Indian Journal of Fibre & Textile Research
Vol. 43, March 2018, pp. 59-65

Effect of wrapper filament characteristics and wrap density on physical properties of wrap-spun jute and jute-viscose blended yarns

Atin Chaudhuri[a]

Department of Jute and Fibre Technology, University of Calcutta, 35 Ballygunge Circular Road, Kolkata 700 019, India

Received 6 August 2016; accepted 16 November 2016

The tensile and other physical properties of jute and jute-viscose blended wrap-spun yarns have been studied. The investigation also includes study on the effect of wrap density and mono and multi wrapper filaments on the rupturing process and physical properties of jute and jute-viscose (70:30) blended yarns. Rupturing process shows the stick-slip oscillations occurred at lower wrap density and gradually reduces the frequency of oscillation with increase in wrap density without any catastrophe. Both jute and jute-viscose wrapped yarn with HDPE monofilament wrapper shows less frequency of stick-slip oscillations and higher tenacity as compared to the both types of wrapped yarns with PP multifilament wrapper. The tenacity of wrap-spun yarns is increased with the increase in wrap density for both type of yarns with all wrapper filaments. Short-term mass irregularity, irregularity index and imperfections are reduced and YQI is improved in case of blended yarns with both the wrapper filaments as compared to jute wrapped yarns.

Keywords: Blended yarn, Catastrophic rupture, Hairiness index, Mass irregularity, Monofilament wrapper, Multifilament wrapper, Stick-slip oscillations, Tenacity, Wrap density, Wrapped yarn, Yarn imperfections, Yarn quality index

1 Introduction

Jute fibre possesses some favourable technical properties such as high tensile strength and bulk, good dyeability, natural fire retardancy property, sound and heat insulation property, low thermal conductivity, dimensional stability and antistatic property. It has also drawbacks like relative coarseness, brittleness, harshness in feel due to presence of lignin in it, rugged appearance, wrinkle behaviour, inextensibility, in washability, fibre shedding, etc. These drawbacks can be improved either by means of blending with other natural or manmade fibres[1] or by chemical treatment[2] to get suitable products at lower cost for different end uses like decorative fabrics, carpets, blankets and also union fabrics. It has been assessed[2] that the blending of small proportion of manmade or natural fibres may produce better eye appeal and novel dyeing effect besides overcoming some of the disadvantages which are associated with all jute products in respect of feel, appearance, resilience, drape, washability, wrinkle behaviour and abrasion resistance, etc.

The technological and economic limitations of conventional jute spinning systems, such as slip-draft flyer spinning, apron draft spinning system, etc. have resulted in the exploration of many new methods of yarn manufacturing system[3]. Wrap spinning system is one of the non-conventional yarn manufacturing technologies in this respect and is completely based on Hollow Spindle Technique[4]. In this system, the yarn is produced by wrapping a continuous sheath filament around a core consisting of straight and parallel fibres[3-5]. The continuous filament exerts a radial pressure[5] providing the necessary frictional forces between the individual staple fibres. The friction increases as the wrapped yarns are subjected to tension, and this provides the strength to the wrapped yarn. Wrapped yarn, being comparatively uniform and having higher elongation as compared to conventional jute and jute-blended yarn, would be very suitable for certain value- added products, such as primary carpet backing, carpet face yarn and also varieties of blended products of jute with synthetic and other fibres[6,7]. It is expected that the rupture of twisted carpet backing yarn during tufting could be minimised by using wrapped yarn in the primary carpet backing cloth.

In view of this, an attempt has been made to investigate the structure, rupture behaviour, tensile and evenness properties of wrap-spun jute and jute-viscose blended yarns using HDPE monofilament and PP multifilament as wrapper elements.

[a]E-mail: atin57@gmail.com

2 Materials and Methods

2.1 Raw Materials

Jute fibres [Tossa-Daise (TD-3)] were used for this study. Variable cut staple length viscose fibres were used for the compatibility of length and fineness with jute fibres. High density polyethylene (HDPE) monofilament and polypropylene (PP) multifilament yarns were used as wrapper filaments. The physical properties of the raw materials are listed in Table 1.

2.2 Sliver Preparation

Jute fibres (TD 3) were processed with the normal jute processing system consisting of softener, breaker card, finisher card and three stages single passage each with screw-gill drawing frame and apron draft sliver spinning frame respectively. Blending of jute with viscose was performed in second drawing stage. The drawing blended slivers were processed twice in finisher drawing with same draft and doubling for homogeneous blending.

2.3 Yarn Preparation

A six spindle Suessen's Parafil (2000-02) spinning frame was used to prepare the yarn samples. The process parameters are listed in Table 2.

2.4 Heat-set Treatment for Wrapped Yarns

The yarns were heat- set for obtaining dimensional stability of the wrapped yarns. Leas of samples were kept inside the drying oven under constant length condition and heat set for 10 min by passing dry hot air through them. The temperature was maintained at 82^0C and 110^0C for HDPE and PP wrapped yarn respectively.

Table 1 — Physical properties of core fibres and wrapper filaments

Material	Linear density, tex	Tenacity g/tex	Breaking extension, %
Jute-fibres	2.02	37.21	2.01
Viscose fibres	0.44	19.34	19.89
HDPE monofilamer	11.00	54.38	26.09
PP multi-filaments	10.00	31.09	56.06

Table 2 — Processing parameters of wrap yarn manufacture [Filament — HDPE 4.2% and PP 3.8%]

Parameter	Jute yarn		Jute-viscose yarn (70:30)	
Linear density, tex	207	276	207	276
Number of sliver feed	2	2	2	2
Total Draft	28.8	38.5	28.8	38.5
Wraps per metre	240	200	240	200
	260	220	260	220
	280	240	280	240
	300	260	300	260
	320	280	320	280

2.5 Evaluation of Testing

Hundred metre (100 m) length of the prepared yarn was weighed and average of 25 such readings were taken for calculation of linear density. Instron universal tensile tester (model 4450) with test length 50cm and test speed 50mm/min was used for tensile test of yarns. Average of 50 readings was taken for calculation of all tensile parameters. Uster evenness tester (UT-3) was used to measure the mass variation, irregularity index, imperfections and hairiness index, as exist in the yarns. The testing was carried out with the test speed of 100m/min for 1 min. These tests were carried out for each sample and the average of 3 readings was taken for evaluation.

2.6 Irregularity Index

Irregularity index was measured by UT-3 evenness tester. It was calculated as the ratio of the total mass CV% and unavoidable minimum CV% arising due to random arrangement of fibre ends along the yarn. Thus, this index can be considered as a measure of spinning technological level or simply "goodness of spinning". Any improvement of spinning technological level will reduce the irregularity index value of the yarn.

2.7 Yarn Quality Index

The yarn quality index (YQI) gives the overall idea of the yarn quality. The YQI is directly proportional to the value of tensile characteristics and inversely proportional to mass variation and calculated as follows:

$$YQI = \frac{\text{Tenacity (cN/tex)} \times \text{Breaking Extension (\%)}}{\text{Uster \%}}$$

3 Results and Discussion

3.1 Influence of Wrapper Filament Characteristics of Wrap Spun Yarn

3.1.1 Effect on Rupturing Process

The rupturing process of jute and jute-viscose (70:30) yarn varies considerably with the change in wrapper filaments characteristics [Figs 1(a)-(d)]. The jute yarns wrapped with PP multifilament show stick-slip oscillations, whereas HDPE monofilament wrapped yarns demonstrate less stick-slip oscillation than PP wrapped yarn at 200 wraps/m. It may be observed that HDPE wrapper filament records higher tenacity at lower strain. Moreover, it is a

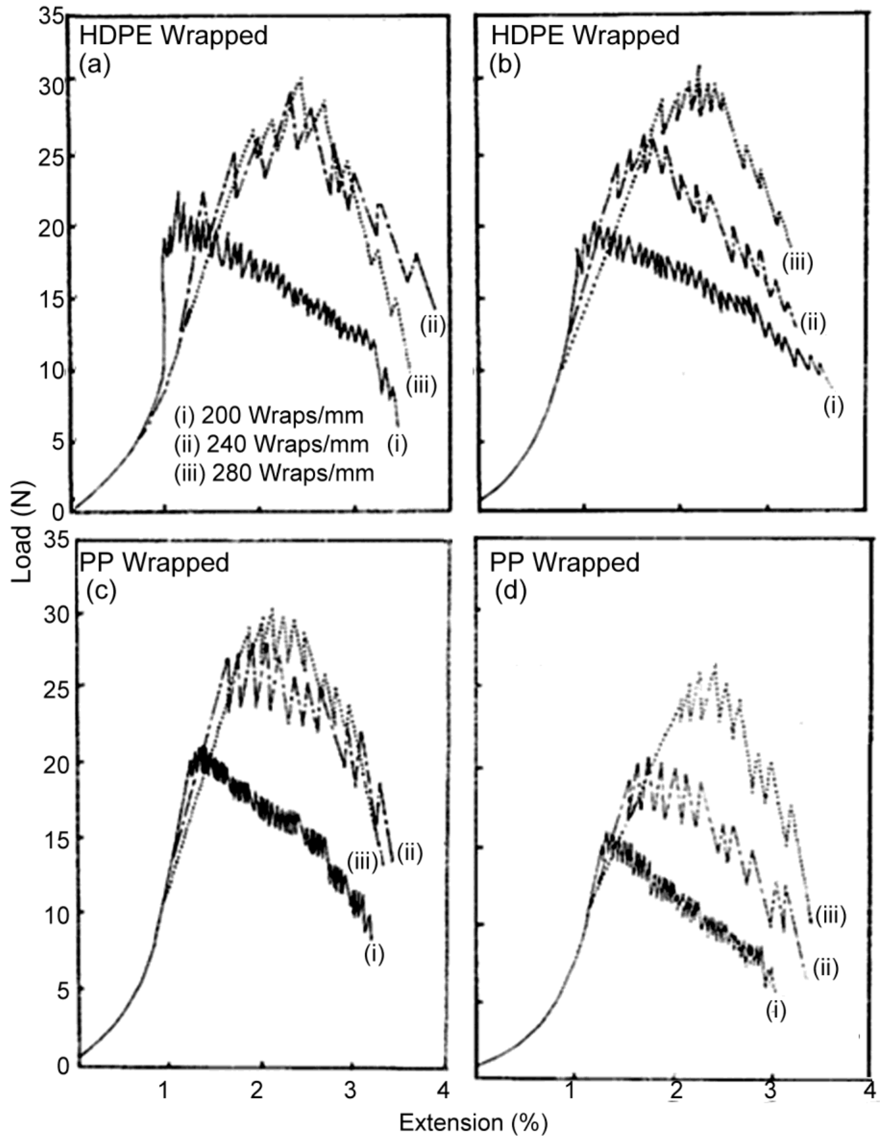

Fig.1 — Load-extension curves for HDPE/PP wrapped jute [(a) & (c)] and jute-viscose [(b) & (d)] yarns

monofilament, whereas PP wrapper is a multifilament that records lower tenacity and higher breaking extension. At the rupturing point of fibres in the wrapped yarn, some core fibres which have already reached their breaking extension rupture and instantaneously the load value falls as the fibres start slipping. During this time, the filament extends and exerts more radial pressure on the yarn surface, hence arresting further fibre slippage. The load value increases again[3-5]. This occurs several times and gives stepwise breaks which continue to much higher extension. The same phenomenon is observed in case of jute-viscose wrap-spun yarn with HDPE monofilament wrapper and PP multifilament wrapper.

HDPE wrapper has lower extensibility and higher tenacity as compared to PP wrapper. This gives higher radial pressure on core fibres. In rupturing process, the proneness of stick-slip effect is reduced for PP multifilament wrapped yarn due to higher radial pressure which does not allow the core fibres to slip easily.

3.1.2 Effect on Tensile Properties

Wrap-spun yarns having HDPE wrapper show higher tenacity as compared to wrap-spun yarns having PP wrapper (Tables 3 and 4). The probable reason may be, HDPE exerts higher compressive force to the core fibres. As a result, the frictional force between the core fibres increases due to higher radial

Table 3 — Tensile characteristics of 276 tex jute and jute-viscose wrap-spun yarns with HDPE monofilament and PP multifilament wrapper.

Wrap density wraps/m	Type of yarn	Breaking load, N		Tenacity, g/tex		Breaking extension, %	
		HDPE	PP	HDPE	PP	HDPE	PP
200	Jute	23.41	21.96	9.20	8.21	3.97	3.89
	Jute-viscose	20.79	16.15	7.47	6.56	5.06	5.27
220	Jute	28.07	25.59	10.84	9.44	3.74	4.08
	Jute-viscose	22.36	20.09	8.66	8.03	4.76	4.32
240	Jute	28.11	27.12	11.37	10.24	5.54	4.49
	Jute-viscose	27.67	21.02	10.75	7.94	4.57	3.87
260	Jute	29.02	28.37	11.59	10.75	5.54	4.61
	Jute-viscose	28.57	23.53	11.18	9.60	4.50	3.44
280	Jute	30.71	29.89	12.61	11.24	4.00	4.71
	Jute-viscose	31.85	25.39	11.85	10.63	4.78	3.99

Table 4 — Tensile characteristics of 207 tex jute and jute-viscose wrap spun yarns with HDPE monofilament and PP multifilament wrapper

Wrap density wraps/m	Type of yarn	Breaking load, N		Tenacity, g/tex		Breaking extension, %	
		HDPE	PP	HDPE	PP	HDPE	PP
240	Jute	20.39	17.18	10.10	8.79	3.72	3.10
	Jute-viscose	17.08	18.15	7.90	8.40	4.28	3.78
260	Jute	21.21	17.52	10.66	9.42	3.27	3.49
	Jute-viscose	17.22	19.16	8.66	9.09	4.33	3.43
280	Jute	21.32	17.99	10.42	9.25	3.68	3.9
	Jute-viscose	20.17	20.67	10.06	9.90	3.78	3.38
300	Jute	22.36	20.16	11.07	10.33	3.68	3.06
	Jute-viscose	21.32	21.16	10.65	10.27	4.89	3.78
320	Jute	23.80	23.18	12.06	12.29	3.05	4.83
	Jute-viscose	22.79	21.27	11.70	10.61	4.30	3.75

pressure and it resists the slippage of core fibres and ultimately show highest tenacity.

It is evident from the study that the breaking extension of wrap-spun yarns may not establish any relationship on the characteristics of wrapper filament.

3.1.3 Effect on Evenness, Irregularity index, Imperfections and Hairiness index of Wrap- Spun Yarn

The values of mass CV% of jute-viscose wrap-spun yarns show reduction as compared to 100% jute yarn for all counts and for all wrapper filament, (Tables 5 and 6). It is also observed that the mass CV% reduces for all types of yarn having higher count. Jute fibres have wide range of fibre length variation and poorer control on fibre movement during drafting operation in pre-spinning stages. Hence, mass CV% of jute yarns is higher for all types of 100% jute yarn wrapped by HDPE and PP filaments. But, in case of jute-viscose blended yarn the regularity of the wrapped yarn has increased due to the presence of viscose fibres which has less variation in fibre length. Moreover, for higher count of yarn, the number of fibres in the yarn cross-section increases, hence produces regular yarn with less CV%.

Any improvement in technological process reduces the irregularity index value. In the case of jute-viscose blend yarn, the irregularity index values decrease than in 100% jute yarn (Tables 5 and 6), as more number of fibres are present in the cross-section of blended yarn as compared to that in 100% jute yarn. Here, type of filament has an insignificant effect on irregularity index of wrap spun yarn.

The jute yarns have shown the presence of large number of thick and thin places and also slubs, irrespective of type of wrapper filament present in the yarn (Tables 5 and 6). The presence of large number of thick and thin places and also slubs in the yarn may affect adversely the smooth appearance of the final fabric and also hamper the efficiency of post spinning operation as well as weaving. On the other hands, jute-viscose blended yarns have shown less number of each imperfection with less irregularity, as more number of fibres is present in the cross-section of jute-viscose blended yarn as compared to that in 100% jute yarn. In this case, the effect of wrapper filament characteristics on imperfections of wrap-spun yarns has shown less significant.

Table 5 — Evenness, imperfections, hairiness and yarn quality index of 276 tex jute and jute-viscose wrap-spun yarns with HDPE monofilament and PP multifilament wrappers

Wrap density wraps/m	Type of yarn	Wrapper filament	U_m%	Index of irregularity	Thin places (-50%) per 100m	Thick places (+50%) per 100m	Slubs (200%) per 100m	Total imperfections	Hairiness index	YQI
200	Jute	HDPE	22.52	1.87	147	77	12	237	11.72	1.622
		PP	19.97	1.68	123	72	13	209	11.07	1.599
	Jute-viscose	HDPE	21.38	1.78	60	85	13	159	10.42	1.768
		PP	20.57	1.72	45	55	12	113	10.86	1.681
220	Jute	HDPE	26.03	1.98	98	76	10	184	10.90	1.557
		PP	21.74	1.81	137	91	12	240	9.90	1.772
	Jute-viscose	HDPE	20.74	1.74	59	81	13	153	10.29	1.988
		PP	19.90	1.69	63	76	11	151	10.21	1.743
240	Jute	HDPE	22.53	1.86	89	65	10	163	9.71	2.796
		PP	21.71	1.78	113	113	23	249	7.62	2.174
	Jute-viscose	HDPE	19.92	1.71	51	86	12	147	10.81	2.466
		PP	18.84	1.62	42	78	12	132	10.12	1.631
260	Jute	HDPE	22.42	1.84	129	111	27	267	11.78	2.864
		PP	21.84	1.79	121	84	13	217	10.62	2.21
	Jute-viscose	HDPE	20.02	1.74	52	87	11	151	10.89	2.513
		PP	19.42	1.69	44	69	11	124	10.04	1.701
280	Jute	HDPE	22.32	1.82	130	110	25	265	10.96	2.26
		PP	21.84	1.79	134	100	17	251	10.58	2.424
	Jute-viscose	HDPE	19.90	1.72	51	71	12	134	10.48	2.846
		PP	18.77	1.62	43	60	12	116	9.40	2.26

Jute yarns have shown high hairiness index value as compared to jute-viscose blended yarn (Tables 5 and 6) for the same wrapper filaments. This is due to the coarseness as well as higher flexural rigidity of jute fibres and also due to the presence of branches in the individual jute filament. The wrap-spun yarns with PP wrapper have shown less hairiness index value as compared to HDPE wrapped yarns. This is due to the greater surface area covered by PP multifilament than by HDPE monofilament.

3.1.4 Effect on Yarn Quality Index

The lower value of yarn quality index (YQI) of PP wrapper wrap-spun all jute and jute-viscose blended yarns is observed as compared to HDPE wrapper both types of wrap-spun yarns (Tables 5 and 6). Wrapped yarns with PP multifilament wrapper have exhibited significantly low tenacity value as compared to wrapped yarns with HDPE monofilament wrapper. Though higher mass variation is observed on the wrapped yarns with HDPE wrapper as compared to PP wrapper, but higher tenacity of HDPE wrapped yarn has a greater impact on YQI value of wrapped yarns.

3.2 Influence of Wrap Density of Wrap-Spun Yarn

3.2.1 Effect on Rupturing Process

Jute/HDPE, jute-viscose/HDPE, jute/PP and jute-viscose/PP wrap-spun yarns show a progressive change in rupturing process (Fig.1) with the increase in wraps per metre (WPM). At 200 wpm, jute and jute-viscose wrap-spun yarns show frequent stick-slip oscillations. The frequency of stick-slip reduces with the increase in wrap density. In case of HDPE wrapped yarns [Figs 1 (a) and (b)], it is noticeable that at the highest wrap density there is negligible amount of stick-slip oscillation occur. With the increase in wrap density the filament to fibre contact area increases which gives higher radial pressure to the core. This increases inter-fibre friction so that core fibres are restrained from slippage. At the lowest wrap density both HDPE and PP wrapped yarns are enough to arrest the slippage of core fibres.

3.2.2 Effect on Tensile Properties

The jute and jute-viscose yarns with HDPE and PP wrapper show the same trend in tenacity values, i.e. it increases with the increase in wrap density (Tables 3 and 4). At very low wrap density the force exerted by the wrapper filaments is not strong enough to pack closely the fibrous core which results in low inter-

Table 6 — Evenness, imperfections, hairiness and yarn quality index of 207 tex jute and jute-viscose wrap-spun yarns with HDPE monofilament and PP multifilament wrapper

Wrap density wraps/m	Type of yarn	Wrapper filament	U_m%	Index of irregularity	Thin places (-50%) per100m	Thick places (+50%) per 100m	Slubs (200%) per 100m	Total imperfections	Hairiness index	YQI
240	Jute	HDPE	22.95	1.93	157	105	19	281	11.78	1.637
		PP	23.02	1.96	179	94	20	293	9.58	1.184
	Jute-Viscose	HDPE	20.85	1.82	80	96	17	193	10.02	1.622
		PP	19.22	1.72	65	73	16	154	9.28	1.652
260	Jute	HDPE	22.86	1.91	150	120	26	296	10.03	1.525
		PP	22.85	1.90	178	106	22	306	8.54	1.439
	Jute-Viscose	HDPE	23.38	1.98	65	94	17	176	9.50	1.604
		PP	19.64	1.76	63	83	18	164	8.28	1.588
280	Jute	HDPE	24.90	2.15	117	114	12	243	9.32	1.54
		PP	24.95	2.19	211	126	24	361	8.43	1.446
	Jute-Viscose	HDPE	20.06	1.81	64	79	14	157	9.12	1.896
		PP	19.54	1.72	48	77	13	138	7.12	1.712
300	Jute	HDPE	23.21	1.95	173	100	18	292	9.44	1.755
		PP	25.12	2.19	233	124	23	380	8.98	1.258
	Jute-viscose	HDPE	19.49	1.68	62	77	14	153	8.86	2.672
		PP	19.36	1.65	50	82	14	146	8.17	2.005
320	Jute	HDPE	24.83	2.09	143	124	14	281	10.52	1.481
		PP	24.85	2.10	231	102	25	358	9.20	2.389
	Jute-viscose	HDPE	19.56	1.70	59	83	20	162	9.00	2.572
		PP	19.94	1.78	73	65	12	150	9.14	1.995

fibre friction between the individual fibres. With the increase in wrap density, the fibrous core becomes more compact and more coherent. This may be due to the action of higher radial compressive forces exerted by the continuous wrapper filament.

It is also evident from the study that the breaking extension of wrap-spun yarns may not establish any relationship on the change in wrap density.

3.2.3 Effect on Evenness, Irregularity index, Imperfections and Hairiness index

The hairiness index of 276 tex jute yarn (Table 5) reduces with the increase in wrap density from 200 WPM to 240 WPM and from 240 WPM to 280 WPM for 207 tex wrapped yarns (Table 6). Thereafter further increase in wrap density increases hairiness index of PP and HDPE wrapped jute and jute-viscose yarns due to the increase in higher radial compressive force, resulting in coming out of branches of jute fibres. This effect has less prominent in case of jute-viscose PP and HDPE wrapped yarns due to presence of finer viscose fibres which have reduced the branches of jute filament in the yarns. The same phenomenon is also observed for 207 tex wrapped yarns (Table 6).

3.2.4 Effect on Yarn Quality Index

Improvement in YQI is observed for all types of wrap-spun yarns with HDPE and PP wrapper with increase in wrap density (Tables 5 and 6). With the increase in wrap density the tenacity of yarn increases (Tables 3 and 4) and reduction in thin places takes place is observed (Tables 5 and 6), resulting in increase in YQI.

4 Conclusion

4.1 The rupture process of jute and jute-viscose wrapped yarns has shown stick-slip oscillations for each wrap density and both HDPE and PP wrapper filaments in the wrap-spun yarn. With the increase in wrap density, the frequency of stick-slip oscillations gradually reduces without any catastrophic break. The proneness of stick-slip oscillations has reduced in case of HDPE monofilament wrapped yarns as compared to that in case of PP multifilament wrapped yarn.

4.2 Jute and jute-viscose wrap-spun yarns having HDPE wrapper have always shown higher tenacity than those having PP wrapper. The tenacity of wrap-spun yarns having HDPE and PP wrapper respectively is also found to be higher for higher wrap density.

4.3 Breaking extension of wrap-spun yarn does not show any established relationship with the change in wrap density and the characteristics of wrapper filaments.

4.4 Mass variation, imperfections, irregularity index and hairiness index of jute-viscose wrap-spun yarns containing both wrappers are found to be reduced as compared to 100% jute wrap-spun yarns. The effect of wrap density and characteristics of wrapper filaments on these properties are found to be insignificant.

4.5 All PP wrapped yarns have shown less hairiness index as compared to all HDPE wrapped yarns for all wrap density. The hairiness index of 276 tex wrap-spun jute yarns has been gradually reduced from 200wpm to 240wpm. Thereafter, the increase in wrap density increases the hairiness index of wrap-spun jute yarns, but such effect is not found prominent in case of jute-viscose wrap-spun yarns.

4.6 The lower value of YQI is exhibited in wrap-spun yarns having PP wrapper filament as compared to those yarns having HDPE wrapper filament.

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