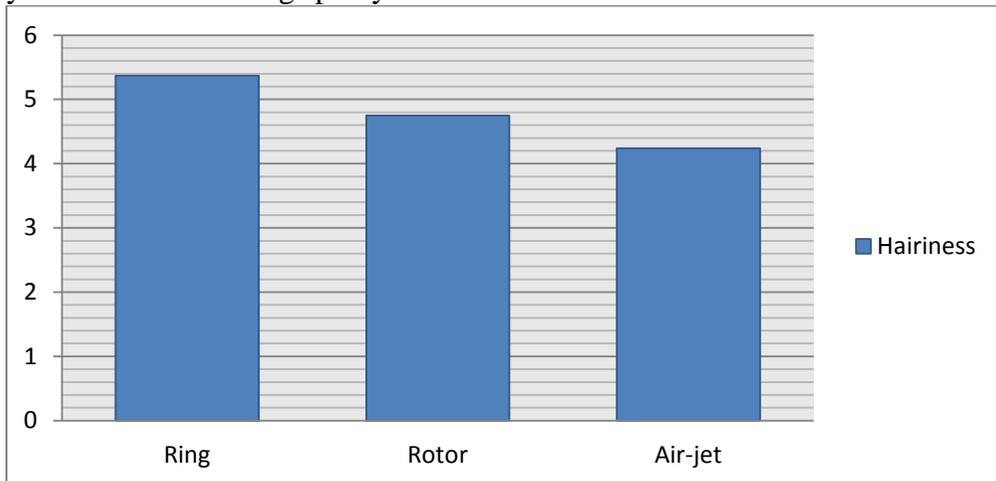


Fig 7: Comparison of Hairiness mass variation among ring, rotor and air jet yarn (From table 2)

The higher hairiness of ring-spun yarns is caused by the uncontrolled passage of edge fibers in roller drafting and friction occurred in balloon control ring. In rotor spinning the wrapping fibers wound crosswise around the yarn help to “bind-in” loose fiber ends.

Comparison of strength (CSP)

Strength of ring spun yarn is higher than rotor spun yarn whereas strength of air jet yarn lies between ring and rotor yarn.

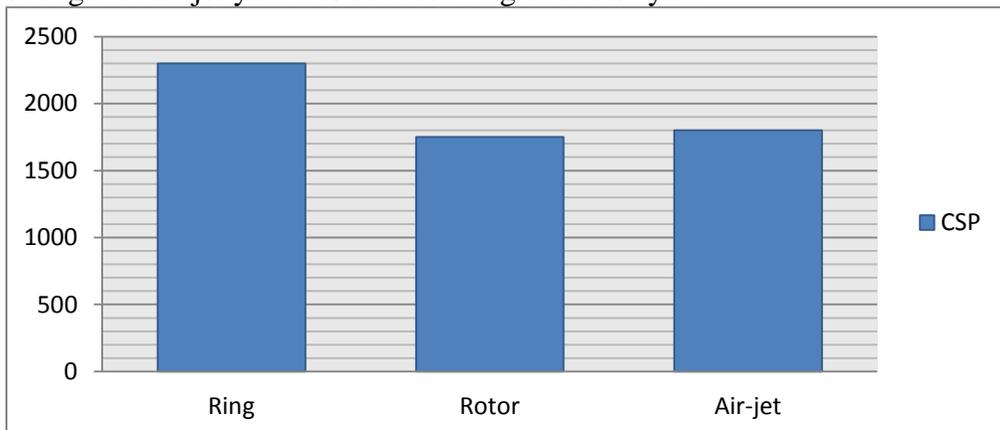


Fig 8: Comparison of CSP mass variation among ring, rotor and air jet yarn (From table 2)

Strength of rotor spun yarn is lower due to its core twist structure.

Summary of the experiment

- **Mass variation** of Rotor spun yarn is about 8% less and air jet yarn is about 12% less than Ring spun yarn.
- **IPI** of Rotor spun yarn is about 27% and air jet is about 30% of Ring spun yarn.
- **Hairiness** of Rotor spun yarn is about 12% less and air jet is about 21% less than Ring spun yarn.
- **Strength** of Rotor spun yarn is about 24% less and air jet is about 20% less than Ring spun yarn.

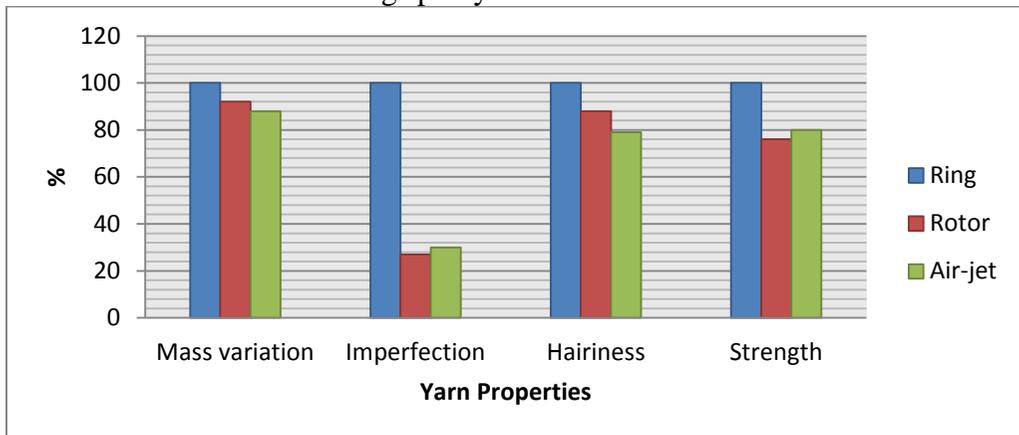


Fig 9: Comparison of all yarn properties of rotor and air jet yarn with ring yarn (From table 2)

Conclusion

Spinners are always trying to produce better quality yarn with low cost. But with the increase of quality cost also increase. Another important parameter is production time. Rotor is the cheapest technique and produced yarn evenness is also better than ring yarn. It is also a fast process. But limitation of rotor yarn is less strength of the produced yarn. If it is possible to increase rotor yarn strength then the yarn will be the best one. So researchers should give emphasize on rotor spinning process. As most of the time we consider yarn strength, almost all the yarns are produced in ring spinning machine as it gives strong yarn. Another reason for greater acceptance of ring yarn is that a wide range of count can be produced by ring spinning system.

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