

Physico-Mechanical Properties of Finished Denim Garment by Stone-Enzymatic Treatment

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ABSTRACT

Washing of fresh-assembled denim garment is a fundamental finishing treatment in textile and garment industries and has the largest effect on the physico-mechanical properties on finished denim garment. In this study, modification of denim garment by washing using pumice stone mixed with cellulase enzyme was investigated. The fresh-assembled denim pants, twill 3/1 weave and composition 100% cotton, have been processed by stone-enzymatic treatment using parameters namely concentrations of pumice stone (10 to 70%) (owg) mixed with concentration of cellulase enzyme (2.0%) (owg) at washing temperature (55°C) and pH (4.5-7.0) for treatment time (40 min) in the fiber to liquor ratio of 1:10 in an industrial sample washing machine. In order to evaluate the influence of these washing parameters on the properties of denim garment like tensile strength, elongation at break, fabric weight, color change, dimensional characteristics, stiffness and water absorption, has been determined. Fabric surface was also examined by scanning electron microscope (SEM) and fluorescence microscope (FM). It can be concluded that the washing parameters had influence on the physico-mechanical properties of finished denim garment. Especially stone-enzymatic treatment helps to get the required color fading effect and softness of denim garment, which gave a new-look appearance and good wear performance to the fabric distinctly. The results indicate that for producing sustainable denim garment the optimized washing condition for the best value is 30% pumice stone mixed with 2.0% cellulase enzyme in the stone-enzymatic treatment.

Keywords: Denim, Pumice stone, Cellulase enzyme, Color change, Tensile strength

Introduction

In 1849, a 20-year-old American people named Levi Strauss manufactured long-wearing pants with pockets to hold tools for the miners, using a very strong and stiff cotton woven fabric loomed in Nimes, France, called serge de Nimes, later shortened to denim (Frings, 1999; Razzaque,

2004). Denim is a cotton and twill-weave fabric that uses colored warp and white weft yarn and used for jeans and work clothes. It is normally dyed with indigo which remains on yarn surface (Grieve et al., 2006), as a result the denim fabric is very stiff and hard. Industrial washing has the largest effect on finished denim garment. Stone-enzyme

washing is a finishing process typically used by the denim garment washing and fashion industry to give worn-look appearance purposely. It also helps to increase the softness and flexibility of denim. The denim with only pumice stone could cause wear and tear of the garment and time consuming and desired color effect may not be achieved. To overcome this problem and achieve desired results, denim garment washing is carried out with the aid of pumice stone-cellulase enzymes in this study. Numerous investigations have been worked in the past for washing denim with enzymes (Kawamura & Wakida, 1989; Walker & Wilson, 1991; Tyndall, 1992; Wood, 1992; Morris & Harper, 1994; Kang et al., 1998). Sustainable apparel design is the new challenge for apparel designers and producers (Khan et al., 2012), because the consumers are concerned in eco-fashion in the last decade. All are now motivated to practice sustainability in design and production throughout the textiles like the use of organic fibers and environmentally safe dyes and chemicals (Gam & Banning, 2011). However, enzymatic stone-wash is popular but there is a lack of literature of sustainable denim garment washing with enzymatic pumice stone-wash. Although Sangita et al. (2010) reported that the popularity of bio-stone-washing (stone-enzyme) for denim is increasing day by day.

If the denim garments are washed by pumice stone-cellulase enzyme washing in order to decrease the loss of minimum strength, then the durability of the denim garment will be increased and believe that it will be sustainable. So, an attempt has been taken to wash denim garment with pumice stone-cellulase enzyme in order to produce today's most preferred fashionable vintage designs in this investigation.

Materials and Methods

Materials

100% cotton twill weave (3/1 LHT. 381 g/m²), construction 70 x 42 / 10 x 9, indigo dyed denim fabric, manufactured in a Textile mill in Bangladesh, is used in this

investigation. Denim garments (trousers) were manufactured using the stated denim fabric. Detergent (Hostapur WCTH, BASF, Germany), desizing agent (Luzyne FR-HP, BASF, Germany), anti-back staining (Antistain-LP30, GDS, India), acetic acid (China), softener (Text-soft, BASF, Germany) and fresh pumice stones (Turkey) of medium size (4-5 cm) were used. Two different natures of cellulase enzymes, acid cellulase (an acid enzyme (AE), Genzyme SL, Multichemi Ltd, Sri Lanka) and neutral cellulase (a neutral enzyme (NE), Bactosol JCP, Clariant Ltd, Swizerland) were used. In addition, mixtures of acid and neutral cellulases 50/50 (ME) mixed enzyme) were also used in this experiment.

Methods

In this experiment, several processing steps are followed in washing of the denim garments. These are desizing, stone-enzyme washing, hydro-extracting, drying, and testing for sustainability evaluation.

Desizing

The fresh denim trousers were loaded to an industrial sample washing machine (model-NS 2205, Ngai Shing, Hong Kong) along with fresh water. Machine was rotated for 2 min before adding the desizing chemicals. Then the denim garments (trousers) are desized with 0.6 g/L detergent (Hostapur WCTH), 1.2 g/L desizing agent (Luzyne FR-HP), 0.4 g/L anti-back staining agent (Antistain-LP30) and material to liquor ratio of 1:10 in washing machine at temperature 60°C for 20 min as pre-treatment in order to remove the size materials of warp yarns which was applied in fabric manufacturing for reducing yarn breakage. After that trousers are washed with hot water at 70°C for 4 min.

Pumice stone-cellulase enzyme treatments

After desizing, denim trousers were treated with pumice stone-enzymes in the same sample washing machine rotating with 30 rpm, at concentrations of pumice stone (10-70%) (owg) combined with cellulase enzymes (i) 2.0% Genzyme SL (an acid

enzyme) in liquor containing 1.0 g/L acetic acid (as an acetic acid buffer solution) to keep the pH at 4.5; (ii) 2.0% Bactosol JCP (a neutral enzyme) in liquor containing without acetic acid at pH 7.0; and (iii) 2.0% the mixture of Genzyme SL and Bactosol JCP (mixed enzyme, a mixture of acid and neutral cellulases 50/50) with 0.6 g/L acetic acid (as an acetic acid buffer) to keep the pH at 5.5 and at temperature 55°C for 40 min. The trousers were then hot washed at 70°C followed by cold water washed at 25°C and softened by Textsoft 0.5 g/L (a softener) for 5 min at 40°C followed by the standard industrial washing procedure.

Hydro-extracting and drying processes

Then stone-enzyme treated denim trousers were squeezed in a laboratory scale hydro-extractor machine (Zanussi, England) to remove excess water from the garments at 200 rpm for 5 min. Then dried in a steam drier (Opti-Dry, Roaches, England) at 65°C for 45 min.

Characterization

Denim trousers were conditioned at 65% RH and at 20°C for 24 h before testing according to ASTM D1776. Tensile strength and elongation at break was determined by the US Standard Grab test method according to ASTM D 5034. Weight loss (%) in fabric was calculated from the difference in fabric weight (GSM) before and after the treatment according to ASTM D 3776. Dimensional changes (shrinkage / extension, %) was calculated from the difference in fabric length before and after washed according to AATCC test method 96. Stiffness was measured from the bending stiffness in fabric by Shirley stiffness tester according to BS 3356. Water absorption of the garment was measured from the differences in rate of uptake according to BS 3449. Scanning electron microscopy was studied using SEM (model-S 3400 N, Hitachi, Japan). Fluorescence microscopy was also studied using FM (model-IX71, Olympus, Japan). Changes in the original color shade of the fabric was rated using Gray scale for color

change according to AATCC evaluation procedure 1.

Results and Discussion

Physico-mechanical tests were performed to evaluate the changes or the improvements of treated denim garments mixed with pumice stone and cellulase enzymes (acid, neutral, and mixture of acid and neutral cellulase) to fulfill the requirements for sustainable denim.

Effects of pumice stone concentration

The effect of pumice stone with various concentrations (10-70%) (owg) on the properties of denim garments was determined and is shown in Tables 1 and 2. On washing at various concentrations of pumice stones the tensile strength decreased due to the rubbing action/mechanical abrasion provided by the pumice stones. The addition of pumice stone in cellulase treatments accelerates more mechanical abrasion and allowing enzymatic hydrolysis quicker which effects on the fabric properties. The weave of the fabric used in this study is a 3/1 twill, so the effect of abrasion is more concentrated on warp yarns surface than weft yarns surface. From the Table 1, it can be seen that warp yarns are more affected by stone in acid enzyme than neutral and mixed enzymes. It is observed that, at low concentration, 10% of pumice stone, the decreases in tensile strength were 14.6%, 9.7% and 7.3% observed in warp for acid, neutral and mixed enzymes. With the increasing of pumice stone concentration (70%) the rate of tensile strength decreased. Acid enzyme with 70% pumice stone caused the highest strength loss (34.9%), whereas the neutral enzyme (30.0%) and mixed enzyme (28.4%) had less effect on the strength properties. Table 1 shows that 5.5% weight loss was obtained for acid enzyme, 4.9% loss for neutral enzyme and 5.2% loss for mixed enzymes. It can be seen from the Table 1 that the color shade also decreased. The Table showed that pumice stone combined with acid, neutral, and mixed enzyme caused up to 60% color loss. Table 2 shows the losses in stiffness of denim

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garment with increasing the stone concentrations up to 70%. It can be seen from Table that pumice stone with acid cellulase caused 31.1- 48.8% stiffness loss; neutral cellulose, 28.8-48.8% loss; and mixed cellulases, 33.3- 51.1% loss. It can be seen from the Table 2 that pumice stone mixed with cellulase caused higher moisture

contents (21.3%) than acid enzyme and neutral enzyme. From the *Table 2* it can be seen that the water absorption is increased when washing was performed by pumice stone with acid, neutral and mixed cellulases due to the loosening of surface fibers by the abrasion of pumice stones.

Table 1. Effect of pumice stone concentrations on the physic-mechanical properties like tensile strength, weight and color shade change.

Ps (%)	Tensile strength loss_warp, (%)			Tensile strength loss_weft, (%)			Weight loss, (%)			Color shade loss, (%)		
	AE	NE	ME	AE	NE	ME	AE	NE	ME	AE	NE	ME
0.0	0	0	0	0	0	0	0	0	0	0	0	0
10	14.6	9.7	7.3	11.0	11.0	9.5	2.3	1.8	1.8	30	20	10
20	18.3	14.6	13.0	16.1	14.7	12.5	3.4	2.6	2.9	30	20	20
30	22.3	17.8	15.8	24.2	22.0	19.8	4.2	3.4	3.9	40	30	40
40	27.2	24.3	20.7	30.1	29.4	28.6	4.5	3.9	4.5	50	40	50
50	29.3	25.2	23.5	33.8	31.6	30.8	4.9	4.5	4.5	60	50	60
60	33.3	26.4	25.2	34.5	33.0	32.3	5.2	4.9	4.9	60	60	60
70	34.9	30.0	28.4	34.5	33.8	33.8	5.5	4.9	5.2	60	60	60

Here, Ps indicates pumice stone; AE for acid, NE for neutral and ME for mixed enzymes

Table 2. Effect of pumice stone concentrations on the stiffness, moisture content and water absorption.

Ps (%)	Stiffness loss_warp, (%)			Stiffness loss_weft, (%)			Moisture content, (%)			Water absorption, (%)		
	AE	NE	ME	AE	NE	ME	AE	NE	ME	AE	NE	ME
0.0	0	0	0	0	0	0	0	0	0	0	0	0
10	31.1	28.9	33.3	9.3	6.2	6.2	14.8	16.2	16.4	15.8	17.5	16.7
20	37.7	35.5	40.0	12.5	9.3	12.5	20.5	18.4	20.2	19.8	20.6	20.6
30	44.4	40.0	46.6	15.6	12.5	15.6	20.7	18.9	20.8	25.4	22.2	26.1
40	46.6	44.4	46.6	15.6	12.5	15.6	20.8	19.7	20.9	26.1	23.8	26.9
50	46.6	44.4	46.6	18.7	18.7	18.7	20.9	20.2	21.3	26.9	25.4	27.7
60	48.8	46.6	51.1	18.7	18.7	18.7	21.0	20.2	21.3	27.7	25.4	28.5
70	48.8	48.8	51.1	18.7	18.7	18.7	21.0	20.2	21.3	27.7	25.4	28.5

SEM and FM Images

The surface appearances of both fresh and pumice stone-enzyme treated denim garments were examined by scanning electron microscopy (SEM). *Figure 1* shows the untreated sample and no fibrils and ruptures in the image. *Figure 2* shows pumice

stone-enzyme treated sample and shows damaged fabric surface due to enzymatic hydrolysis and rubbing action by pumice stone during processing in the washing machine. As mentioned previously (Betrahet, 1980; Li & Hardin, 1998), the enzyme attacks the cellulose of cotton progressively.

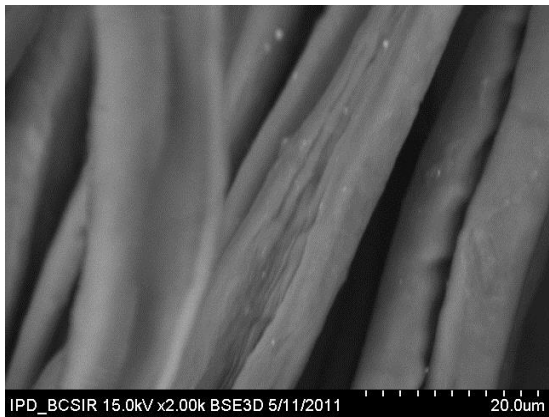


Figure 1. SEM image of untreated sample.



Figure 2. SEM image of treated sample.

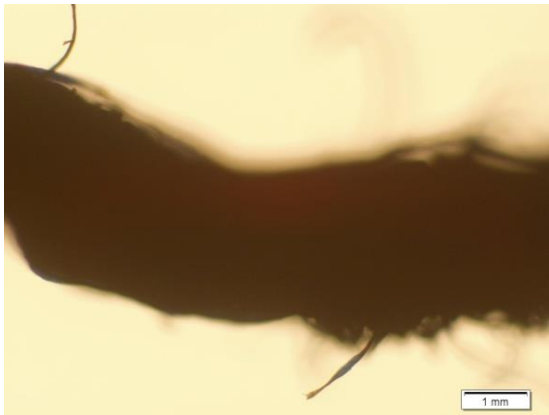


Figure 3. FM image of untreated warp yarn.

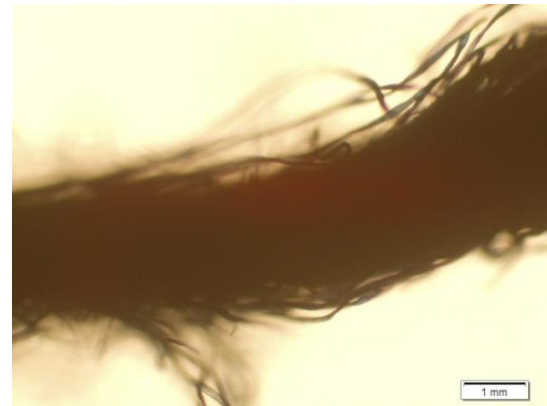


Figure 4. FM image of treated warp yarn.

The surface appearance of the fibers in the denim garment was also studied by fluorescence microscopy (FM). Figures 3 shows the fluorescence microscopy image (model IX71, Olympus, Japan) of untreated warp yarn and shows smooth surface because the yarns are coated with size materials and projecting fibers are not visible on surface

and Figure 4 shows the treated warp yarn and observed highly damaged surface by the rubbing action of pumice stone during washing in the machine.

Conclusions

The physico-mechanical properties of denim garments like tensile strength, weight, and fiber surface damage by the physical abrasion of pumice stones. But, in some cases it improved from the aesthetic point of view (elongation, stiffness and water absorption) with the effect of pumice stone in enzyme washing and the pumice stone is very effective in denim washing. It is observed that untreated denim samples were stiff and harder than stone-enzyme treated denim samples. Rubbing by stone and enzymatic hydrolysis of the denim garments caused enhanced color fading, softness and water absorption; meanwhile, tensile strength is decreased. Examination of the treated denim by SEM and FM shows more cracked and hairy fiber surface, resulting strength losses and soft-hand feel of denim garments. It can be concluded that durability of denim garment depends on the concentration of pumice stone in denim garment washing.

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