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EFFECT OF VARIOUS WASHING PROCESS ON PROPERTIES OF FOUR WAY STRETCH DENIM FABRIC

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***Abstract*: Effect of various washing process on the properties of indigo dyed four-way stretch denim fabric was studied in this research. The different washing techniques (Dark wash- enzymatic treatment, Medium wash- enzymatic treatment with pumice stone, Bleach wash- enzymatic treatment with bleaching powder and pumice stone, Acid Wash-Enzymatic treatment with potassium permanganate and pumice stone) were applied on the fabric. Properties of four-way stretch denim fabric like tear strength, dimensional stability to washing, color fastness to washing, color fastness to water, color fastness to perspiration, color fastness to light, color fastness to ozone, color fastness to rubbing, fabric weight were investigated and compared with each other before and after washing process. All tests were carried out according to the ISO standards. Pollution load of washing effluent of different washing techniques were also evaluated to measure their impact on the environment. The surface analysis of the different washed fabric was examined by scanning electron microscope (SEM). From the result was examined then the best result observed in the fabric of medium wash in terms physico-mechanical properties, chemical properties, pollution load of washing effluent, cost comparison, morphological changes of fabric surface. The results indicated that the durable and sustainable wash process for four-way stretch denimfabric is medium wash (enzymatic treatment with pumice stone).**

Keywords: 4-way Stretch Denim Fabric, Washing type, Dimensional Stability, Color Fastness, SEM.

1. Introduction:

Denim is one of the world's oldest fabric's which is most commonly associated with jeans. Denim is very strong, stiff and hard wearing fabrics [1]. Denim is cotton and twill weave fabric that uses colored warp and white weft yarn and used for jeans, work clothes and casual wear [2]. Denim wear has gained popularity all over the world. As a result jeans wear is one the most prominent apparel items in the world [3]. The evolution of the denim market has led to the development of some unique and creative denim fabrics and opened new worlds of possibility for finishes [4].Four way stretch denim is basically cotton-spandex and twill fabric. At present, people of all ages, especially the youth have a

great interest on the four way stretch denim because of high stretch ability and comfort ability. Without finishing treatment (washing), the denim garment is uncomfortable to wear, due to it's weaving and dyeing effects. The manufacturing process of denim is little bit different than any other fabric. It is special process in which only the surface of the warp yarn is dyed, the core stays white. They are hard wearing, high density fabrics with a high mass per unit area [5]. So, washing practice becomes a crucial issue for the denim apparel to make it softer, suppler, smooth and comfortable to wear performance [6]. During the finishing (scouring and bleaching) the structural changes in the fabric appear after applying a finishing agent and high temperature [7-11]. The changes in fabric density, thickness and mass which usually results in dimensional changes that depend upon the raw material of the fabric and on the level of dimensional stability. Stretchable fabrics are dimensionally unstable, compared with conventional fabrics [11-14].There have been many attempts to use chemicals in denim garment washing. The most commonly used denim washing methods are enzyme wash, bleach wash, acid wash, stone wash etc. Although enzymatic method is eco-friendly but enzyme treatment on cellulosic garment degrades cellulose chains, yielding shorter chain cellulose polymers and reduces its mechanical strength severely [15-16]. The term novel design refers to eco-friendly sustainable apparel design which is the new challenge for apparel designers and producers, because the consumers are concerned in eco-fashion in the last decade. In the fast changing fashion trends, 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 [17]. Again, consumer's environmental attitudes and apparel purchasing behavior has been increased now and their purchasing behavior is also influenced by aesthetic attributes of the product [18]. Many researchers are engaged in research to investigate the effect of various washing on physical, mechanical and color fastness properties of rigid & stretch denim fabrics. But, there is lack of research on the determination of environment-friendly and sustainable wash process for four way stretch denim fabric to develop new designs as fashion with longevity as higher wear performance by an enzymatic method in terms of physico-mechanical properties, chemical properties, pollution load of washing effluent, morphological changes of the fabric surface. In this view the present investigation is design to innovate an environment-friendly and sustainable process for washing of the four way stretch denim fabric. The aim of the present work will be on the determination of physical, mechanical & chemical properties of non-wash four way stretch denim fabric. Evaluation the effects of various washing process on properties of four way stretch denim fabric. Investigation of various washing process off our way stretch denim fabric on pollution load of the washing effluent. Analysis of the changes in fabric surface due to various washing process by SEM.

2. Materials and Methods

2.1 Materials

2.1.1 Fabric

71% Cotton 14% Viscose 11% Polyester 4% Elastane with 3/1 right hand twill weave construction C/R 10/40DSL x R/T 18/70D (Finished construction), 92x59(Type of yarn). The fabric weight 11.1 oz/ GSM (357gm) (Before wash) and 13.5 oz/GSM (458gm) (After wash). The indigo slasher dyed four ways stretch denim fabric is used in this investigation. The shrinkage (warp x weft) of four way stretch denim fabric: warp: -9% to -14% , weft: -10 % to -13%. Stretch %(weft): warp 20.6% /weft 40.3%.This fabric was collected from China supplier Dayin Textile Ltd.

2.1.2 Chemicals

a) Desizing Agent: Soda ash (Sodium Carbonate) was us used as desizing agent in this investigation. This chemical was imported from China.

b) Bleaching Powder: A bleaching powder (Bleach KCI, 35% available chlorine) was used for washing denim garments. This chemical was imported from India.

c) Detergent: Hotspur (BASF), this chemical was imported from Germany.

d) Enzyme: Genzyme SL (Cellulase enzyme) was imported from Srilanka.

e) Stone: Fresh pumice stones of size (2-3cm) were used for the experiment. This stones were collected from Germany.

f) Softener: Text-soft (BASF), this chemical was imported from Germany.

2.2 Machineries Used in the Experiment

2.2.1 Garments Washing Machine

In this research work, washing machine is the machine used to wash the various types of clothes without applying any physical efforts. The washing machine is also called as clothes washer [19]

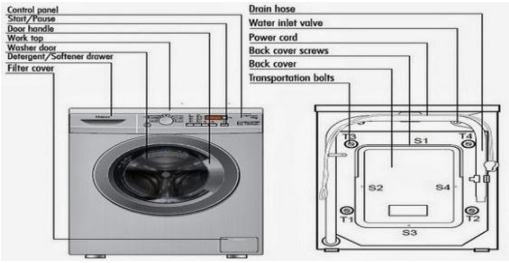


Fig. 1. Garments Washing Machine

2.2.2 Color Fastness to Light

In this research work, light fastness tester is used to determine the color fastness of textiles against sunlight**.** All dyed material experience change in color when exposed to daylight for a sufficiently long period because of the action of sunlight [20].

Fig. 2. Color Fastness to Light Machine

2.2.3 Color Fastness to Ozone Machine

In this research work, the machine is used to change the color of garments after washing and also this machine is for washing purpose [21].

Fig. 3. Color Fastness to Ozone Machine

2.2.4 Color Fastness to Washing Machine

In this research work, washing fastness tester is used for determining color fastness of textile materials to washings. The color fastness of textile material is determined by way of mechanical hesitation of a specimen of textile with the piece of specified adjacent fabrics in Standard Soap Solution followed by rinsing and drying. Thereafter, the change in color of specimen and stains of the adjacent fabrics are assessed with standard grey scale [20].

Fig.4. Color Fastness to Wash Machine

2.2.5 Color Fastness to Water Machine

Color fastness to water machine is designed to measure the resistance to water of dyed, printed, or otherwise colored textile yarns and fabrics. The test method by which this test is carried out is AATCC 107-1991 or ISO 105 E01 [20].

Fig.5.Color Fastness to Water Machine

2.2.6 Color Fastness to Perspiration Test Machine

In this research work, perspirometer is used for determining the resistance of the color of textiles of all kinds and in all forms to the action of human perspiration [20].

Fig.6.Color Fastness to Perspiration Machine

2.2.7 Scanning Electron Microscope (SEM)

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. In research work, four SEM images of the fabrics were taken by this machine [22].

Fig.7.Scanning Electron Microscope Machine

2.3 Washing Procedure

In this research work, four washed sample was prepared with different washing effects such as dark wash (enzymatic treatment), medium wash (pumice stone with enzymatic treatment), light wash (bleaching with enzymatic treatment), acid wash (acid & pumice stone with enzymatic treatment)

2.3.1 Dark Wash (Enzymatic Treatment)

A. Desizing

Samples were desized using detergent and soda ash. This treatment was conducted in liquor containing soda ash (1.1g/l), detergent (0.6g/l), and desizingagent (0.6g/l), and material to liquor ratio of 1:30 in a laboratory scale sample washing machine at 50°C for 10 min. The samples were then washed with hot water (50°C) followed by cold water wash.

B. Cellulase Treatment

Desized samples were treated using cellulose enzyme. This process was conducted in liquor containing acetic acid (1g/l) at pH 5.5 and material to liquor ratio of 1:30. The enzyme treatment was carried out at concentration of Genzyme SL (4g/l), temperatures 40°C and treatment time 20 min. After desired time temperature was raised to 90°C for 1 min to stop enzyme action. The samples were then washed with hot water and then washed with cold water. Finally, samples were softened with Text soft softener (2.5g/l) at room temperature for 5 min.

C. Hydro-Extracting and Drying

After treatment, the washed samples were squeezed in a laboratory scale hydro-extractor machine at 200 rpm for 3-4 min to remove excess water and then dried in a steam drier at 75°C for 35-40 min. These are done for enzyme-stone washed samples.

C. Hydro-Extracting and Drying

After treatment, the washed samples were squeezed in a laboratory scale hydro-extractor machine at 200 rpm for 3-4 min to remove excess water and then dried in a steam drier at 75°C for 35-40 min. These are done for enzyme washed samples.

Fig.8. Dark Wash Sample

2.3.2 Medium Wash (Pumice Stone-Enzymatic Treatment)

A. Desizing

Samples were desized using detergent and soda ash. This treatment was conducted in liquor containing soda ash (2 g/l), detergent (0.6g/l), and desizingagent (0.6g/l) material to liquor ratio of 1:30 in a laboratory scale sample washing machine at 50°C for 10 min. The samples were then washed with hot water (50°C) followed by cold water wash.

B. Pumice Stone-Cellulase Treatment

The samples were treated using cellulose enzyme mixed with pumice stone in the same sample washing machine at concentration of Genzyme SL(2g/l) with fixed amount of pumice stone(30% owg),fixed at temperatures 40°C and treatment time 20 min. This process was conducted in liquor containing acetic acid (1g/l) at pH 5.5 and material to liquor ratio of 1:30.All treatments were involved in the rotary cylindrical sample washing machine at 30 rpm. The samples were then washed with hot water and then washed with cold water. Finally, samples were softened with Text soft softener (2 g/l) at room temperature for 5 min.

Fig. 9.Medium Wash Sample

2.3.3 Light Wash (Bleaching Powder-Enzymatic Treatment)

A. Desizing

Samples were desized using detergent and soda ash. This treatment was conducted in liquor containing soda ash (1.1g/l), detergent (0.6g/l), and desizingagent (1.5g/l) material to liquor ratio of 1:30 in a laboratory scale sample washing machine at 50°C for 10 min. The samples were then washed with hot water (50°C) followed by cold water wash.

B. Bleaching Powder-Cellulase Treatment

The samples were treated using bleaching powder mixed with cellulose enzyme in the same sample washing machine at concentration of bleaching powder, KCI(1.1g/l) and Genzyme SL(2g/l), temperatures 40°C and treatment time 20 min with fixed amount of pumice stone(30% owg). This process was conducted in liquor containing acetic acid (1g/l) at pH 5.5 and material to liquor ratio of 1:30.All treatments were involved in the rotary cylindrical sample washing machine at 30 rpm. The samples were then washed with hot water and then washed with cold water. At room temperature for 5 min. Before softening, samples were neutralized by treating with Hypo (1.1g/l) finally, samples were softened with Textsoft softener (2.5g/l) at room temperature for 5 min.

C. Hydro-Extracting and Drying

After treatment, the washed samples were squeezed in a laboratory scale hydro-extractor machine at 200 rpm for 3-4 min to remove excess water and then dried in a steam drier at 75°C for 35-40 min. These are done for enzyme-stone washed samples.

Fig.10. Light Wash Sample

2.3.4 Acid Wash (Acid-Pumice Stone-Enzymatic Treatment)

A. Desizing

Samples were desized using detergent and soda ash. This treatment was conducted in liquor containing soda ash (1.1g/l), detergent (0.6g/l), and desizing agent (1.5g/l) material to liquor ratio of 1:30 in a laboratory scale sample washing machine at 50°C for 10 min. The samples were then washed with hot water (50°C) followed by cold water wash.

B. Cellulase Treatment

Desized samples were treated using cellulose enzyme. This process was conducted in liquor containing acetic acid (1g/l) at pH 5.5 and material to liquor ratio of 1:30. The enzyme treatment was carried out at concentration of Genzyme SL (2g/l), temperatures 40°C and treatment time 20 min. After desired time temperature was raised to 90°C for 1 min to stop enzyme action. The samples were then washed with hot water and then washed with cold water. Finally, samples were softened with Text soft softener (2.5g/l) at room temperature for 5 min.

C. Soaking of Pumice Stone

The fresh pumice stones were soaked at room temperature for 5 min by shuffling using potassium permanganate(5gm/l) and phosphoric acid(1gm/l) containing the liquor 1:2.Pumice stones are naturally perforated, hence pick up the solution very quickly[59].After the desired soaking of pumice stone, the completely dried desized samples were treated with them(damp pumice stone) at room temperature at the sample washing machine at 30 RPM without additional water followed by the standard washing procedure. After the treatment the pumice stone were unloaded from the machine.

D. Neutralization and Softening Treatment

The acid washed samples were conducted by a neutralization process, a detergent wash and a softening process respectively. The neutralization process was carried out by sodium metabisulphite (4gm/l) at room temperature for 5 min, detergent wash by super excel(2gm/l) at 50°C for 10 min to remove breaking stone dust and adhering chemicals and softening was carried out by Text-soft softner (2.5gm/l) at room temperature for 5 min.

E. Hydro-Extracting and Drying

After treatment, the washed samples were squeezed in a laboratory scale hydro-extractor machine at 200 rpm for 3-4 min to remove excess water and then dried in a steam drier at 75°C for 35-40 min. These are done for enzyme-stone washed samples

Fig. 11. Acid Wash Sample

2.4 Methods

2.4.1 Determination of Tear Strength

The tear strength of different wash fabric samples was measured according to BS EN ISO 133937-1.According to this method a test specimen was taken. Warp and weft direction of the fabric was identified. Two strips were cut from the fabric in both directions having dimensions of 100 x 63.5 mm. The sample was then fixed in the jaws of the tearing tester. A cut of 20 mm was made along the width of the fabric using the cutter in the tearing tester. By using falling pendulum of the tearing tester the fabric was tear and the readings were noted from the Elmendorf's tester's scale. The average tear readings were recorded as tear strength.

2.4.2 Determination of Dimensional Stability to Washing

The dimensional stability to washing of different wash fabric samples was measured according to BS EN ISO 6330.According to this method lay the sample on the table with fold (without any crease).Then put the template on the sample with edge parallel (10-15 cm interior from the edge).Marking outside (50x50) cm then cut the sample and sew the specimen together at three sides. Marking the sample three pairs (35x35) cm. conditioning the sample at least 4 hours with 20°C and 65% RH. Measurement the three pairs then average and note the result (length& width).

Make 2 kg load with & specimen & specimen. Take detergent 17.6 gm ECE & 4 gm Sodium per borate and put on the machine with 50°C.After complete washing take specimen and ballast then put on the dryer machine. Start machine with medium temperature. Complete drying the sample conditioning at least 4 hour with 20°C and 65% RH. After conditioning measure and calculate the dimensional change.

Dimensional Change (%)

= (After Wash Dimension - Original Dimension) x 100 / Original Dimension

2.4.3 Determination of Color Fastness to Washing

The color fastness to washing of different wash fabric samples was measured according to BS EN ISO 105C06:2010.According to this method cut the sample & multifibre 40 mm x 100 mm. sew the sample on the wool side. Prepared solution with required reagent(if required adjust pH).Take the required solution, steel ball and put on the canister and set time then start machine. After wash stop machine and remove sample. Wash two times in 100 ml of distilled water bat 40°C for 1 min periods. Extract the excess water. Dry the sample by hanging in air temperature not exceeding 60°C.Then evaluate by using grey scale.

2.4.4 Determination of Color Fastness to Water

The color fastness to water of different wash fabric sample was measured according to BS EN ISO105-E01.According to this test method cut the sample 100 mm x 40 mm out of the test fabric and attach a piece of multifibre the same size by sewing along one of the shorter edges. Place the sample in a separate container by immersing in distilled water, liquor ratio (1:50) at room temperature (18-28°C) and wet the specimen completely. Pour off the solution and wipe the excess liquor off the sample between two glass rods. Place the sample between two glass and acrylic plate under a pressure of 12.5 KPa and place the test device which has been preheated to test temperature. Up to ten test samples/each separated from the next by one plate, may be tested one device simultaneously. Place the test devices containing the sample into the oven for 4 hour s at 37°C.After four hours, remove the sample and dry them in air temperature not exceeding 60°C with the parts in contact

only at the line of stitching. Then assessed the color change and staining to the multifibre fabric with reference the original sample under illuminant 065 by using grey scales.

2.4.5 Determination of Color Fastness to Perspiration

The color fastness to perspiration of different wash fabric sample was measured according to BS EN ISO105-E04.According to this test method cut the sample 100 mm x 40 mm out of the test fabric and attach a piece of multifibre the same size by sewing along one of the shorter edges. Place the sample in a separate container by immersing in acid and alkali solution (100ml per fabric) at room temperature (18-28°C) for 30 min and wet the specimen completely. Pour off the solution and wipe the excess liquor off the sample between two glass rods. Place the sample between two glasses or acrylic plate under a pressure of 12.5 KPa and place the test device which has been preheated to test temperature. Up to ten test samples/each separated from the next by one plate, may be tested one device simultaneously. Place the test devices containing the sample into the oven for 4 hour s at 37°C.After four hours, remove the sample and dry them in air temperature not exceeding 60°C with the parts in contact only at the line of stitching. Then assessed the color change and staining to the multifibre fabric with reference the original sample under illuminant 065 by using grey scales.

2.4.6 Determination of Color Fastness to Light

The color fastness to light of different wash fabric sample was measured according to BS EN ISO105-B02: 2013.According to this test method cut the sample fabric of at least 45x 10 mm and places it into a cardboard. Place as well as blue scale onto another cardboard. Cover a part of the fabric with the stencil plate by pressing it carefully onto the sample to achieve clear lines between illuminated and not illuminated parts. Place the specimen into the tester. Black Panel temperature should be 63°C and relative humidity should not be more than 30% RH. Illuminate the fabric (sample and blue scale) with the xenon light until the contrast between illuminated and not illuminated part of meets grade 4 of grey scale. The final assessment proceeded by using the blue scale.

2.4.7 Determination of Color Fastness to Ozone

The color fastness to light of different wash fabric sample was measured according to BS EN ISO105G03:1993. The sample under test along with control fabric is exposed in a chamber generating ozone at a specified concentration (ppm) of ozone level with specified atmospheric condition so as to obtain definite color change. This will constitute one cycle. The sample is exposed to one or two cycles as case might be compared with original specimen for color change (yellowness).

2.4.8 Determination of Color Fastness to Rubbing

The color fastness to light of different wash fabric sample was measured according to BS EN ISO105-X12: 2002.According to this test method cut the four pieces sample (50x140) mm, two for lengthwise and two for widthwise. One for dry rub & one for wet rub(length & width).Before carrying out the wet rubbing ensure 95% to 100% pick up(with distilled water).Machine run for 10 min(1rub/sec).After the test the wet cotton rubbing dried at room temperature not exceeding 60°C.Then evaluated with grey scale.

2.4.9 Methods of Pollution Load Testing

The BOD test of different washing effluent was measured according to EPA 10099 450.1/SM 5210/ ISO5815-1, 2/DINEN1899-1. According to this test method, take two samples of water. Recorded the DO level (mg/l) of one immediately. Place the second water sample in an incubator in complete darkness at 20°C for 5 days. If did not have incubator , wrap the water sample bottle in aluminum foil or

black electrical tape and store in a dark place at room temperature(20°C or 68°F).After five days, took another dissolved oxygen reading(mg/l) using the dissolved oxygen kit. Subtracted day five from day one reading to determine the BOD level. Finally recorded the BOD result in mg/l.

3. Results and Discussions

3.1: Effect of various washing process on color fastness to wash, water& perspiration (color change & staining) of four way stretch denim fabric

Table 1: Color fastness to wash, water& perspiration (color change & staining) of different washed four way stretch denim fabric

Sample Type	Grading for color change	Grading for color staining					
		Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Before wash	2	2	3-4	3	3-4	3	3
Dark wash	3	2	2-3	2	3	2-3	2-3
Medium wash	4-5	4-5	4-5	4-5	4-5	4-5	4-5
Light wash	4	4	4-5	4-5	4-5	4-5	4-5
Acid wash	3-4	3-4	4-5	4	4-5	3	4

Table1 signifies that wash process have profound influence on color fastness to wash, water & perspiration of four way stretch denim fabric The table 1 shows that medium washed fabric has excellent color fastness to wash, water & perspiration. Then light and acid washed fabric has good color fastness to wash, water & perspiration. But, dark washed fabric has poor color fastness to wash, water & perspiration. In the practically point of view that desizing is not done properly during dark wash due to shade maintaining as a result, some unfix dyes and coating substances are present in the fabric and insufficient neutralization in dark wash, enzyme remains active in the fabric surfaces which causes poor fastness to wash, water & perspiration. On the other hand, during medium, light and acid wash sizing material and coating substances easily removed from the fabric surface due to proper desizing. From the result, it is observed that medium wash is the most sustainable wash process for four way stretch denim fabric in terms of color fastness to wash, water & perspiration.

3.2Effect of various washing process on color fastness to light of four way stretch denim fabric

Table 2: Color fastness to light of different washed four way stretch denim fabrics

Sample Type	Grading For Light Fastness
Dark wash	4
Medium wash	4
Light wash	4
Acid wash	4

Table 2 indicates that wash process has no significance effect on color fastness to light of four way stretch. Table 2 shows that dark, medium, light, acid washed fabric has same grade which is very good and their degree of fade is very slight. That means there is no significant effect of various wash on color fastness to light of various washed four way stretch denim fabric. From the result, it is observed that dark, medium, light, acid wash are the most suitable wash process for four way stretch denim fabric in terms of color fastness to light.

3.3 Effect of various washing process on color fastness to ozone of four way stretch denim fabric

Table 3: Color fastness to ozone of different washed four way stretch denim fabric

Sample Type	Grading For Ozone Fastness
Dark wash	3-4
Medium wash	3-4
Light wash	2-3
Acid wash	3

Table 3 points out that wash process have noticeable influence on color fastness to ozone of four way stretch denim fabric. The table 3represents that dark & medium washed fabric has excellent color fastness to ozone. Then acid washed fabric has poor color fastness to ozone. But, light washed fabric has very poor color fastness to ozone. In the practical point of view, back staining occurred in four way stretch denim fabric during enzymatic treatment with bleaching powder and subsequent neutralizing/hot rinsing have been done. The residual color present after enzymatic treatment will tend yellow after exposure during light wash. From the result, it is observed that medium wash and dark wash is the most sustainable wash process for four way stretch denim fabrics in terms of color fastness to ozone.

3.4Effect of various washing process on color fastness to rubbing of four way stretch denim fabric

Table 4: Color fastness to rubbing of different washed four way stretch denim fabric

Sample Type	Color Fastness to	
	Dry Rub	Wet Rub
Before wash	2	1
Dark wash	3-4	1
Medium wash	4	2-3
Light wash	4	2-3
Acid wash	3-4	1-2

Table 4 designates that wash process has little effect on color fastness to rubbing of four way stretch denim fabric. The table 4 shows that light and medium washed fabric has excellent color fastness to rubbing. Then acid washed fabric has good color fastness to rubbing. But, dark washed fabric has poor color fastness to rubbing. In the practically point of view that desizing is not done during dark wash due to shade maintaining as a result, some unfix dyes and coating substances are present in the fabric surface and noticeable amount of color staining occurred during rubbing of dark washed fabric. From the result it is observed that medium wash and light wash is the most sustainable wash process for four way stretch denim fabrics in terms of color fastness to rubbing.

3.5 Effect of various washing process on tear strength of four way stretch denim fabric.

Table 5: Tear strength of different washed four way stretch denim fabric

Sample Type	Avg. Tear Strength(lbs)-Warp way	Standard Deviation (Warp way)	Avg. Tear Strength(lbs)-Weft way	Standard Deviation (Weft way)
Before wash	21.16	0.82	16.36	0.21
Dark wash	11.28	0.20	12.97	0.31
Medium wash	12.13	0.17	14.1	0.44
Light wash	6.2	0.39	9.31	0.45
Acid wash	8.46	0.27	10.71	0.26

Table 5 indicates that wash process has noticeable effect on tear strength of four way stretch denim fabric. The table 5 represents the effects of various washing process on tearing strength of four way stretch denim fabric in the warp & weft way direction. The value of tearing strength is the average result of four no. of observation tear strength which is measured from tear strength tester in both warp and weft way direction. The diagram shows that the tear strength noticeably decreased in light washed fabric in both direction of fabric. This is occurred due to the bleaching powder first attacked on dyed yarn portion, decomposed them slowly and fibers are partly degraded from the yarn chain and step by step penetrated inside fabric. Therefore, the chemical bonds of primary wall (outer layer) are broken by the decomposition of the aqueous solution of hypochlorite bleach.

That it attacked on secondary wall. The result of this reaction is that the primary wall (outer layer) of the cotton fiber is loosened and broken down quicker with the frictional (Mechanical forces) of rotating cylinder of the washing machine. The second maximum tear strength loss is occurred in dark wash due to the improper neutralization of enzyme and that enzyme remains active in indigo dyed denim fabric surface which reduces the tear strength. The

third maximum tear strength decreased in acid wash due to the acid wash process reacts with fabric surface and also destroys the fabric. The lowest tear strength loss in medium wash fabric due to the friction between denim fabrics and pumice stone. From the result, it is observed that medium wash is the most durable wash process for four way stretch denim fabric in terms of tears strength properties because less amount of tear strength loss in this wash compare than the other wash.

3.6 Effect of various washing process on dimensional stability to washing of four way stretch denim fabric.

Table 6: Dimensional stability to washing of different washed four way stretch denim fabrics

Sample Type	Shrinkage (%)		Acceptable limit of Shrinkage (%)	
	Warp way(Shrinkage)	Weft way(Shrinkage)	Warp way(Shrinkage)	Weft way(Shrinkage)
Dark wash	11.28	10.69	9 to 14	10 to 13
Medium wash	13.46	12.87		
Light wash	13.66	12.87		
Acid wash	11.80	11.80		

Table 6 points out that wash process has significant effect on dimensional stability to washing of four way stretch denim fabric. The table.6shows the highest shrinkage occurred in light washed and medium washed fabric due to the weaving of four way stretch denim fabrics that were subjected to considerable tensions, particularly in the warp direction. In subsequent finishing processes such as calendaring this stretch was increased and temporarily set in the fabric. The fabric is then in a state of dimensional instability. Subsequently when the denim garment was thoroughly wetted in bleach washing, it tended to revert its more stable dimensions which results in the contraction of the yarns. This effect is usually remarkable in the warp direction than in the weft direction.

In medium wash due to friction between denim fabric and pumice stone, noticeable shrinkage occurred. The third highest shrinkage occurred in enzyme wash. The lowest shrinkage occurred in acid wash due to the lower concentration of potash and processing time. From this result, it is observed that light wash and medium wash more suitable wash process for four way stretch denim fabric in terms of dimensional stability to washing due to light washed and medium washed fabric shrinkage occurred within the maximum range of shrinkage in the both warp and way direction as per fabric specification sheet which positively impact on wearer's comfort and fitting.

3.7 Effect of various washing process on pollution load of washing effluent of four way stretch denim fabric.

Table 7: Pollution load of washing effluent of different washed four way stretch denim fabrics

Washing Type	Pollution load in terms of			
	BOD(mg/l)	COD(mg/l)	TDS(mg/l)	pH
Dark wash	41	65	850	7.7
Medium wash	98	360	2060	6.8
Light wash	102	350	2730	12
Acid wash	37	102	1070	2.6

Table 8: Standard value of pollution load parameter in accordance to ECR 1997

Pollution load parameter	Unit	Standards for waste from industrial units(mg/l)
BOD	mg/l	250
COD	mg/l	400
pH		6-9
TDS	mg/l	2100

The table 7 shows that the BOD level of dark, light, medium and acid wash effluent under recognized standard level less than 250 mg/l. The table 7 also shows that the COD level of dark, light, medium and acid wash effluent under recognized standard level less than 400 mg/l. TDS level of light wash effluent exceeds the allowed standard level more than 2100 which pollutes the water. Also pH level of light wash effluent exceeds the standard ranges (6-9) which causes the pollution of water. In the practical point of view, huge amount of chemical used in light wash. From this discussion, it is indicated that dark wash, medium wash and acid wash are the environment friendly most suitable wash process for four way stretch denim fabrics.

3.8 Effect of various washing process on washing cost of four way stretch denim fabrics

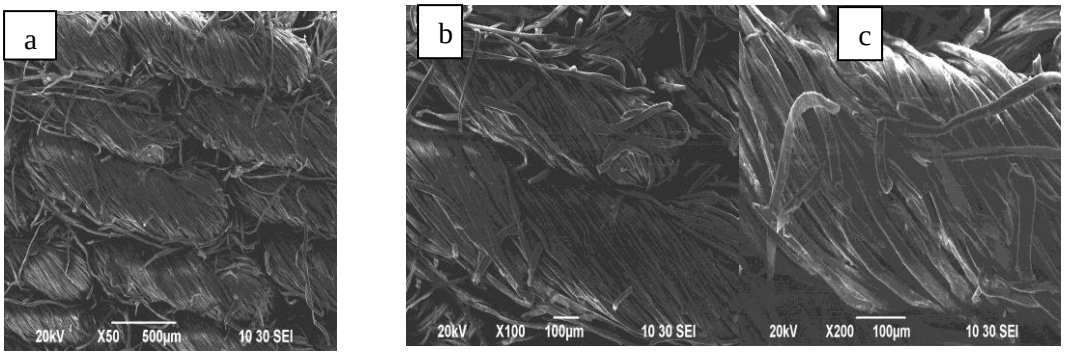
Table 9: Washing cost of different washed four way stretch denim fabrics

Washing type	Wash Cost(Taka)/Pc for Ladies Long pant
Dark wash	45
Medium wash	50
Light wash	80
Acid wash	120

The table 9 represents the cost (BD taka) of dark, medium, light, acid wash process of four way stretch denim fabrics. It is significantly visualized that dark wash and medium wash involves with lower cost than the others wash process. On the other hand, light wash and acid wash involves with maximum cost due to the use of higher amount of chemical substrates. From the discussion, it is observed that dark wash and medium wash is most economical wash process for four way stretch denim fabrics.

3.9 Analysis of Changes of the Fabric Surface due to Various Washing types of 4-Way Stretch Denim Fabric by SEM

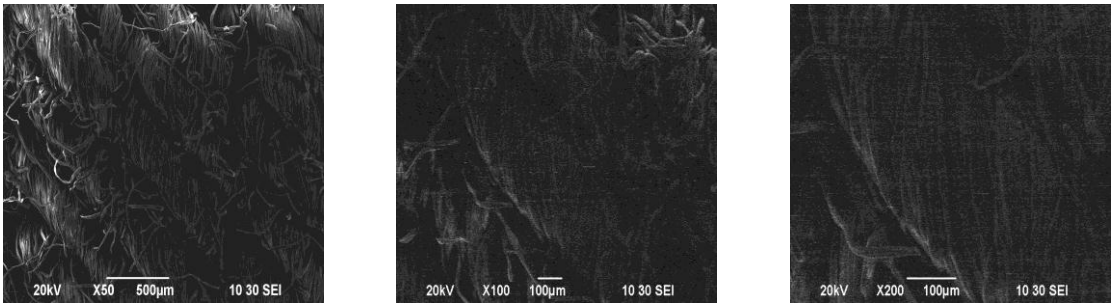
The morphological of the four way stretch denim fabric is examined by scanning electron microscopy (SEM) on untreated and different washed samples. Figure 12(a) shows SEM images (20.0KV X50, 500 micrometer 10 30 SEI) of untreated sample, figure 12 (b) shows the SEM images (20.0KV X100, 100 micrometer 10 30 SEI, magnification 2X) of untreated sample and figure 12(c) shows the SEM images (20.0KV X200, 100 micrometer 10 30 SEI, magnification 4X) of untreated sample.



a b c

Fig. 12: Scanning electron micrograph of four way stretch denim fabric (a) untreated sample (magnified) (b) untreated sample(magnified 2X)(c)untreated sample(magnified 4X).

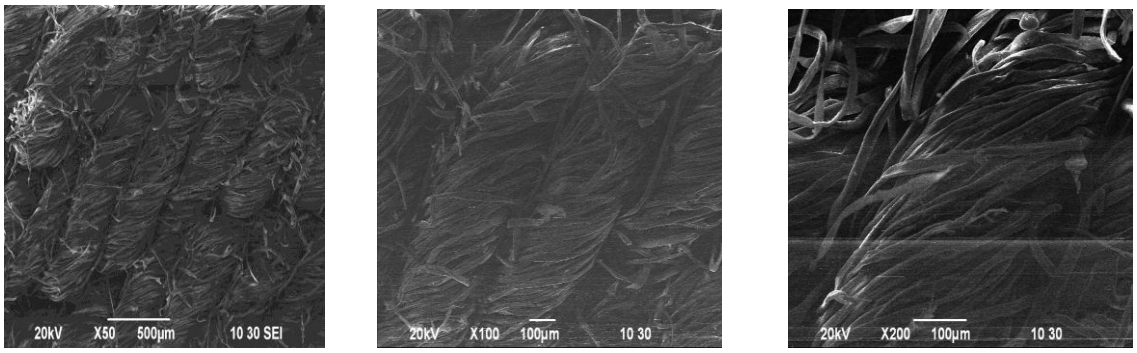
Fig. 12 shows smoothened surfaces, parallel ridges and no fibrils (projecting fibers) and ruptures visible in the images, because yarns are coated with size materials and projecting fibers are not visible on surface.



a b c

Fig. 13: Scanning electron micrograph of four way stretch denim fabric (a) dark wash sample (magnified) (b) dark wash sample(magnified 2X)(c)dark wash sample(magnified 4X).

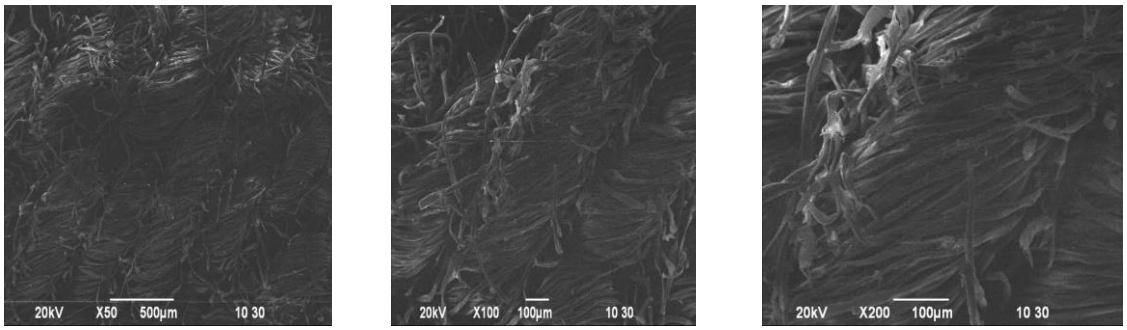
For fig. 13, the washing condition is followed by 4% cellulose for 20 min at pH 5.5 and 40°C in the fiber liquor ratio 1:30.Figure 13 shows loosened, disoriented and wrinkled surfaces due to fiber degradation by hydrolysis and abrasion were due to mechanical friction by the washing machine during processing. The enzyme attacks the cellulose of cotton progressively, the primary wall being the first target. As observed in figure 13, there are more cracks on the surface of fibers. This is caused by cellulose washing of four way stretch denim fabric.



a b c

Fig. 14: Scanning electron micrograph of four way stretch denim fabric (a) medium wash sample (magnified) (b) medium wash sample(magnified 2X)(c)medium wash sample(magnified 4X).

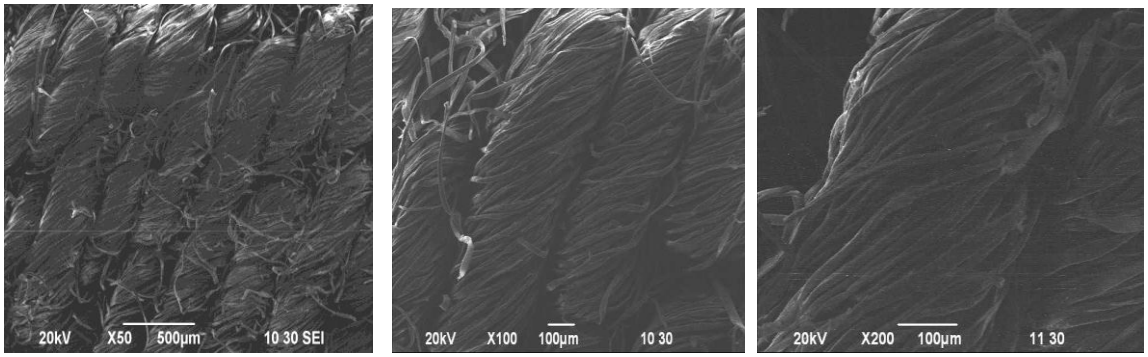
For fig.14, the washing condition is followed by 2% cellulose with fixed amount pumice stone (30% owg) for 20 min at pH 5.5 and 40°C in the fiber liquor ratio 1:30.Figure.14 shows loosened, damaged, ruptured due to the abrasion and rubbing by pumice stone in washing machine.



a b c

Fig.15: Scanning electron micrograph of four way stretch denim fabric (a) light wash sample (magnified) (b) light wash sample(magnified 2X)(c) light wash sample(magnified 4X).

For fig.15, the washing condition is followed by treating bleaching powder and 2% cellulose with fixed amount pumice stone (30% owg) for 20 min at pH 5.5 and 40°C in the fiber liquor ratio 1:30.Figure 15 shows more damaged and ruptured surfaces that are produced with the aqueous solution of bleaching powder and abrasions were due to rubbing by pumice stone in washing machine. As observed from fig. 15, there are more damages on the surface of fibers.



a b c

Fig.16: Scanning electron micrograph of four way stretch denim fabric (a) acid wash sample (magnified) (b) acid wash sample(magnified 2X) (c) acid wash sample(magnified 4X).

For fig. 16, the washing condition is followed by treating bleaching powder and2% cellulose with fixed amount pumice stone(30% owg)for 20 min at pH 5.5 and 40°C in the fiber liquor ratio 1:20 and shuffling with potash(5gm/l) and phosphoric acid(1gm/l) for 5 min. Figure 16 shows more projecting fiber and ruptured surfaces that are produced with the aqueous solution of bleaching powder & potash, abrasions were due to rubbing by pumice stone in washing machine. As observed from fig. 16, there are more loosened and wrinkled on the surface of fibers. From the above discussion, the SEM images of medium & dark washed of four way stretch fabric surface comparatively less disoriented, damaged and ruptured than the fabric surfaces of other washed process. It indicates that the medium & dark wash process is the most durable wash process for four way stretch denim fabric in terms of morphological surface analysis by SEM.

4. Conclusions

In this research work, four way stretch denim fabric was treated with different washing condition and process to find out the sustainable ,durable, environment friendly and most economical wash process in terms of physical & chemical properties, comfort ability, longevity , pollution load of washing effluent, morphological surface properties. The results indicated that the durable and sustainable wash process for four way stretch denim fabric is medium wash. The findings of this research work have been summarized below:

a) Medium washed fabric showed excellent color fastness properties to wash, water and perspiration than the dark wash, light wash and medium wash.

b)It was observed that the color fastness to light of dark, medium, light and acid washed four way stretch denim fabric showed excellent result due to degree of fade of that fabrics were very slight.

c) It was noticed that the color fastness to ozone of dark and medium washed fabric was excellent. Acid washed fabric showed satisfactory result. Light washed fabric showed very poor performance due to back staining occurred during enzymatic treatment with bleaching powder in light wash.

d) It was indicated that the color fastness to rubbing of dark washed fabric showed very poor. In dark wash, indigo dyes remained after enzymatic treatment in the fabric surface. The excellent result was found in medium washed fabric. The color fastness to rubbing of acid and light washed fabric was found satisfactory.

e) It was designated that the tear strength of light washed fabric was decreased noticeably in both warp and weft direction due to action bleaching powder and abrasion with pumice stone during treatment, Tear strength of dark and acid washed fabric was satisfactory.

f) It was pointed out that the highest shrinkage was occurred in medium washed fabric which positively impacted on wearers comfort. Comparatively less shrinkage was occurred in dark, light and acid washed fabric.

g) The pollution load (BOD, COD, TDS, pH)of washing effluent of dark, medium wash were the permissible range according to the ECR 1997,Bangladesh.But, pH range of acid & light wash effluent and TDS of light wash effluent exceeded the permissible range. In cost comparison of different wash, dark and medium wash were most economical than acid and light wash due to require less amount of chemical and lower treatment time compare than the acid and light wash.

i) SEM images of untreated fabric surface showed smoothened surfaces, parallel ridges and no projecting fibers and rupture. On the other hand, treated fabric surfaces (dark wash, medium wash, light wash, acid wash) showed loosened, disoriented, damaged and ruptured surfaces.

j**)** SEM images of medium & dark washed of four way stretch fabric surface comparatively less disoriented, damaged and ruptured than the fabric surfaces of other washed process. It was indicated that the medium & dark wash process is the most durable wash process for four way stretch denim fabric in terms of morphological surface analysis by SEM.

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