

Effect of Different Washing Methods on Mechanical Properties of Egyptian Denim Fabrics

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Abstract:

The aim of this paper is to study the effect of different washing methods on mechanical properties of denim fabric manufactured in Egypt. Cotton 100% and cotton/spandex 98.5% - 1.5% denim washed fabrics were selected to carry out the experiment, washing parameter; Enzyme Wash (EW), Enzyme wash with bleach (EWB), Enzyme wash with stone (EWS) and Enzyme wash with stone and bleach (EWSB). Specimens were washed for different durations, these were: 10, 30, 50, 70 and 90 minutes.

An Instron tensile tester was used and the procedure followed the ASTM 5034 – 09, standard test method for breaking strength and elongation of textile fabric (Grab Test) for evaluation the tensile strength properties of denim fabric.

The study focused on the comparison of the tensile properties on the denim washed fabric, the effect of changing the test specimens washing duration was also considered.

It was found that the tensile strength of these samples became weaker in both fabric directions. It also was found that comparing with four of the washing types, enzyme wash with stone were less damage for the tensile strength.

Keywords:

- *Denim Fabrics,*
- *Stone Wash,*
- *Enzyme Wash,*
- *Tensile Strength.*

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1 Introduction:

Denim - one of the world's oldest fabrics - is most commonly associated with jeans. Today, denim jeans are one of the most popular clothing items, which are loved by many people around the globe regardless of the gender, culture, climate conditions, seasons, and social occasions. Denim is very strong, stiff and hard wearing woven fabric [8]. Denim is cotton and twill weave fabric that uses colored warp and white weft yarn and used for jeans, work clothes and casual wear [11].

The birth of denim jeans is credited to the Bavarian-born businessman, Levi Strauss, who made his way to the Gold Rush in San Francisco nearly 150 years ago. Since then, the denim fabric has run the gamut from a basic work wear fabric to a fashion trendsetter, it is one of the most fashionable items in the fashion and textile industry today and the original focus on durability and practicality has changed to fashion. 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. [9]

Denim was traditionally colored blue with the indigo dye. Indigo dye is one of the dyestuffs with a distinctive blue color. For the natural dye which come from some of the several

species of plant. But nowadays, the indigo procedure is synthetic and not natural. [3]

Denim can provide the durability and different appearance effect for the garment when it is conduct the different denim garment, and most people wearing the denim garment. Deterioration in the denim fabric of the textile product is often important to the physical properties in deciding when the article has reached the end of its using life [7].

The objective of this study is to assess the effect of denim washing on tensile strength, using the tensile strength method to compare the tensile properties on different types of the denim washed fabric.

In this study, all of the denim woven fabrics came from the same manufacturer (Fourtex Co.), and the denim washing was carried out under different combinations of washing parameter, such as Enzyme Wash, Enzyme wash with bleach, Enzyme wash with stone and Enzyme wash with stone and bleach. All of these include 10, 20, 30, 40, 50, 60, 70, 80 and 90 minutes washing duration. After, tensile strength test will be conducted to compare the difference between different washing condition and their properties. In order to have a deeper understanding about issue of the washing characteristic of denim fabric, it will be essential to carry out the laboratory testing.

By carrying out the above experiment and evaluation, the objectives of this study can be achieved.

1.1 Denim and Spandex Fiber

The yarn used in denim is a simple yarn, that is describes as a spun yarn based for the fiber length. Spun yarn is composed of staple fibers that are twisted together. When there are the higher count number, the thinner the yarn and vice. Normally, in denim fabric, warp yarn are thicker that the weft because weaving process, the warp yarn need held in a higher tension.

Denim is the heavy fabric with the wide fabric range there are from 5 to 16 oz per sq. yard. Traditionally, it is usually weaving from the 100% cotton, made from yarn dyed warp and undyed weft yarn. The typical cotton construction is a warp - faced 3/1 right hand side twill. As more dyed warp yarns are faced on one side of the fabric, the face side of the denim is bluer. Meanwhile, denim is a cotton twill fabric that dyed with the indigo. Indigo is one of the natural dye come from the plant. As indigo only can dye on the surface of the thread, when there have the stone washes or the enzyme washes, the color will be faded. Hence the irregular fading will appear on the fabric.

Spandex fiber is a soft, elastic and flexible with a hand much like of a rubber band. When the chemical property of spandex is taking into consideration, it has resistance to most of the acid or the dry cleaning solvents but will damage by the alkalis. However spandex fiber can be degraded by the sodium hypochlorite chlorine bleach, Generally speaking, spandex is less susceptible to deterioration by the light and the chemicals. It is easier to handle because it can allow machine washable and dry cleanable.

1.2 Stone Washing

Stone washing is one of such wash type used purposely for Denim. In stone-washing the freshly dyed jeans are loaded into large washing machines and tumbled with pumice stones to achieve a soft hand and desirable look. Pumice stones give the additional effect of a faded or worn look as it abrades the surface of the jeans like sandpaper, removing some dye particles from the surfaces of the yarn. Stone should be selected of the proper hardness, shape, and size for the particular end product. It should be noted that large, hard stones last longer and may be suited for heavy weight fabrics only. [2]

Denim is basically cotton and very stiff fabric and the warp yarns are dyed with indigo which remains on surface. During washing they are spun

together in the washing machine and lighter the colour of the garment and produce better contrasts distressed look. [5]

The degree of color fading depends on the time that denim fabric and stone spinned together. The ratio and size of the stone, liquor ratio and the time setting, is very important for the stone wash. There have some limitations for stone wash which is the cause of the tear for the fabric. Although there have limitation of stonewashing, some factories continuous to use because it can provide the vintage and used look on the garment, and these varying degree for the abrasion will appear in pocket side, seam, waistband and the body. [2]



Figure (1) Industrial machine used to wash jeans by pumice stone

1.3 Enzyme Wash

In order to minimize the adverse effect of stone-washing, the denim garments are washed with enzymes. The enzyme breaks the surface cellulose fibers of the denim fabric and removes during Washing. During enzyme washing certain amount of indigo dye and cellulose fibers from the surface of the fabric are removed. [2]

Enzyme provides more softened the hand feel of the fabric and can remain the strength of the fabric, when compared with the traditional stone wash. In addition, it can reduce abrasion intensity on the fabric. Other benefit is that it can prevent the formation of the fuzz and pills on the surface of the fabric, increase the smoothness, luster, and uniformity of the color, and improve the handle and durability [10]

The stonewashing effects achieved by pumice stones can be replaces by enzyme washing which chemically degrade cotton in less abrasive way compare with the traditional stonewashing to give out the washed - outlook.

In order to exempt the extra processing by the customer, the denim fabric manufacturers conduct the pre-washing jeans and abrade the denim with stone or cellulose enzyme to achieve the softness hand feel and the unique style.

Actually, if the manufacturers necessary to abrade the surface of the denim fabric, they will select the

stone washing or the cellulose enzyme. For Stone washing, it is physically abrading the fabric and cellulose enzyme is providing the chemical abrasion. [4]

1.4 Indigo Dye

Indigo dye, which is the important of the natural dyes there have been sustained to use. Indigo is a blue dye come from India. The group of the colorants Indigo is one of the oldest known as the natural dyes. Indigo dye is imparting in a blue color and has a good wet fastness property. Indigo have the moderate light fastness, and even there have the fading of the color, there without change of the color and are available for using in the jeans and the denim item. [12]

1.5 Tensile Strength

Tensile strength, is one of the important properties in relation to measure the strength, and the modified for about the grab test can be used the tensile fabric. Strength is very important for the textile industry and most of the product will conduct this test to ensure the quality. During

measure the quality, it is also include the flexibility, dye affinity resilience or other more. Beside, the product quality will depend on much of the end use, such as the acid will reduce the cotton fiber strength. [6]

2. Research Question:

Are different washing methods having an effect on tensile strength of denim fabrics?

3. Materials and Methods:

3.1 Materials

100% Cotton and Cotton/Spandex 98.5% - 1.5% denim fabrics manufactured in Egypt, by Fourtex Co. Specimens were pre-conditioned in standard environment according to ASTM d1776 [1], before measuring the fabric specification. Beside, the specifications were collected by using the standard method. So in this research, the effect of washing on tensile strength of denim fabric was investigated. For this purpose, the specifications of selected specimens show in Table (1) & (2).

Table (1): Represents Specifications of 100% Cotton Denim Specimens

Name	Composition	Construction	Weight	Width	Density	
					Warp	Weft
Denim Moon	100% Cotton	3/1 Right Hand Twill	10 oz/yd ²	150±2 cm	66ends/inch	51ends/inch

Table (2): Represents Specifications of Cotton/ Spandex Denim Specimens

Name	Composition	Construction	Weight	Width	Density	
					Warp	Weft
Stretch Denim Perto	Co. 98.5% + Span. 1.5%	3/1 Right Hand Twill	10.5 oz/yd ²	150±2 cm	70ends/inch	57ends/inch

3.2 Methods

Specimen was cut 4 x 6 inches, so that the direction of test is in the longer direction. To prevent the edge of the specimen slippage during washing process, lock stitch in necessary before washing. All of the specimens were conditioned under standard atmospheric pressure at 65% ± 2% relative humidity and 21°C ± 1°C for at least 24

hours prior to denim washing.

Cotton and cotton/spandex denim fabric were treated with different washing method such as Enzyme Wash, Enzyme Wash with Bleach, Enzyme Wash with Stone and Enzyme wash with Stone and Bleach. The experimental arrangement was shown on Table 1 & 2.



Figure (2) Industrial Dryer machine



Figure (3) Side Loading Cellulase Washing Machine



Figure (4) Instron, Tensile Tester

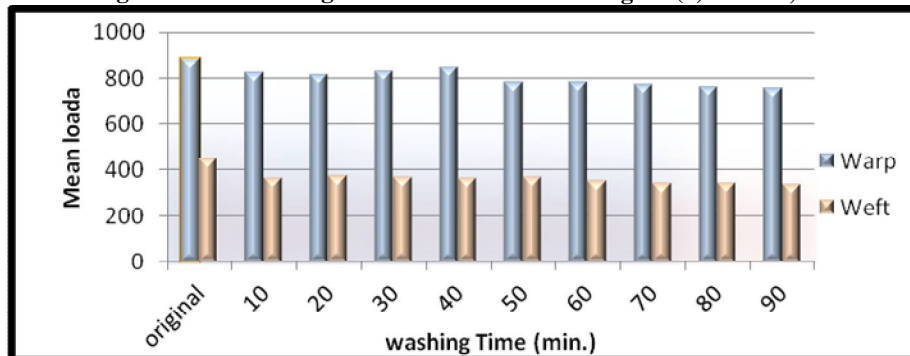


Figure (5): Enzyme Wash in Warp & Weft Direction of 100% Denim Cotton Specimens - (Tensile Strength)

4. Results & Discussion:

Following figures represent the results of denim fabric strength (warp & weft) under different washing methods.

According to the Figure (5), specimen strength tends to be weaker (warp) after 50 minutes of washing. When the washing time of 40 minutes to 50 minutes significantly decrease the tensile strength and so it is decrease about 7% of tensile force.

Beside, the yarn strength tends to be stable from 60 minutes to 90 minutes, respectively.

Specimen (weft) before wash and after washing in 10 minutes have significantly changed in terms of tensile strength, approximately changes in 15% in tensile strength.

Specimen after enzyme wash in different time tends to be stable in terms of tensile strength. However, from 50 minutes to 90 minutes, it was found that the tensile strength become weaker.

Warp wise tensile was greater than the weft wise strength. And the washing sample is slightly weaker than the original. For the Enzyme washed sample, all of the warp wise and weft wise tensile strength were smaller than those of the original sample, and decrease gradually as the processing time from 10 minutes to 90 minutes.

Moreover, all of the warp wise and weft wise tensile strength have slightly up and down trend, according this information, it can see the alter of warp wise and weft wise is very similar.

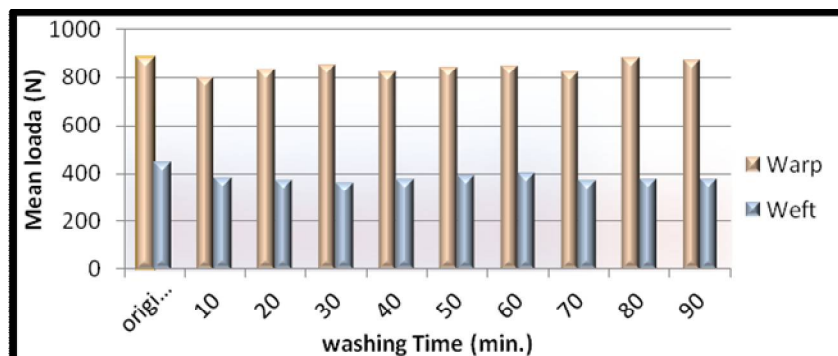


Figure (6): Enzyme Wash with Bleach in Warp & Weft Direction of 100% Denim Cotton Specimens- (Tensile Strength)

Based on Figure (6), specimen before wash and after washing in 10 minutes have significantly

change in terms of tensile strength (warp) approximately 10% in tensile strength.

It is surprise to find that the tensile strength from to 10 to 90 minutes has an up and down tends. However, it becomes stronger after longer times of washing.

After washing in 90 minutes the tensile strength decreases 1 percent. The possible explanation could be that the yarn after washing becomes higher level of shrinkage. Therefore the higher density between the yarns as the results of yarns could share the loading and withstand tensile force.

Specimen before wash and after washing in 10 minutes has significantly changed in terms of

tensile strength approximately 15% in tensile strength.

Moreover, it was found that the tensile strength (weft) from to 10 to 90 minutes has an up and down tends and from 70 to 80 minutes, it has major decline. From 80 to 90 minutes, it has slightly increased in terms of tensile strength.

Warp wise tensile was larger than weft wise strength, specimen after washing is a little weaker than the original one. For the enzyme wash with bleach sample, all of the warp wise and weft wise strength have the slightly up and down trend, which means that both are very consistent.

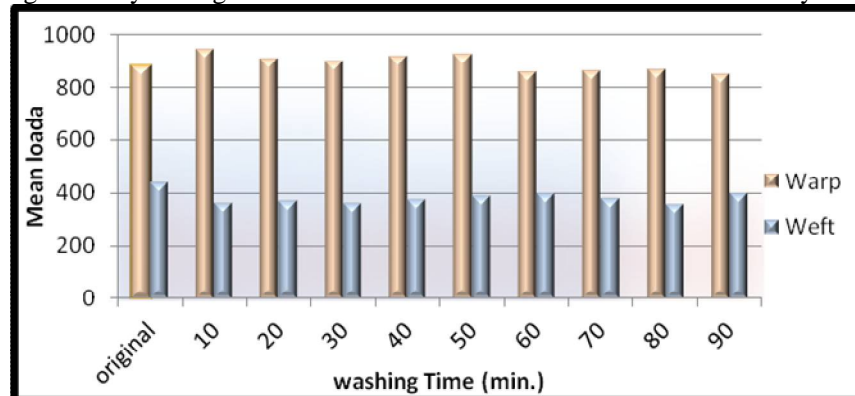


Figure (7): Enzyme Wash with Stone in Warp & Weft Direction of 100% Denim Cotton Specimens - (Tensile Strength)

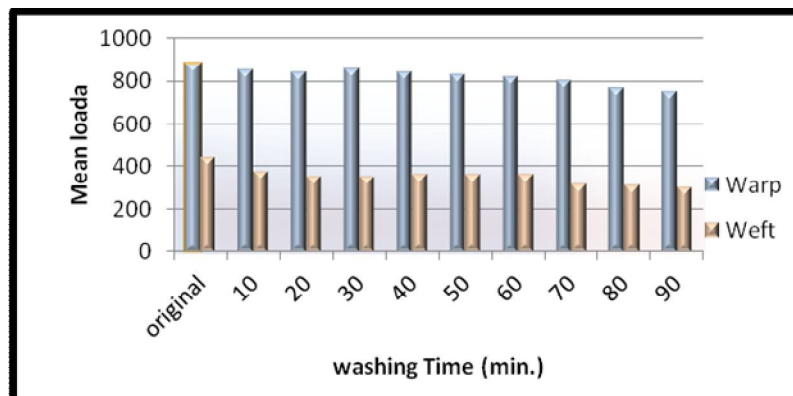


Figure (8): Enzyme Wash with Stone and bleach in Warp & Weft Direction of 100% Denim Cotton Specimens - (Tensile Strength)

For Figure (7), it is surprise to find that the specimen tensile strength before wash and after washing in 10 minutes increase in 7.6%. This result is abnormal; because in normal situation, the fabric before wash should be stronger than that of fabric after washing in term of tensile strength.

In addition, it was find that that the tensile strength from to 10 to 90 minutes has an up and down tends. However, the washing time of 50 minutes to 60 minutes significantly decrease the tensile strength about 7% of tensile force.

After 50 minutes of rinsing time. The enzyme

chemical and stone continue to damage of the yarn. The yarn strength tends to be weaker after 60 minutes of washing.

Specimen before wash and after washing slightly changes in tensile strength (weft).

From 10 to 60 minutes have down tends. From 60 to 70 minutes, tensile strength becomes stronger. But after 80 minutes, the tensile strength becomes weaker than 70 minutes.

Warp wise tensile was stronger that the weft wise strength and it is similar with the normal prototype. However, there have significant

different than normal pattern in warp wise yarn, it is significant weaker than the 10 minutes to 50 minutes washing. After 60 minutes to 90 minutes, decrease gradually.

Beside, weft wise tensile strength was smaller than those of the original sample, and decrease slowly from 10 minutes to 90 minutes.

According to Figure (8), specimen before and after 10 minutes wash is slightly changed in terms of tensile strength approximately about 2% in tensile strength (warp).

In addition, the yarn strength after washing in longer time has significant decrease in terms of tensile strength.

In additional, it was observed that the tensile strength from to 10 to 40 minutes has an up and down tends and from 40 to 90 minutes, it has major decline for tensile strength.

Specimen before wash and after washing in 10 minutes has significantly changed in terms of tensile strength approximately 15% in tensile strength (weft).

From 10 to 70 minutes, tend to be stable in terms of tensile strength. However, from 70 minutes to 80 minutes, it was found that the tensile strength drop down suddenly.

Warp wise tensile was better than weft wise strength. And the washing specimen is slightly weaker than original one. After 80 minutes to 90 minutes, there have significant decrease in tensile strength compare with the original one.

both warp wise and weft wise tensile strength were smaller than those of the original, and their decrease trend is very similar, and the structure of the fabric is quite consistent and have not the major different of warp yarn and weft yarn.

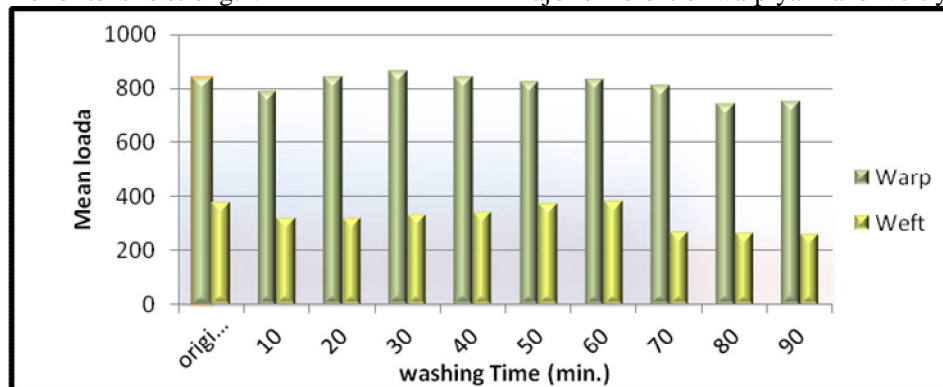


Figure (9): Enzyme Wash in Warp & Weft Direction of Denim Cotton/ Spandex Specimens - (Tensile Strength)

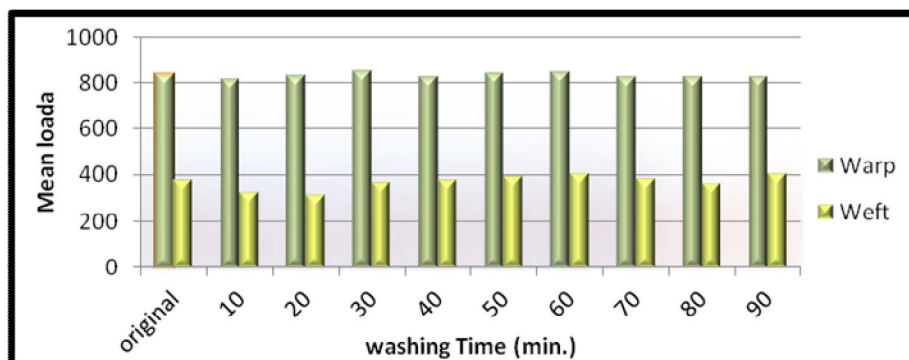


Figure (10): Enzyme Wash with Bleach in Warp & Weft Direction of Denim Cotton/ Spandex Specimens- (Tensile Strength)

For the data in Figure (9), shows specimen before and after washing in 10 minutes have significantly change in terms of tensile strength (warp) approximately 6% in tensile strength.

In 10 minutes washing the tensile strength declining when compared with before washing. In 20 minutes washing tensile strength declining in compare with 10 minutes of washing time. It also occurred an up and down tends between 10 minutes to 90 minutes washing. In addition, longer

time of washing have more harmful impacts in terms of tensile strength. While weft yarn weak will result in interdependency issues which make warp yarn tends to be easy to break.

Specimen before and after washing in 10 minutes has much change in terms of tensile strength approximately 17% in tensile strength.

After enzyme wash in different types of washing time, tend to be stable in terms of tensile strength. However, from 70 minutes to 90 minutes, it was

found that the tensile strength become weaker, there is about 263.53 (N) to 255.07 (N).

Warpwise yarn strength have significant stronger than weft wise yarn. both warp wise and weft wise tensile were smaller than those of the original specimen.

Warp wise have the slightly up and down trend and the weft wise have decrease gradually as the processing time increase from 10 to 90 minutes. As it seen warp yarn and weft yarn have slightly various.

For Figure (10), specimen before and after washing in 10 minutes has slightly changed in terms of tensile strength (warp) approximately 5% in tensile strength (warp).

It was occurred an up and down tends between 10 minutes to 90 minutes washing, from 70 to 90 minutes, the tensile strength becomes stable.

Sodium hypochlorite chlorine bleach can damage the spandex fiber, as known as the fabric is weaving together, when the weft yarn weak will result in interdependency issues which allow the strength of warp yarn weaker.

Specimen before and after washing in 10 minutes has much change in terms of tensile strength approximately 15% in tensile strength (weft).

From 10 to 90 minutes, it have slightly up and downs tends, but the trend is stable and when there have longer time washing, there have more damage impacts as the strength of the fabric become weaker.

Moreover, weft yarn twisted with the spandex fiber, and spandex could damage by the sodium hypochlorite chlorine bleach, so that the strength result would become weaker.

Warp wise yarn strength have major stronger than weft wise yarn. After enzyme washing with bleach, both warp wise and weft wise was smaller than both of the original ones.

As seen that in warp wise direction, there have an up and down trend but in weft wise have not. It can observe that the enzyme washing with bleach have more effect to the warp yarn. Even the enzyme washing with bleach will affect the weft yarn after 10 minutes, afterward, the strength is become stable and it is decrease a little gradually.

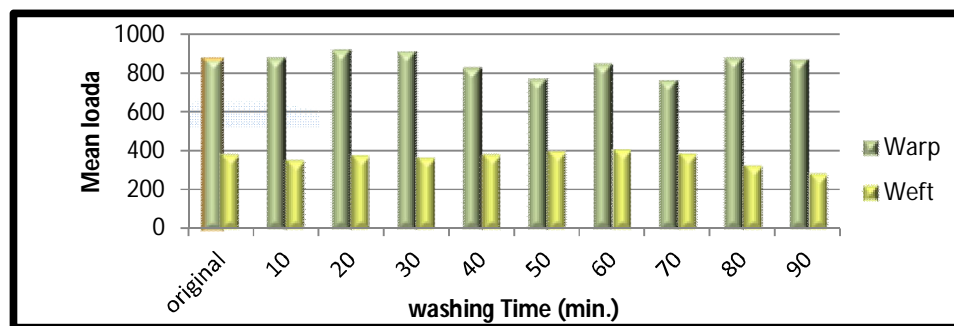


Figure (11): Enzyme Wash with Stone in Warp & Weft Direction of Denim Cotton/Spandex Specimens - (Tensile Strength)

According to Figure (11), it was astonished to find that tensile strength that before wash and after washing in 10 minutes approximately 4%. This is irregular, because in neutral circumstances, fabric after washing should be weaker than before wash in term of tensile strength (warp).

Moreover, from 10 to 90 minutes, it was occurred the up and down tends. However, we observe that the washing time of 40 to 50 minutes have significantly decreased the tensile strength about 7% of tensile force. In additional, for 60 to 70 minutes, it also has significantly decreased in strength about 10% of tensile force.

it can observe that specimen before and after washing in 10 minutes have slightly change in terms of tensile strength approximately 8% in tensile strength (weft).

In terms of weft yarn strength after washing, its

strength tends to be weaker after washing in overall.

From 10 minutes to 80 minutes, there have a little up and downs tend. In 80 minutes to 90 minutes, there have significant drop down, approximately 13% in tensile strength.

Weft wise yarn is significant weaker than warp wise yarn. On the other hand, the original warp wise yarn is slightly weaker than the after 10 minutes, but compare with 20 minutes to 90 minutes, the original warp wise is stronger than the after washing once. Beside, it also observe that the warp yarn have the up and down trend between 20 to 90 minutes.

Actually, weft wise is more traditional because the after wash is weaker than the original, and the strength of the weft wise is decrease slowly.

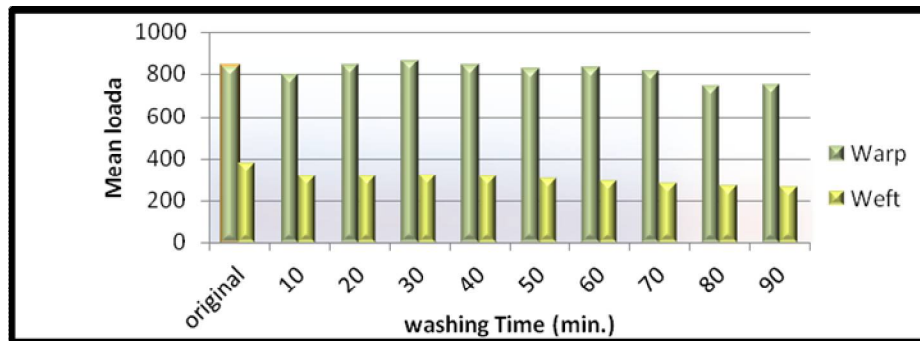


Figure (12): Enzyme Wash with Stone and bleach in Warp & Weft Direction of Denim Cotton/Spandex Specimens - (Tensile Strength)

For the Figure (12), it was found that specimen before and after washing in 10 minutes have slightly change in terms of tensile strength approximately 5% in tensile strength (warp).

In 10 minutes washing tensile strength declining when compared with before washing. In 20 minutes washing tensile strength declining in compare with 10 minutes of washing time. For 10 minutes to 90 minutes, it occurred as unstable trend. Moreover, longer time washing have more damage impacts in terms of tensile strength.

As known as the fabric is weaving together, the weft yarn weak will result in interdependency issues which allow the strength of warp yarn weaker, since of this when the sodium hypochlorite chlorine bleach damage the spandex fiber in weft yarn, it also will affect the warp yarn. Specimen before and after washing in 10 minutes has large change in terms of tensile strength approximately 17% in tensile strength (weft).

From 10 to 20 minutes, it is very stable. In 30 minutes, tensile strength increase slightly. From 30 to 90 minutes, the trends are to tend to become weaker. It is because there for have a longer washing time and so there have more damage impacts in terms of tensile strength. Moreover, sodium hypochlorite chlorine bleach damage the spandex fiber is one factor carry out the weft yarn will became weaker in tensile strength result.

Both warp wise yarn have the significant stronger than weft wise yarn. After the enzyme wash with stone and bleach, the warp wise yarn and weft wise yarn is smaller then those of the original specimen.

Actually, the trend of the warp wise have slightly up and down, however, the weft wise yarn is decrease step by step, as the weft wise is more traditional.

5. Conclusion:

Following frequent evaluations of washing condition of the cotton fabric and cotton spandex fabric, the result obtained can be concluded as

follows:

During washing, the starch surface fibers and some of the dyestuff were removed by the abrading stone or hot water. The tensile strength of these samples became weaker in both fabric directions. The loss in the durability depended on the processing time, as the longer of the processing time, the lower the durability.

According to the analysis data, it could see the strength of the enzyme wash with stone and bleach was the weaker. This was due to the chemical degradation of cotton and cotton spandex fiber by the oxidizing agent, sodium hypochlorite and the abrasion action of the pumice stone. Compare with four of the washing types, enzyme wash with stone were less damage for the tensile strength. For the analysis, some of the fabric is suddenly become strength and some are decreases.

Enzyme wash with stone wash have the biopolishing effect as it was found out that the original fabric was weaker than the after wash fabric. This is due to that the cellulase can increase the biopolishing of the cotton fabric to enhance the handle value. Although the effects of the cellulase hydrolysis can stay as the surface phenomena, much of the physical aspects of the fabric like the tensile strength take place during the processing.

According to the investigation, when the stone wash and bleaching processes are properly controlled, the durability will be retained at an acceptable level, in the study, four of the cellulase washing condition with on enzyme concentration was selected for analysis. The effect of the different levels of the factors such as the different temperatures, pH condition, enzyme concentration, liquor ratios, treatment times and quantity of mechanical agitation can be used for the further study.

Concern with the durability and physical use of denim garment, they have the concept that they can provide the good function for long time to use. However, after the different washing condition on the denim fabric, the percentage of shrinkage or

the strength of the fabric will also change.

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