COMPARITIVE STUDIES ON RING ROTOR AND VORTEX YARN KNITTED FABRICS

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Abstract:

Ring, Rotor and Air vortex spinning systems provide yarn with different structures and properties. Each system has its limitations and advantages in terms of technical feasibility and economic viability. 30's Ne, 100%cotton yarns were produced from the above systems and knitted in single jersey machine .The Rotor Spun yarns found with frequent breakage during knitting. Comparatively good knitting performances have shown by the Ring and Air vortex yarns. Tensile, evenness and hairiness of the yarns and bursting strength, abrasion resistance, pilling, drapability and color matching of the knitted fabrics were studied. The Ring spun yarns have high strength, low imperfection, and good bursting strength. It has high 'S3' value. Abrasion resistance of Rotor and Vortex yarns made fabrics were found higher than the ring spun yarns. Ring yarn knitted fabric has high bursting strength, Air-vortex yarn knitted fabric has poor drape due to stiffer yarn structure and the MVS yarn fabric has poor pilling resistance. Rotor, MVS yarns made fabrics have good abrasion resistance. Drapability of Vortex yarn knitted fabrics was poor than ring and Rotor yarn knitted fabrics. Good and equal depth of dye shade was found with Ring and Air vortex yarn made knitted fabrics. Ring yarn knitted fabric has shown smooth feeling than the other two fabrics.

Keywords:

Yarns, knitted fabrics, properties, ring, rotor and air vortex

1. Introduction

Three major yarn production systems are ring , rotor, and vortex spinning. Ring spinning is a continuous spinning system in which twist is inserted into a yarn by a tiny circulating traveler. Yarn twist insertion and winding take place simultaneously. Ring yarn structure generally accepted as the basic structure in spun yarn technology. In rotor spinning, fibers bundle from the sliver feed stock are separated into individual fibers with an opening roller in an air stream and separated fibers are re-collected in the rotor groove. Many open-end spinning methods have been invented, but none have been successful than rotor spinning. In rotor spinning the Production rate are up to 200 mpm, this can be achieved for yarn counts up to 20 Tex. The Murata vortex spinning based on the air jet spinning technology used for a wider range of fiber length. In the vortex system, drafted fibers are introduced into a spindle orifice by an air vortex. While entering and passing through the orifice, fibers are twisted by the swirling air. It can deliver yarn at up to 400 mpm.

A visual observation of the yarns (Fig 1) shows that the fibers, which form the body of the yarn, lie parallel along the helix of twist. Ring spun yarn is usually assumed to have an ideal cylindrical helical structure uniforms specific volume and each helix having the same number of turns per unit length. The average helix angle of fibers in ring spun yarn was found to be 17.2°. While noticing the configurations of tracer fibres of ring spun yarn, it was observed that the helix angle varies along the length of the fibres confirming the presence of definite fiber migration in the yarn structure [2].

The rotor spun yarn shows a bipartite structure (two-zone structures) comprising a core of fibres this are aligned with the helix of the inserted twist and form the bulk of the yarn, than an outer zone of wrapper fibres, which occurs irregularly along the core length. The wrapper fibres are classified into two types, short and long wrappers. The average helix angle of fibres in rotor spun yarn is significantly higher than that of rings spun yarns. This is because, for same yarn count, rotor yarn demands more TM than the ring yarn to keep the end breakage rate at a lower level. The higher average yarn diameter of rotor spun yarn compared to ring spun yarn signifies that fibres are loosely packed in rotor yarn.
In spite of higher TM, high bulk of rotor yarn can be attributed to the more number of folded fibres, which need extra volume, and less

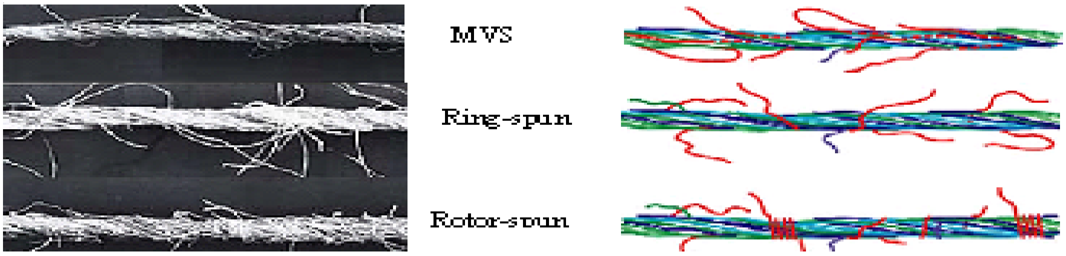

Figure 1. Ring rotor and air vortex yarns structure.

spinning tension in rotor spinning as compared to the ring spinning. In addition, the different twist in order yarn structure also increase the bulk because of the extra volume brought about by crossing fibres.

Rotor yarns are less irregular than the ring spun yarn because of multiple doubling or back doubling of fibres in the rotor groove and ultimate thickness of rotor spun yarn is made up of many thin layers of fibres. Moreover, rotor spun yarns, being made from sliver and with opening roller drafting, are not as affected by roller drafting wave as ring yarns [2]. However, in this experimentation the 30's Ne rotor spun yarn results with high imperfection due to less back doubling than the courser count yarn.

The vortex spun yarn has a two-part structure (core and sheath). MVS spinning technology is favorable for cotton spinning and produces a yarn with more rings –like appearance than MJS spinning technology. the This can be simply revealed by untwisting a vortex yarn by hand. None of the conventional twist measurement methods is suitable for the rotor and air vortex yarns. In studies on 36's Ne P/C blend, vortex yarns exhibit lower elongation than the air jet yarns. This offset gains in tenacity and resulted in an insignificant difference in the work of rupture.

2. Effect of yarn characteristics on knitting performance

Count, twist, frictional behavior, bending rigidity, knots; yarn defects and yarn strength are playing critical role on deciding knitting performance of a yarn. Short fibre content is also playing a key role in knitting machine performance.
Gauge of a knitting machine cannot be changed (as the distance between two needles is fixed). Hence, a particular yarn can be knitted on a particular gauge machine. The count suitability is calculated by using an empirical relationship between yarn count and machine gauge. For circular knitting machine,

Cotton count = (gauge) ^{2}/18.

The yarn has to pass through the space in between two sinkers. If the space between two sinkers is not sufficient as compared to yarn diameter, it will lead to end breakage in knitting process. The choice of yarn and machine gauge combination is largely governed by empirical relationship with undefined tolerance.

Usually in knitting, the low twisted yarns are used because high twisted yarn will create its impression on the fabric feel and create a fabric defect known as spirality (due to unrelieved torque in yarn). In a knitting machine, the yarn has to cover a long path i.e., from package via different guides, through feeder to the needle. The snarls will falls slack in between package and feeder so a small length of double yarn will be fed to the knitting machine. As the needle hook has got fixed dimension, this snarl (double yarn) will create hook breakage. To avoid this problem, yarn tensioning devices should have to set slightly higher level. This causes an increase in yarn input tension and maximum yarn tension inside knitting zone. Hence, there will be always a greater chance of yarn breakage during knitting. Further-more due to the high twist in yarn, the loops in fabric have a tendency to bend. This causes the wales in the fabrics to be at a diagonal, instead of perpendicular, to the course in the fabric. This fabric defect is known skew ness or spirality.

Frictional behavior depends upon yarn surface characteristic. The frictional resistance is generated when the yarn was flowing over or under the same or different surfaces. During the process of knitting the yarn has to pass over and under number of different surfaces. Due to wrap around the needle and sinker the tension in yarn rises, which can be calculated from the Amonton's equation

$$T = T_i e^{\mu m} \sum_{i=1}^{n} e_i \ \ then \ \ i = 1,2,...n$$

T_i input yarn tension µm, coefficient of yarn/metal friction. T, output yarn tension, , angle of wrap and n, number of contact points. It is observed from equation that with the rise of yarn/ metal coefficient of friction, the output tension rises exponentially.

Bending rigidity is defined as the force required for bend the material through unit curvature. The rigidity of the yarn will be decided on what force will be needed to bend the yarn in order to form a loop. The same force will also be acting on needle hook and needle but as a reaction force. If the rigidity of the yarn is very high, then due to high reaction force there will be a greater chance in needle hook or butt breakage. In order to eliminate this problem, it is wiser to select a flexible yarn for knitting (particularly for finer gauge machine).

The yarn defects such as imperfection, thick places, slub, loose fluffs create difficulty during the process of knitting. Any diameter higher than the average yarn diameter may create problem in performance of knitting due to the insufficient space available in between two sinkers. In order to run a knitting machine smoothly, the spinner should have aimed to engineer the yarn in such a way that the yarn should be of uniform diameter though out its lengths.

3. Experimental

3.1. Materials

30's Ne Yarns from three different spinning systems were produced and the properties yarns and knitted fabrics were studied. MCU-5 cotton was used for this purpose. It has 2.5% of span length of 28.2mm, uniformity ratio of 47% and fibre fineness of 3.6 µg/ per inch. Process parameters maintained

Table 1. Process parameters.

Code/Process parameters	Y1	Y2	Y3
Delivery speed	17 m/min	153 m/min	380 m/min
Total draft	45	200	97
Sliver hank	-	0.148	0.295
Rotor	-	T331BD	-
Rotor speed	-	120,000rpm	-
Opening roller	-	8000rpm	-
Spl. speed rpm	15,000	-	-
Ring diameter	40 mm	-	-
Take up ratio	-	-	0.99
Feed ratio	-	-	1.0
Nozzle type	-	-	75,holder 130d, 8.8
Air pr. (kg/cm^2)			N15.5
Yarn Count	30's Ne	30's Ne	30's Ne

in the spinning systems are shown in the table1. The Knitted fabrics were coded as FI, F2 and F3 for the ring rotor and air vortex yarn knitted fabrics respectively.

3.2. Methods

Single yarn tenacity was measured in Premier Tensomax. The test was conducted in an atmosphere of 21^{0}C and 60% RH. The yarns tested for 20seconds breakage. Test length of the specimen is about 500mm and pre-Tension of 0.50cN/ tex is maintained during the tests.

Table 2. Production of knitted fabrics.

Machine	Description
Make	Mayer & Cie
Diameter	18"
Gauge	24
Number of needles	1368
Loop length	0.26cm
Yarn delivery speed	66mpm

Unevenness was measured in Uster tester 4-SE.The test carried out at 400mpm.The hairiness test for yarn was carried out in Zweigle G566 hairiness tester with a test speed of 50mpm for length of 1000 meters .The produced yarns have been converted in to fabrics in the Mayer &Cie knitting machine. The process parameters are given in the table 2.

The knitted fabrics were bleached with hydrogen peroxide (1%owm) in a winch for about 1 hour at a temperature of 75-85^{0}C and then dyed with 3% reactive dye for the inter comparison of the shade variation. The process parameters have shown in the table 3.

Table 3. Dyeing of fabrics.

Dye	3 % (Mouse color)
NaCl	40gpl
Na_2CO_3	4gpl
Material: liquor	1:20
Time	12hours
Temperature	70-80^{0}C
Machine	Winch

Hydraulic bursting strength tester is used to test the bursting strength of knitted fabrics. The pressure is indicated by the tester pressure gauge. Since the rubber diaphragm requires a certain pressure to stretch it, corrections are made by doing a blank test [1].

Martindale abrasion fabric Tester is used to test the abrasion resistance of the fabrics. It uses the principles of two simple harmonic motions working at right angles. The knitted sample was cut into 40mm diameter and subjected to a load of 200gms weight. The loss in weight of the samples was calculated after visual examination of the fabrics.

$$AR\% = \frac{\text{Original weight} - \text{Weight loss}}{\text{Original weight}} \times 100$$

where AR - Abrasion Resistance.

Table 4. Arbitrary standards.

No. of pills	Standard (Grade)
0-4	5
5-10	4
11-20	3
21-40	2
40-60	1
60 & above	0

Pills are small knots or balls of mixture of large number of small fibers accumulated at the surface of the fabric and entangled by the mild frictional action during processing or wearing. These are tested through the I.C.I pillbox tester. Pills are soft, firmly held on the surface of the material. A piece of fabric measuring 127X127mm is stitched so as to be a firm fit when placed round a rubber tube of 152mm long, 32mm outside dia and 3mm thick. The cut ends of the fabric are covered by cellophane tape. Four such tubes encircled by the fabrics are placed in the pillbox tester (229 X 229 X 229mm), which has inner lining with cork. The box is then rotated at 60 rpm for 5 hours. The extent of pilling is assessed visually by comparison with the arbitrary standards, which are given in the table 4.

Drapability of a fabric is determined using Drape meter and is expressed in terms of Drape Co-efficient. A circular specimen of diameter 254mm is supported on a circular disc of diameter 127mm. When doing so, the unsupported area of the fabric drapes over the edge of the supporting disc. The drape co-efficient, F is the ratio between the projected area of the draped specimen and its undraped specimen and its undraped area, after the deduction of the area of the supporting disc.

W_S = Weight of the paper whose area is equal to the projected area of the specimen,
W_d = Weight of the paper whose area is equal to the area of the supporting disc,
W_D = Weight of the paper, whose area is equal to the area of the specimen,
F = Drape co-efficient,

$$F = \frac{W_S - W_d}{W_D - W_d}$$

The thickness of the paper to trace the outline must be uniform. The small value of F indicates better drapability of the fabric and the large values of F indicate the bad drapability [1].

The Macbeth spectrophotometer was used to determine the colour difference. It is used to assess a shade for deciding whether it matches a given standard within the acceptable tolerance limit. The colour difference (DE) is given by CIELAB system. If the colour is specified in terms of L, C, and H, then the colour difference

$$dE = (dL^2+dC^2+dH^2)^{1\backslash 2}$$

Where:
dL =L (Sample)-L (Standard)
dC =C (Sample)-C (Standard)
dH =H (Sample)-H (Standard)

F1 is taken as standard fabric. F2 and F3 fabric were compared with the standard. The tolerance factor is one for assessing the colour difference in knitted dyed samples. If dE value is lesser than 1 than no significance. If the dE value is greater than one it has significance [8].

Table 6. Hair-length distribution of yarns.

Yarns	1mm	2mm	3mm	4mm	6mm	8mm	10mm	S3
Y1	22315	1104	4386	856	20	754	4	6621
Y2	49761	339	522	211	24	186	3	946
Y3	10412	5	675	66	2	190	1	935

Table 7. Bursting Strength of Fabrics in lbs/inch^2.

Fabrics	1	2	3	4	5	Avg.
F1	200	192	195	180	168	181.6
F2	105	125	130	125	118	120.6
F3	143	143	150	155	149	148

4. Results and discussion

For this study, 30 Ne (100%) cotton yarns were knitted into single jersey fabric from three different spinning systems namely ring, rotor and air vortex. These systems provide yarn with different structures and properties. Each system has its limitations and advantages in terms of technical feasibility and economic viability. The Rotor Spun yarns found with frequent breakage during knitting. Comparatively good knitting performances have shown by the Ring and Air vortex yarns.

4.1 Yarn properties

4.1.1. Single yarn strength

Y1 has higher RKm value than Y3. Y3 has higher RKm value than Y2 yarns. CSP of Y1 is 24% higher than Y3 and 40% higher than Y2. Ring yarn is found with more or less round shape.

Table 5. Single yarn tensile properties.

Yarn/Tensile Properties	Y1	Y2	Y3
Tex	20.3	19.86	19.88
Breaking elongation (%)	3.56	5.46	4.14
RKm (g/tex)	13.93	11.66	13.30

The rotor yarn is found with more impurities. The MVS yarn was found with harsh feel than the other two yarns. The Y2 yarns structure assists for the higher elongation. The tensile properties have shown in the table 5.

4.1.2. Yarn evenness

Y2 yarns total imperfection was higher than the other two yarns. This is due to the poor preparation of the sliver. The Y1 yarns were found with low Imperfection per Km due to good processing and cleanliness of the sliver. The Y3 yarns total imperfection was significantly higher then the Y1 yarns.

The Y1 and Y3 yarns show good results than the rotor spun yarns. Due to Y2 yarn fine sliver hank, the yarn breakage occurs frequently. It needs the tender piecing frequently. The Y1 yarn has less U% then the other two yarns because of the uniform continuous spinning process.

4.1.3. Hairiness

The fibers protruding out of the yarn cause hairiness in the spun yarn. This fuzzy appearance to the yarn reduces the value of the yarn. Due to thin layer of wrapper fibres with Y3 and structure, this prevents fibers from protruding from the

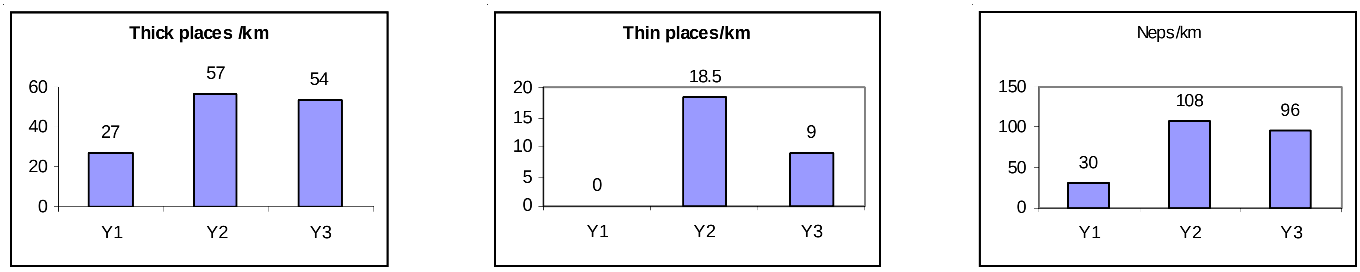

Figure 2. Yarn evenness properties.

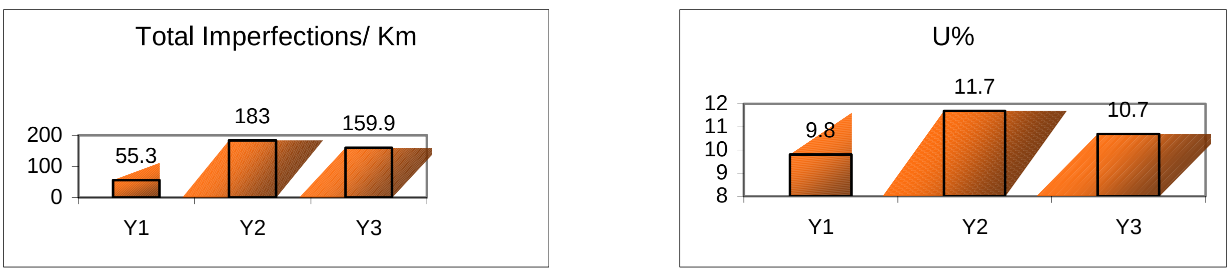

Figure 3. Yarn imperfection properties.

Table 8. Abrasion resistance % of Fabrics.

Fabric	1	2	3	4	5	Avg.
F1	92.85	92.34	91.80	93.12	91.45	92.31
F2	97.23	96.92	96.80	97.33	95.67	96.79
F3	96.07	96.03	95.79	96.12	96.32	96.06

Table 9. Pilling of knitted fabrics.

Fabrics	Grade
F1	4
F2	4
F3	3

Table 10. Drape Co-efficient

Fabrics	1	2	3	Avg.
F1	0.265	0.270	0.264	0.266
F2	0.265	0.277	0.274	0.272
F3	0.326	0.333	0.313	0.324

Table 11. Ring spun yarn fabric Vs Rotor spun yarn fabric

Types	DL	dC	dH	dE
D65	1.03	-0.05	0.04	1.03
TL84	1.04	0	0.09	1.04
A	1.02	-0.01	0.07	1.02

Table 12. Ring spun yarn fabric Vs Vortex spun yarn fabrics

Types	DL	dC	dH	dE
D65	0.29	0.57	0.24	0.68
TL84	0.33	0.58	0.3	0.73
A	0.36	0.51	0.29	0.69

Table 13. Fabrics Parameters.

Fabrics/ properties	F1	F2	F3
CPC	21.25	22.04	22.83
WPC	13.17	14.96	12.59
Stitch Length	0.26	0.26	0.26
GSM	147.6	145.6	148..4
Thickness (mm)	0.4505	0.475	0.513

main yarn body and forming wild fiber loops along the yarn axis.

The Y1 yarns spinning triangle and twisting process induces hairiness. 1mm hairs with Y2 and Y1 are higher than the Y1yarn due to open-end process.

4.2. Fabric properties

4.2.1. Bursting Strength

With high imperfection, the F2 shows low bursting strength than the other two fabrics. The F1 has the highest bursting strength due to high tenacity and uniformity, F3 and F2 fabrics follow the strength values of its respective yarn tenacity.

4.2.2. Abrasion resistance

The table 8 shows F1 fabric has the low abrasion resistance due to easy fiber migration. F2 and F3 fabrics do not have any significance and they have high abrasion resistance due to the presence of wrapper fibers, which resist the movement of fibers during abrasion.

4.2.3. Pilling

The extent of pilling is assessed visually by comparison with the arbitrary standards .The F1and F2 fabrics are almost having equal amount of pills and F3 fabric produces high pills due to high number of the wrapper fibers and its configuration [6].

4.2.4. Drapability

F3 is having bad drape when compared to F1 and F2 fabrics. There is no significant difference in drape between F1and F2 fabrics. The table 10 shows Y3 yarns are stiffer than ring yarns, which have the highest tenacity values [6].

4.2.5. Color Matching

D65 = Daylight, TL84 = Tube light and A = Artificial light . There is significant shade variation between fabrics F1and F2 as shown in table 11 due to color difference value is more than the tolerance value (Tolerance value = 1).

There is no significant shade variation between fabrics F1 and F3, hence the shade is almost similar on both the fabrics shown in the table 12. F3 and F2 were higher bulkier than the F1.

5. Conclusion

For the 30Ne, the ring spun yarn (Y1) has high strength (13.39 g/ tex), it has S3 value around 6621 and having low imperfections. The ring yarn fabric (F1) has good bursting strength (181.6 lbs/inch^2). Abrasion resistance of rotor spun yarn fabric (F2) and vortex spun yarn fabric (F3) are 96.79% and 96.07% respectively, which is better than ring spun yarn fabric (92.31%). Drapability of F3 is found to be poor .It shows drape co-efficient of 0.324. Pilling is found to be high in case of F3. Ring spun fabric (F1) and vortex spun yarn fabric (F3) have similar depth of dye shade. The vortex spun yarn fabric (F3) shows bulky appearance and harsh feel than the other two fabrics.

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