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An Experimental Investigation of Different Washing Processes on Various Properties of Stretch Denim Fabric

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Abstract

This research work was designed to explore the effect of different washing processes (enzyme wash, enzyme stone wash, enzyme stone wash with bleaching, heavy enzyme stone wash with bleaching) on various properties of stretch denim fabric. Different properties like tensile strength, 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 rubbing, changes in fabric weight were investigated in context with different washing processes for stretch denim fabric. All tests were carried out according to the ISO (International Organization for Standardization). Enzyme washed fabric illustrated better performance regarding tear strength, tensile strength and dimensional stability; but showed moderate performance in different color fastness properties. But the color fastness to rubbing of heavy enzyme stone wash was excellent. No significant change was observed regarding the grade of color change and color staining for color fastness to wash, color fastness to perspiration and color fastness to light with respect to different types of washing processes like enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for dry rubbing and wet rubbing was comparatively better for enzyme wash rather than other washing processes. The GSM (gram per square meter) of stretch denim fabric also increased accordingly after different kinds of washing process rather than untreated stretch denim fabric. The dimensional stability of stretch denim fabric also altered after going through different washing process. The highest shrinkage was occurred in weft direction for heavy enzyme stone wash with bleaching.

Keywords

Enzyme Wash, Stone Enzyme Wash, Stretch Denim, Bleaching, Tensile Strength

1. Introduction

Technically denim is durable and strong cotton warp-faced textile material in which the weft thread passes under two or extra warp threads [1] [2]. This twill weave structure produces a diagonal design which differentiates it from cotton duck fabric [3] [4]. Denim is considered as the oldest fashion products in the world [5] [6] [7]. Denim fabric is made of cotton twill weave structure with 100% cotton and very comfortable to feel [8] [9]. This fabric is used to manufacture jeans, jackets, shirts, purses, bags, and many other fashion items for men and women of all ages around the world [10] [11] [12]. Denim fabric constitutes sturdy outlook, durable textile prepared from cotton fibers using twill weave structure [13] [14]. In modern fashion world, it also secures substitute usage as performance and application-based textile materials for the manufacturing of seat covers, mobile cases, insulation textiles [15] [16]. There is no denying of the fact that, scientific and leading-edge technological advancement regarding the product development, process optimization in textile manufacturing significantly changes the concepts of traditional manufacturing in lieu of sustainable manufacturing [17] [18] [19]. Moreover, over the last few decades, denim garments unquestionably hold position in the fashion industry and her ability to adapt creativeness in fashion inclinations through her extraordinariness along with numerous advanced washing effects [20] [21]. Stretch denim is a type of jeans product mostly associated with cotton-polyester blend that assimilates a small amount of elastane known as spandex [22] [23]. Structurally stretch denim constructed with indigo dyed warp thread and white weft thread alongside encompasses about 1% - 3% elastane [24] [25]. The weft threads of the denim fabric extend along the entire width of the fabric [26]. For denim washing, enzymes are primarily used to obtain a cleaner surface [27]. For aesthetic finish and improving the attractiveness of the denim fabric, enzymes have played a significant role not only providing an artistic outlook but also reducing pills, increasing smoothness, luster, brightness, improvement of fabric maneuverability and coating ability, and enlightening vintage effects that encounter trend requirements in modern fashion world [28] [29].

Among different processing involved in denim garments manufacturing, washing process is considered as one of the important process parameters [30]. Washing process imparts value addition attributes to the final product [31]. Several washing methods involved in denim processing persuade different effects like fading and vintage [32]. Traditional washing process constitutes acid wash, enzyme washing, spray techniques, stone enzyme washing with strong bleaching agents such as sodium hypochlorite, potassium permanganate although these processes are not sustainable and environmentally friendly [33] [34]. Furthermore, cellulase enzymes instead of pumice stones help to achieve not only an abrasive effect but also special outlook on denim garments [35]. Technological advancement regarding the sustainable washing, green dyeing also took place for textile materials processing during the recent years [36] [37]. Various types of

newly introduced denim of exotic designs supplemented with lightness, smoothness and comfortability sensational features have added a new height to the fashion arena [38]. Recently conducted various research works emphasized about the development of various washing treatments for denim processing [39] [40]. So, current research work about the understanding of different washing treatment on various properties like tensile strength, 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 rubbing, changes in fabric weight for stretch denim fabric will contribute to enrich the scopes of study on denim washing. Therefore, the primary aim of this study was to determine the different properties of stretch denim fabric treated with various washing process.

2. Materials and Methods

2.1. Material

Fabric

In this research work, 99% of cotton 1% of elastane indigo dyed stretch denim fabrics was used. The fabric GSM (grams per square meter) was 340 (Before wash), 3/1 right hand twill fabric; width 57 inch.

Chemicals

For the experimentation, de-sizing agent soda ash (sodium carbonate), detergent (Hotspur, BASF), bleaching powder (Bleach KCI, 35% available chlorine), enzyme (Genzyme SL (cellulase enzyme)), silicone (Text-soft, BASF) softener were also used for this study.

Experimental Instruments

For this experiment, washing machine, hydro extractor machine, tumble dryer machine, fabric GSM cutter, perspirometer perspiration tester for testing the color fastness to perspiration, crockmeter/rubbing fastness tester, electronic balance and fabric pH meter were used.

2.2. Methodology

2.2.1. Working Procedure of Enzyme Wash

In the garments washing, de-sizing is the first step of enzyme wash. This step was used for removing dirt, dust and other foreign materials from garments surface. Here wetting agent was used to increase the penetrating property of liquid into the garments. Material and liquor ratio were kept at 1:8; then run the machine with addition of de-sizing agent 1.1 g/l, soda ash 2 g/l and wetting agent 1.5 g/l. The temperature was set 50˚C for 15 minutes. Then the liquor was dropped out by following cold wash. In the bio-abrasion process, hairy fibers were removed and coloring materials were also removed by the activity of enzyme. Then addition of anti-back staining agent about 2.0 g/l with acid enzyme 0.6% was done accordingly. The pH for acid enzyme was maintained for 4.5 to 5.5 and the temperature was kept 55˚C to run the process for 50 minutes. Then

dropped the liquor and cold wash was done. For conducting back wash, material and liquor ratio were kept for 1:8; then run the machine by adding 3.0 g/l anti back staining with soda ash 0.3 g/l. The temperature was maintained at 70˚C to run for 10 minutes. Then dropped the liquor and rinse wash was done. Subsequently softening operation was conducted and the temperature was kept cold to run for 5 minutes. Then liquor was dropped by following rinse wash. After completing the aforementioned washing process the liquor was dropped out, unload the garments and hydro extracted at 200 rpm for 3 - 4 min to remove the excess water. At last garments were dried at 75˚C for 35 - 40 min by steam dryer.

2.2.2. Working Procedure of Stone Enzyme Wash

Enzyme stone washing process generally used to produce worn-out outlook on denim fabric. This stone washing process was conducted by washing stretch denim fabric with pumice stones in a rotating drum by using chemicals to create desired appearance. Here stone enzyme washing process was conducted by different steps like de-sizing, bio-abrasion, addition and tumble of pumice stones with enzyme along with acetic acid and anti-stain agent at 40˚C - 50˚C for 40 - 60 minutes depending on the desired outlook, drain the liquor and separate the garments from pumice stones, softening with softener accordingly and hydro extracting procedures.

2.2.3. Working Procedure of Stone Enzyme Wash with Bleaching

De-sizing is the first step of enzyme wash. This step was used for removing dirt, dust and other foreign materials from garments surface. Material and liquor ratio were about 1:8; then run the machine with addition of de-sizing agent 1.1 g/l, soda ash 2 g/l and wetting agent 1.5 g/l. Wetting agent was used to increase the penetrating property of liquid into the fabric sample. The temperature was kept 50˚C for 15 minutes. Then the liquor was dropped out by following cold wash. For bio-abrasion, addition of anti-back staining agent about 2 g/l with acid enzyme 0.6% was performed. The pH for acid enzyme was 4.5 to 5.5 and the temperature was maintained 55˚C to run for 50 minutes. Then dropped the liquor and cold wash was done. Then the samples were treated with cellulase enzyme in the washing machine at 1.1 g/l concentration of bleaching powder (KCI) and Genzyme SL (2 g/l), temperature 40˚C and the time was kept 20 mins with pumice stones. This process was conducted containing acetic acid (1 g/l) at pH 5.5 and material to liquor ratio 1:8. All of the treatments were performed in the rotary cylindrical washing machine at speed of 30 rpm. Then samples were washed with hot water and cold water at room temperature for 5 minutes. Finally, samples were softened with Text-soft softener (2.5 g/l) at room temperature for 5 minutes. For back wash process, material and liquor ratio also kept for 1:30; then run the machine by adding 3 g/l anti back staining agent with soda ash 0.3 g/l. The temperature was controlled for 70˚C to run for 10 minutes. Then the liquor was dropped out followed by rinse wash. After completing the above-mentioned washing process the liquor was dropped, unload the garments and hydro ex-

tracted at 200 rpm for 3 - 4 min to remove the excess water**.** At last garments were dried at 75˚C for 35 - 40 min by gas dryer or steam dryer.

2.2.4. Working Procedure of Heavy Stone Enzyme Wash with Bleaching

Heavy enzyme stone washing with bleaching process was conducted by washing stretch denim fabric with pumice stones in a rotating drum by using chemicals to create desired appearance. In this experiment, different steps like de-sizing, bio-abrasion, addition and tumble of pumice stones with enzyme along with acetic acid and anti-stain at 40˚C - 50˚C for 40 - 60 minutes depending on the desired outlook, drain the liquor and separate the garments from pumice stones, so. Then the samples were treated with cellulase enzyme in the washing machine at 1.3 g/l concentration of bleaching powder, KCI and Genzyme SL (2 g/l), temperatures 40˚C and the time was kept 20 mins with pumice stones. This process was conducted in liquor containing acetic acid (1 g/l) at pH 5.5 and material to liquor ratio 1:8. All treatment were performed in the rotary cylindrical washing machine at 30 rpm. Then the samples were washed with hot water along with cold water at room temperature for 5 minutes. Then softening process was done with softener accordingly followed by hydro extracting procedures.

2.2.5. Measurement of Color Fastness Properties

The following color fastness tests were done for this research work [41] [42] [43] [44] [45]:

- Color fastness to wash (Method: ISO 105 C10)
- Color fastness to rubbing (Method: ISO 105 X12)
- Color fastness to light (Method: ISO 105 B02)
- Color fastness to water (Method: ISO 105 E01)
- Color fastness to perspiration (Method: ISO 105 E04)

2.2.6. Determination of Dimensional Stability

Dimensional stability of the sample was measured according to ISO 23231 [46] which postulates about an accelerated procedure for the understanding of dimensional changes of fabrics those will be used to produce garments and will be laundered in a variety of situations. This standard signifies a procedure which implies an apparatus with programmable settings simulate numerous domestic and industrial laundering actions and wet processing operations in fabric manufacturing. In this research, this standard method was used for the determination of dimensional change. After washing, drying, conditioning and measuring the specimen, the change in dimension was calculated.

Dimensional Change (%) = {(Dimension after wash − Original dimension) × 100}/Original dimension.

Sample Conditioning: Conditioning specimen at least 4 hours as per ISO 139 prior to preparing and measuring.

Testing Condition: Temperature – (20 ± 2)˚C and Relative humidity (65 ± 4)%.

Specimen size: As per template.

2.2.7. Determination of Tensile Strength

This tensile strength test was conducted according to ISO 13934 [47]. This method specifies about the determination of the maximum force of textile fabrics known as the grab test. For experimentation, test specimen gripped in its center part by jaws of specified dimensions, extended at constant rate until it ruptures. Then the maximum force was recorded.

Testing Method: ISO 13934-2 (grab test).

Testing Condition: Temperature = (20 ± 2)˚C, Relative humidity = (65 ± 2)%.

Sample size: 200 mm × 100 mm.

Apparatus: Titan-Universal Strength Tester, air compressor, computer.

2.2.8. Determination of Tear Strength

The determination of tear strength of different fabric samples treated with various washing processes were measured according to ISO 13937-1 [48]. Tear strength is the resistance of the fabric against tearing or force required to propagate the tear once it is initiated. The tear strength is required in high performance applications and in conventional textiles like bulletproof jackets, tents, aesthetic apparel. This is also important in the industrial textiles where heavy duty work is performed. The average reading was recorded as tear strength in N.

Sample Conditioning: Conditioning specimen at least 4 hours as per ISO 139.

Testing Condition: Temperature – (20 ± 2)˚C and Relative humidity (65 ± 4)%.

Specimen size: As per template.

Apparatus: Tearing tester, different capacity load, conditioning rack, calibrated ruler.

3. Results and Discussion

3.1. Determination of Color Fastness to Wash for Different Types of Washing Processes of Stretch Denim Fabric

Table 1 represents about the result of color fastness to wash of stretch denim fabric for enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for color change and

Table 1. Effect of various washing processes on color fastness to wash of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Grade (Change in Color)	Grade (Color Staining on Multi Fiber)					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
1	Enzyme wash	3	3	3 - 4	3	4	3	3
2	Enzyme stone wash	3 - 4	3 - 4	4	3 - 4	4	4	3 - 4
3	Enzyme stone wash with bleaching	4	4	4	4	3 - 4	4	4
4	Heavy enzyme stone wash with bleaching	4	4	4	4	4	4	4

color staining was moderate for enzyme wash rather than others. In case of enzyme wash, fabric lost its appearance when it came in contact with water during washing. On the other hand, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching illustrated relatively good performance rather than enzyme and enzyme stone wash.

3.2. Determination of Color Fastness to Water for Different Types of Washing Processes of Stretch Denim Fabric

Table 2 represents about the result of color fastness to water of stretch denim fabric for enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for color change and color staining was almost same for every aspect and no significant change was observed.

3.3. Determination of Color Fastness to Perspiration (Acidic and Alkaline) for Different Types of Washing Processes of Stretch Denim Fabric

Table 3 and Table 4 illustrate about the result of color fastness to perspiration (acidic and alkaline) of stretch denim fabric for enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for color change and color staining was almost same for every aspect and no significant change was observed.

Table 2. Effect of various washing processes on color fastness to water of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Grade (Change in Color)	Grade (Color Staining on Multi Fiber)					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
1	Enzyme wash	3 - 4	4	3 - 4	3	4	3	3 - 4
2	Enzyme stone wash	4	4	4	3 - 4	3 - 4	4	4
3	Enzyme stone wash with bleaching	4	4	4	4	4	4	4
4	Heavy enzyme stone wash with bleaching	4	4	4	4	4	4	4

Table 3. Effect of various washing processes on color fastness to perspiration (acidic) of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Grade (Change in Color)	Grade (Color Staining on Multi Fiber)					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
1	Enzyme wash	3 - 4	4	3 - 4	3	4	3	3 - 4
2	Enzyme stone wash	4	4	4	4	4	4	4 - 5
3	Enzyme stone wash with bleaching	4	4 - 5	4	4	4	4	4
4	Heavy enzyme stone wash with bleaching	4	4	4	4 - 5	4	4 - 5	4

Table 4. Effect of various washing processes on color fastness to perspiration (alkaline) of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Grade (Change in Color)	Grade (Color Staining on Multi Fiber)					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
1	Enzyme wash	3 - 4	4	3 - 4	3	4	3	3 - 4
2	Enzyme stone wash	4	4	4	4 - 5	4	4	4 - 5
3	Enzyme stone wash with bleaching	4	4	4	4	4 - 5	4	4 - 5
4	Heavy enzyme stone wash with bleaching	4	4	4	4	4	4 - 5	4

3.4. Determination of Color Fastness to Light for Different Types of Washing Processes of Stretch Denim Fabric

Table 5 illustrates about the result of color fastness to light of stretch denim fabric for enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The performance was almost same for every aspect and no significant change was observed.

3.5. Determination of Color Fastness to Rubbing for Different Types of Washing Processes of Stretch Denim Fabric

Table 6 represents about the result of color fastness to rubbing of stretch denim fabric for enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for dry and wet rubbing was relatively better for enzyme wash rather than others.

3.6. Determination of Tensile Strength for Different Types of Washing Processes of Stretch Denim Fabric

Figure 1 represents about the effect of washing process for tensile strength of stretch denim fabric. Highest strength was obtained in warp direction for enzyme washed stretch denim fabric due to the formation of weaving 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. Enzyme wash was more suitable and durable because the tensile strength showed great result rather than others.

3.7. Determination of Tear Strength for Different Types of Washing Processes of Stretch Denim Fabric

Figure 2 represents about the effect of washing process for tensile strength of stretch denim fabric in the warp and weft way direction. The diagram shows that the tear strength noticeably decreased in heavy enzyme stone wash with bleaching washed fabric in both direction of fabric. This was occurred due to bleaching powder first attacked on dyed yarn portion, decomposed them slowly and fibers are partly degraded along with polymer chain and step by step penetrated inside

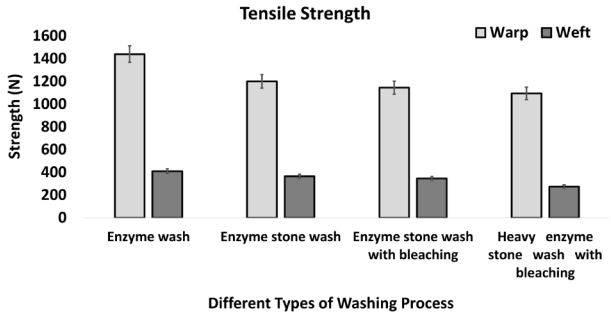

Figure 1. Variation of washing process for tensile strength of stretch denim fabric.

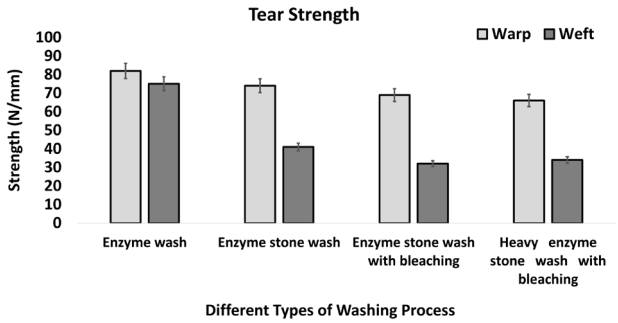

Figure 2. Variation of washing process for tear strength of stretch denim fabric.

Table 5. Effect of various washing processes on color fastness to light of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Fastness Rating according to Blue Wool Standard Grading
1	Enzyme wash	5
2	Enzyme stone wash	5 - 6
3	Enzyme stone wash with bleaching	5 - 6
4	Heavy enzyme stone wash with bleaching	5 - 6

Table 6. Effect of various washing process on color fastness to rubbing of stretch denim fabric.

Sl. No.	Different Types of Washing Processes	Grade (Dry Rubbing)	Grade (Wet Rubbing)
1	Enzyme wash	4 - 5	4 - 5
2	Enzyme stone wash	3	3 - 4
3	Enzyme stone wash with bleaching	3 - 4	3
4	Heavy enzyme stone wash with bleaching	3	3

the fabric. Therefore, the chemical bond of primary wall (outer layer) is broken by the decomposition of the aqueous solution of hypochlorite bleach which attacked on secondary wall. For this consequence, the primary wall (outer layer) of the cotton fiber was loosened and broken down quicker with the friction (me-

chanical forces) of rotating cylinder of the washing machine. The second maximum tear strength loss was observed in heavy stone enzyme wash with bleaching due to the improper neutralization of enzyme and that enzyme remained active in indigo dyed denim fabric surface which reduced the tear strength. Experimentally, enzyme wash was the most durable washing process for stretch denim fabric in terms of tearing strength because less amount of strength loss was observed here compared to the other washing process.

3.8. Determination of Fabric GSM for Different Types of Washing of Stretch Denim Fabric

Figure 3 shows about the effect of various washing process on fabric GSM. From the diagram it can be observed that the maximum fabric weight was obtained from the enzyme wash process because of there is no use of bleaching powder in this washing process. In stone washing the friction between stone and fabric took place because of the use of pumice stone. Higher the GSM constitute higher compactness in yarn of stretch denim fabric and increase the strength of the fabric due to compactness.

3.9. Determination of Dimensional Stability for Different Types of Washing Processes of Stretch Denim Fabric

Table 7 illustrates about the result for dimensional stability in terms of shrinkage % of stretch denim fabric for different types of washing process like enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. It can be observed that the dimensional stability of

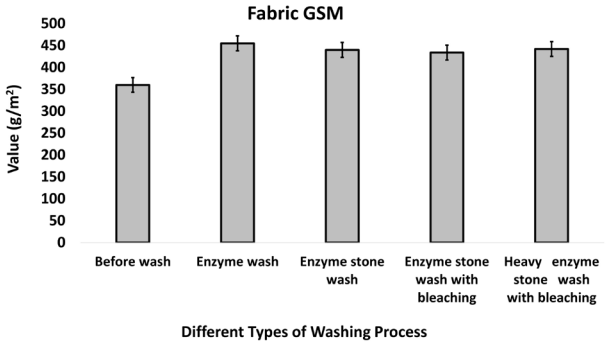

Figure 3. Variation of washing process for GSM of stretch denim fabric.

Table 7. Effect of various washing processes on dimensional stability of stretch denim fabric.

Sl. No.	Different types of washing processes	Shrinkage	
		Warp	Weft
1	Enzyme wash	0.0%	−1.0%
2	Enzyme stone wash	+1.0%	−1.0%
3	Enzyme stone wash with bleaching	+0.5%	−1.5%
4	Heavy enzyme stone wash with bleaching	−0.5%	−1.5%

enzyme wash was good in warp and weft direction compared to the other washing process. Stretch denim fabric was subjected to considerable tensions, particularly in the warp direction. In subsequent finishing process such as calendaring; this stretch was increased and temporarily set in the fabric. The fabric was then in a state of dimensional instability. Subsequently when the denim garment was thoroughly wetted in bleach washing, it tended to retire its more stable dimensions which results in the contraction of the yarns. This effect was remarkable in the warp direction than in the weft direction. In different enzyme stone washing process, friction was occurred between denim fabric along with pumice stones and noticeable shrinkage% were occurred.

4. Conclusion

In this research work, different types of washing processes like enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching were applied on stretch denim fabric to investigate the changes in fabric weight, dimensional stability, tensile strength, tearing strength and different color fastness properties. Stretch denim was selected particularly to conduct this experiment because in modern fashion arena, this type of denim fabric is considered as the one of the most popular type denim fabrics. The grade for color change and color staining was moderate for enzyme wash. No significant change was observed for the grade of color change and color staining of color fastness to wash, color fastness to perspiration and color fastness to light with respect to different types of washing processes like enzyme wash, enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The grade for dry and wet rubbing was relatively better for enzyme wash rather than other washing processes. Stretch denim fabric treated with enzyme wash illustrated more suitable and durable performance because the tensile strength and tearing strength showed great result in warp and weft direction rather than enzyme stone wash, enzyme stone wash with bleaching and heavy enzyme stone wash with bleaching. The dimensional stability of stretch denim fabric also is changed by applying different washing processes. The highest shrinkage was occurred in weft direction for heavy enzyme stone wash with bleaching. Better performance was observed in warp direction for enzyme wash. The GSM of stretch denim fabric also increased accordingly after different kinds of washing processes rather than untreated stretch denim fabric. In a nutshell, engineers and concerned authority will be more thoughtful about the application of relevant washing process for stretch denim fabrics processing based on this research. This scientific exploration will surely benefit consumers and manufacturers to attain the best possible outcome from the finished goods based on the knowledge of different washing processes in reference to fabric weight, dimensional stability, tensile strength, tear strength and color fastness properties.

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Compliance with Ethics Requirements

This article does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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