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【Technical Paper】

Effect of Alkaline Hydrolysis of Jute / Polyester Union Fabrics on Low-Stress Mechanical Properties

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Abstract: Hydrophobicity of polyester is the main problem being faced in the processing of polyester from fibre to yarn formation stages. Manufacturing of polyester with improved moisture properties have been tried but the static problem of polyester is not answered by the research. Alkaline hydrolysis is a more versatile process for polyester with commercial name as Weight reduction process will not only impart the silk like feeling but also enhances the moisture management properties. On the other hand, Jute is being a natural fibre, will be undergoing 'woollanisation' effect following treatment with Caustic. In this research, a passionate attempt is made to treat the polyester /jute union fabrics with an aim to improve the low-stress mechanical properties. Two groups of union fabrics are considered for the study and are hydrolyzed in alkali medium with identical conditions. The products were characterized for KES-F data and results were analysed statistically.

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1. Introduction

Jute, being a natural fibre, finds extensive use in clothing and apparels in recent times. Jute is blended with polyester to improve the total performance of the fabric. Jute has been blended with polypropylene to produce blankets, and these were found to confer excellent comfort properties. On the other hand polyester fibre has had a phenomenal growth over the past 7 decades and it's the most widely used in apparel filed. Excellent strength, good crease recovery, low bending rigidity..etc, have acclaimed the polyester fibre as the fibre of the millennium (Hayavadana, 1997). Polyester is one of the versatile manmade fibres finding its use from apparel to industrial field. Polyester apparels are becoming more popular in these days. However, Polyester suffers from the deficiency as far as comfortability is concerned. In this regard, many suggestions have been considered by the producers. Thus efforts are being made for its scientific modifications to impart greater comfort, good draping qualities, improved moisture regain and a more natural silky appearance. In this context, weight reduction polyester has already acclaimed popularity in industry. There are three ways of modifying the polyester to impart silky feeling: (a) modification of the cross-section of the fibres (b) production of the fine denier filament; they are more effective in producing elegant gloss and soft hand, and (c) after-treatment of polyester textiles. It was in the year 1952; ICI came out with a patent disclosing the action of sodium hydroxide on polyester giving silky feeling, and was supported by other patent Dupont Co. in 1958. As was disclosed in the patent, by treating polyester with sodium hydroxide, polyester loses its weight progressively as the regular monofilament is reduced to fine denier and leaves scars on the filament surface.

In this context, if jute is used as warp and polyester as weft, the union fabric woven can find an outlet in apparel sector. With this premise, samples of jute polyester fabrics were manufactured, and they were subjected to alkaline hydrolysis. This will have dual effects on the fabric namely swelling of jute fibres and hydrolysis of polyester component. In this research work the low stress mechanical properties of Jute warp and texturised (crimped) polyester weft blended union fabrics subjected to weight reduction process are described.

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2. Literature review

There have been strenuous efforts in research to study the effect of various chemical agents especially alkali on the behavioural aspects of jute. The concept of modification of jute by various treatments stemmed up from the findings of Hermans (1946), who worked on the study of swelling of cotton with alkylamides at low temperatures followed by cyanoethylation. These have resulted in the improvement of moisture regain, dyeability and lustre of jute fibres. In this regard, to improve the accessability of jute, decrystallization of Jute cellulose by swelling with different concentrations of alkali at various temperatures followed by cyanoethylation was investigated by Reddy and Bhaduri (1990). It may be noted that for jute, being heterogeneous polymer of α-cellulose hemicellulose, and lignin, with varied moisture absorption of these components, this treatment results in the lower absorbtion power due to predominance in crystallinity of α-cellulose than the other two. Hence, if the crystallinity of jute fibre cellulose decreases, the amorphous portion in total fibre increases there by making it more hygroscopic. Reddy and Bhaduri (1990) conclude that the moisture regain of jute fibre increases with alkali treatments resulting in soft surface.

The action of caustic on polyester fibres leading to loss in weight and thus imparting silky feel has been discussed by Zeronian and Collin (1989) and an exhaustive work on alkaline hydrolysis of polyester fibres is reported by Hayavadana (1997). The review of literature indicates that polyester was treated with catalyst like CTMAB to influence the alkaline hydrolysis. Several reports published include the heat setting of polyester and weight reduction there upon, treatment with swelling agents followed by weight reduction, etc., and all these have resulted in imparting the silky feeling to polyester. Hence, it can be said that by treating the Jute/PET fabric with caustic, the handle properties can be improved. Although a considerable amount of work on the surface modification of PET fabric, and a method to improve the absorbency of jute fabric has been carried out separately, less emphasis has been placed on the study of low stress mechanical properties of alkaline hydrolysed jute warp and texturised (crimped) polyester weft union fabrics. The thrust of the present work detailed is to explore the said possibility.

Weight reduction of polyester fabric using sodium hydroxide solutions with additives cetyltrimethyl ammonium bromide and [BMIM]Cl was studied by Rakesh Musale and Sanjeev shukla in 2017. Alkaline hydrolysis and pretreatment of trilobal high dimethyl 5-sulfoisophthalate sodium cationic dyeable polyester was reported by Xiaoyan Li et.al., (2018)

Shirin Nourbakhsh et.al., (2018) studied the Zinc oxide nano particles coating on polyester fabric functionalized through alkali treatment. In an another interesting research by Wijianto et.al.(2019), considered the role of NaOH concentration, Treatment on Tensile Strength, Flexure Strength and Elasticity Modulus of Banana Fiber Reinforced Polyester Resin to explain the application of alkaline hydrolysis of polyester in industrial textile filed.

Although a considerable work is being reported on the alkaline hydrolysis of polyester, information on the weight reduction effect on jute/ polyester union fabric low stress mechanical properties is scanty in the literature and thus the thrust of the present work was to explore the same.

3. Materials and methods

3.1 Materials

Table 1 show the details of the materials selected. The chemicals used for the alkaline hydrolysis were of LR grade and were not purified further.

3.2 Weaving of jute /polyester union fabrics at laboratory (Table 2)

3.2.1 Preparation of jute warp

The cones containing jute yarns were creeled at the combined sectional warping and sizing machine. The yarn from the creel passes through the sowbox which is an integral part of the machine and is impregnated with jute sizing materials and the are squeezed by a pair of squeezed rollers to remove excess size. The yarn sheet was then dried over air heated cylinders, and wound on to the weavers beam following the beaming process. The warp was drawn through the heald wires and reed by the routine standard method of drawing-in and denting-in process.

3.2.2 Preparation of Polyester weft

87/36dtex texturised (crimped) polyester tubes were used to prepare the pirn on an automatic pirn winder. The pirns were collected in polythene bags to avoid the oil and other stains and thus to facilitate better handling.

3.2.3 Weaving

The sized and drawn warp was gaited on a plain loom (Table 4.5) and the fabric was woven with two

Table 1 Constructional details of laboratory woven jute/polyester union fabrics

<table>
<tr><th rowspan="3">Sample code</th><th colspan="4">Nominal Yarn Linear Density (tex X tex)</th><th colspan="4">Threads / cm</th><th colspan="2">Fabric wt (g/m²)</th><th colspan="4">Crimp (%)</th><th rowspan="3">Weave</th></tr>
<tr><th colspan="2">Warp</th><th colspan="2">Weft</th><th colspan="2">Warp</th><th colspan="2">Weft</th><th rowspan="2">Grey</th><th rowspan="2">Finished</th><th colspan="2">Warp</th><th colspan="2">Weft</th></tr>
<tr><th>Grey</th><th>Finished</th><th>Grey</th><th>Finished</th><th>Grey</th><th>Finished</th><th>Grey</th><th>Finished</th><th>Grey</th><th>Finished</th><th>Grey</th><th>Finished</th></tr>
<tr><td>A</td><td rowspan="2">98.4 tex</td><td rowspan="2">69.47 tex</td><td rowspan="2">87/36 tex crimped</td><td rowspan="2">64/36tex (26.43%)</td><td rowspan="2">14</td><td rowspan="2">16 (−14.28%)</td><td>13</td><td>15 (−15.38%)</td><td rowspan="2">160</td><td>144 (10.0%)</td><td rowspan="2">2.8</td><td rowspan="2">3.2 (−14.28%)</td><td>8.15</td><td>12.58 (−5.43%)</td><td rowspan="2">Plain</td></tr>
<tr><td>B</td><td>16</td><td>18 (−12.5%)</td><td>148 (7.5%)</td><td>8.68</td><td>14.25 (−6.41%)</td></tr>
</table>

*- Parenthesis give the % shift following finishing or alkaline hydrolysis

Table 2 Weaving particulars of jute/polyester union fabric

Warping type employed	Sectional warping with combined sizing unit
Pirn winding type employed	Automatic (12 head), 550 mpm speed
Loom particulars	52” (R.S), overpick, Fast Reed, Semiautomatic, 120 picks per minute.

Table 3 KESF instrument setting for fabric test

Compression	Rate of Compression Maximum Force Area compressed High Sensitivity Rate of Compression Maximum Force Area compressed	0.02 mm/sec (20 m/S) 50 gf/cm (5 kPa) 2.0 cm^2 circle 20/3 μm/Sec/10 gf/cm^2(1 kPa) 2.00 cm^2 circle
Bending	Rate of Bending Maximum curvature Sample size (LXW)	0.5 cm^{-1}/Sec =2.5 cm 20 cm × 1 cm
Surface	Rate of traverse Tension on sample Normal force friction Contact force, roughness Distance marked	1 mm/Sec 10 gf/cm 50 gf 10 gf 3 cm
Shear	Rate of shearing Maximum shear angle Tension on sample Sample size (LXW)	0.417 mm/Sec ± 8 (=0.14 rad) 10 gf/cm 5 cm × 20 cm
Tensile	Rate of extension Maximum tensile force Sample size (LXW)	0.1 mm/Sec 50 gf/cm 5 cm × 20 cm

Table 4 An outline of key parameters involved in the KESF-TESTS

Parameters	Symbols	Characteristic Value	Units
Tensile	EM LT WT RT	Elongation Linearity Tensile Energy Resilience	% none J/m^2 %
Bending	B 2HB	Bending Rigidity Hysteresis	N.m mN.mm
Shearing	G 2HG 2HG5	Shear rigidity 139.6 mrad Shear Strain Hysteresis at 8.7 mrad shear strain Hysteresis at 87 mrad shear strain	N/m N/m N/m
Compression	LC WC RC	Linearity Compressional energy Resilience	none J/m^2 %
Surface	MIU MMD SMD	Coefficient of friction Mean deviation of MIU Geometrical roughness	None None Micron
Weight	W	Weight/Unit area	mg/cm^2
Thickness	T_o	Thickness at 0.5 gf/cm^2	mm
Thickness	T_m	Thickness at 50 gf/cm^2	mm

Table 5 Data on handle of jute/polyester fabrics

KES-F DATA	Sample Code				KES-F DATA	Sample Code			
	34 A	**35 A'**	**36 B**	**37 B'**		**34 A**	**35 A'**	**36 B**	**37 B'**
HF* (gms)	2550	1750	2850	1850	**Shear**				
Tensile					G-1 (N/m)	0.5292	0.3724	0.6297	0.4458
LT-1	0.84	0.857	1.001	0.9	G-2 (N/m)	0.3724	0.3418	0.4582	0.321
LT-2	0.587	0.473	0.619	0.507	G (N/m)	0.4508	0.3571	0.5439	0.3884
LT	0.713	0.665	0.81	0.703	2HG-1 (N/m)	1.1883	0.6076	1.5876	0.6272
WT-1 (J/m^2)	2.57	4.39	2.94	5.39	2HG-2 (N/m)	1.737	1.4651	1.6489	1.0927
WT-2 (J/m^2)	22.17	34.62	31.48	37.48	2HG (N/m)	1.4627	1.0364	1.6182	0.6599
WT (J/m^2)	12.37	19.5	17.21	21.44	RS (degrees)	1.622	1.4511	1.487	1.12
RT-1 (%)	50.54	48.29	40.98	40.99	2HG5-1 (N/m)	1.4602	0.8232	2.2466	0.9065
RT-2 (%)	46.86	39.35	40.4	38.75	2HG5-2 (N/m)	1.9575	1.6097	2.0948	1.2519
RT (%)	48.7	43.82	40.69	39.87	2HG5 (N/m)	1.7089	1.2164	2.1707	1.0792
EMT_1 (%)	1.23	2.05	1.18	2.4	**Compression**				
EMT_2 (%)	15.18	29.33	20.45	29.57	LC	0.274	0.312	0.316	0.338
EMT (%)	8.2	15.69	10.81	15.99	WC (J/m^2)	0.231	0.24	0.21	0.32
EMT_2/EMT_1	12.34	14.3	17.33	12.32	EMC (%)	4.87	20.1	17.17	13.15
Bending					RC (%)	55.63	52.81	60.37	54.62
B-1 (μN.m)	479.8	246.2	546	211.9	**Surface**				
B-2 (μN.m)	1.36	1.13	2.66	2.89	MIU-1	0.2242	0.2248	0.2309	0.2848
B (μN.m)	240.6	123.7	274.3	107.4	MIU-2	0.2021	0.2057	0.1654	0.2457
B/T_m (μN.m/mm)	320.8	167.1	334.5	108.5	MIU	0.2132	0.2153	0.1981	0.2652
2HB-1 (μN)	53.62	15.66	54.88	15.21	MMD-1	0.0264	0.0295	0.0274	0.0244
2HB-2 (μN)	0.124	0.118	0.204	0.132	MMD-2	0.0583	0.031	0.0631	0.035
2HB (μN)	26.87	7.89	27.54	7.673	MMD	0.0423	0.0303	0.0453	0.0297
RB-1 (%)	89.94	94.01	90.86	93.3	SMD-1 (μm)	6.33	5.47	4.86	6.51
RB-2 (%)	91.64	96.02	92.87	95.63	SMD-2 (μm)	31.43	25.54	23.34	21.76
KN-202-Ladies thin dress material					SMD (μm)	18.88	15.5	14.1	14.11
Koshi	10	8.9	10.87	8.4	SMD/T_m (μm/μm)	25.77	20.94	17.19	14.25
Numeri	1.1	3.02	0.84	3.43	Thickness T_o (μm)	0.96	0.95	0.99	1.14
Fukurami	3.26	4.49	3.03	5.37	Thickness T_m (μm)	0.75	0.74	0.82	0.99
THV (W)	1.5	2.46	1.21	2.79	Weight (mg/cm^2)	33.69	33.69	37.21	34.76
Koshi	10.1	8.21	10	7.25					
Shari	9.89	7.87	9.98	6.98					
Fukurami	4.49	4.59	3.46	3.97					
Hari	10	7.36	10	6.28					
THV(S)	1.14	2.26	1.69	3.21					
TAV	2.25	3.86	2.98	3.99					

A - Control   A' - 18.29% Weight loss
B - Control   B' - 13.89% Weight loss

levels of pick spacing (14 and 16 picks/cm) at normal speed of 120 rpm. The fabrics were then subjected to alkaline hydrolysis.

3.3 Alkaline Hydrolysis

In all the cases of polyester substrates, alkaline hydrolysis was carried out in sealed flasks or beakers at 100 °C and 130 °C. (1: 20 bath ratio, hold time 30 min) as the case may be with mild mechanical agitation on laboratory model HTHP dyeing machine. To terminate the hydrolysis, samples were rinsed in deionized water to eliminate excess alkali and neutralised for 2 min in 0.1% HCl. The specimens were then washed in deionised water until the rinsed water was neutral to litmus paper. The products were then dried in hot oven to a constant weight and cooled in a desiccators (Zeronian & Collins, 1989).

4. Testing

4.1 Conditioning and preparation

The experimental materials, prepared as explained above, were conditioned prior to testing at standard atmospheric condition of 65 ± 2% RH and 25 ± 2 °C temperature as per IS: 6359-1971.

4.2 Determination of geometrical properties

The geometrical properties of experimental fabrics are shown in the Table 1. The table also give the details following finishing and the percent shift upon finishing.

4.2.1 Yarn count and fabric sett

Yarn count (weight per unit length) was determined as per IS: 3442-1966. An average of twenty replications represented this parameter in decitex (dtex). Fabric sett (threads per unit length) was determined as per IS: 1963-1969. The average of 10 measurements was reported.

4.2.2 Fabric weight per square meter

The linear density in g/m^2 of the fabrics was determined as per IS: 1964-1970. An average of five measurements was expressed as weight per square metre.

4.2.3 Determination of weight loss (%)

In all the cases, weight loss was calculated by using the formula:

$$\frac{X_1 - X_2}{X_1} \times 100 \tag{1}$$

where X_1 − Initial weight, X_2 − Final weight

4.3 Measurement of the low stress mechanical properties by KES-F

The KESF system was used for objective evaluation of the various fabrics used in the study. Instrument setting and an outline of key parameters details are given in the Tables 3 & 4.

4.4 Measurement of the fabric withdrawal force

4.4.1 Apparatus

A simple apparatus designed by Hayavadana (1997) was sued for determining the handle force.

5. Results and discussion

The low stress mechanical properties of union fabrics are given in the Table 5. The changes in the low stress mechanical properties of union fabrics are given in the Table 6. The changes upon finishing was calculated by percent shift using the following formulae where, X_1 Average of properties before finishing, X_2 Average of properties after finishing

$$X\,\% = \frac{X_1 - X_2}{X_1} \times 100 \tag{2}$$

5.1 Effect of alkaline hydrolysis on density

Zeronion (1989) in his research has mentioned that action of caustic on polyester is limited to surface, and the action is described as "topo chemical reaction" leading to a conclusion that the density of polyester will not be influenced by alkaline hydrolysis. However, Shouhua Niu and Tomiji Wakida (1992), in their findings on the study of alkaline hydrolysis of heat set polyester have concluded that density will vary from surface to core due to changes followed after heat treatment. However, in contrast to this, the present study does not include the heat pre- treatment of jute/polyester union fabric and hence it is concluded that density of weight reduced jute/polyester fabrics will remain unchanged and thus the study does not include the measurement of IR spectra or X-ray analysis.

5.1.1 Effect of alkaline hydrolysis on handle force

Handle force is a best measure of all the deformations of fabric to which the fabric is subjected during wear. Alkaline hydrolysis has a significant influence on handle force as observed from Tables 5 & 6. The percent shift of 27.45 for A' and 38.59 for B' is mainly due to the softening wollanisation effect of jute and caustic action on polyester. The difference in percent shift between A and B fabrics is attributed to construction particulars are in Table 1.

5.2 Low stress mechanical properties upon finishing

In this section, eighteen mechanical parameters obtained on the jute/polyester fabrics by KESF have been analysed. The discussion is mainly centered on the effect of alkaline hydrolysis on these parameters and hence the handle of the fabric. Table 8 gives the overall correlation between the KESF parameters and the extraction force. The results are in agreement with the correlation between the mechanical properties as reported in Kawabata's research studies.From Table 6 it clear that the two group of fabric show different response to alkaline hydrolysis due to their geometrical properties. (Table 1) and this is observed for the entire KES-F data.

5.2.1 Handle and Tensile Properties

The most important properties affected are WT and EMT; these properties show very large increases upon finishing, the percentage increase ranging from 5 to 110 (Tables 5 and 6). There is a large increase in fabric extensibility after finishing in both principal thread directions especially in weft direction in union fabrics. This may be due to the nature of weft yarn (87/36d.tex Texturised polyester). Since overall increase in WT and EMT is common to both principal fabric directions, it must be explained separately for warp and weft. Jute in warp direction gets softening action by NaOH and polyester in weft direction suffers from the loss of weight due to disodium terephthalate and pits formation on the surface leading to loss in tensile strength and elongation %. Thus, the significant increase in EMT and WT is an indication that fabrics have become soft after finishing. Relation of WT and

Table 6 Data on handle of jute/polyester union fabrics upon finishing

KES-F DATA	A'	B'	KES-F DATA	A'	B'
HF* (gms)	27.45	38.59	**Compression**		
Tensile			LC	−13.86	2.53
LT-1	−2.08	10.08	WC (J/m^2)	−4.76	−53.33
LT-2	19.76	18.09	EMC (%)	8.09	23.41
LT	6.73	13.2	RC (%)	−13.86	−6.96
WT-1 (J/m^2)	−70.81	−83.33	**Surface**		
WT-2 (J/m^2)	−56.15	−19.12	MIU-1	−0.26	−23.39
WT (J/m^2)	−57.63	−24.57	MIU-2	−1.78	−48.54
RT-1 (%)	4.45	−0.02	MIU	−0.98	−33.87
RT-2 (%)	16.02	4.08	MMD-1	−1174	10.94
RT (%)	10.02	2.01	MMD-2	46.82	47.53
EMT_1 (%)	−66.66	−103.38	MMD	28.36	37.43
EMT_2 (%)	−93.21	−44.59	SMD-1 (mm)	13.58	−3.39
EMT (%)	−91.34	−47.91	SMD-2 (mm)	18.74	7.02
EMT_2/EMT_1	−15.88	28.9	SMD (mm)	17.9	−0.09
Shear			SMD/T_m (mm/mm)	16.8	17.1
G-1 (N/m)	29.62	29.2	Thickness T_o (mm)	1.09	−24.29
G-2 (N/m)	8.21	29.94	Thickness T_m (mm)	1.33	−20.73
G (N/m)	20.78	29.5	Weight (mg/m^2)	6	6.58
2HG-1 (N/m)	48.86	60.49	**KN-202-Ladies thin dress material**		
2HG-2 (N/m)	15.65	33.73	Koshi	17.66	27.65
2HG (N/m)	29.14	46.86	Numari	−174.56	−308.33
RS (degrees)	10.53	24.68	Fukurami	−37.73	−77.22
2HG5-1 (N/m)	31.51	59.65	THV (W)	−64	−130.57
2HG5-2 (N/m)	17.76	40.23	Koshi	17.78	30.06
2HG5 (N/m)	28.81	50.28	Shari	13.45	24.54
Bending			Fukurami	−2.22	−14.73
B-1 (mN.m)	48.69	61.19	Hari	20.02	32.87
B-2 (mN.m)	16.91	8.69	THV (S)	137.85	153.87
B (mN.m)	48.6	60.8	TAV	−1.75	461.11
B/T_m (mN.m/mm)	47.9	67.58			
2HB-1 (mN)	70.79	72.28			
2HB-2 (mN)	-2.41	35.29			
2HB (mN)	70.63	72.13			
RB-1 (%)	−4.52	−2.68			
RB-2 (%)	−1.9	−2.97			

* - Handle force
m*, o* - Changes upon finishing

RT is shown in Fig. 2. The results are highly significant at 0.05 level of significance in Table 7.

On the other hand, there is also a change in the values of LT and RT after finishing which may be attributed to the softening of jute during finishing, and the changes in the values are significant statistically (Table 5 and 6). The results are highly significant at 0.05 level of significance in Table 7.

5.2.2 Shear Properties

Fabric hand is strongly dependent on the shear behavior In grey state fabrics, there is a high normal load due to the bending of the threads over one another at the cross-over points and hence higher shear rigidity values are observed from Table 5 and 6. from Fig. 3, It is clear that the shear rigidity and hysteresis values have dropped by 20 to 50% and this is no doubt due to the reduction of inter yarn pressure in the fabrics. These results are almost in agreement with the observations made by various workers for different textile fabrics (Kilby 1963, Brenner *et al.*, 1966, Cednas 1961, Kopke 1970, Rosenberg 1963, Kawabata *et al.*, 1973, Hamilton and Postle 1976 and Goswami 1978). The results are highly significant at 0.05 level of significance in Table 7.

5.2.3 Bending properties

The finishing process has an appreciable effect on bending properties as addressed by Table 6. It has been found that finishing process in general has an enormous effect on most of the mechanical properties of fabrics. It can be explained that the major effect of finishing is in

Table 7 Analysis of variance of KESF data of jute/polyester union fabrics

Sl.No.	Parameters	Sample Code	
		A and A'	B and B'
		Fcal	Fcal
1	LT	300.5	312.67
2	WT	280.4	272.52
3	RT	217.23	213.98
4	G	250.48	248.5
5	2HG	268.73	266.72
6	2HG5	238.18	222.18
7	B	198.49	192.62
8	2HB	212.32	210.07
9	LC	312.91	289.92
10	WC	199.38	188.32
11	RC	189.43	183.48
12	MIU	159.29	152.38
13	MMD	229.39	227.32
14	SMD	189.29	178.99
15	T_0	230.45	274.68
16	W	218.69	243.63

Ftab: 4.89

the reduction of the frictional component of the bending moment. In Fig. 4, A reduction of 40-60% as seen in B for group 1 and group 2 finished fabrics, but the reduction in 2HB is almost 70% (Table 5). These results are a direct consequence of the relationship between the level of inter yarn pressure acting within the fabric, and the frictional resistance to deformation. It follows that the finished fabrics have greater reduced resistance to bending deformation together with a greatly increased degree of elastic recovery from the deformation. The greater sensitivity of the frictional parameters (2HB) is a direct result of stress relaxation with in the fabric leading to reduced interfibre and interyarn pressure in the finished fabrics. The results are highly significant at 0.05 level of significance (Table 7).

5.2.4 Compressional properties

There is a moderate increase in LC and WC values of union fabrics (Table 6). This shows clearly that the fabrics have become softer upon finishing. The results

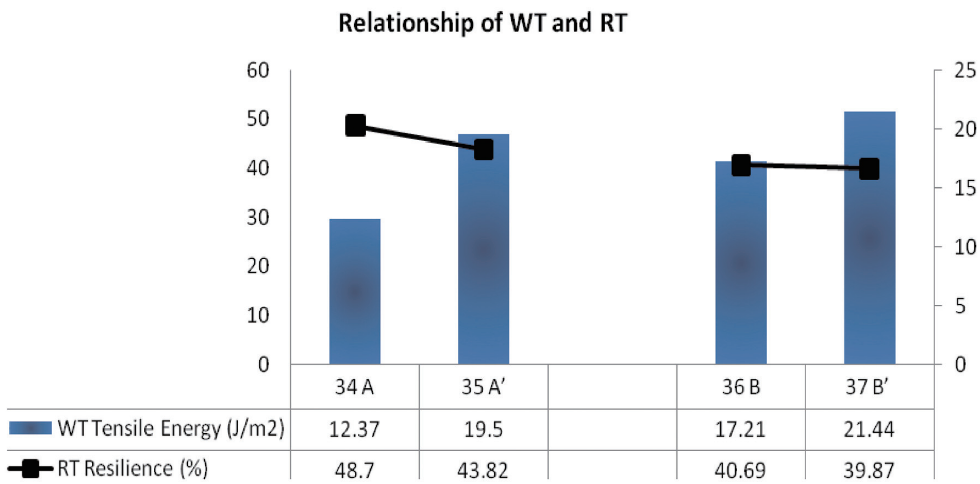

Fig. 2 Relationship of WT Tensile Energy (J/m2) and RT Resilience (%)

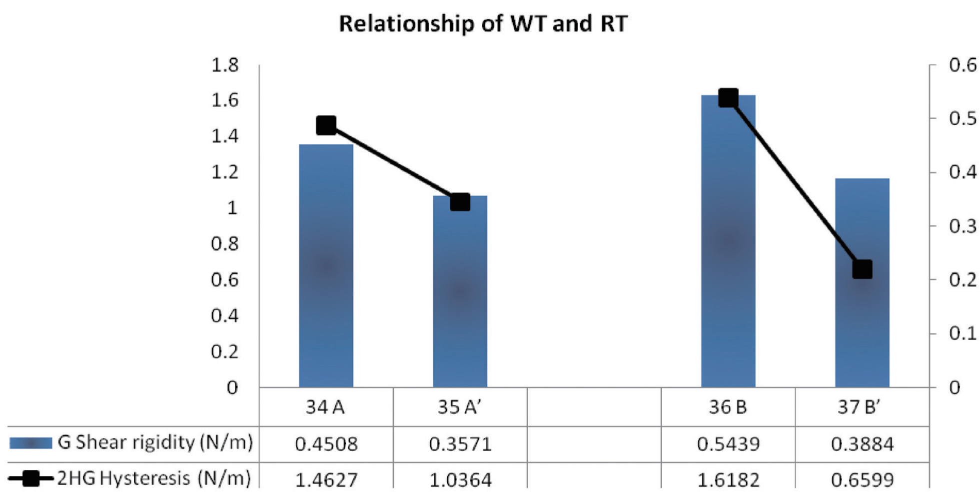

Fig. 3 Relationship of G Shear rigidity (N/m) and 2HG Hysteresis (N/m)

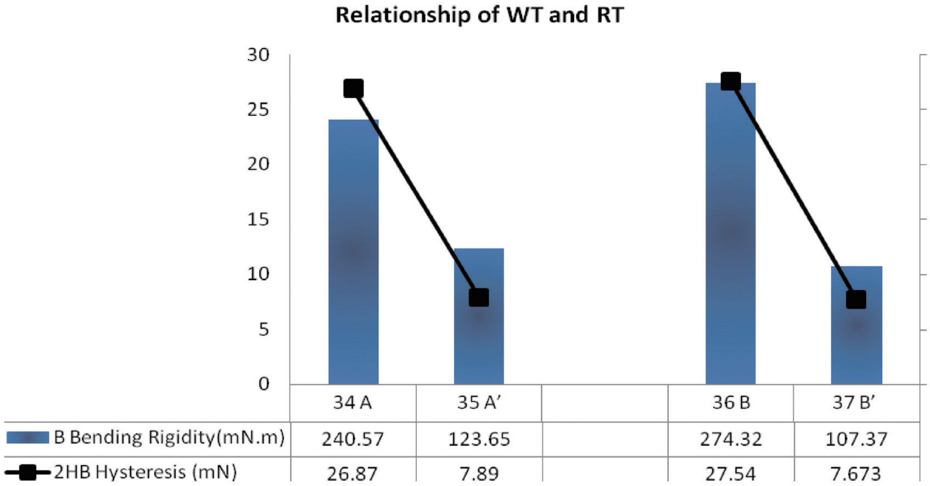

Fig. 4 Relationship of B Bending Rigidity(mN.m) and 2HB Hysteresis (mN)

obtained are consistent with the observations made for wool fabrics by Dhingra *et al.*, (1989). The results are highly significant at 0.05 level of significance (Table 7).

5.2.5 Surface properties

Table 6 shows an increase in the Co-efficient of friction (MIU) upon finishing by 30% for B and B' fabrics than A and A' fabric; this may be attributed to the an increase in pick density yarns, which upon finishing, increases MIU values and the corresponding shrinkage of weft results in the higher MIU values in warp direction as weft is in texturised form. It can be concluded that the increase in the MIU values is significantly greater in the weft direction (MIU-2) than in the warp direction. This is obviously because due to the large increase in the weft yarn crimp upon finishing (Table 1). On the other hand, there is a reduction in values of MMD upon finishing. This is because of the consolidation effects of fabric sett upon finishing (Table 6). A drop of 15–18% in SMD values is noticed following the finishing in the union fabrics. The softening action of caustic may be accounted for in both the directions. The decrease is more pronounced in weft way surface roughness (SMD-2) in both union fabrics which is shown in Table 6. The results are highly significant at 0.05 level of significance (Table 7).

5.2.6 Thickness and Weight

Fabric samples obviously show a decrease due to action of NaOH. But the weight before and after has not changed; i.e the softening action of the NaOH in both principal thread directions resulting in loss of weight has been compensated for by the consolidation of thread sett. The results are highly significant at 0.05 level of significance (Table 7).

5.3 Effect of finishing on primary hand values

5.3.1 Effect on Koshi

The finishing process has an effect on the Koshi of

Table 8 Correlation coefficients between the handle force and mechanical properties of jute/polyester fabrics

Sl. No.	Parameter	LT	WT	RT	G	2HG	2HG5	B	2HB	LC	WC	RC	MIU	MMD	SMD	T_0	W
1.	**LT**	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
2.	**WT**		1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
3.	**RT**			1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
4.	**G**				1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
5.	**2HG**					1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
6.	**2HG5**						1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
7.	**B**							1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99
8.	**2HB**								1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99
9.	**LC**									1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99
10.	**WC**										1.00	1.00	1.00	0.99	0.99	0.99	0.99
11.	**RC**											1.00	1.00	0.99	0.99	0.99	0.99
12.	**MIU**												1.00	0.99	0.99	0.99	0.99
13.	**MMD**													1.00	1.00	1.00	1.00
14.	**SMD**														1.00	1.00	1.00
15.	**T_0**															1.00	1.00
16.	**W**																1.00

the Jute/polyester union fabrics in both the union, and the effect is significant at 5% level of significance. This may be attributed to the (1) increase in weight per unit area of fabric (2) decrease in RC values of the fabrics (3) an increase in warp and weft way elongation of the fabric (4) reduced tensile resilience and shear hysteresis 2HG and 2HG5. All these mechanical properties together might have contributed to the decrease in the stiffness of the fabric. The difference in Koshi values of grey and finished fabrics is significant at 5% and 1% level and thus indicating that control fabrics are stiffer than finished (Table 7). The difference in Koshi values between the two groups of fabrics is significant at 1% and 5% levels.

5.3.2 Effect on Numeri

Like Koshi, Numeri has been affected by the finishing process. The effect is significant at 1% and 5% levels of significance. (Table 7). This may be due to following reasons: 1) decrease in surface roughness of the fabric (SMD) 2) decrease in tensile resilience 3) increase in tensile elongation 4) decrease in compressional resilience. The numeri values of grey and finished fabric samples of both the groups are statistically significant.

5.3.3 Effect on Fukurami

Alkaline hydrolysis on Jute/Polyester fabric has a significant effect on the Fukurami of union fabrics at both 5% and 1% levels of significance, F-values are shown in the Table 7. The increase in Fukurami values after finishing may be attributed to the consolidation effect of warp sett on finishing due to relaxation shrinkage of warp and weft yarns. Further, this may be due to the reduction of the inter yarn pressures in the ultimate fabrics.

5.3.4 Effect on total hand value (THV)

It is evident from the Table 5, that total hand value has improved upon finishing and the values are significant at both 5% and 1% levels (Table 7). The difference in the THV of samples in each group considered is highly significant.

5.3.5 Correlation between handle force and Low stress mechanical properties

Table 8 show clearly a very high degree of correlation between the handle force and KES-F data and the trend is concomitant with the findings of various research works (Pan *et al*., (1993), Grover *et al*., (1993). Vasantha, 1995).

6. Conclusions

Following conclusions can be drawn from the above study.

1. The low stress mechanical properties are improved after alkali treatment. At first, the bending properties namely B, 2HB have shown improvement following weight reduction; secondly, the surface properties namely MIU, MMD and SMB have improved following the alkaline hydrolysis treatment. On the other hand EMT, WC, WT values have shown positive increase indicating the softness imparted to the fabrics by weight reduction treatment.
2. The fabrics have become soft as evident from the parameters like G, 2HG, 2HG5 and B which are largely decreased following the treatment.
3. 2HB values have drastically reduced indicating the 'Woollenisation' effect on the union fabric.
4. The primary hand values show a decreasing trend following finishing.

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