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Kawabata evaluation of enzyme-treated cotton knitted fabric

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Industrial trial of the enzymatic treatment of cotton knitted fabric with cellulase enzyme Denifade has been carried out under optimised conditions and the various low-stress mechanical properties of the treated fabrics have been assessed in the Kawabata system. The results show an improvement in the surface smoothness and a decrease in the bending and shear rigidities. The improvement in handle is reflected by the decrease in tensile and compressional energies.

Keywords: Bending rigidity, Cotton, Denifade, Enzyme, Knitted fabric, Low-stress mechanical properties

1 Introduction

Treatment of cotton knitted fabric with enzyme cellulase leads to various surface modifications[1-9]. These effects are distinguished by smoothness, clarity of surface structure, freedom from fluff, anti-pilling characteristics[10] and softness[11]. Knitted fabrics with a roughened, pilled surface exhibit the properties and appearance of high-grade goods after the treatment. Cellulase has a large molecular structure which does not easily penetrate the crystalline areas of the cellulosic fibre. Due to this, the cellulose molecules are only catalytically split in the outer fibre areas, but not inside the fibre. With increasing intensity of decomposition, however, material weight and breaking strength are reduced. The function of cellulase is thus based on exterior bio-catalytic splitting of cellulose molecules and the loosening of the knitted structure[2]. Studies have been carried out on bio-finishing of cotton knits to optimize the *p*H, time and temperature conditions for the enzyme Denifade[1]. Based on the process of optimisation at laboratory scale, the industrial trials (batch quantity, 150 kg) were taken in the present work. The enzyme-treated fabrics thus obtained were evaluated using the Kawabata system and tested for various physical properties. The behaviour of both white and dyed samples is reported.

2 Materials and Methods

2.1 Fabrics

20s combed knitted cotton fabric (weight, 195 g/m^2) and 20s carded knitted cotton fabric (weight, 205 g/m^2), both having 40 courses/in. and 32 wales/in. were used.

2.2 Recipe

Enzyme (Denifade) (Activity = 407.4 FPU/ml)[12]	:	10 % owf
Buffer (citric acid and NaOH)	:	*p*H 5.0
Lissapol D	:	1 % owf
M:L	:	1:20

2.3 Enzyme Treatment

The winch was thoroughly cleaned to remove enzyme toxins. The buffer solution was put in the winch along with other ingredients as mentioned in the recipe. The scoured and bleached fabric was treated at 50°C for 45 min. After the enzyme treatment was over, the fabric was given a hot wash at 80°C for 30 min to deactivate any enzyme on the fabric surface. Subsequent to this, a cold and a hot wash were given.

2.4 Dyeing

The 20s carded fabric samples, both control and enzyme treated, were dyed at 0.25% shade with

Procion Blue MR (reactive dye) in winch with commercial chemicals.

2.5 Tests

2.5.1 Yarn Tenacity

As per IS: 1670-1970 using Uster tensorapid instrument.

2.5.2 Air Permeability

As per ASTM standard D 734-75 (1980). It was tested on Shirley air permeability tester with 10 psi pressure and 5.0 cm^2 test area.

2.5.3 Wettability

As per IS:2349-1963.

2.5.4 Abrasion Resistance

As per ASTM standard D 3885-92. It was tested on Universal wear tester. The diaphragm pressure was 4.5 psi and the pressure head was 0.5 lb.

2.5.5 Hunter Whiteness, Colour Difference and *K/S*

These were evaluated on ACS computer colour matching machine.

2.5.6 Low-Stress Mechanical Properties

These were evaluated on the Kawabata evaluation system.

3 Results and Discussion

The enzyme-treated fabrics as well as the control (i.e. scoured-bleached) fabrics were evaluated in the Kawabata system for low-stress mechanical properties. The results are given in Tables 1 and 2. The other physical properties of the fabrics are given in Table 3 and the whiteness index and colour evaluation data are presented in Table 4.

Fig. 1 illustrates the profile of the mechanical properties measured for the enzyme-treated samples compared to those for the untreated ones. Since sixteen different properties (Table 1) are to be compared, for ease of comparison, 16 radially projecting lines have been drawn from a common origin, each representing a parameter as shown in Fig. 1. An outer circle with an arbitrary radius is drawn from the origin O. The points at which another circle, drawn at half the radius, cuts the radial lines represents the value of the parameter obtained for the untreated (control) sample. Since the units of different properties are different, to normalise, the values have been plotted as percentage of the corresponding value of the control sample. The scale has been so chosen that the origin "O" represents −100% whereas the outer circle represents +100% change in the property. Such a plot results in a property profile which can be easily visualised for comparison purposes[13].

Fig. 1(a) shows that for 20s combed (white) fabric, there is a decrease in the tensile and compressional energy upon treatment of the fabric with enzyme. This implies that a lower amount of energy is required to either extend or compress the fabric. In general, the lowering in the value of

Table 1—Low-stress mechanical properties of cotton knitted fabrics

Mechanical property	20s combed (white)		20s carded (dyed)	
	Control	Enzyme treated	Control	Enzyme treated
Elongation, %	13.3800	11.8750	11.1100	10.4400
Linearity of load- extension curve	0.8540	0.8330	0.8870	0.8445
Tensile energy, gf.cm/cm^2	2.8550	2.4650	2.4350	2.1900
Tensile resilience, %	38.5100	33.3550	38.5100	31.8750
Bending rigidity, gf.cm^2/cm	0.0345	0.0260	0.0349	0.0380
Hysteresis of bending moment, gf.cm/cm	0.0592	0.0415	0.0597	0.0600
Shear rigidity, gf/cm.angle	0.6800	0.6650	0.8000	0.7800
Hysteresis of shear force, gf/cm	2.0750	2.2050	2.3600	2.8150
Coefficient of friction	0.2358	0.1962	0.2409	0.2169
Mean deviation of MIU	0.0132	0.0119	0.0175	0.0173
Geometrical roughness, micron	4.2980	3.3745	5.7460	5.2005
Linearity of compression- thickness curve	0.6540	0.6770	0.6770	0.6550
Compressional energy, gf.cm/cm^2	0.0880	0.0740	0.0740	0.0710
Compressional resilience, %	54.4300	59.0900	59.0900	62.1400
Thickness, mm	1.1800	1.0330	1.2330	1.0760
Weight per unit area, mg/cm^2	19.5160	18.4300	20.8000	19.2080

Table 2—Primary hand values of cotton knitted fabrics

Hand		Control		Enzyme-treated	
Japanese	English	Summer	Winter	Summer	Winter
		20s Combed (white)			
Koshi	Stiffness	7.32	7.32	6.87	6.87
Fukurami	Fullness & softness	6.56	6.56	6.42	6.42
Shari	Crispness	3.20	—	2.65	—
Numeri	Smoothness	—	5.84	—	6.37
		20s Carded (dyed)			
Koshi	Stiffness	8.08	8.08	8.24	8.24
Fukurami	Fullness & softness	6.03	6.03	6.50	6.50
Shari	Crispness	4.22	—	3.99	—
Numeri	Smoothness	—	4.72	—	5.28

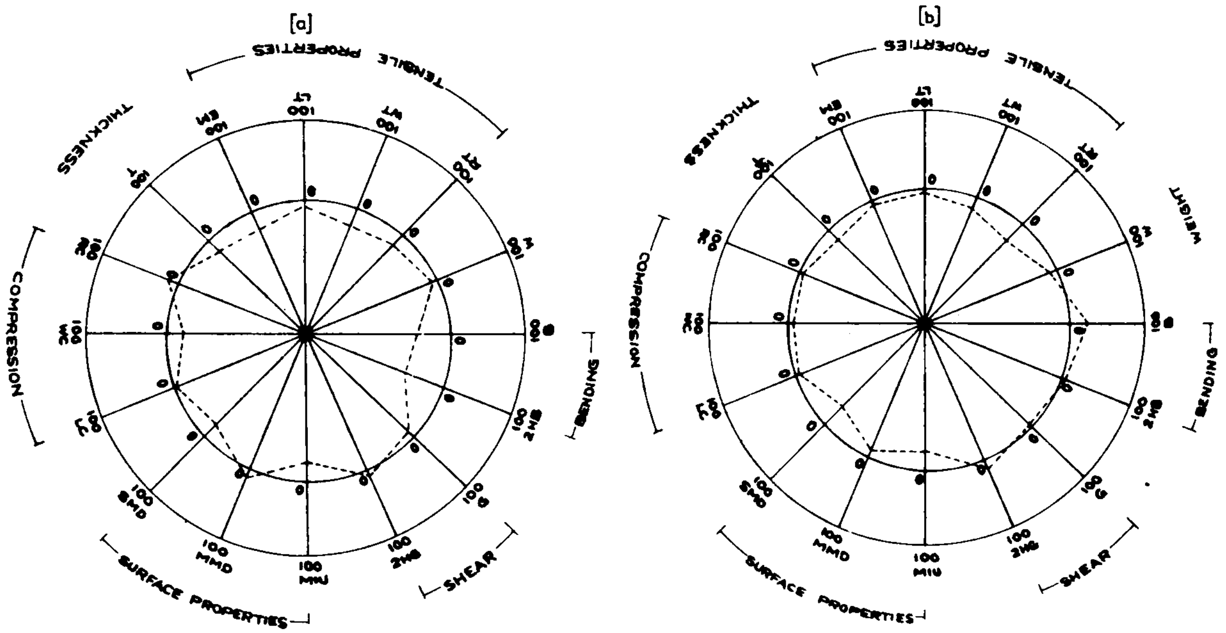

Fig. 1—Mechanical properties obtained after enzyme treatment (-------) of cotton knitted fabrics: (a) 20s combed (white) and (b) 20s carded (dyed) [EM—Elongation (%); LT—Linearity of load-extension curve; WT—Tensile energy (gf.cm/cm^2); RT—Tensile resilience (%); G—Shear rigidity (gf/cm.angle); 2HG—Hysteresis of shear force (gf/cm); B—Bending rigidity (gf.cm^2/cm); 2HB—Hysteresis of bending moment (gf.cm/cm); LC—Linearity of compression-thickness curve; WC—Compressional energy (gf.cm/cm^2); RC—Compressional resilience (%); MIU—Coefficient of friction; MMD—Mean deviation of MIU; SMD—Geometrical roughness (micron); W—Fabric weight per unit area (mg/cm^2); and T—Fabric thickness (mm)]

tensile and compressional energy means an improvement in the handle of the fabric. Thus, enzyme-treated fabrics have an improved handle.

The bending rigidity and shear rigidity too show a decrease in value when the fabric is treated with enzyme. A decrease in the value of these properties indicates a softer fabric. Hence, it can be said that the enzyme-treated fabrics are softer than the untreated ones.

The thickness data indicates a decrease in the value after enzyme treatment. The reduction in thickness is as a consequence of enzymatic hydrolysis of cotton, which subsequently improves the handle of the fabric. The reduction in the fabric density (or weight) too follows the same trend.

Table 2 shows the values of the primary hand for 20s combed (white) cotton knit. It may be seen from this table that the stiffness (Koshi) decreases after

Table 3—Physical properties of the cotton knitted fabrics

Property	20s combed (white)		20s carded (dyed)	
	Control	Enzyme treated	Control	Enzyme treated
Weight, g/m^2	195.2	184.3	208.0	192.1
Courses/inch	40	40	40	40
Wales/inch	32	32	32	32
Weight loss, % (on enzyme treatment)	—	5.58	—	7.64
Air permeability, cc/s	203.3	217.8	204.2	265.2
Wettability, s	3	1	1	1
Abrasion resistance cycles	151	169	170	267
Yarn tenacity, gf/tex	13.52	12.78	14.35	12.62
Yarn strength loss, % (on enzyme treatment)	—	5.47	—	12.06

Table 4—Hunter whiteness of 20s combed (white) and colour evaluation of 20s carded (dyed) samples

Property	20s combed (white)		20s carded (dyed)	
	Control	Enzyme treated	Control	Enzyme treated
Hunter whiteness	74.04	73.54	—	—
K/S	—	—	0.3707	0.3958
DE	—	—	ref.	0.76
DL*	—	—	—	−0.65
Da*	—	—	—	−0.38
Db*	—	—	—	−0.08

enzyme treatment. Shari (crispness) values too show a decrease for enzyme-treated fabric. Crispness is the feeling which comes from crisp and rough surface of the fabric. A decrease in the value indicates that the enzyme-treated fabric is less crisp or rough. The Numeri values indicate increase in the softness of the enzyme-treated fabric. Numeri or smoothness is a feeling coming from smooth, limber and soft value. Hence, enzyme-treated samples exhibit smoother feeling compared to untreated ones. The Fukurami or fullness values don't show much change.

The same trend is observed in the case of 20s carded (dyed) cotton knit (Fig. 1b). A slight variation in bending rigidity in this case can be due to local variations in the fabric. The Fukurami values in Table 2 clearly show an increase in the fullness and softness of the fabric after enzyme treatment. Thus, dyed fabric too shows similar trends.

It may be seen from Table 3 that there is a decrease in the fabric weight and yarn tenacity of the treated fabrics due to the action of the enzyme. Consequently, an increase in the air permeability value of the treated fabric is observed. An increase in the abrasion resistance values indicate that the friction between the abrader and the fabric surface has reduced after the treatment, implying thereby a smoother surface of the treated fabric compared to that of the control. This may be attributed to the fact that since the carded fabric surface is more rough compared to that of the combed fabric, the effect of enzyme treatment is more prominent in case of the carded fabric as is evident from the comparative changes in the physical properties of the two varieties.

Table 4 shows that for 20s combed fabric, the whiteness is almost same for both control and enzyme-treated samples. The *K/S* values of 20s carded dyed samples are slightly higher for enzyme-treated fabrics. This implies that enzyme-treated samples will appear comparatively darker. The DE value indicates that the colour of both control and enzyme-treated samples matches completely.

4 Conclusions

Enzymatic treatment improves the various properties of knitted fabrics. The surface smoothness is increased and consequently the bending rigidity and shear rigidity decrease. The improvement in handle is also reflected by decrease in the tensile and compressional energies of the treated fabrics. Thus, enzyme treatment leads to overall value addition to the handle and feel of cotton knitted fabrics.

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