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Evaluation of Mechanical Properties of Denim Garments after Enzymatic Bio-Washing

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Abstract: Denim washing is the vital part of finishing process to provide aged look and comfort by reducing the stiffness of the garments. This experiment was carried out to observe the effects of bio-friendly enzyme wash on the mechanical properties of denim garments constructed by 3/1 twill weave pattern. Cullulase enzyme in combination with stone and without stone is used for washing followed by multiple steps. In this study, it is found that, a garments construction is affected largely by washing especially gram per square meter (GSM). On the other hand, physical properties in terms of tensile strength, stiffness and shrinkage are changed significantly due to the effect of washing. Denim garments washed with liquid and powder enzyme in combination with stone losses maximum strength compared to other samples whereas F/S shows more reduction in stiffness than B/S. Dimensional stability in terms of shrinkage was found excellent. Enzymatic washing of denim garments can be a successful replacement of environmentally harmful chemical washing and garments damaging stone wash.

Key words: Cellulase · Enzyme · Washing · Stone · Warp · Weft

INTRODUCTION

Washing of clothing materials improve the comfort properties. The treatments of finishing garments during washing are the important parameters influencing cloth shade and the garments mechanical properties. The application of these treatments and their succession in finishing garments is advisable to have more and more increased whiteness. Nevertheless, all these treatments that cause a more worn appearance and aged look for garment reduce greatly the mechanical properties [1]. Industrial washing is one of the finishing methods applied on Garments which together with the use of new technologies and equipment enables to obtain the desired results. For finishing of denim garments, a range of treatment methods are used. They all are aimed at new possible effects of Garments appearance, namely millwash or rinsewash, stonewash, moonwash, sandwash, bleach, overdyed-look, damaged-look, scrubbed-look [2]. Now a days, enzyme treatment gained popularity in denim garment washing due to its low destructive nature on garments surface and eco-friendly nature compared to stone washing. The major constituents of cellulase are the β-1, 4-gluconases. It actually consists of a complex mixture of acting enzymes. The β (1-4) linkages between adjacent repeat units in cellulase polymer chain are the sites for catalytic hydrolysis by cellulase. They catalyze the primary reaction of hydrolytically splitting the β-1, 4-glycosidic linkages in cellulase chain molecule [3]. The production of aged denim garments with cellulases is the most successful enzyme process that has emerged in the textile industry in the last decade. With the advent of finishing treatments of stone washing and enzymatic stone washing it has become more acceptable over the last few years [4]. The treatment of cellulase and protease enzymes changes the physical properties of the garments (for example garments strength and weight) [5]. Traditionally, denim jeans manufacturers have washed

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their garments with pumice stones to achieve a soft handle as well as a desirable worn look. Natural pumice stone is widely used in denim garment washing process has disadvantages, the difficulty of removing residual pumice from processed clothing items and the damage to the equipment by the overload of tumbling stones and the pumice stones and particulate material can also clog machine drainage passages and drains and sewer lines at the machine site. Denim washing with cellulases is thus a standard technique, providing an environmentally friendly process to achieve a desirable appearance and soft handle for garments. During the enzymatic treatment, the removed indigo dye can redeposit on the white yarn of denim garments. This process is called back staining and it can diminish the look of denim garment. An ideal bio-stoning enzyme would possess high abrasive activity as well as low back staining. Since cellulases strongly adsorbed to their substrates, this phenomenon can be explained by dye binding to the bound enzyme protein [6]. The cellulase enzyme can also be combining with the pumice stone. This is recommendable for heavy stone wash finish. The same result can be reach in a shorter time. Bio-stone washing has opened up new possibilities in denim finishing by increasing the variety of finishes available. For example, it is now possible to fade denim to a greater degree without running the risk of damaging the garment. Productivity can also be increased because laundry machines contain fewer stones or no stones and more garments. The use of less pumice stone results in less damage to garment and machine and results in less pumice dust in the laundry environment [7]. There are mainly three kind of celllulase being used for Denim washing, Neutral, Acid and Bio polishing Enzyme. Enzyme are very sensitive with parameters in washing cycle i.e. pH, Temperature and time [8]. Neutral enzymes require longer cycle times, less aggressive but give no back staining when it is achieve at the same effect. Acid enzymes have are faster reactions and more aggressive when the result in more chemical abrasion and loss for the strength [9].Enzymatic treatment can replace a number of mechanical and chemical operations, which have been applied to improve the comfort and quality of garments. Cellulase enzyme treatments have been successful at improving flexibility and soft hand feels of cotton denim garments [10-11]. In enzyme washing, cellulases attack primarily surface of the garments, leaving the interior of the garments as it is by removing the dye present in the surface layer of garments and the chemistry of action of cellulase enzyme shown in the Figure 1 [9].

This study explores the effect of enzyme on aging of denim garments and the changes occur in the properties of denim garments including stone and excluding stone.

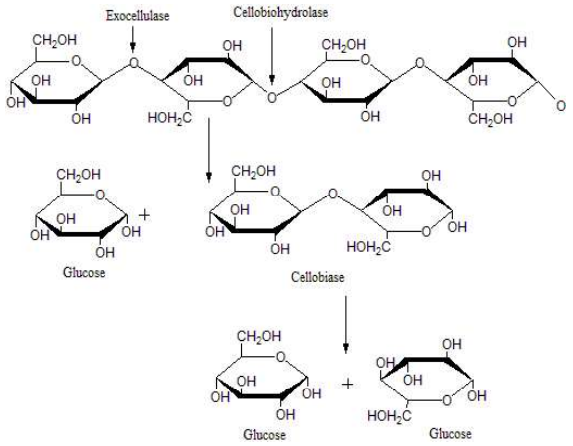

Fig. 1: Chemistry of Action of Cellulase Enzyme

MATERIALS AND METHODS

Materials: Indigo dyed denim garments used for this experiment is commercially available 100% cotton with 3/1 twill weave construction which is shown in Figure 2. The cross sign (X) and dash sign (-) presents warp yarn up and down in the entire twill woven fabric respectively. Number of ends per inch (EPI) and picks per inch (PPI) are 72 and 41 respectively. The linear density of warp and weft yarn is 9 Ne and GSM is 390. The denim was processed with different industrial washing techniques such as desizing, washing with cellulase enzyme and washing with enzyme along pumice stone of medium weight. The liquid enzyme used in this process is GENZYME 200 and the powder enzyme is Bactosol. The recipe was prepared based on the M:L ratio 1:10, acetic acid 0.6 gram/liter, enzyme 1 gram/liter and anti black staining agent of 0.8 gram/liter was used.

Method of Desizing: Desizing was carried out on the denim garments for 15 min at 60°C with neutral pH by 50 gm desizing agents and 20 gm anti-back staining agents and 2.5 kg pumice stone was used with the required desizing process. The weight of the sample used in this process was 5 kg.

Washing with Acidic Cellullase Enzyme (Liquid/Powder) Without Pumice Stone:

Process Sequence: Sample → Add water→ Machine Run→ Enzyme→ Acetic Acid→ Anti Back Staining Agent→ Machine Run 30 min→ Neutralization → Rinse 2 times.

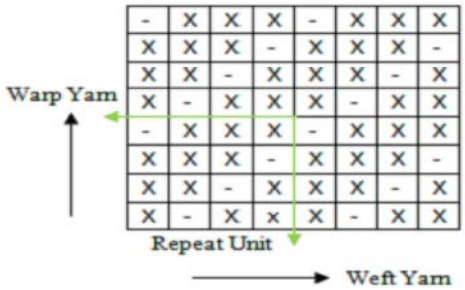

Fig. 2: Graphical presentation of denim garments

Washing with Acidic Cellullase Enzyme (Liquid/powder) with Pumice Stone: Process sequence: Sample _¨Add water_¨ Machine Run_¨ Stone _¨ Enzyme_¨ Acetic Acid_¨ Anti Back Staining Agent_¨ Machine Run 30 min_¨ Neutralization _¨Rinse 2 times

Neutralization: After washing denim with enzyme along with stone or without stone it is required to neutralize the garments. Neutralization is carried out with 50 liter water and 100 gm soda ash for 3 min at 45°C. Finally, rinsing is done for 2 times with 150 liter water each time.

Hydro Extracting and Drying: Hydro extracting is performed in the machine for 1.5 to 2 min. Denim sample is kept in gas dryer at 80°C for 30 min – 45 min and drying is completed.

Recipe for Washing: Different types of recipes for washing with stone are denoted by "A", "B" and "C" for liquid enzyme, liquid and powder enzyme and powder enzyme respectively as well as "D", "E" and "F" for washing without stone. All the recipes for washing are given below-50 liter water was mixed with 30 gm acetic acid. The pH of acetic acid used in the washing process contains pH of 5.0 for sample A and D; 5.5 for sample B and E; and 6.0 for sample C and F respectively. 40 gm anti back-staining agent was used along with 50 gm either liquid/powder enzyme or mixture of liquid and powder enzyme. The amount of pumice stone used for washing was 2.5 kg. The washing process was carried out at 45°C temperature for 30 min and pH of washing was maintained by 4.5 – 5.0.

Determination of Garments Specifications: EPI and PPI are calculated by using counting glass according to ISO 7211/2. Yarn linear density is measured by Beasley's balance by following ISO 7211/5. GSM cutter is used to determine the area density of the denim garments according to ISO 3801.

Determination of Strength: BS 2576 Method is used for determination of breaking strength and elongation (strip method) of woven garments [12].

Determination of Shrinkage and Stiffness: AATCC 135 is used for determination of shrinkage, while cantilever test principle following ASTM D 1388 is used for the determination of stiffness. Shrinkage was calculated by using the following formula-

$$S\% = \frac{B-A}{A} \times 100 \quad (1)$$

Where

B= dimension after treatment, A= original dimension.

RESULTS AND DISCUSSIONS

To investigate the different effects of washing on denim garments, changes in garments structures and certain physical properties were determined. Both warp wise and weft wise tensile strength, warp wise and weft wise stiffness of face side (F/S) and back side (B/S) and warp wise and weft wise shrinkages were evaluated. In these results only average value of 7 tests is shown for the better and easy demonstrations. Structural characteristics of denim before washing and after washing are presented in Table 1.

From the above result shown in Table 1 it is found that, treatment of denim with different enzymes and stones may causes different effects. As the protruding and loose fibers are being removed by the bio-polishing effect of enzyme, GSM lessen with the action of enzyme and lowering gradually with the use of stone due to friction takes place between fibers and stones. Yarn linear density of weft yarn is comparatively unchanged, while the warp yarn linear density increased a little with the treatment of enzymes. This occurs due to the washing actions which removes all of the sizing ingredients. As a result the diameter of yarn reduces hence warp yarn count increases. EPI is same in case almost all sample but an increase by value 1 is found in sample B and E. Conversely, PPI increased in all sample except sample E due to relaxation shrinkage of the garments.

Figure 3 as shown above depicts the tensile strength of bio-washed denim garments in warp direction. From the Figure 3 it is found that warp wise tensile strength is reduced significantly after washing with different recipes. When stone is used along with enzyme then the strength of the garments is reduced more compared to the sample washed without stone using enzyme. Highest reduction

Table 1: Structural characteristics of different sample

Sample	GSM	Count Warp	Count Weft	EPI	PPI
A	383±0.03	10±0.09	9±0.04	72±0.08	42±0.04
B	386±0.06	9±0.05	10±0.07	73±0.06	42±0.02
C	387±0.04	9±0.07	8±0.09	72±0.05	43±0.04
D	383±0.06	11±0.08	9±0.03	72±0.06	42±0.03
E	382±0.02	10±0.08	9±0.06	73±0.02	42±0.01
F	384±0.03	10±0.06	9±0.06	72±0.03	41±0.02
Raw	390±0.05	9±0.02	9±0.07	72±0.06	41±0.01

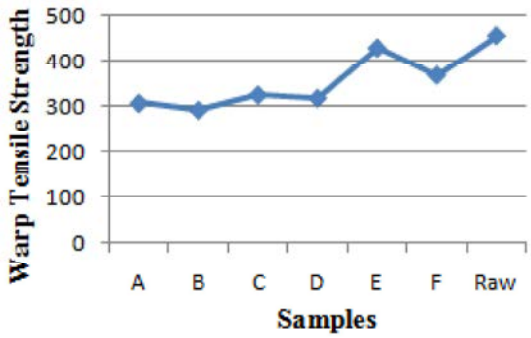

Fig. 3: Warp wise tensile strengths

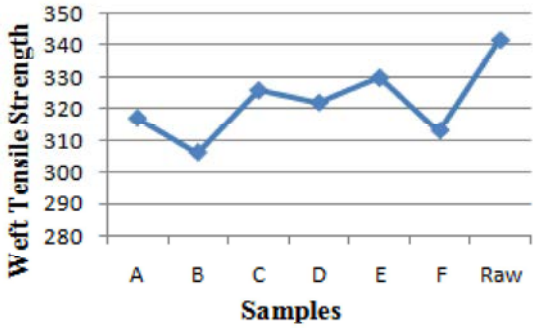

Fig. 4: Weft wise tensile strengths

of tensile strength in warp direction is observed in sample B when washed with stone using liquid and powder enzyme. This is due to the combined action of liquid and powder enzyme which cause more aggressive corrosion on the surface of fibers. Sample A, C and D shows almost same amount of reduction with little variation. On the other hand sample F shows moderate amount of reduction in tensile strength in warp direction by value 370 compared to raw sample due to the moderate action of powder enzyme.

Above Figure 4 represents the weft wise tensile strength of the denim garments. From the Figure 4 it is observed that reduction of weft wise tensile strength is lower than warp wise tensile strength. Weft wise maximum reduction in tensile strength was calculated by 10.52%

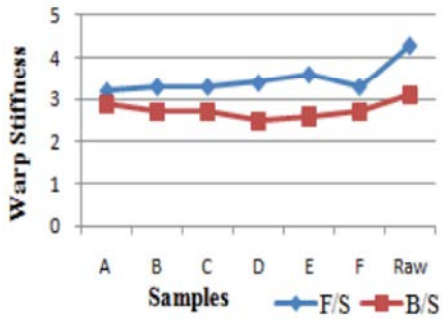

Fig. 5: Comparison of stiffness in warp direction

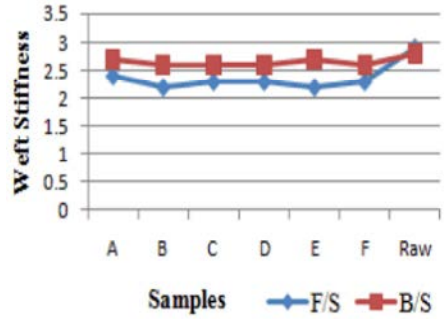

Fig. 6: Comparison of stiffness in weft direction

whereas warp wise maximum reduction was found to be 35.67% which indicates 25.15% less reduction in tensile strength in weft direction. This is may be due to construction of garments since the garments were 3 ends up warp face twill weave. As a result warp yarns faces highest amount of friction than weft yarns. Weft yarn faces very high fluctuation in the reduction of tensile strength which may be the reason of construction pattern of the garments. Single weft yarn is down to the three warp yarn hence the contact of enzyme and stone with the weft yarn may be varied.

Figure 5 and Figure 6 placed above show the comparison of warp wise and weft wise stiffness both face and back side of the garments. From the Figure 5 it is evident that highest reduction of warp stiffness for F/S and B/S are 25.58% and 19.35% respectively. Sample A shows the highest reduction in stiffness in F/S by value 3.2 while sample D shows the highest reduction in stiffness in B/S by value 2.5. Figure 6 indicates the weft wise reduction in stiffness in F/S from 17.24% to 24.14%. On the other hand B/S stiffness shows nearly consistent trends and maximum reduction is found to be 7.14%. The F/S of the garments shows the greater reduction in stiffness compared to B/S due to the front facing structure of the garments. Cellulase used in washing destroys some

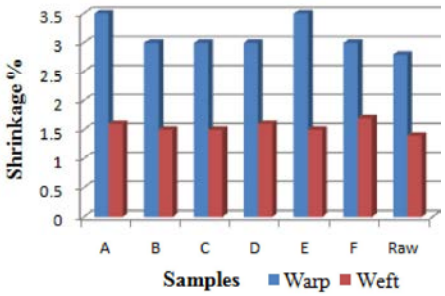

Fig. 7: Comparison of shrinkage in warp and weft directions

amounts of fiber as well as friction between stone and fibers also reduce the strength of yarn. As a result, the twists of fiber are break down and/or destroy in some extent which leads in reduction of stiffness of the garments.

Figure 7 as shown below presents the comparison of shrinkage both warp and weft directions. Both warp wise and weft wise shrinkage for raw and bio-washed samples does not cross the standard set by ISO 5077:1984. Most of the samples after treating with cellulase show a higher value of shrinkage compared to untreated sample. Maximum increases of shrinkage in warp direction from untreated sample are found in sample A and E by 25% while other samples show same amount of shrinkage by value 3.14%. In weft direction maximum increase of shrinkage is found 21.43% for sample F compared to raw sample. Sample A and D show almost 7.14% more shrinkage than rest of the samples when compared to untreated sample. Since the strength and stiffness of yarn is reduced, then ultimately the dimensional stability of the garments also reduced. In this regard, more shrinkage is found in the samples after washing compared to unwashed samples but this does not affects the comfort properties and draping of the garments.

CONCLUSION

In this paper the effects of enzyme with stone and without stone is observed. From this study it is found that, by the treatment of enzyme the constructions of the garments is not changed a lot except GSM. The frictions caused by the stone reduce the weight of yarn hence lower GSM is obtained. On the other hand although strength of the garments is reduced but it is within the acceptable range and also reduces the stiffness which is essential for wearing comforts. Shrinkage of the garments does not exceed the required level after enzyme treatment. Cellulose treatment with stone ensures greater tensile loss and stiffness loss which results in more worn out looks of the garments. So enzymatic washing without stone produce moderate aged looks of the garments as well as comfort. Cellulase treatment for washing is a bio friendly process so this process can successfully be applied for cleaner production with minimum damage to environment.

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