Influence of Yarn quality of Ring and Rotor spinning systems for the development of 100% bamboo and bamboo/cotton blended denim fabrics

G. Nagarajan[1], Dr.T. Ramachandran[2]

[1]Research Scholar, Karpagam Academy of Higher Education, Coimbatore.
[2]Principal (Rtd.) Karpagam Institute of Technology, Coimbatore.

***ABSTRACT*: This paper is focused on the properties of the yarns spun from ring and rotor spinning system, spun using bamboo / cotton blends and used for the development of the denim apparel fabrics. Twenty carded yarn samples of linear densities Ne 10 and Ne 16 were spun in three blend proportions of 70:30 B/C , 50:50 B/C and 30:70 B/C , and also in 100% cotton and bamboo fibers produced using ring and rotor spinning systems. Yarn quality like Unevenness (U %), Imperfections, Single yarn tenacity / elongation, yarn friction and yarn abrasion were evaluated. The experimental results indicated that the 100% bamboo yarns spun on the two spinning systems for both the counts Ne 10 & Ne 16 exhibited better evenness, lower imperfections, higher breaking strength and good abrasion resistance than 100% normal cotton yarns as compared to the other four yarn samples. Whereas among the ring and rotor spinning systems, better evenness, lower imperfections, higher elongation at break and good abrasion resistance were observed in the rotor spun yarns in all the blends as compared to its counterpart ring spinning system. However, single yarn tenacity of the rotor yarns was found to be lower than the ring yarns in all the blends. It is due to its bipartite yarn structure and the presence of wrapper fibers on the sheath of the rotor yarns. Yarn friction in both the counts does not show any significant difference in ring and rotor spinning systems. Among the three blend proportions, 70:30 B/C had resulted better quality characteristics than the other blends in both the spinning systems.**

***Keywords*: Abrasion, Bamboo, Friction, Ring spun yarns, Rotor spun yarns, Tenacity,.**

1.0. Introduction

Bamboo is a natural anti-bacterial and anti-fungal fiber as it possesses inherent natural properties like anti bacterio static agent called "bamboo Kun". The bamboo Kun in bamboo fabric stops odor-producing bacteria from growing and spreading in the bamboo cloth allowing bamboo clothing to be more hygienic and to remain fresh. It is available in abundant quantity and also a cheap natural resource. Products made of bamboo fibers are in high demand in the market because of its inherent anti-microbial, UV protection, smoothness and good moisture management properties and quick drying capability. Bamboo fiber contains Staphylococcus Aureus and Monilia Albican anti-bacterial agents of 99.06% and 94.09% respectively, which is practically absent in the cotton fibers. This property has been utilized in the making of apparel fabrics both in knitted and woven construction. Various blended fabrics have been manufactured like polyester/bamboo and acrylic/bamboo blends. In the fiber structure of bamboo fiber, the cross-section of the bamboo fiber is filled with various micro-gaps and micro-holes. Hence, it is possible for the yarn and fabric made out of bamboo fabrics to absorb and leave out the sweat from the human body rapidly. This means that bamboo fabrics can be worn directly next to skin and will not cause any skin allergies or irritation to the wearer. In addition, bamboo is naturally odor resistant fiber and the fabrics made out of them resist bacteria which causes unpleasant odors. In addition, bamboo fabrics have excellent wicking and insulating properties. Bamboo fiber has been used in various textile products, decorating items and as a high performance material in the composite materials. Bamboo fiber has been used in the manufacture of knitted fabrics like T-shirts, socks, undergarments and in sportswear. Textile materials made out of other natural fibers are particularly more prone to microbial attack. In general, denim fabrics have been manufactured from natural fibers like cotton. Ring and Rotor yarns are used in the warp and filling direction of the fabrics or the same yarns are used in both the directions for the fabric construction. It is the tendency of the denim wearer to wash the fabrics after many days of use, as it is more comfortable and provides warmth to the wearer. However, since it is left unwashed for several days, the denim fabrics are more prone to the growth of microbes. In the present scenario, environmentally friendly products which are biodegradable are mostly liked by the consumers. Many research studies have been made on the bamboo and bamboo/blended fabrics in knitted articles. With the increase in awareness of the customers on health and hygiene against microbes, the unparalleled advantages of bamboo fibers has been utilized in the making of denim fabrics with cotton as counterpart.

Blending of dissimilar fibers is a very common practice followed in spinning mills. The primary objective of blending different fibers is to enhance the characteristics of the resultant fiber mix and also for optimizing the cost of the raw material. The yarn qualities of the blended yarns are dependent upon the fiber properties of the constituent fibers in the blend and their compatibility. In addition to that, the proportion of fibers in the blending is of significance. It means that the stronger fiber component has to be mixed with certain proportion in order to have better tensile properties of the resultant yarn. It has been observed that the longer and finer fibers have a tendency to migrate towards the yarn core, while short and coarser fibers concentrate near the surface during the spinning process. Manufacturing of rotor spun yarns, especially in the coarser and medium varieties, started at the beginning of the 60s. The process sequence is simple in the rotor spinning and the ease of automation has made the spinning system a better replacement for the ring spun yarns, especially in the coarser and medium count ranges. The principle of yarn manufacture by ring and rotor yarns varies inevitably resulting in differences in the yarn structure produced out of the respective spinning system. Ring spun yarn structure has more uniform helical configuration and packing density as opposed to the dense structure of the rotor yarns due to the more typical and horizontal wrapper fibers or belts. This makes the yarn to appear darker or duller in appearance and less reflective of light than the ring spun yarns. However, rotor spun yarns have many advantages like lower yarn irregularity, less uneven places, greater bulk and higher abrasion resistance. The tenacity of the rotor yarn is 15% – 20% lower than the ring spun yarn due to its denser and voluminous yarn structure. The loss in tenacity values is however compensated for in better elongation than the corresponding ring spun yarns. Hence, in the present research work, an attempt has been made to make denim fabrics using the bamboo and cotton yarns in three blend proportions like 70:30, 50:50 & 30:70 bamboo/cotton blends. Also 100% bamboo & cotton yarns were also manufactured to assess their yarn characteristics with the blend proportions. .

2.0. Materials and Methods

Ring and Rotor spun yarns of Ne 10 & Ne 16 were spun from bamboo and cotton fibers from 100% bamboo, 100% cotton and blend proportions of 70:30, 50:50 & 30:70 bamboo/cotton blends. Physical properties of bamboo and cotton fibers are shown in Table 1.The fibers were then processed from blow room to ring spinning for ring spun yarns and from blow room to rotor spinning with one passage of draw frame sliver material. In ring spinning the process parameters like roving count, spindle speed and twist multiplier were maintained as 0.72s (738tex), 11000 rpm and 4.4 respectively. In rotor spinning, rotor diameter, rotor speed, opening roller speed and twist multiplier were 43mm, 60000 rpm, 8000 rpm and 4.8.

Table 1 Physical properties of Bamboo and Cotton fibers

Physical properties	Bamboo fiber	Cotton fiber
Fiber length (mm)	38	29
Fiber denier	1.52	1.48
Bundle fiber strength (g/tex)	28	22
Elongation (%)	18.35	5.5

The yarn samples produced were tested for their properties like unevenness (U%), imperfections, hairiness in Uster Evenness Tester (UT 4). Tensile properties of the yarns were tested for their single yarn strength and elongation in Uster Tenso rapid (UTR4) at a testing speed of 5000mm/min and a gauge length of 500mm.

(b) Test Method adopted

Fiber and yarn samples were tested according to the standard test method followed and also with standard laboratory conditions of R.H. 65% +/- 2% and temp 21 degree +/- 1 degree C.is shown in Table 2

Table 2 Test methods

Properties	Testing instruments and Method
Bamboo fiber	Lenzing ASTM D 1577 -07 (2012)
Cotton	HVI 1000 ASTM D 5867 -2012 e (HVI mode)
Yarn irregularity	UT 4 (ASTM D 1425/D 1425 M-2014
Yarn tensile strength and elongation	UTR 4 ASTM D 2256/D 2256 M -10 (2015)
Yarn Friction	Lawson-Hemphill CTT ASTM D -3108/D 3108 M -13
Yarn abrasion	MAG Solvics – SITRA

3.0. Results and Discussion

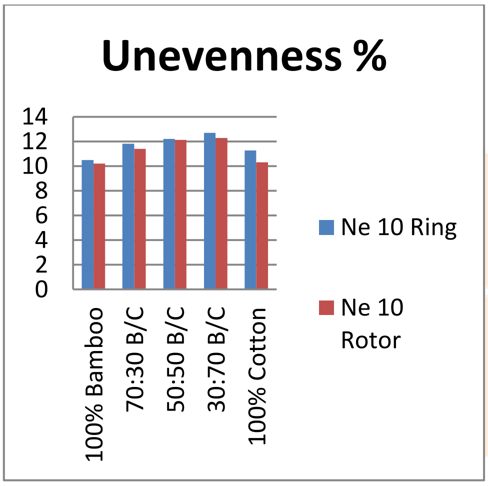
3.1. Yarn Irregularity

The yarn irregularity, imperfections of Ne 10 & Ne 16 Ring and rotor yarns tested in UT 4 instrument and the results are shown in Table 3 & Table 4.

Table 3 Unevenness U% and Imperfections/km of Ne 10 Ring and Rotor yarns

Properties / Blend	Ne 10 Ring					Ne 10 Rotor				
	100% Bamboo	70:30 B/C	50:50 B/C	30:70 B/C	100% Cotton	100% Bamboo	70:30 B/C	50:50 B/C	30:70 B/C	100% Cotton
Unevenness (U%)	10.49	11.8	12.2	12.7	11.27	10.2	11.40	12.12	12.29	10.30
Thin (-50%)	4	4	6	9	2	0	4	7	8	1
Thick (+ 50%)	38	69	92	113	62	21	48	69	89	47
Neps (+200%(+280%)*	25	87	122	162	71	17	65	80	126	56
Total IPI/km	67	160	220	284	135	38	117	151	223	94

*For rotor yarns, nep is measured at +280%.



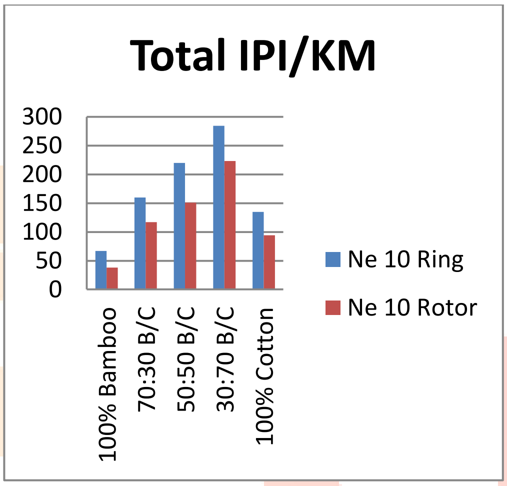
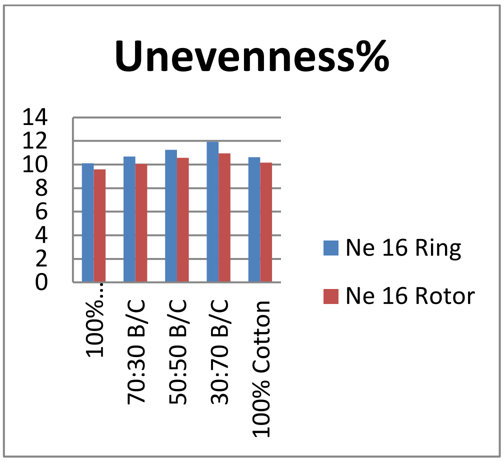
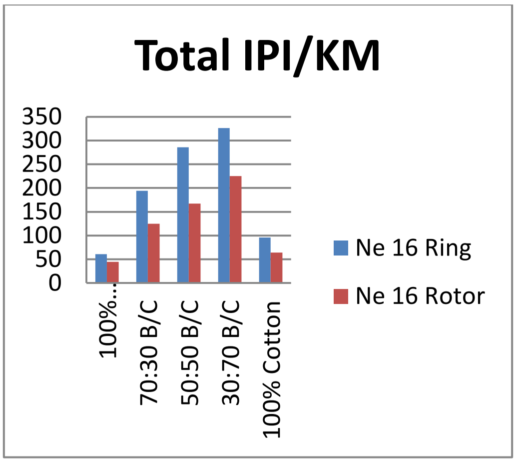


Table 4 Unevenness U% and Imperfections/km of Ne 16 Ring and Rotor yarns

Properties / Blend	Ne 16 Ring					Ne 16 Rotor				
	100% Bamboo	70:30 B/C	50:50 B/C	30:70 B/C	100% Cotton	100% Bamboo	70:30 B/C	50:50 B/C	30:70 B/C	100% Cotton
Unevenness(U%)	10.10	10.68	11.24	11.92	10.62	9.58	10.04	10.58	10.94	10.16
Thin (-50%)	0	2	2	4	1	0	2	4	3	7
Thick (+ 50%)	27	102	120	142	46	19	64	71	86	17
Neps (+200%(+280%)	36	90	164	180	49	26	49	92	129	40
Total IPI/km	63	194	286	326	96	45	115	167	223	64





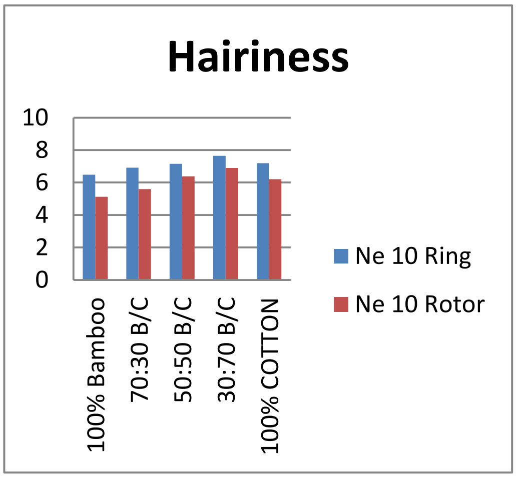
From Tables 3 and 4, it is observed that the total imperfections/km of the 100% bamboo yarns in ring and rotor is better than the yarns spun in other blend ratios. This is attributed to the uniformity of the bamboo fibers as compared to the cotton fibers. However, the imperfections increase substantially due to the presence of cotton fibers in all the blends by 45 % and 68% in 50:50 and 30;70 bamboo-cotton blends. This is ascribed to the variability in the fiber length and the short fiber content in the cotton. The same trend is observed in the rotor yarns also. Imperfections level in other two blends like 50:50 & 30:70 show increasing trend due to the increase in the percentage of cotton fibers in the blends as observed in both the ring and rotor yarns. The evenness and imperfections of the rotor yarns are better than the ring spun yarns in all the blends. The uniformity of rotor yarns is due to the short processing sequence by the elimination of the intermediate processes like speed frame for its better yarn quality as compared to its counterpart ring spun yarns. A possible explanation for this uniformity is the fiber doublings and fibre orientation in the rotor groove which is dependent upon the rotor diameter and the twist per metre in the yarn. In the ring spinning system, the processing sequence from Blow room to spinning which introduces drafting irregularities in the drafting system with pronounced drafting waves in the yarn is attributed to its lower yarn uniformity. Similar trend is observed in Ne 16 counts in ring and rotor yarns as expected.

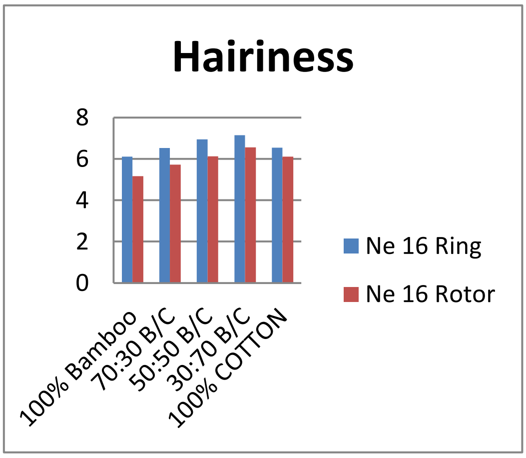
3.2. Yarn Hairiness

Yarn hairiness is the parameter which defines the total number of protruding fibers from the yarn body. Hairiness index (H) of the yarn is measured by counting the number of hairs per unit length of 1cm. Hairiness results for the yarn counts of ring and rotor is shown in the Table 5

Table 5 Hairiness Index (H) of Ne 10 & Ne 16 Ring and Rotor yarns

Count / Blend	Ne 10		Ne 16	
	Ring	Rotor	Ring	Rotor
100% Bamboo	6.48	5.13	6.10	5.17
70:30 B/C	6. 92	5.60	6.52	5.72
50:50 B /C	7.15	6.38	6.95	6.12
30:70 B /C	7.65	6.90	7.14	6.56
100% Cotton	7.19	6.20	6.54	6.10





From Table 5, it was observed that in ring spun yarns, the hairiness index (H) of 100% bamboo fibers is better than the other blend proportions in both the yarn counts. It is ascribed to the better uniformity of the bamboo fibers. The increase in hairiness in the other blend ratios is due to the presence of cotton fibers with higher short fiber content and poor integration of the fibers in to the yarn structure. It is also evident that the hairiness index increases significantly with the increase in cotton fibers in the blend proportion as observed in the 50:50 and 30:70 B/C.

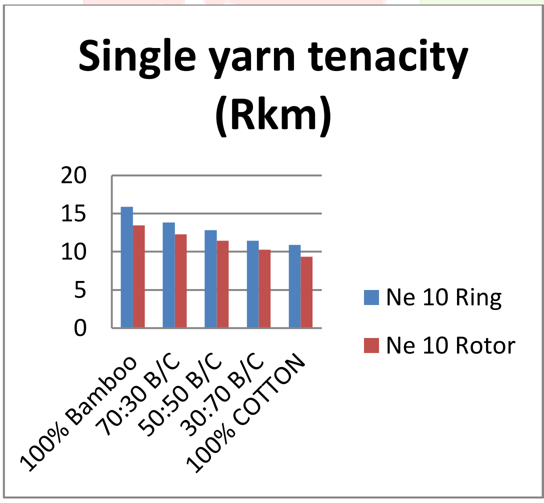
In rotor spinning, the hairiness index of 100% bamboo yarns is lower than the other blends which is as expected. A similar trend of increase in hairiness values in the other blend proportions is also observed in the rotor spun yarns. However, when the hairiness index of rotor and ring yarn are compared, rotor yarns exhibited lower hairiness index by around 15 to 20% as compared to ring spun yarns. The reason for the higher hairiness of ring yarns is attributed to the trailing ends of the fibers, which are preferentially thrown outside the periphery of the yarn due to the migration behavior of the fibers caused by the combination of various factors like spinning balloon, spinning triangle, spindle speed and traveller mass which build up the tension in the ring spinning process. Low hairiness values of rotor spun yarns is ascribed to less tension in the rotor spinning as the twisting and winding operations are separated. In rotor spinning, the fibers are better controlled in the rotor groove and the migration behavior of the fibers from inside to outside i considerably less than that of its counterpart.

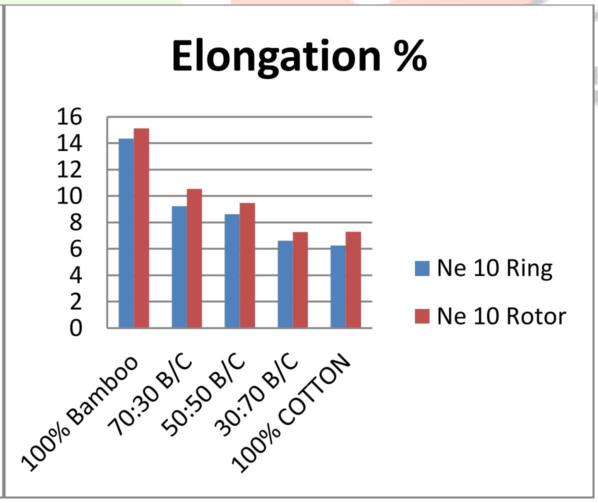
3.3. Tensile properties

Single yarn tenacity and Elongation (%) of Ne 10 & Ne 16 ring and rotor yarns is shown in Table 6

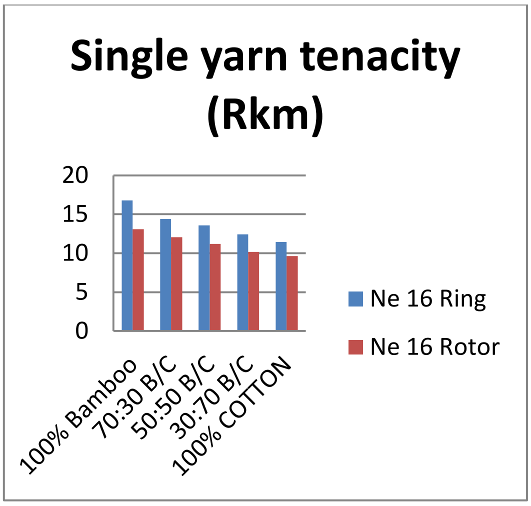
Table 6 Single Yarn tenacity (Rkm) and Elongation (%) of Ne 10 & Ne 16 Ring and Rotor yarns

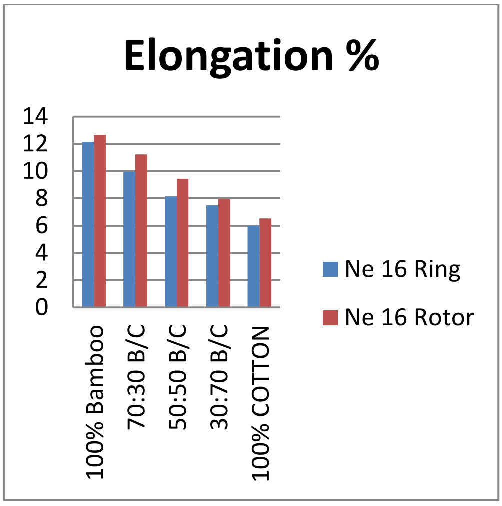
Property / Blend	Ring yarn Ne 10		Rotor yarn Ne 10		Ring yarn Ne 16		Rotor yarn Ne 16	
	Rkm	Elongation%	Rkm	Elongation%	Rkm	Elongation%	Rkm	Elongation%
100%Bamboo	15.90	14.34	13.44	15.12	16.78	12.14	13.09	12.66
70:30 B/C	13.81	9.23	12.29	10.53	14.41	9.96	12.05	11.22
50:50 B/C	12.84	8.63	11.46	9.47	13.56	8.14	11.20	9.45
30:70 B/C	11.44	6.62	10.25	7.26	12.42	7.48	10.15	7.96
100% Cotton	10.90	6.25	9.35	7.30	11.42	5.99	9.65	6.52





From Table 6, Single yarn tenacity and elongation of the two counts spun on ring spinning systems, the tenacity values for 100% bamboo yarns is higher than 100% cotton by around 18%. It is attributed to the fiber properties of bamboo fibers of higher bundle strength than the cotton fibers. In the other blend proportions (70:30, 50:50 &30:70), the tenacity and elongation values decrease due to the presence of cotton fibers. Among the three blend proportions, 30:70 bamboo-cotton blend produces the weakest yarn. It may be attributed to the lower breaking strength and elongation of the cotton fibers and the higher blend of cotton in the yarn. Although bamboo fibers have good strength and elongation, during the tensile testing of yarns, the breaking point is achieved earlier due to the poor load bearing capacity of the cotton fiber component, which leads to the rupture of the yarns.





Tenacity of rotor spun yarns are considerably lower than that of the ring spun yarns by 18% in both counts and in all the blends. In ring spun yarns, a majority of the fibers are twisted along the longitudinal axis of the yarn and during tensile testing; all the fibers contribute to the overall strength of the yarn. The weakness of the rotor yarns is largely attributed to the folded fibers on the outer surface and poor fiber migration due to less tension in the spinning process. Rotor yarns are characterized by the wrapper fibers or belts on the outer surface, which are folded in different directions on the yarn surface. This reduces the fiber extent and the presence of wrapper fibers is responsible for the lower yarn strength. However, rotor yarns have higher elongation values than its ring counterpart. This may be attributed to the yarn structure of the rotor yarns due to the presence of wrapper fibers with poor orientation of fibers in the yarn structure which supports the other fibers.

3.4. Yarn Quality Index (YQI)

Yarn quality index (YQI) is a factor which relates to the single yarn strength, percentage elongation at break and Unevenness of the yarn.

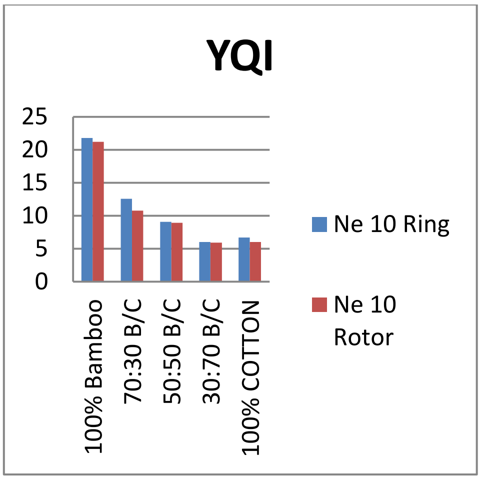
$$YQI = \frac{Rkm \; * \; \% \text{ Elongation at break}}{U\%}$$

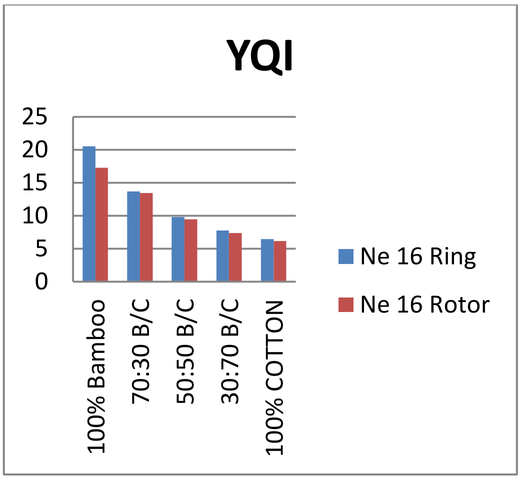
Yarn quality index for the counts Ne 10 and Ne 16 spun on ring and rotor spinning systems are compared and the results are shown in Table 7

Table 7 Yarn Quality Index (YQI)

Property / Blend	YQI Ne 10		YQI Ne 16	
	Ring	Rotor	Ring	Rotor
100% Bamboo	21.79	21.21	20.50	17.26
70:30 B/C	12.58	10.80	13.70	13.46
50:50 B/C	9.08	8.95	9.80	9.45
30:70 B/C	6.05	5.95	7.79	7.38
100% Cotton	6.69	6.05	6.44	6.19

From Table 7, it is observed that the YQI of ring spun yarns are better than the rotor yarns although it is not significant. The reason is that although ring yarns are characterized by its higher yarn tenacity, the U% and elongation behavior of rotor yarns are better than those of its counterpart.



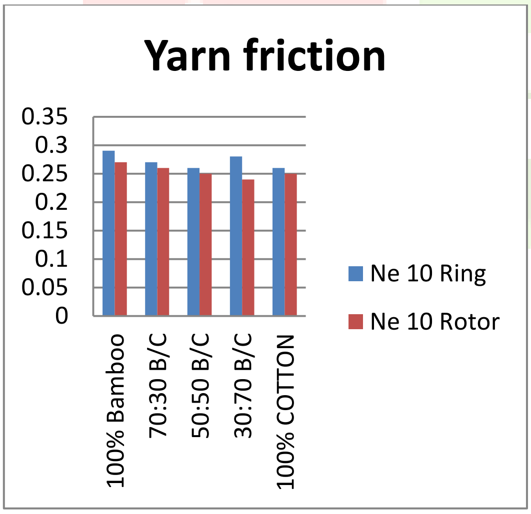


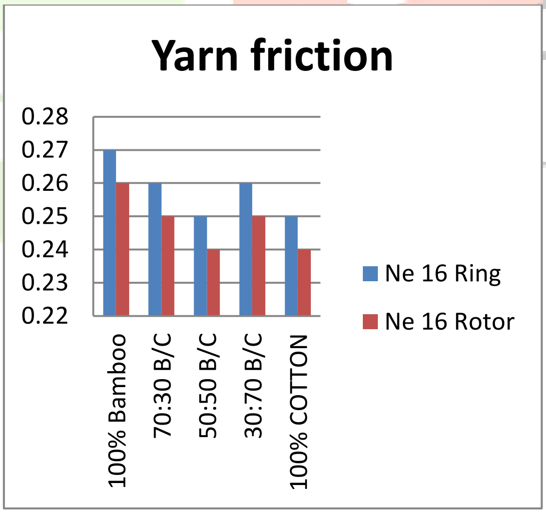
3.5. Yarn friction

Yarn to metal frictional property of Ne 10 & Ne16 ring and rotor yarns is shown in Table 8

Table 8 Yarn friction of Ne 10 & Ne 16 Ring and Rotor yarns

Property / Blend	Yarn friction Ne10		Yarn friction Ne 16	
	Ring	Rotor	Ring	Rotor
100%Bamboo	0.29	0.27	0.27	0.26
70:30 B/C	0.27	0.26	0.26	0.25
50:50 B/C	0.26	0.25	0.25	0.24
30:70 B/C	0.28	0.24	0.26	0.25
100% Cotton	0.26	0.25	0.25	0.24





Yarn to metal friction for ring and rotor yarns for the two counts and its blends is shown in Table 8. It is observed that the friction value of ring and rotor yarns is dependent on the surface structure of the respective fibers (bamboo and cotton) and its corresponding yarn structure and compressibility. Cotton fibers are characterized by their surface structure like convolutions, flat ribbon shaped on their cross section. Bamboo fibers have smooth surface with the presence of crimp on its surface. Hence bamboo fibers, even though they are smooth, the presence of crimps on the surface is responsible for higher coefficient of friction than the cotton fibers. The lower coefficient of friction in cotton fibers is attributed to the presence of fat and wax on its surface which act as lubricant. Ring spun yarn is characterized by helically arranged fibers with a hairy surface. In contrast, rotor yarns may be attributed by disorderly arranged twisted fibers. In addition, the yarn surface consists of wrapper fibers in the form of belts with less hairy surface than the ring spun yarns. The other factor which has an effect on yarn friction is compressibility. A highly compressible yarn will have more contact area between two yarn segments or between a yarn and a solid body. For the same count spun on both ring and rotor, yarn diameter is higher for rotor yarns with increased bulkiness. Hence the friction values are less for rotor yarns than its corresponding ring yarns due to their bulkiness and higher area of contact. This is observed in both the counts and in all the blends. However, no significant difference is observed among all the counts between the two spinning systems.

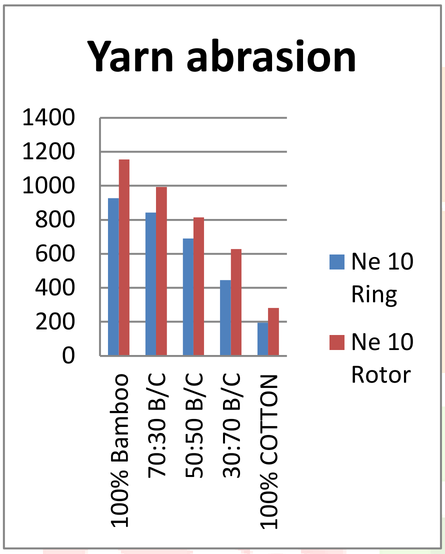
3.6. Yarn abrasion

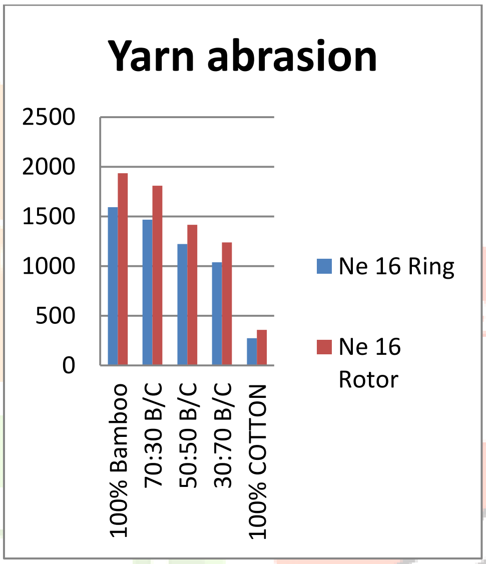
The yarn abrasion test results of Ne 10 & Ne16 ring and rotor yarns is shown in Table 9

Table 9 Yarn abrasion of Ne 10 & Ne 16 Ring and Rotor yarns

Property / Blend	Ne 10 Ring		Ne 10 Rotor		Ne 16 Ring		Ne 16 Rotor	
	Abrasion	RRI*	Abrasion	RRI*	Abrasion	RRI*	Abrasion	RRI *
100% Bamboo	927	4578	1155	3006	1592	7869	1935	9557
70:30 B/C	843	2144	992	2581	1469	7260	1810	8939
50:50 B/C	690	1667	815	2121	1221	6030	1415	6989
30:70 B/C	445	1158	627	1632	1040	5140	1240	6128
100% Cotton	195	508	281	732	274	1353	358	1768

*RRI – a factor Relative Resistance Index. It is calculated based on the abrasion strokes multiplied by tension weight in gms and the whole divided by square root of tex value of the yarn. Tension wt (gms) Ne 10 = 20: Ne 16 = 30 gms.





From Table 9, it is observed that the abrasion resistance of the 100% bamboo yarns spun on ring spinning (Ne 10 & Ne 16) exhibit better abrasion characteristics than 100% cotton yarns. It is attributed to the higher strength of the bamboo fibers, which resist severe abrasion stress cycles. However, the abrasion resistance decreases in the blend proportions of 70:30, 50:50 & 30:70 bamboo-cotton blends. This is due to the lower strength of the cotton fibers, which cannot withstand the abrasive cycles for longer duration. Similar trend is observed in rotor spun yarns also. However, rotor spun yarns have resulted in higher abrasion values than their ring spun counterpart. This is observed in both the counts and also in blends. The structure of the rotor yarns is bulkier in nature than the corresponding ring yarns due to the presence of wrapper fibers on the surface. During the abrasion test of the yarns, wrapper fibers withstand the stresses as it flattens and protects the inner core structure from early damage. A factor relates the abrasion strokes and the count of the yarn is Relative resistance Index (RRI). The higher the value of abrasion strokes the higher the RRI.

4.0. Conclusions

In this study, ten yarn samples are produced with bamboo/cotton using ring and rotor spinning systems and the yarn properties are analyzed**.** Yarn irregularity of rotor spun yarns is found to be 15% to 20% lower than the corresponding ring spun yarns in both the counts. This is mainly attributed to the short process sequence and back doublings in the rotor spinning. 100% bamboo yarns in both the ring and rotor yarns have better yarn irregularity by 35% to 40% as compared to other blend proportions. Tenacity of ring yarns yarns is higher by 15% to 20% than the rotor yarns in all the blends in both the counts. It is attributed to the more uniform, helical configuration and close packing of fibers in the yarn structure. In the rotor yarns, the presence of wrapper fibers on the surface is responsible for its lower tenacity. Yarn abrasion of rotor spun yarns is comparatively better by 7% to 10% than the ring yarns in all the blends and in both the counts. The wrapper fibers in the rotor yarn structure withstand severe stress during the abrasion cycle and protect the inner core structure of the yarn from initial damage. Further, rotor yarns have good elongation property than the ring yarns which are due to the wrapper fibers and fiber entanglements on its surface, which support the yarn during tensile strain. Bamboo-cotton blend of 70:30 shows better yarn irregularity, tenacity/elongation and abrasion resistance than the other blend proportions. Yarn friction of bamboo and bamboo-cotton blends in both the spinning systems does not show any significant difference. Yarn quality index (YQI) does not show any significant difference between ring and rotor yarns in all the blends.

References

1. G.Rameshkumar, P. Anandkumar, P.Senthilnathan, R.Jeevitha and N. Anbumani, Studies on ring, rotor and vortex yarn woven fabrics
2. S.Iqbal and A.W.Kolhatkar, Denim fabrics - Ring and Rotor yarns, Indian Textile J, 2009, Oct
3. K.N.Seshan,P.Chellamani, K.P.R.Pillay, S.K.Khurana, R.M.Mittal, M.C.Sood, N.Balasubramanian and A.N.Desai, Rotor spinning comparisons -Spinning, Weaving, Processing and Overview, A joint project paper presented at 26th Joint Technological Conference, 1985, RP 1
4. R. Zhu and D. Ethridge, Predicting hairiness for ring and rotor spun yarns and analyzing the impact of fibre properties, Textile Research J, 1997, 67, p 694
1.
5. . Li.X.B Physical, chemical and mechanical properties of Bamboo fibers. Msc. Thesis, Lousiana state University, Baton Houge, 2004.

6. Erlumulu N, Ozipek.R. " Investigation of regenerated bamboo fiber and yarn characteristics." Fibers and Textilein Eastern Europe. Vol 16, No.4 (69) 2008, Page no.43 -47.

7. Zhang.O., Jiang.S.. "Industrial utilization of Bamboo". INBAR Technical report No.26,2012.

8. Wojciechowska D, Wlochowicz A,. "Bamboo fibers". -their properties and ways of application. On XIII Scientific Conference of Faculty of Material Technologies and Textile Design 2010, TDI, LODZ, 2010.

9. Denim Fabric Manufacturing – Technical Bulletin, Cotton Incorporated. NC State University
10. Abhijit Majumdar, samrat Mukhopadyay, Ravindra yadav. Properties of ring spun yarns made from cotton and regenerated bamboo fibers, IJFTR, Vol 36, March 2011, pp 18-23.