Studies on Cottonized Jute Composite Structures Spun on Ring, Rotor and Air Jet Spinning Systems

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Abstract
Technical fibers and filaments, which have low extensibility and high tenacity, can be used along with jute in heterogeneous blends for making jute-based yarns as jute fibre contributes positively in the physical properties of the yarn but at a much lower cost. Jute is one of the world's most important fibers, being exceeded in quantity only by cotton. It is highly modulus, moderately strong, lustrous and naturally biodegradable fibre.
The present study investigated the spinning performance for rotating ratios of jute/cotton, jute/viscose and jute/polyester blends to improve the tensile behaviour of composite structures for new diverse uses of cottonised jute blended yarns, fabricated at ring, rotor and air jet spinning systems.

Keywords: Cottonized jute, Composite structures, ring, rotor and air jet spinning systems, yarn tenacity.

INTRODUCTION

Jute is one of the world's most important fibrous crops, being exceeded in quantity only by cotton. It has long been known to people and known as golden fibre. It is highly modulus, moderately strong, lustrous, yellowish brown in colour and is a naturally biodegradable fibre. Jute is one of the cheapest, eco-friendly fibres which is renewable, light in weight and sound absorbent. Jute fibre possess some advantageous physical and chemical properties, like high tensile strength, specific stiffness, low thermal conductivity, antistatic properties and good dying ability, but has drawbacks like relative coarseness, brittleness, hardness in feel, rugged appearance, inextensibility, poor washing ability, prickliness and fibre shedding.

Jute has a specific strength, which is greater than that of aluminum and mild steel, as well as specific stiffness, greater than those of nylon and cotton. Thus on specific stiffness basis jute is a favorable reinforcing material.

A large area of consumption of jute is converting jute fibre into the blended textiles in combination with viscose, cotton and other fibres to spin finer yarns for home textile use. Effective blending (fibre to fibre homogeneous mixing) of jute with cotton and other man made fibres in the back process of ring or rotor-spinning system is gaining appreciation. Effective blending provides a better scope for utilizing the advantage of the intrinsic properties of the component fibres and performed mainly to endow the required characteristics to the end products, compensate for variation in the characteristics of the raw materials and to hold down raw material cost.

Open-end spun yarns of similar count, breaking strength and elongation are lower in value than for equivalent ring spun yarns [1]. The strength of rotor yarn is 20-30% lower than that of ring spun yarn [2]. The fibre properties had a significant effect on yarn strength. Strength of yarn depends on how well its constituent fibres can equally share the tension induced by the load applied to the yarn. Rotor yarn is 21% weaker than conventional ring spun yarns whose breaking elongation is high than other yarns of similar counts [3]. In rotor spun jute/viscose yarn blends the yarn strength falls by roughly 0.6% for every 1 % increase in jute content [4]. Where as the strength of comparable P/C air jet spun yarns were greater than that of rotor yarns [5]. The jute/viscose blended yarn studies revealed that an increase in percentage of jute in blended yarns recorded a decrease, both in its tensile strength as well as elongation, while it helped to obtain an improved initial modulus [6]. Similarly, Air-jet spinning system produces yarns of lower tenacities than their ring spun counterparts because the structure of those yarns are different from that of ring spun yarn [7]. The tensile and visco elastic characteristics of rotor and friction (Dref-2) spun jute blended yarns depends partly on fiber alignment and partly on the non-compatibility of the tensile properties of their component fibers and with the increase of jute % in both the rotor spun jute/cotton and jute/viscose blends, yarn tenacity drops gradually [8]. Condensed yarn is the best ring yarn, with low hairiness, better fibre utilization, higher yarn resistance, and elongation resulting in high work capacity. It is spinable at lower twist than conventional yarns [9].

MATERIALS AND METHODS

The present research project “Studies on cottonized jute composite structures spun on ring , rotor and air jet Spinning systems, was initiated in the Department of Fibre Technology, University of Agriculture, Faisalabad, and mainly conducted at Nafees Textile Mills Ltd., Muzafar Garh. Some jute fibre testing was done in Cresent jute products, Jaranwala. The material used was cotton, cottonized jute, polyester, and viscose.

Preparation of Samples for Evaluation

All fibres, of 51 mm cut length, except cotton (28.5 mm), were selected for this study. The cotton, polyester, viscose and jute fibres were processed separately in the blow room and carding section at normal machinery adjustments. The card slivers of Jute, polyester, cotton and viscose were fed to the breaker drawing, after breaker process different blending ratios were produced on the drawing frame as it provides the best blend in the longitudinal direction. Blends were further processed through inter and finisher drawing frames to improve the blending, as well as uniformity of sliver. The slivers of 65 grains/yard were processed.

Spinning system	**Components of yarn**	**Blending ratios Jute/other fibres**
S1=Ring spinning **S2=Open end spinning** **S3=Air jet spinning.**	**F1=Jute/cotton** **F2=Jute/viscose** **F3=Jute/polyester**	**B1=20/80** **B2=35/65** **B3=50/50** **B4=65/35**

After processing in the simplex machine the roving of 0.88 hanks fed to ring to spin the yarn of 30s count. For open-end and air jet spinning systems, direct drawing sliver was fed to spun 30s yarn count.
It was initially planned to process the five blend ratios but B5 (with 80 percent jute) was practically unattainable. Similarly B4 (65/35) blend of jute/cotton was also not viable to spin. Finally (B5) treatments were deferred, and missing data under (B4) treatments were taken as zero to facilitate statistical process. The following yarn characteristics were compared for the manufactured yarn.

Yarn Characteristics
The 30^S polyester, viscose and cottonized jute blend specimens under all possible settings were tested for the following physical yarn parameters and evaluated according to the procedures laid down by ASTM Committee (2005).
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Tensile Properties of Yarn
Tensile properties viz., single yarn strength and elongation were measured at Uster Tensorapid, which applies the principle of constant rate of extension (CRE) for testing. CRE describes the simple fact that the moving clamp is displaced at the constant velocity. As a result the specimen between the stationary and moving clamp extended by a constant distance per unit time and the force required to do so is measured. The breaking tenacity is calculated from the peak force, which occurs any where between the beginnings of the test and the final rupture of the specimen. The breaking elongation is calculated from the clamp displacement at the point of peak force. The procedure adopted is given in detail ASTM Standard (2005a).

Atmospheric Conditions
The testing work was carried out under standard laboratory conditions, which were maintained at 65 ± 2% relative humidity and 20 ± 2˚C temperatures.

Statistical Analysis
A Completely Randomized Design was applied for the analysis of variance of data to measure the differences among various quality characters as suggested by Faqir [10]. Duncan's Multiple Range test was also applied for the individual comparison of mean values among various quality characters. The data was subjected to statistical manipulation on a computer employing M-Stat Microcomputer Program devised by Freed [11].

RESULTS AND DISCUSSION

Single Yarn Strength
The statistical analysis of variance and comparison of individual means for single yarn strength is presented in Table 1 and 1a respectively. The results indicate that the difference in the mean values of single yarn strength, due to different spinning systems, fibre components and blend ratios are highly significant. Similarly all their interactions also recorded highly significant effects.

Table 1. Analysis of variance for Single Yarn Strength.

S.O.V.	Df	S.S.	M.S.	F. Value	Prob.
S	2	113155.833	56577.917	1832.505	0.0000**
F	2	259232.500	129616.250	4198.147	0.0000**
B	3	326648.194	108882.731	116.958	0.0000**
S×F	4	14444.167	3611.042	3526.608	0.0000**
S×B	6	1423.056	237.176	7.681	0.0000**
F×B	6	30286.389	5047.731	163.491	0.0000**
S×F×B	12	8263.611	688.634	22.304	0.0000**
Error	144	4445.947	30.875		
Total	179	757899.697			

** = Highly significant NS = Non significant C.V. = 1.61%

Table 1(a). Individual Comparison Between treatment Mean Values.

Spinning system	Mean	Components of yarn	Mean	Blend ratios	Mean
S_1	351.1a	F_1	248.5c	B_1	412.0a
S_2	294.6c	F_2	321.3b	B_2	349.7b
S_3	323.1b	F_3	399.0a	B_3	322.2c
				B_4	207.8d

Note: Any two mean values not sharing a letter in common differ significantly at $\alpha = 0.05$ level of probability

Duncan's multiple range test (Table-1a) reveals that among different spinning systems, the highest mean value of single yarn strength is registered under S_1 (ring yarn) followed by S_3 (air jet yarn) and S_2 (open-end yarn) with values as 351.1, 323.1 and 294.6 grams respectively. On the basis of these results it can be inferred that single yarn strength of ring yarn is higher than the rest of the spinning systems (open end & air jet). Previous research revealed that the strength of rotor yarn is 20-30% lower than that of ring spun yarn [2]. The strength of yarn depends on how well its constituent fibres can equally share the tension induced by the load applied to the yarn. The rotor yarn is 21% weaker than conventional ring spun yarns of identical counts [3]. Condensed yarn is the best ring yarn, its low hairiness, better fibre utilization, higher yarn resistance, and elongation results in high work capacity [9], whereas the strength of PC air jet yarn is greater than that of rotor yarn.

In the case of the fibre components, the highest mean value obtained for single yarn strength is recorded at F_3(Jute/Polyester) as 399.0 followed by F2(Jute/Viscose) and F_1(Jute/Cotton) with their respective values as 321.3 and 248.5 grams. It is evident that jute: polyester fibre components produced the strongest yarn as compared to other fibre components because the strength of polyester fibre is higher than viscose and cotton. This is justified by results obtained from the research of Yonghua and Yan (1990) who concluded that fibre properties had significant effect on yarn strength.

With regard to the effect of blend ratios, the highest values for single yarn strength is obtained at B_1 (with 20 percent Jute) as 412.0 followed by B_2 (with 35 percent jute), B_3 (with 50 percent jute) and B_4 with their respective values as 349.7, 322.2 and 207.8 grams. These values differ significantly from one another. The present research indicates that as the percent of jute is increased in the blend, single yarn strength decreases gradually. From these findings it is inferred further, that single yarn strength is inversely proportional to the percentage of jute in blends, because the strength of jute is less than those of cotton, polyester, and viscose. In the jute/viscose blended yarns it was concluded that the increase percentage of jute in the blended yarn resulted in a decrease in both its tensile strength and elongation while it helped to obtain an improved initial modulus [6]. The rotor spun jute/viscose yarn tests showed that yarn strength falls by roughly 0.6% for every 1 % increase in jute content.The tensile and visco-elastic characteristics of rotor and friction (Dref-2) spun jute blended yarns depends partly on fiber alignment and partly on the non compatibility of the tensile properties of their component fibers and with the increase of jute percentage both in the rotor spun jute/cotton and jute/viscose [4].

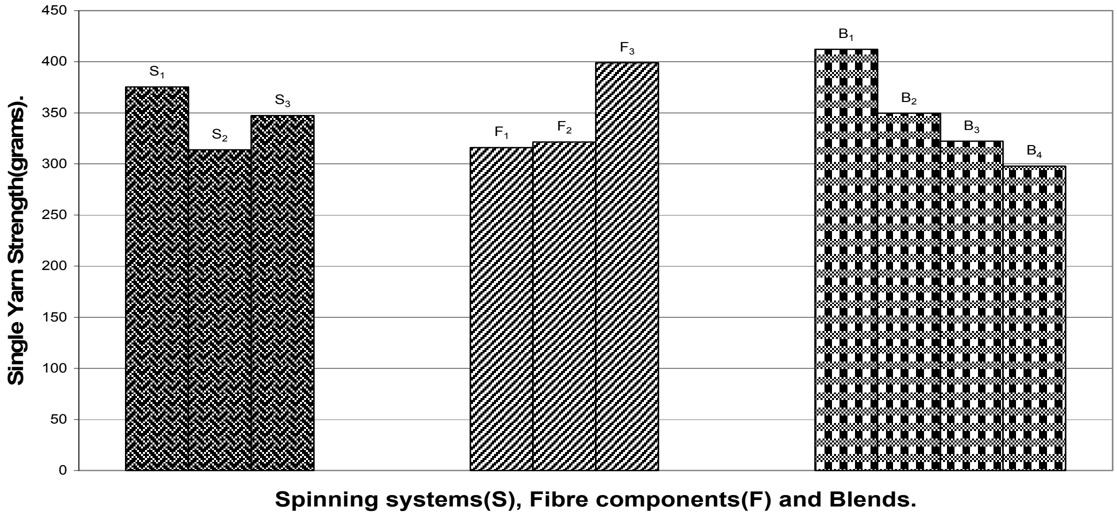
TABLE-1(b). INTERACTION (S×F×B) FOR Single Yarn Strength

	S_1			S_2			S_3		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
B_1	377.0h	430.0d	537.0a	317.0o	360.0j	452.0c	395.0fg	348.0k	492.0b
B_2	350.0k	370.0i	413.0e	299.0p	304.0p	350.0k	350.0k	328.0m	383.0h
B_3	320.0no	326.0mn	401.0f	273.0r	274.0r	336.0l	301.0p	300.0p	369.0i
B_4	289.0q	299.0p	390.0g	231.0u	250.0t	320.0no	290.0q	266.0s	345.0k

The Table 1(b) shows the effect of S×F×B (interaction of spinning systems x fibre components x blend ratios). The overall range is plotted between 250 to 537.0 grams. The best value is obtained for ring spun yarn with minimum share of jute as 537 grams and the worst value obtained under the combination (S_2xF2xB_4) as 250 grams.

Under the S1 (ring spinning) the trend is evident. That is the yarn with highest share of polyester posses maximum strength while the addition of jute in the blend drops the strength of yarn gradually. Similar observation can be noted for rotor and air-jet spun yarn. Ring spun yarn has a maximum single yarn strength and similar observation can be noted for the cotton and viscose blended with jute.

Fig 3. Graphical Representation of Single Yarn Strength.



Yarn Elongation

The statistical analysis of variance and comparison of individual means for yarn elongation is given in Table 2 and 2a respectively. The results indicate that the difference in the mean values for yarn elongation due to different spinning systems, fibre components and blend ratios is highly significant. Similarly all the interactions are also highly significant.

Table -2. Analysis of variance for Yarn Elongation.

S.O.V.	Df	S.S.	M.S.	F. Value	Prob.
	2	19.127	9.564	994.868	0.0000**
F	2	306.092	153.046	15920.922	0.0000**
B	3	692.5812	230.837	24013.351	0.0000**
S×F	4	0.772	0.193	20.085	0.0000**
S×B	6	1.966	0.328	34.088	0.0000**
F×B	6	40.057	6.676	694.502	0.0000**
S×F×B	12	3.991	0.333	34.601	0.0000**
Error	144	1.384	0.010		
Total	179	1065.902			

** = Highly significant NS = Non significant C.V. = 1.66%

Table 2(a). Comparison Between Individual Treatment Mean Values.

S	Mean%	F	Mean%	B	Mean%
S_1	6.12a	F_1	3.94c	B_1	8.08a
S_2	5.32a	F_2	6.13b	B_2	6.78b
S_3	5.67b	F_3	7.04a	B_3	5.13c
				B_4	2.82d

Note: Any two mean values not sharing a letter in common differ significantly at $\alpha = 0.05$ level of probability.

Duncan's multiple range test (Table-2a) reveals that in case of different spinning systems the highest mean value of yarn elongation is found at S_1 (ring) followed by S_3 (air jet) and S_2 (Open end) with the values 6.12, 5.67 and 5.37 percent respectively. Results indicate that a ring spinning system produces yarn with the highest elongation. This is due to the fact that yarn elongation to some extent depends upon single yarn strength and the ring spinning system produces yarn with the highest single yarn strength as compared to rotor and air jet spinning systems. On the basis of these results it can be inferred that yarn elongation of ring spun yarn is higher than other spinning systems. The air-jet spinning system produces yarns of lower tenacities than their ring spun counterpart [7].Comparison of different yarns revealed that yarn of similar counts, breaking strength and elongation of open-end spun yarn are lower than for equivalent ring spun yarns [1].

In the case of fibre components the highest mean value for yarn elongation is recorded at F_3 (Jute/Polyester) as 7.04 percent, followed by F_2(Jute/Viscose) and F_1(Jute/Cotton) with their respective values as 6.13 and 3.94 percent. It is evident from these results that jute/ polyester component fibrous structures produce better yarn elongation because this composition produced greater single yarn strength as compared to other yarn structures and also because the yarn elongation to some extent depends upon single yarn strength like-wise fibre properties had a significant effect on yarn strength and the strength of polyester is higher than that of cotton and viscose [5].

With regards to the effect of blend ratios the highest values for yarn elongation is obtained at B_1 (with minimum jute) at 8.08 percent followed by B_2(35percent jute), B_3(50 percent jute) and B_4(65 percent jute) with their respective values as 6.78, 5.13 and 3.85 percent. These values differ significantly from each other. The present results indicate that as the percent of jute increases in the blend, yarn elongation drops progressively. This is due to the fact that the single yarn strength of a blend decreases with an increase in the amount of jute in a composite structure and as such the yarn elongation to some extent depends upon the single yarn strength [6].

From these findings it is further inferred that yarn elongation is inversely proportional to the percentage of jute in blends. The physical properties of jute yarn had been related to blend ratio and twist multiplier [9]. Similarly in jute/viscose blend yarns, an increase in percentage of jute in the blended yarn registered a decrease both in its tensile strength as well as elongation, while it helped to obtain an improved initial modulus [6].

The comparison of individual treatment means concerning the yarn elongation due to interaction of (SxF) is given in table 5c. Results show that for S_1 the maximum yarn elongation (7.37 percent) is obtained at S_1xF_3 and minimum at S_1xF_1 as 5.20 percent. For S_2 maximum yarn elongation is obtained at S_2xF_3 as 6.70 percent and minimum yarn elongation (4.70 percent) at S_2xF_1. For S_3 maximum yarn elongation is obtained at S_3xF_3 as 7.05 percent and minimum yarn elongation 4.57 percent at S_3xF_1. The over all best combination is S_1xF_3 (ring spinning system and jute: polyester fibre component) and worst combination emerged is S_2xF_1 i.e. rotor spinning system and jute: cotton fibre component.

The comparison of individual means concerning the yarn elongation due to interaction of (SxB) is given in table 5d. Results show that for S_1 the maximum yarn elongation (8.39 percent) is obtained at S_1xB_1 and minimum at S_1xB_4 as 4.21 percent. For S_2 maximum yarn elongation is obtained at S_2xB_1 as 7.83 percent and minimum yarn elongation (3.47 percent) at S_2xB_4. For S_3 maximum yarn elongation is obtained at S_3xB_1 as 8.00 percent and minimum yarn elongation 3.87 percent at S_3xB_4. The over all best combination is S_1xB_1 (ring spinning system and 80: 20 blend ratio) and worst combination is S_2xB_4 i.e. rotor spinning system and 35: 65 blend ratio.

The comparison of individual means concerning the yarn elongation due to interaction of (FxB) is given in Table 2b. Results show that for F_1(JxC) the maximum yarn elongation (6.83 percent) is obtained at F_1xB_1(jute/cotton ratio 35:65$_)$ and minimum at F_1xB_4 (jute/cotton 65/35) as 3.06 percent. For F_2(jute/ Viscose) the maximum yarn elongation is obtained at F_2xB_1 (20/80) as 8.27 percent and minimum yarn elongation (3.74 percent) at F_2xB_4 (65/35). For F_3 (jute/ polyester) the maximum yarn elongation is obtained at F_3xB_1 (20/80) as 9.12 percent and minimum yarn elongation 4.74 percent at F_3xB_4 (65/35). The over all best combination is F_3xB_1 (jute: polyester fibre component at 20: 80 blend ratio) and worst combination is F_2xB_4 i.e. jute: viscose fibre component at 65: 35 blend ratio.

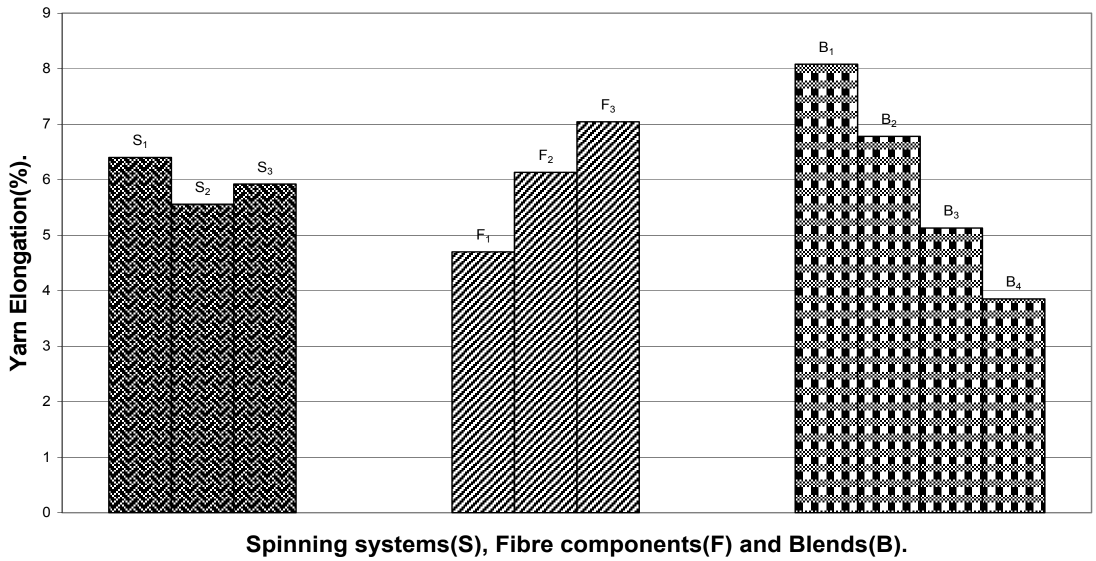
The Table 2(c) shows the effect of S×F×B (interaction of spinning systems x fibre components x blend ratios). The overall range lies between 2.80 to 9.28 percent. The best values are obtained under the combination $S_1xF_3xB_1$ as 9.28 percent and the worst, under the combination $S_2xF_1xB_4$ as 2.80 percent.

Table 2(C). Interaction (S×F×B) For Yarn Elongation.

	S_1			S_2			S_3		
	F_1	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**	**F_1**	**F_2**	**F_3**
B_1	**7.50g**	**8.40c**	**9.28a**	**6.40j**	**8.10e**	**9.00b**	**6.60i**	**8.30cd**	**9.10b**
B_2	**6.13k**	**7.60g**	**8.20de**	**5.10o**	**6.00l**	**7.80f**	**5.40n**	**6.70i**	**8.10e**
B_3	**3.80s**	**6.40j**	**6.90h**	**3.00u**	**5.20o**	**5.70m**	**3.30t**	**5.70m**	**6.20k**
B_4	**0.00v**	**4.12r**	**5.12o**	**0.000v**	**3.30t**	**4.30q**	**0.000v**	**3.80s**	**4.80p**

F1 blends with 65 percent jute components under cotton could not be spun on any system. For the statistical analysis its value is tabulated as zero.

Fig 5. Graphical Representation of Yarn Elongation.



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