Indian Journal of Fibre & Textile Research
Vol. 43, September 2018, pp. 381-384

Low-stress mechanical properties and fabric hand of cotton and polylactic acid fibre blended knitted fabrics

R Guruprasad[a], G Krishna Prasad, G T V Prabu, Sheela Raj & P G Patil

ICAR- Central Institute for Research on Cotton Technology, Matunga, Mumbai 400 019, India

Received 20 October 2016; revised received and accepted 12 June 2017

Low-stress mechanical behavior of cotton-rich/polylactic acid blended fabrics has been investigated and the results are compared with cotton and polylactic acid fibre fabrics. The polylactic acid fibres are mixed with cotton fibres in two different proportions, namely 20% and 35% and spun into 14.76 tex (40^s Ne) yarn. The yarns are then knit into single jersey structure followed by chemical pretreatments and relaxation. The relaxed fabrics are tested for low-stress mechanical properties using Kawabata evaluation system for fabrics (KES-F) and the hand values are calculated. The results show that the addition of PLA fibres to cotton enhances the smoothness and softness of the blended fabrics. The total hand value of the fabrics ranges between 3.2 and 3.5.

Keywords: Cotton, Fabric handle, Knitted fabric, Low-stress mechanical property, Objective measurement, Polylactic acid

The phenomenon of fabric hand is one of the most significant characteristics in determining the fabric marketing, and for providing the fabric scope of end-uses, performance and appearance. The sensations of stiffness or limpness, hardness or softness, and roughness or smoothness constitute fabric hand. Subjective assessment of fabric hand by human judges rely on psychophysical approaches or psychological techniques. The pioneering work on objective assessment of fabric was done by Peirce[1] and the concept of fabric hand was studied by many workers[2-7]. The basic elements that can fundamentally affect fabric hand are the fibre characteristics, yarn type, fabric construction and type of dyeing and finishing processes[8, 9]. The Kawabata evaluation system for fabrics (KES-F) measures physical, mechanical and surface properties of fabrics in low stress region, and total hand value (THV) of the fabric is calculated based on these measurements.

Cotton fibre is known for its excellent comfort properties. As it is well known that a single fibre cannot impart all the desirable properties, cotton fibres are blended with other fibres to meet different end-use requirements. For example, cotton is blended with polyester to improve crease recovery and durability. The low-stress mechanical properties of blended fabrics have been studied by many researchers. Sharma *et al.*[10] studied low stress mechanical properties of 100% wool and 55/45 polyester: wool fabrics. Behera and Mishra[11] studied the fabric handle of wool: cotton, wool: linen, wool: silk and silk: linen fabrics. Frydrych and Matusaik[12] investigated the fabric hand of cotton and cotton/polyester fabrics. However, no published literature is available on the low-stress mechanical behavior of cotton/PLA blended fabrics. PLA fibre is a biodegradable synthetic fibre made from lactic acid, which is obtained from the purification and fermentation of sugars from corn, sugar beet, or wheat starch. PLA fibres are generally circular in cross-section and have a smooth surface. The density of the fibre is 1.25 g. cm^{-3} and the moisture regain is 0.4–0.6% (ref. 13). The blending of PLA with cotton can enhance the softness, smoothness and moisture management properties of the resultant fabric. In a recent study[14], the usefulness of cotton/PLA blend for sportswear application was reported. In this study, the low-stress mechanical behavior of cotton-rich/PLA blended fabrics has been investigated and compared with 100% cotton fabric.

Experimental

The cotton (MCU-5 variety) and polylactic acid (PLA) fibres were sourced from a local industry manufacturing blended yarns. The properties of cotton and PLA fibres are given in Table 1.

The staple length and fineness are the two most important fibre properties that need to be matched for satisfactory processing of blends. The cotton fibres were processed up to the stage of combing, and then combed cotton was taken back to the blowroom for mixing with PLA fibres[15]. The PLA fibres were mixed with cotton fibres in two different proportions, namely 20% and 35%. The blended fibres were then

[a]Corresponding author.
E-mail: guruprasad.rg@gmail.com

spun into yarns using a compact ring spinning system to a nominal count of 14.76 tex (40s Ne) with a twist factor of 36.4 (3.8 TM); 100% cotton and 100% PLA yarns were also spun to the same count to enable comparison between the yarns.

The yarns were then knitted into fabrics using a KNITMAC 16 inch diameter, 24 gauge single jersey knitting machine equipped with 27 numbers of positive storage feeders to a GSM of 110.

The plain knitted fabrics were scoured and bleached by adopting a single-stage scouring and bleaching process. The 100% PLA fabric was given a mild scouring treatment to remove added impurities during mechanical processing. The fabrics were then subjected to dry and wet relaxation treatments before conditioning and testing. The construction particulars and the bursting strength of knitted fabrics are given in Table 2. The GSM of fabrics was in the range of 130-135.

The samples were tested for low-stress mechanical properties using KES-F tester, which include measurement of tensile, shearing, bending, compression and surface properties. Specimens of size 20 cm × 20 cm were used. Each value is the average of four test results. Testing was carried out at standard laboratory conditions (20 ± 2 °C and 65 ± 2% relative humidity (RH). From the low-stress mechanical properties, primary hand values of Koshi (Stiffness), Fukurami (resilience) and Numeri (Softness) were obtained. From the primary hand values, total hand value (THV) of the fabrics was obtained.

Results and Discussion

The results of low-stress mechanical behaviour of materials measured using Kawabata evaluation system are given in Table 3.

Table 1 — Fibre properties of cotton and PLA

Fibre properties	Cotton	PLA
Length, mm (2.5% span length)	30	38
Fineness, den	1.2 (3.4 mic)	1.4
Tenacity, g/tex	25 (Bulk)	32
Elongation , %	6.7	25

Table 2 — Construction particulars and properties of fabrics

Parameter	Cotton	Cotton/PLA (80/20)	Cotton/PLA (65/35)	PLA
Yarn count, tex	14.96	14.58	14.67	14.82
Yarn diameter, mm	0.249	0.236	0.231	0.192
Fabric count, wales/cm × courses/cm	17 × 23	18 ×23	18×23	18×23
Stitch length, mm	2.46	2.46	2.47	2.46
Fabric weight, g/m^2	135	133	130	132
Bursting strength, kg/cm^2	8.2	7.9	7.3	6.3

Tensile Properties

In the tensile test, tensile linearity (LT), tensile energy (WT), tensile resilience (RT) and extensibility (EMT) have been measured. The LT values of cotton and PLA do not show much difference. Cotton fabric shows a higher WT value compared to PLA fabric. RT value of PLA is better than that of 100% cotton fabric, indicating that the PLA can recover well and can retain its shape well. The values for blends are found close to that of cotton as expected. The higher EMT [%] of PLA fabric is due to better elongation property of PLA material as compared to that of cotton and it blends.

Shear Properties

In the shearing test, properties such as shear stiffness (G), shear stress at 0.5° (2HG) and shear stress at 5° (2HG5) have been measured. Lower value of shear rigidity of PLA indicates lesser resistance to shear and better drape. It has been observed that the shear hysteresis of cotton fabric is higher than that of PLA material, indicating poor recovery from shear stress.

Table 3 — Low stress mechanical properties

Property	Cotton	Cotton/PLA (80/20)	Cotton/PLA (65/35)	PLA
Tensile				
LT [-]	1.03	1.06	1.01	0.97
WT, gf.cm/cm^2	2.53	2.46	2.35	2.02
RT, %	36.0	36.6	37.5	43.8
EMT, %	9.7	11.4	13.2	14.2
Shear				
G, gf/cm deg	1.21	1.19	1.06	1.04
2HG, gf/cm	6.68	5.57	5.27	5.76
2HG5, gf/cm	5.99	5.00	4.91	5.29
Bending				
B, gf.cm^2/cm	0.0295	0.0281	0.0201	0.0187
2HB, gf.cm/cm	0.0380	0.0372	0.0254	0.0226
Compression				
LC [-]	0.543	0.531	0.528	0.527
WC, gf.cm/cm^2	0.068	0.065	0.056	0.043
RC, %	56.82	58.31	60.98	77.98
Surface				
MIU [-]	0.231	0.229	0.219	0.206
MMD [-]	0.0130	0.0154	0.0144	0.0117
SMD, μm	4.65	4.65	3.67	3.62
Weight				
W, mg/cm^2	13.56	13.26	13.01	13.18
Thickness				
To, mm	0.835	0.820	0.780	0.704
Tm, mm	0.583	0.558	0.550	0.542

Bending Properties

The values given in Table 3 show that 100% cotton fabric has the maximum bending rigidity in comparison to blended fabrics and 100% PLA fabric. The addition of the PLA component to cotton reduces the bending rigidity; the reduction is almost proportional to the blend percentage. The higher bending rigidity of cotton is due to higher diameter of cotton yarns in comparison to blended yarns and 100% PLA yarn. The bending rigidity and bending hysteresis are positively correlated to each other. As expected, the 100% cotton fabric shows the maximum hysteresis loss which is followed by cotton/PLA (80/20) and cotton/PLA (65/35) fabrics. The PLA (100%) fabric shows the lowest bending rigidity and hysteresis because of the lowest yarn diameter and smooth surface of fibres which results in lower inter-yarn friction.

Compression Properties

Compression properties of cotton fabrics such as fabric thickness at a pressure of 0.5 gf/cm^2 (T_0) and 50 gf/cm^2 (Tm), compressional linearity (LC), compressional energy (WC) and compressional resilience (RC) have been measured. The LC values of the samples are more or less in the same range. The low work compression values (WC) of PLA fabric shows that it has less compressibility than cotton. The lower yarn diameter of PLA also justify the results as the yarn is more compact. However, the recovery from compression (RC) of PLA material is better than cotton and cotton-rich blends. Even with 65/35 proportion, the compressional recovery is similar to that of cotton.

Surface Properties

The surface characteristics of a fabric influence the handle, comfort and aesthetic properties of the cloth. Cotton fabric shows higher coefficient of friction (MIU) and geometric roughness (SMD) than PLA fabric. Higher coefficient of friction of cotton is due to the surface characteristics of yarn like the hairiness, etc. PLA has a smooth surface structure and hence shows a lower friction value. The blended fabric friction falls in between cotton and PLA. The MIU and SMD values are not much affected with the addition of 20% PLA fibre in the blend. However, with 65/35 blend, the coefficient of friction and geometrical roughness shows a significant reduction, implying an increase in smoothness of fabric.

Hand Values of Fabrics

The results of primary and total hand values are shown in Table 4. These hand values are evaluated from the low-stress mechanical properties of fabrics. The fabric are evaluated for use as knitted innerwear application. It can be seen that the stiffness of cotton fabric are high as compared to PLA material. The smoothness value of PLA is high as compared to cotton and cotton-rich blends. The total hand values (THV) of samples are found to be in the range of 3.2 - 3.5, with PLA showing slightly better values than cotton.

Table 4 — Hand values of different single jersey fabrics

Sample	Koshi (Stiffness)	Fukurami (Fullness & Softness)	Numeri (Smoothness)	THV
Cotton	8.99	4.69	3.46	3.22
Cotton/PLA (80:20)	8.55	4.72	3.75	3.26
Cotton/PLA (65:35)	8.44	4.85	4.64	3.34
PLA	8.40	5.74	5.69	3.54

The low-stress behavior of fabric is governed by fibre properties, yarn structure, fabric geometry and finish applied to the fabric. In the present investigation, the effect of fibre material on the low-stress mechanical behavior and fabric hand has been brought out and all other parameters like yarn structure, twist, knit design and fabric weight are kept almost at the same level. The fabrics are also not subjected to any kind of finishing treatment like softening finish. It has been found that with the addition of 20% PLA fibres to cotton, there is a significant positive change in the properties of fabrics. The changes become more pronounced at the higher level of 65/35 blend proportions. The total hand value (THV) of fabrics investigated ranges between 3.2 and 3.5.

References

1 Peirce F, *J Text Inst*, 21 (1930) T377.
2 Matsuo T, Nasu N & Saito M, *J Text Mach Soc Japan*, 17 (1971) 92.
3 Kawabata S, *The Standardisation and Analysis of Hand Evaluation* (Textile Machinery Society of Japan, Osaka), 1980.
4 Mahar T J, Wheelwright P, Dhingra R & Postle R, *Text Res J,* 60 (1990) 7.
5 Pan N, Zeronian, S H & Ryu H S, *Text Res J*, 63 (1993) 33.
6 Behera B K & Hari P K, *Indian J Fibre Text Res*, 19 (1994)168.
7 Behery H M, *Effect of Mechanical and Physical Properties on Fabric Hand* (Woodhead Publishing Limited, Cambridge), 2005, 2.
8 Schwartz E R, *Am Dyes Rep*, 28 (1939) 138.
9 Owen J D, *Shirley Link*, 4 (1971) 18.

10 Sharma K R, Behera B K, Roedel H & Schenk A, *Indian J Fibre Text Res*, 29 (2004) 57.
11 Behera B K & Mishra R, *Indian J Fibre Text Res*, 32 (2007) 72.
12 Frydrych I & Matusaik K, in *Effect of Mechanical and Physical Properties on Fabric Hand,* edited by H M Behery (Woodhead Publishing Limited, Cambridge), 2005, 239.
13 Farrington D W, Lunt J, Davies S & Blackburn R S, in *Biodegradable and Sustainable Fibres*, edited by R S Blackburn (Woodhead Publishing Limited, Cambridge), 2005, 191.
14 Guruprasad R, Vivekanandan M V, Arputharaj A, Saxena S & Chattopadhyay S K, *J Ind Text*, 45 (2014) 405.
15 Salhotra K R, *Spinning of Manmades and Blends on Cotton System* (The Textile Association of India), 2004, 62.