Faculty of Engineering
Department of Textile Engineering

Studies on the effect of Bleaching and Stone-Enzyme Wash on the characteristics of Denim Fabric

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A thesis submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science in Textile Engineering

Advance in Textile Wet Processing Engineering

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DECLARATION

We hereby declare that this project was conducted under the supervision of Mr. Tanvir Ahmed Chowdhury who serves as an Assistant Professor in the Department of Textile Engineering within the Faculty of Engineering at Daffodil International University. We also confirm that neither this project nor any part of it has been submitted elsewhere for the award of any degree.

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LETTER OF APPROVAL

This project report, authored by Md. Nasim Alam (ID: 201-23-894) and Md. Rakibus Sultam (ID: 071-23-354) has been approved in Partial Fulfillment of the Requirement for the Degree of Bachelor of Science in Textile Engineering. The students completed their project work under my supervision. Throughout the research period, I found them to be sincere, hardworking, and enthusiastic.

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Finally, we would like to express a sense of gratitude to our beloved parents and industrial relatives for their mental support, strength and assistance throughout writing the project report.

ABSTRACT

This thesis explores the consequences of enzyme-stone wash and bleach wash on denim apparel, concentrating on factors such as size reduction, mass decrease, and alterations in physical attributes. Denim washing is a critical stage in garment manufacturing aimed at meeting consumer preferences, and comprehending these outcomes is crucial for upholding quality benchmarks. The research scrutinizes various washing methods, encompassing enzyme-stone wash and bleach wash, assessing their influence on apparel dimensions, visual appeal, and mechanical traits. By meticulously analyzing samples obtained from a denim producer, the investigation uncovers significant observations: enzyme-stone wash induces noticeable shrinkage and mass reduction, resulting in heightened EPI and PPI values, while bleach wash similarly leads to diminished garment measurements and mass loss. These findings offer beneficial insights for textile engineering professionals, assisting in refining denim washing techniques to attain desired garment finishes and effectively satisfy market requirements.

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Chapter -1

Introduction

1.1 Background of the Study

Denim washing involves various physical adjustments customized to meet the preferences of buyers. After denim garments are stitched, they undergo washing procedures, often resulting in alterations to their dimensions. However, it is essential to ensure that the quality and measurements of the garments meet the standards set by the buyer. To understand the changes in denim garments before and after washing, a thorough analysis is conducted, including evaluations of weight loss, fluctuations in ends per inch (EPI) and picks per inch (PPI), and shrinkage. This thesis aims to clarify the required allowances for a denim five-pocket pant before washing and offer insights into the changes in physical appearance after washing.

1.2 Objectives

- Investigating the procedures utilized in Enzyme-stone wash and Bleach wash to achieve desired denim garment finishes.
- Determining the extent of shrinkage experienced by garments through post-washing measurements, typically expressed as a percentage.
- Detailing the crucial stages involved in planning denim garment production to meet the specific requirements and preferences of buyers.
- Examining the physical characteristics of denim garments, including factors such as picks per inch (PPI), ends per inch (EPI), weight, and how the fabric behaves under different conditions.
- Identifying the various patterns and types of color fading that occur in garments over time due to factors such as wear, washing, and exposure to sunlight.

1.3 Significant

As a newcomer to the field of textile engineering, grasping the behavior of garments before and after washing holds immense importance. This comprehension can prove invaluable across different facets of your work, including planning, production, and satisfying the demands of buyers. Furthermore, considering your current position with a denim manufacturer, delving into the intricacies of denim washing techniques will undoubtedly enhance your prospects for career growth and advancement in the future.

Chapter -2

Literature Review

2.1 Denim Wash

The primary goal of enhancing denim fabric is to boost its visual appeal and durability, with a strong emphasis on ensuring comfort and softness. Current fashion trends lean towards a worn-in look, featuring faded seams, often achieved through specialized garment treatments. Dry denim is particularly attractive because it naturally fades over time, reflecting the wearer's lifestyle and activities, creating a more authentic and individualized appearance compared to artificially distressed denim. Finishing techniques are typically applied post-sewing, underscoring the importance of understanding how specific washing methods affect fabric to maintain garment quality, a consideration that starts during the garment design phase. Washing is a common practice in today's sewing industry, applied to various fabrics like cotton and linen. Recent research often examines how different finishing methods affect textile color, recognizing that consumers often base their buying decisions on color preferences. Moreover, the mechanical properties of the fabric play a crucial role in both the durability and aesthetic appeal of garments, significantly influencing their wear ability and enjoyment.

Legend has it that the term "jean" originated from "Genoa," referring to the fabric used by sailors from Genoa in their trousers. Initially, this fabric was a rough blend of cotton, wool, and/or linen from Italy, following the tradition of naming materials after their place of origin. By the late 16th century, jeans were being produced in Lancashire, England, evolving to 100% cotton composition by the 18th century. Today, "jeans" typically describe garments with five pockets (two in front, two in back, and a small change pocket), made from various fabrics like corduroy, twills, or bull denim. Well-known brands like Levi's and Wrangler dominate this field.

In contrast, the term "denim" has its roots in late 16th-century France, where a fabric called "serge de Nimes" (twill from Nimes) became popular. There's uncertainty about whether "denim" directly originated from this French fabric or the twill known as "nim," also used in France at that time. "Serge de Nimes" was a blend of silk and wool, leading some historians to question if it truly gave rise to modern-day denim. Nonetheless, both jeans and denim fabrics gained popularity, with denim being the stronger and more expensive option. Notably, denim was woven with one colored thread (the warp) and the other white (the weft), while jean was woven with two colored threads, distinguishing the two fabrics. Denim was mainly used for workwear, while jeans were preferred for lighter clothing with less durability requirements.

By the late 19th century, American weavers adopted the twill style of European denim, utilizing locally available cotton fibers. Despite frequent washes, the material earned a reputation for its durability and resilience.

2.1.1 Bleach Wash

The traditional method of bleaching involved laying fabrics and cloth outdoors, allowing them to naturally whiten under the sun and water. However, the development of modern bleaches is attributed to breakthroughs made by 18th-century scientists. Swedish chemist Carl Wilhelm Scheele's discovery of chlorine, coupled with French scientist Claude Berthollet's understanding of its bleaching properties, led to the creation of sodium hypochlorite, commonly referred to as Eau de Javel or Javel water, named after the Parisian area where it was initially produced. Antoine Germain Labarraque also made significant contributions by uncovering the disinfecting properties of hypochlorites. Scottish chemist and industrialist Charles Tennant further propelled the field forward by developing solutions of calcium hypochlorite and solid calcium hypochlorite, known as bleaching powder.

In 1818, Louis Jacques Thénard synthesized hydrogen peroxide by reacting barium peroxide with nitric acid. Although hydrogen peroxide was first utilized for bleaching in 1882, it didn't gain widespread commercial importance until after 1930. Sodium perborate, another laundry bleach, had been in use in Europe since the early 20th century but didn't gain popularity in North America until the 1980s.

Figure 2.1: Random Bleach Wash Effect [13]

2.1.2 Enzyme wash

Enzyme wash is a sustainable garment washing technique, favored in the industry due to enzymes' natural origins. It's commonly used to counteract the adverse effects of stone washing. In this process, enzymes break down the surface cellulose fibers of the fabric, which are subsequently washed away. The enzyme action can be stopped by adjusting the bath's alkalinity or temperature once the desired color is reached. During enzyme washing, some indigo dye and cellulose fibers from the fabric's surface are also removed. The final stages of enzyme washing typically include rinsing and softening to complete the process.

Figure 2.2: Random Stone enzyme stone wash [13]

2.1.3 Stone wash

Stone washing is a popular technique, especially among young people, known for giving garments, typically cotton, a distinctive worn-in appearance. This process specifically targets denim garments, utilizing special stones, often pumice stones, to achieve a heavily washed effect. The primary purpose of stone washing is to create a fading effect on denim items. White stones, combined with enzymes during washing, play a crucial role in achieving the desired faded look on the garment's surface. As the fabric interacts with the stones during washing, the rubbing action contributes to the fading of the color. Furthermore, stone washing enhances the softness and flexibility of fabrics like canvas and denim, which tend to be stiff and rigid. It's worth noting that while stone washing can lead to color fading in jeans, it also involves increased water usage during the washing process.

Figure 2.3: Enzyme stone in washing machine.

CHAPTER – 03

Survey Details, Methods and Materials

3.1 Materials

3.1.1 Garments Samples

Garment samples collected from Creative Wash Ltd., Ha-Meem Group. Garments brought for different wash, Enzyme-stone wash and bleach wash.

3.1.2 Chemicals

SF Ultra (Enzyme), Acetic Acid, Anti-back stain, Bleaching Agent, Stone, Soda Ash, Sodium Metabisulfite, softener & De-sizing agent.

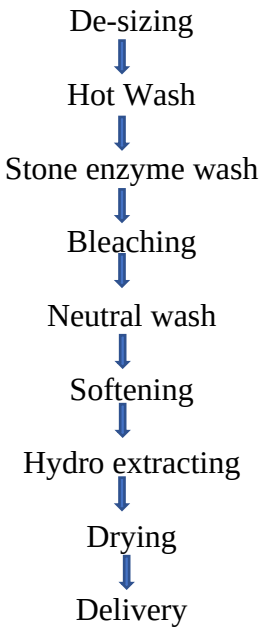
3.1.1 Washing Machine

Name: DANIS front loading Washing Machine, M/C capacity: 500 kg, heating source: Steam.

3.2 Methods

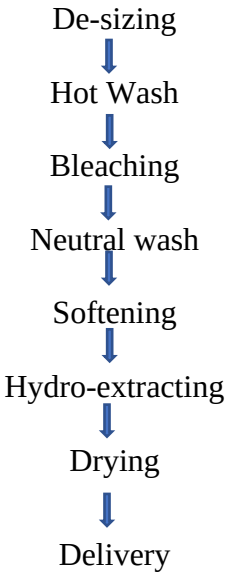
3.2.1 Enzyme Stone wash

Process flow chart for stone enzyme wash:



3.2.2 Bleach wash

Process flow chart of bleach wash:



3.2.3 Drying

Hydro-extraction = 10 minutes, then drying = 15 minutes at 80°C.

3.2.4 Determination of Shrinkage %

The shrinkage percentage was determined using the following formula:

$$S\% = \frac{B-A}{A} \times 100$$

A = original dimension.

B = dimension after treatment

3.3 Recipe Calculation

3.3.1 Enzyme-Stone wash

Firstly, De-sizing-

Weight of Material .... ……..60 kg
Liquor Ratio……1: 10
Water ……. 600 litter
Temperature ..... …… 60ºC
Anti-back stain ..... 600 gm.
De-sizing Agent (SUPRADET NF)……... 300 gm

Second step: Hot wash

Liquor Ratio…….1: 10
Water…….600 litters
Temperature……...60ºC
Time……...……5 min

Third step: Stone-Enzyme

Liquor Ratio…….……...1: 10
Water…….....600 litters
Stone (Near Stone Mineral) ..... 30 KG (Half of Material Weight)
Enzyme (SF Ultra) ..... 900 gm.
Acetic Acid….....320 gm.
Anti-back stain… ..... 420 gm.
Temperature..... 45ºC
Total Time… .....65 min

Fifth step: Neutral

Liquor Ratio…….1:10

Water……...600 liters

Sodium Metabisulfite .....1800 gm.

Temperature.....45ºC

Time… ..... 10 min

Softening:

Time…….10 min

Liquor ratio……1:10

Water……..…. .....600 L

Acetic Acid…. 320gms

Softening agent (Asucell WF)..... 600 gm.

3.3.2 Bleach washing

Firstly, De-sizing

Weight of Material ..... 60 kg Denim Pant. (Long)

Liquor ratio…….1: 10

Water. ..... 600 liters.

Temperature……. 60° C

De-sizing agent (SUPRADET NF) .....600 gm.

Anti-back stain ..... 600 gm.

Time. .....30 min.

Second Step: Hot Wash

Liquor Ratio……1: 10

Water……...600 liters.

Temperature..... 65°c.

Time. ..... 5 min.

Third Step: Bleaching

Liquor Ratio ……1: 10

Water……. 600 liters.

Bleaching Agent (Calcium Hypo chloride) ..... 6000 gm.

Na_2CO_3.....3000gm.

Temperature .....60°c.

Time……. 20 minutes

Fourth Step: Neutral Wash

Liquor Ratio……1: 10

Water.....600 liters.

Sodium Metabisulfite……..... 1800 gm

Temperature…… 40°c.

Time.....10 min.

Fifth Step: Softening

Liquor Ratio…….1:10

Water .....600 liters.

Citric Acid .....360 gm.

Softener (ASUCEL WF)..... 600 gm.

Time. ..... …….5 min

3.4 Survey Report

3.4.1 Determine the Inseam Length & Side seam length

The seam lengths of the sample garments were assessed using a measuring tape in centimeters (cm).

Table 3.1: Effect of Garment Properties on the Application of Enzyme-Stone Washing.

Calculated Area	Pre-Wash	Post-Wash	Difference	Average	Shrinkage %	Average %
Side Seam	92	89.5	4.5	4.3	4.81275225	4.812834
	92	89	4		4.255663149	
	92	89.5	4.5		4.812811225	
	92	89.5	4.5		4.812835825	
	92	89	4		4.255341149	
Inseam	75	66	4	3.9	5.405865405	5.405405
	75	66	4		5.4054052205	
	75	66.5	3.5		4.6979145577	
	75	66	4		5.525405405	
	75	66	4		5.4054055845	

The table shown above demonstrates that enzyme-stone washing brings about a significant change in the properties of the garment. Notably, there is a considerable alteration observed in garment shrinkage, particularly in the side seam direction, where shrinkage reaches up to 4.8%, and in the inseam direction, where shrinkage reaches up to 5.4%. In side seam areas. The mean variance observed between measurements taken before and after washing. is 4.3, while in inseam areas, it is 3.9. This implies a reduction in the garment's length following washing.

Table 3.2: Impact of clothing characteristics following a bleach wash.

Calculated Area	Before Wash	After Wash	Difference	Average	Shrinkage %	Average %
Side Seam Area	95	86.5	8.5	8.7	4.42775	4.5443
	95	86	9		4.2791	
	95	86.3	8.7		4.69641	
	95	86.5	5.5		4.42775	
	95	86	9		4.16791	
Inseam Area	75	67.5	5.5	7.8	3.703704	3.47704
	75	67	8		4.41194	
	75	67.5	7.5		3.70704	
	75	67	8		4.47194	
	75	67	8		4.47694	

The table presented above illustrates that bleach washing leads to a notable transformation in the properties of the garment. Particularly noteworthy is the significant change observed in garment shrinkage, especially in the side seam direction, where warp shrinkage measures up to 4.04%, and in the inseam direction, where warp shrinkage reaches up to 3.7%. In side seam areas, the average difference between pre-wash and post-wash measurements is 3.7, while in inseam areas, it is 2.8. This confirms that the garment's length decreases after undergoing bleach washing.

3.4.2 Determine the Picks Per Inch (PPI) and Ends Per Inch (EPI)

Draw a square with sides measuring one inch on the sample and count the number of warp ends and weft picks within that square.

Table 3.3: The effect of Picks Per Inch (PPI) and Ends Per Inch (EPI) properties is significant when using enzyme-stone wash techniques.

Measurement Area	Before Wash	After Wash	Difference	Average
PPI	48	50	2	2
	48	50	2	
	48	51	3	
	48	49	1	
	48	50	2	
EPI	92	96	4	3.6
	92	96	4	
	92	95	3	
	92	95	3	
	92	96	4	

The provided table suggests that after garment washing, the Picks Per Inch (PPI) increased, with an average rise of up to 2. Specifically, the PPI number elevated from 48 before washing to 50 afterward. Likewise, the Ends Per Inch (EPI) also experienced an increase post-wash, with an average difference of up to 3.6. Prior to washing, the EPI stood at 92, ascending to thereafter. This indicates that after enzyme-stone washing denim garments, both EPI and PPI numbers tend to increase, mainly due to shrinkage.

Table 3.4: Impact of PPI (Pore Per Inch) and EPI (Ends Per Inch) characteristics on the application of bleach washing.

Measurement Area	Before Wash	After Wash	Difference	Average
PPI	48	50	2	1.4
	48	49	1	
	48	50	2	
	48	49	1	
	48	49	1	
EPI	92	95	3	3
	92	94	2	
	92	95	3	
	92	95	3	
	92	96	4	

The data from the table indicates a clear rise in EPI (Ends Per Inch) following the bleach garment wash. On average, there is a 3-unit increase in EPI, shifting from a pre-wash value of 92 to a post-wash value of 95. Similarly, the PPI (Pore Per Inch) also sees an uptick after the garment wash, with an average difference of 1.4 units. Initially, the PPI was noted at 48 before washing, which then rose to 50. It's essential to note that the increase in both EPI and PPI numbers after the bleach wash of denim garments is somewhat dampened due to shrinkage.

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3.4.3 Determine the weight/ Mass

The weight of the garments was assessed manually using an electric balance, with measurements recorded in grams (g).

Table 3.5: Impact on the denim garments weight due to Enzyme-Stone wash

Calculated Area	Pre-Wash	Post-Wash	Difference	Average
Garments weight	600	585	15	17
	600	580	20	
	600	585	15	
	605	590	15	
	610	590	20	

The alterations in garment weight (GSM) before enzyme-stone washing, as depicted in the figure above, are 600, 605, and 610. Post enzyme-stone washing, the weights are recorded as 585, 590, and 590, respectively. The differences between pre-wash and post-wash are 15, 15, and 20, with an average difference of 17. This demonstrates that after enzyme-stone wash, the weight of the denim garment is reduced.

Table 3.6: Impact of bleach wash on the weight of denim garments.

Calculated Area	Pre-Wash	Post Wash	Difference	Average
Weight of the garments	585	575	10	11.6
	580	567	13	
	585	570	15	
	590	580	10	
	590	580	10	

The provided details suggest a decrease in the weight of denim garments, measured in GSM (Grams per Square Meter), after undergoing bleach washing. Prior to the bleach wash, the garment weights were 585, 580, and 590 GSM. Following the bleach wash, these weights decreased to 575, 567, and 580 GSM, respectively. The differences between the pre-wash and post-wash weights were 10, 13, and 10 GSM, resulting in an average difference of 11.6 GSM. This indicates that the weight of the denim garments tends to decrease after undergoing bleach washing,

3.4.4 Measurement of Garment Body Dimensions (Half Thigh)

Garment body width was measured using a measuring tape in centimeters (cm).

Table 3.7: The width of denim garments is altered as a result of Enzyme-Stone wash.

Calculated Area	Pre Wash	Post Wash	Difference (Cm)	Average	Shrinkage %	Average %
Half Thigh (width)	24.5	22	2.5	2.72	2.272727273	2.272727
	24.5	22	2.5		2.272727273	
	24.5	21.4	3.1		5.140186916	
	24.5	21.5	3		4.651162791	
	24.5	22	2.5		2.272727273	

The changes in the width of denim garments resulting from the enzyme stone wash are evident from table no.7. Initially, the half thigh area measured 22.5 before the enzyme stone wash. However, after the wash, the half thigh measurements decreased to 22 and 21.5. The average difference between pre-wash and post-wash measurements is 0.72, indicating a reduction in half thigh width and an increase in shrinkage following the enzyme stone wash.

Table 3.8: Change in the denim garments Width resulting from Bleach wash

Calculated Area	Before Wash	After Wash	Difference e	Average e	Shrinkage %	Average %
Half Thigh (width)	24.5	20	4.5	4.5	4.5	4.5
	24.5	20.1	4.4		3.9	
	24.5	19.8	4.7		5.5	
	24.5	19.8	4.7		5.5	
	24.5	20	4.5		4.5	

The change in the width of denim garments due to bleach wash is evident from table no.8. Prior to the bleach wash, the half thigh area measured 20.5. Following the bleach wash, the measurements decreased to 20, 20.1, and 19.8. The average difference between pre-wash and post-wash measurements is 0.5, indicating a reduction in half thigh width and an increase in shrinkage after the bleach wash.

3.5 Out look

3.5.1 Enzyme-Stone wash

Figure 3.1: Effect of Enzyme-stone wash on the garments.

3.5.2 Bleach wash

Figure 3.2: Effect of Bleach wash on the garments.

Chapter -04

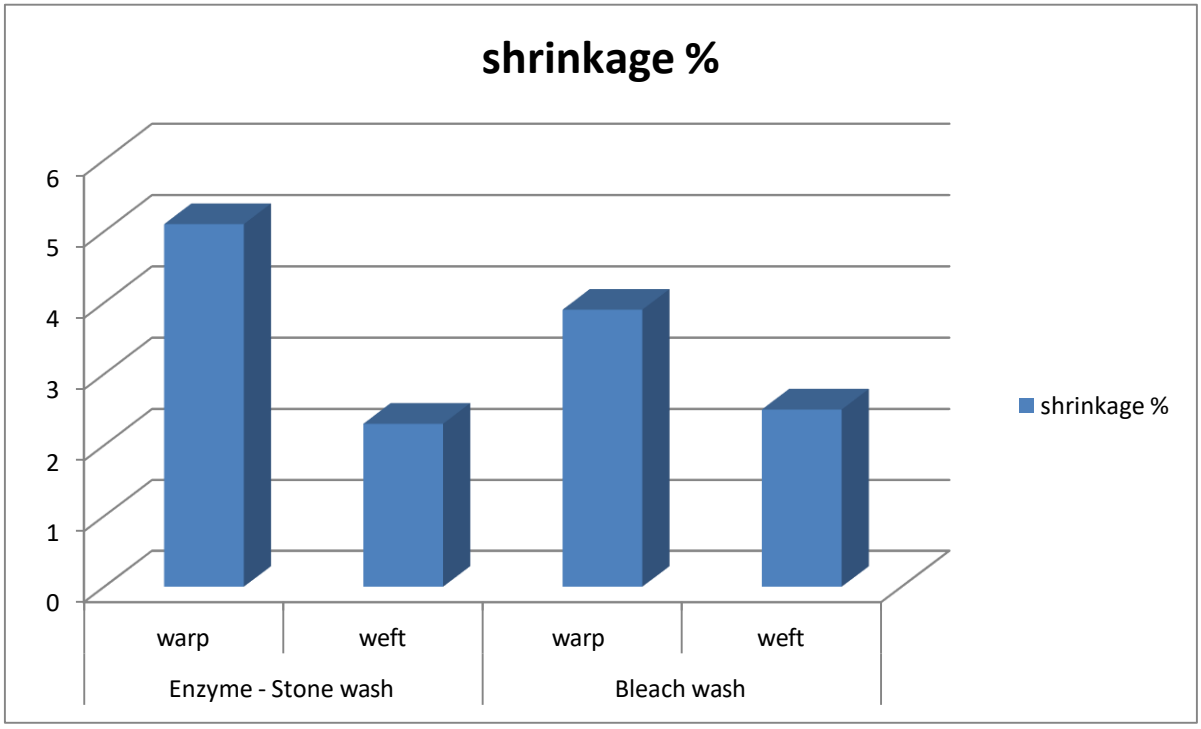
Discussion & Result

To analyze the physical attributes of denim garments treated with enzyme-stone wash and bleach wash, assessments were conducted for both warp and weft properties. Seam length measurements from Table (1) and Table (2) were employed to compute shrinkage percentages for warp-wise characteristics in both enzyme-stone and bleach washes. Variations in EPI (Ends Per Inch) and PPI (Pores Per Inch) for enzyme-stone and bleach washes were evaluated in Table (3) and Table (4). Weight fluctuations were examined in approximately Table (5) and Table (6), while weft-wise shrinkage was investigated in Table (7) and Table (8).

4.1. Shrinkage

Graph 4.1: Variations in shrinkage for enzyme- stone and bleach wash.

In this study, regarding enzyme-stone wash, the shrinkage rate is more pronounced in the warp

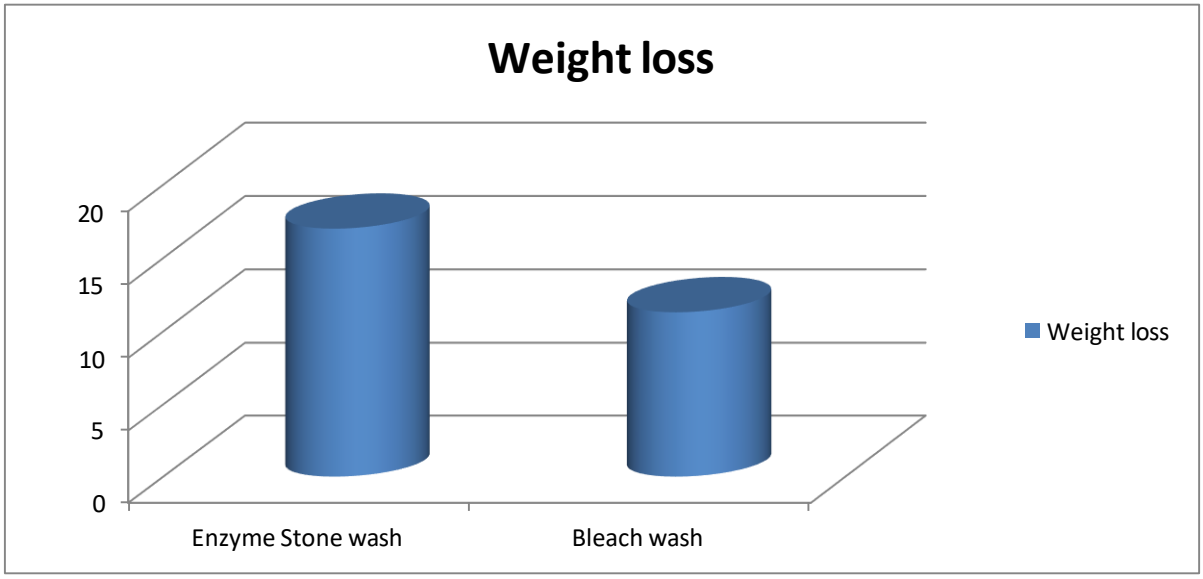


direction than in the weft direction. To be precise, the shrinkage in the warp direction amounts to roughly 5.1%, while in the weft direction, it is approximately 2.3%. Conversely, for bleach wash, the shrinkage rate in the warp direction is about 3.9%, whereas in the weft direction, it is only around 2.5%

The findings from the investigation suggest that shrinkage is more pronounced in the warp direction for both standard wash and enzyme-stone wash. Notably, the enzyme-stone wash process results in considerably greater shrinkage.

4.2. Weight loss

Enzyme-stone wash results in a greater weight loss compared to bleach wash, mainly due to increased abrasion with pumice stone. In this experiment, garments underwent a weight loss of 17g with enzyme-stone wash, whereas only 11.6g weight loss was observed with bleach wash. Enzymes specifically target the surface area of the garment, removing protruding fibers and dye substances.

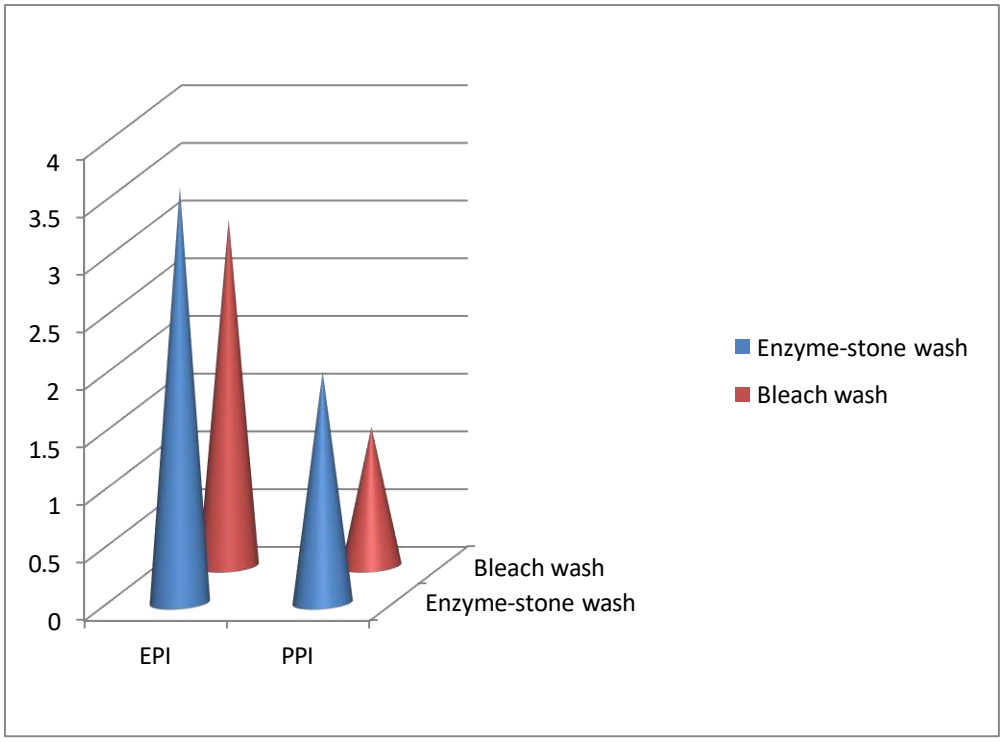


Graph 4.2: Graphical representation of weight loss over time for enzyme-stone wash and bleach wash.

During denim weaving, cotton fabrics experience tension primarily in the warp direction. Subsequently, during calendaring in the finishing section [11], additional stretching is applied to render the fabric dimensionally stable. However, when the fabric is cut and sewn for garments and undergoes washing, particularly in bleach, it tends to revert to it less stable dimensions, causing yarn contraction. This contraction is more noticeable in the warp direction than in the weft direction, leading to relaxation shrinkage. Consequently, the PPI (Pores Per Inch) increases, contributing to weight loss. Weight loss improves the fabric's hand feel and enhances abrasion resistance.

4.3. EPI & PPI

As understood, changes in EPI and PPI can occur due to shrinkage. In our investigation, we observed average EPI variations of 3.6 for enzyme-stone wash and 3 for bleach wash. Similarly, the average PPI variations were approximately 2 and 1.2 for enzyme-stone wash and bleach wash, respectively. Since enzyme-stone wash induces more shrinkage than bleach wash, it leads to more significant changes in both EPI and PPI variations. Notably, the variation in EPI is higher than that in PPI.



Graph 4.3: Variation of EPI & PPI for Enzyme-stone wash and Bleach wash

During enzyme washing, cellulose undergoes hydrolysis with the help of enzymes. Initially, these enzymes target the protruding fibers, breaking them down. Subsequently, they penetrate the yarn portion within the fabric, undergoing partial hydrolysis, which leads to a faded appearance. The addition of stones during the washing process causes uneven fading and increased weight loss, as they rub against the garments during washing, resulting in heightened abrasion and subsequent reduction in weight is gained for the using for pumice stone in enzyme wash then the bleach wash. And better hand feel provided by compact position of warp and yarn as they shrink or EPI & PPI increased.

Chapter-5

Conclusion

The quality of denim garments is predominantly influenced by the finishing process, particularly the washing stage. This report provides analytical insights into shrinkage, EPI & PPI, and weight loss of denim garments:

- Enzyme stone washing results in a noticeable reduction in garment length post-washing.
- Both bleach wash and enzyme stone wash contribute to decreased garment weight due to abrasion.
- EPI and PPI exhibit more significant increases in enzyme stone wash, although it diminishes the pilling tendency in garments.
- Shrinkage during bleach washing leads to elevated EPI and PPI values in garments.
- The alteration in garment width is mitigated as shrinkage intensifies.

Throughout my internship, I diligently gathered original data to complete this report.

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Faculty of Engineering Department of Textile Engineering Studies on the effect of Bleaching and Stone-Enzyme Wash on the characteristics of Denim Fabric Course title: Project (Thesis) Course code: TE4214 Submitted by: Md. Nasim Alam ID: 201-23-894 Md. Rakibus Sultan ID: 071-23-354 Supervised by: Mr. Tanvir Ahmed Chowdhury Assistant Professor Department of Textile Engineering Daffodil International University A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Textile Engineering Advance in Textile Wet Processing Engineering Spring 2024 DECLARATION We hereby declare that this project was conducted under the supervision of Mr. Tanvir Ahmed Chowdhury who serves as an Assistant Professor in the Department of Textile Engineering within the Faculty of Engineering at Daffodil International University. We also confirm that neither this project nor any part of it has been submitted elsewhere for the award of any degree. Md. Nasim Alam ID: 201-23-894 Department of Textile Engineering Daffodil International University Md. Rakibus Sultan ID: 071-23-354 Department of Textile Engineering Daffodil International University LETTER OF APPROVAL This project report, authored by Md. Nasim Alam (ID: 201-23-894) and Md. Rakibus Sultan (ID: 071-23-354) has been approved in Partial Fulfillment of the Requirement for the Degree of Bachelor of Science in Textile Engineering. The students completed their project work under my supervision. Throughout the research period, I found them to be sincere, hardworking, and enthusiastic. Tanvir Ahmed Chowdhury Assistant Professor Department of Textile Engineering Faculty of Engineering Daffodil International University iii | P a g e ACKNOWLEDGEMENT Firstly, we express my gratitude to Almighty Allah for His divine blessings, which have enabled us to successfully complete this project. We are thankful for the support and direction given by supervisor Tanvir Ahmed Chowdhury who serves as an Assistant Professor in the Department of Textile Engineering within the Faculty of Engineering at Daffodil International University. Our supervisor's boundless patience, scholarly guidance, constant encouragement, constructive criticism, and invaluable advice, coupled with his dedication to meticulously reviewing numerous drafts and correcting them at every stage, have been instrumental in enabling me to successfully complete this project. Finally, we would like to express a sense of gratitude to our beloved parents and industrial relatives for their mental support, strength and assistance throughout writing the project report. ABSTRACT This thesis explores the consequences of enzyme-stone wash and bleach wash on denim apparel, concentrating on factors such as size reduction, mass decrease, and alterations in physical attributes. Denim washing is a critical stage in garment manufacturing aimed at meeting consumer preferences, and comprehending these outcomes is crucial for upholding quality benchmarks. The research scrutinizes various washing methods, encompassing enzyme-stone wash and bleach wash, assessing their influence on apparel dimensions, visual appeal, and mechanical traits. By meticulously analyzing samples obtained from a denim producer, the investigation uncovers significant observations: enzyme-stone wash induces noticeable shrinkage and mass reduction, resulting in heightened EPI and PPI values, while bleach wash similarly leads to diminished garment measurements and mass loss. These findings offer beneficial insights for textile engineering professionals, assisting in refining denim washing techniques to attain desired garment finishes and effectively satisfy market requirements. Table of

..... 31 vii | P a g e List of Figures Figure 2.1: Random Bleach Wash Effect _____ 7 Figure 2.2: Random Stone enzyme stone wash _____ 8 Figure 2.3: Enzyme stone in washing machine. _____ 9 Figure 3.1: Effect of Enzyme-stone wash on the garments. _____ 23 Figure 3.2: Effect of Bleach wash on the garments. _____ 24 List of Graphs Graph 4.1: Variations in shrinkage for enzyme- stone and bleach wash _____ 26 Graph 4.2: Graphical representation of weight loss over time for enzyme-stone wash and bleach wash _____ 27 Graph 4.3: Variation of EPI & PPI for Enzyme-stone wash and Bleach wash _____ 28 viii | P a g e List of Tables Table 3.1: Effect of Garment Properties on the Application of Enzyme-Stone Wash _____ 16 Table 3.2: Effect of garments properties after Bleach wash. _____ 17 Table 3.3: The effect of Picks Per Inch (PPI) and Ends Per Inch (EPI) properties is significant when using enzyme-stone wash techniques _____ 18 Table 3.4: Impact of PPI (Pore Per Inch) and EPI (Ends Per Inch) characteristics on the application of bleach washing _____ 19 Table 3.5: Impact on the weight of denim garments due to Enzyme-Stone wash _____ 20 Table 3.6: Impact of bleach wash on the weight of denim garments _____ 20 Table 3.7: The width of denim garments is altered as a result of Enzyme-Stone wash _____ 21 Table 3.8: Change in the width of denim garments resulting from Bleach wash _____ 22 Chapter -1 Introduction 1.1 Background of the Study Denim washing involves various physical adjustments customized to meet the preferences of buyers. After denim garments are stitched, they undergo washing procedures, often resulting in alterations to their dimensions. However, it is essential to ensure that the quality and measurements of the garments meet the standards set by the buyer. To understand the changes in denim garments before and after washing, a thorough analysis is conducted, including evaluations of weight loss, fluctuations in ends per inch (EPI) and picks per inch (PPI), and shrinkage. This thesis aims to clarify the required allowances for a denim five-pocket pant before washing and offer insights into the changes in physical appearance after washing. 1.2 Objectives • Investigating the procedures utilized in Enzyme-stone wash and Bleach wash to achieve desired denim garment finishes. • Determining the extent of shrinkage experienced by garments through post-washing measurements, typically expressed as a percentage. • Detailing the crucial stages involved in planning denim garment production to meet the specific requirements and preferences of buyers. • Examining the physical characteristics of denim garments, including factors such as picks per inch (PPI), ends per inch (EPI), weight, and how the fabric behaves under different conditions. • Identifying the various patterns and types of color fading that occur in garments over time due to factors such as wear, washing, and exposure to sunlight. 1.3 Significant As a newcomer to the field of textile engineering, grasping the behavior of garments before and after washing holds immense importance. This comprehension can prove invaluable across different facets of your work, including planning, production, and satisfying the demands of buyers. Furthermore, considering your current position with a denim manufacturer, delving into the intricacies of denim washing techniques will undoubtedly enhance your prospects for career growth and advancement in the future. Chapter -2 Literature Review 2.1 Denim Wash The primary goal of enhancing denim fabric is to boost its visual appeal and durability, with a strong emphasis on ensuring comfort and softness. Current fashion trends lean towards a worn-in look, featuring faded seams, often achieved through specialized garment treatments. Dry denim is particularly attractive because it naturally fades over time, reflecting the wearer's lifestyle and activities, creating a more authentic and individualized appearance compared to artificially distressed denim. Finishing techniques are typically applied post-sewing, underscoring the importance of understanding how specific washing methods affect fabric to maintain garment quality, a consideration that starts during the garment design phase. Washing is a common practice in today's sewing industry, applied to various fabrics like cotton and linen. Recent research often examines how different finishing methods affect textile color, recognizing that consumers often base their buying decisions on color preferences. Moreover, the mechanical properties of the fabric play a crucial role in both the durability and aesthetic appeal of garments, significantly influencing their wear ability and enjoyment. Legend has it that the term "jean" originated from "Genoa," referring to the fabric used by sailors from Genoa in their trousers. Initially, this fabric was a rough blend of cotton, wool, and/or linen from Italy, following the tradition of naming materials after their place of origin. By the late 16th century, jeans were being produced in Lancashire, England, evolving to 100% cotton composition by the 18th century. Today, "jeans" typically describe garments with five pockets (two in front, two in back, and a small change pocket), made from various fabrics like corduroy, twills, or bull denim. Well-known brands like Levi's and Wrangler dominate this field. In contrast, the term "denim" has its roots in late 16th-century France, where a fabric called "serge de Nimes" (twill from Nimes) became popular. There's uncertainty about whether "denim" directly originated from this French fabric or the twill known as "nim," also used in France at that time. "Serge de Nimes" was a blend of silk and wool, leading some historians to question if it truly gave rise to modern-day denim. Nonetheless, both jeans and denim fabrics gained popularity, with denim being the stronger and more expensive option. Notably, denim was woven with one colored thread (the warp) and the other white (the weft), while jean was woven with two colored threads, distinguishing the two fabrics. Denim was mainly used for workwear, while jeans were preferred for lighter clothing with less durability requirements. 5 | P a g e By the late 19th century, American weavers adopted the twill style of European denim, utilizing locally available cotton fibers. Despite frequent washes, the material earned a reputation for its durability and resilience. 2.1.1 Bleach Wash The traditional method of bleaching involved laying fabrics and cloth outdoors, allowing them to naturally whiten under the sun and water. However, the development of modern bleaches is attributed to breakthroughs made by 18th-century scientists. Swedish chemist Carl Wilhelm Scheele's discovery of chlorine, coupled with French scientist Claude Berthollet's understanding of its bleaching properties, led to the creation of sodium hypochlorite, commonly referred to as Eau de Javel or Javel water, named after the Parisian area where it was initially produced. Antoine Germain Labarraque also made significant contributions by uncovering the disinfecting properties of hypochlorites. Scottish chemist and industrialist Charles Tennant further propelled the field forward by developing solutions of calcium hypochlorite and solid calcium hypochlorite, known as bleaching powder. In 1818, Louis Jacques Thénard synthesized hydrogen peroxide by reacting barium peroxide with nitric acid. Although hydrogen peroxide was first utilized for bleaching in 1882, it didn't gain widespread commercial importance until after 1930. Sodium perborate, another laundry bleach, had been in use in Europe since the early 20th century but didn't gain popularity in North America until the 1980s. Figure 2.1: Random Bleach Wash Effect [13] 2.1.2 Enzyme wash Enzyme wash is a sustainable garment washing technique, favored in the industry due to enzymes' natural origins. It's commonly used to counteract the adverse effects of stone washing. In this process, enzymes break down the surface cellulose fibers of the fabric, which are subsequently washed away. The enzyme action can be stopped by adjusting the bath's alkalinity or temperature once the desired color is reached. During enzyme washing, some indigo dye and cellulose fibers from the fabric's surface are also removed. The final stages of enzyme washing typically include rinsing and softening to complete the process. Figure 2.2: Random Stone enzyme stone wash [13] 2.1.3 Stone wash Stone washing is a popular technique, especially among young people, known for giving garments, typically cotton, a distinctive worn-in appearance. This process specifically targets denim garments, utilizing special stones, often pumice stones, to achieve a heavily washed effect. The primary purpose of stone washing is to create a fading effect on denim items. White stones, combined with enzymes during washing, play a crucial role in achieving the desired faded look on the garment's surface. As the fabric interacts with the stones during washing, the rubbing action contributes to the fading of the color. Furthermore, stone washing enhances the softness and flexibility of fabrics like canvas and denim, which tend to be stiff and rigid. It's worth noting that while stone washing can lead to color fading in jeans, it also involves increased water usage during the washing process. Figure 2.3: Enzyme stone in washing machine. CHAPTER – 03 Survey Details, Methods and Materials 3.1 Materials 3.1.1 Garments Samples Garment samples collected from Creative Wash Ltd., Ha-Meem Group. Garments brought for different wash, Enzyme-stone wash and bleach wash. 3.1.2 Chemicals SF Ultra (Enzyme), Acetic Acid, Anti-back stain,

Bleaching A g e n t , Stone, Soda Ash, Sodium Metabisulfite, softener &De-sizing agent. 3.1.1 Washing Machine Name: DANIS front loading Washing Machine, M/C capacity: 500 kg, heating source: Steam. 3.2 Methods 3.2.1 Enzyme Stone wash Process flow chart for stone enzyme wash: De-sizing Hot Wash Stone enzyme wash Bleaching Neutral wash Softening Hydro extracting Drying Delivery 3.2.2 Bleach wash Process flow chart of bleach wash: De-sizing Hot Wash Bleaching Neutral wash Softening Hydro-extracting Drying Delivery 3.2.3 Drying Hydro-extraction = 10 minutes, then drying = 15 minutes at 80°C. 3.2.4 Determination of Shrinkage % The shrinkage percentage was determined using the following formula: S% = $\frac{A-A}{A}$ ×100 A A = original dimension. B = dimension after treatment 3.3 Recipe Calculation 3.3.1 Enzyme-Stone wash Firstly, De-sizing- Weight of Material ....60 kg Liquor Ratio.....1: 10 Water ..... 600 litter Temperature .... 60ºC Anti-back stain ..... 600 gm. De-sizing Agent (SUPRADET NF)..... 300 gm Second step: Hot wash Liquor Ratio.....1: 10 Water.....600 litters Temperature.....60ºC Time.....5 min Third step: Stone-Enzyme Liquor Ratio.....1: 10 Water.....600 litters Stone (Near Stone Mineral) ..... 30 KG (Half of Material Weight) Enzyme (SF Ultra) ..... 900 gm. Acetic Acid.....320 gm. Anti-back stain... ..... 420 gm. Temperature..... 45ºC Total Time... .....65 min Fifth step: Neutral Liquor Ratio.....1:10 Water.....600 liters Sodium Metabisulfite .....1800 gm. Temperature..... 45ºC Time... ..... 10 min Softening: Time.....10 min Liquor ratio.....1:10 Water..... .....600 L Acetic Acid... ..... 320gms Softening agent (Asucell WF) ..... 600 gm. 3.3.2 Bleach washing Firstly, De-sizing Weight of Material ..... 60 kg Denim Pant. (Long) Liquor ratio.....1: 10 Water. ..... 600 liters. Temperature..... 60° C De-sizing agent (SUPRADET NF) .....600 gm. Anti-back stain ..... 600 gm. Time. .....30 min. Second Step: Hot Wash Liquor Ratio.....1: 10 Water.....600 liters. Temperature..... 65°c. Time. ..... 5 min. Third Step: Bleaching Liquor Ratio .....1: 10 Water..... 600 liters. Bleaching Agent (Calcium Hypo chloride) ..... 6000 gm. Na2CO3.....3000gm. Temperature ..... 60°c. Time..... 20 minutes Fourth Step: Neutral Wash Liquor Ratio.....1: 10 Water..... 600 liters. Sodium Metabisulfite..... 1800 gm Temperature..... 40°c. Time..... 10 min. Fifth Step: Softening Liquor Ratio.....1:10 Water ..... 600 liters. Citric Acid ..... 360 gm. Softener (ASUCEL WF)..... 600 gm. Time. ....5 min 15 | P a g e 3.4 Survey Report 3.4.1 Determine the Inseam Length & Side seam length The seam lengths of the sample garments were assessed using a measuring tape in centimeters (cm). Table 3.1: Effect of Garment Properties on the Application of Enzyme-Stone Washing. Calculated Area Pre-Wash Post- Wash Difference Average Shrinkage % Average % Side Seam 92 92 92 92 92 89.5 89 89.5 89.5 89 4.5 4 4.5 4.5 4 4.3 4.81275225 4.255663149 4.812811225 4.812835825 4.255341149 4.812834 Inseam 75 75 75 75 75 66 66 66.5 66 66 4 4 3.5 4 4 3.9 5.405865405 5.4054052205 4.6979145577 5.525405405 5.4054055845 5.405405 The table shown above demonstrates that enzyme-stone washing brings about a significant change in the properties of the garment. Notably, there is a considerable alteration observed in garment shrinkage, particularly in the side seam direction, where shrinkage reaches up to 4.8%, and in the inseam direction, where shrinkage reaches up to 5.4%. In side seam areas. The mean variance observed between measurements taken before and after washing. is 4.3, while in inseam areas, it is 3.9. This implies a reduction in the garment's length following washing. Table 3.2: Impact of clothing characteristics following a bleach wash. Calculated Area Before Wash After Wash Difference Average Shrinkage % Average % Side Seam Area 95 95 95 95 95 86.5 86 86.3 86.5 86 8.5 9 8.7 5.5 9 8.7 4.42775 4.2791 4.69641 4.42775 4.16791 4.5443 Inseam Area 75 75 75 75 75 67.5 67 67.5 67 67 5.5 8 7.5 8 8 7.8 3.703704 4.41194 3.70704 4.47194 4.47694 3.47704 The table presented above illustrates that bleach washing leads to a notable transformation in the properties of the garment. Particularly noteworthy is the significant change observed in garment shrinkage, especially in the side seam direction, where warp shrinkage measures up to 4.04%, and in the inseam direction, where warp shrinkage reaches up to 3.7%. In side seam areas, the average difference between pre-wash and post-wash measurements is 3.7, while in inseam areas, it is 2.8. This confirms that the garment's length decreases after undergoing bleach washing. 3.4.2 Determine the Picks Per Inch (PPI) and Ends Per Inch (EPI) Draw a square with sides measuring one inch on the sample and count the number of warp ends and weft picks within that square. Table 3.3: The effect of Picks Per Inch (PPI) and Ends Per Inch (EPI) properties is significant when using enzyme-stone wash techniques. Measurement Area Before Wash After Wash Difference Average PPI 48 48 48 48 48 50 50 51 49 50 2 2 3 1 2 2 EPI 92 92 92 92 92 96 96 95 95 96 4 4 3 3 4 3.6 The provided table suggests that after garment washing, the Picks Per Inch (PPI) increased, with an average rise of up to 2. Specifically, the PPI number elevated from 48 before washing to 50 afterward. Likewise, the Ends Per Inch (EPI) also experienced an increase post-wash, with an average difference of up to 3.6. Prior to washing, the EPI stood at 92, ascending to thereafter. This indicates that after enzyme-stone washing denim garments, both EPI and PPI numbers tend to increase, mainly due to shrinkage. Table 3.4: Impact of PPI (Pore Per Inch) and EPI (Ends Per Inch) characteristics on the application of bleach washing. Measurement Area Before Wash After Wash Difference Average PPI 48 48 48 48 48 48 50 49 50 49 49 2 1 2 1 1 1.4 EPI 92 92 92 92 92 95 94 95 95 96 3 2 3 3 4 3 The data from the table indicates a clear rise in EPI (Ends Per Inch) following the bleach garment wash. On average, there is a 3-unit increase in EPI, shifting from a pre-wash value of 92 to a post- wash value of 95. Similarly, the PPI (Pore Per Inch) also sees an uptick after the garment wash, with an average difference of 1.4 units. Initially, the PPI was noted at 48 before washing, which then rose to 50. It's essential to note that the increase in both EPI and PPI numbers after the bleach wash of denim garments is somewhat dampened due to shrinkage. . 3.4.3 Determine the weight/ Mass The weight of the garments was assessed manually using an electric balance, with measurements recorded in grams (g). Table 3.5: Impact on the denim garments weight due to Enzyme-Stone wash Calculated Area Pre-Wash Post-Wash Difference Average Garments weight 600 600 600 605 610 585 580 585 590 590 15 20 15 15 20 17 The alterations in garment weight (GSM) before enzyme-stone washing, as depicted in the figure above, are 600, 605, and 610. Post enzyme-stone washing, the weights are recorded as 585, 590, and 590, respectively. The differences between pre-wash and post-wash are 15, 15, and 20, with an average difference of 17. This demonstrates that after enzyme-stone wash, the weight of the denim garment is reduced. Table 3.6: Impact of bleach wash on the weight of denim garments. Calculated Area Pre-Wash Post Wash Difference Average Weight of the garments 585 580 585 590 590 575 567 570 580 580 10 13 15 10 10 11.6 The provided details suggest a decrease in the weight of denim garments, measured in GSM (Grams per Square Meter), after undergoing bleach washing. Prior to the bleach wash, the garment weights were 585, 580, and 590 GSM. Following the bleach wash, these weights decreased to 575, 567, and 580 GSM, respectively. The differences between the pre-wash and post-wash weights were 10, 13, and 10 GSM, resulting in an average difference of 11.6 GSM. This indicates that the weight of the denim garments tends to decrease after undergoing bleach washing, 3.4.4

Measurement of Garment Body Dimensions (Half Thigh) Garment body width was measured using a measuring tape in centimeters (cm). Table 3.7: The width of denim garments is altered as a result of Enzyme-Stone wash. Calculated Area Pre Wash Post Wash Difference (Cm) Average Shrinkage % Average % 24.5 22 2.5 2.272727273 Half Thigh (width) 24.5 24.5 22 21.4 2.5 3.1 2.72 2.272727273 5.140186916 2.272727 24.5 21.5 3 4.651162791 24.5 22 2.5 2.272727273 The changes in the width of denim garments resulting from the enzyme stone wash are evident from table no.7. Initially, the half thigh area measured 22.5 before the enzyme stone wash. However, after the wash, the half thigh measurements decreased to 22 and 21.5. The average difference between pre-wash and post-wash measurements is 0.72, indicating a reduction in half thigh width and an increase in shrinkage following the enzyme stone wash. Table 3.8: Change in the denim garments Width resulting from Bleach wash Calculated Before After Difference Average Shrinkage Average Area Wash Wash e e % % Half Thigh (width) 24.5 24.5 24.5 24.5 24.5 20 20.1 19.8 19.8 20 4.5 4.4 4.7 4.7 4.5 4.5 4.5 3.9 5.5 5.5 4.5 4.5 The change in the width of denim garments due to bleach wash is evident from table no.8. Prior to the bleach wash, the half thigh area measured 20.5. Following the bleach wash, the measurements decreased to 20, 20.1, and 19.8. The average difference between pre-wash and post-wash measurements is 0.5, indicating a reduction in half thigh width and an increase in shrinkage after the bleach wash. 3.5 Out look 3.5.1 Enzyme-Stone wash Figure 3.1: Effect of Enzyme-stone wash on the garments. 3.5.2 Bleach wash Figure 3.2: Effect of Bleach wash on the garments. Chapter -04 Discussion & Result To analyze the physical attributes of denim garments treated with enzyme-stone wash and bleach wash, assessments were conducted for both warp and weft properties. Seam length measurements from Table (1) and Table (2) were employed to compute shrinkage percentages for warp-wise characteristics in both enzyme-stone and bleach washes. Variations in EPI (Ends Per Inch) and PPI (Pores Per Inch) for enzyme-stone and bleach washes were evaluated in Table (3) and Table (4). Weight fluctuations were examined in approximately Table (5) and Table (6), while weft-wise shrinkage was investigated in Table (7) and Table (8). 4.1. Shrinkage Graph 4.1: Variations in shrinkage for enzyme- stone and bleach wash. In this study, regarding enzyme-stone wash, the shrinkage rate is more pronounced in the warp shrinkage % 6 5 4 3 shrinkage % 2 1 0 warp weft warp weft Enzyme - Stone wash Bleach wash direction than in the weft direction. To be precise, the shrinkage in the warp direction amounts to roughly 5.1%, while in the weft direction, it is approximately 2.3%. Conversely, for bleach wash, the shrinkage rate in the warp direction is about 3.9%, whereas in the weft direction, it is only around 2.5% The findings from the investigation suggest that shrinkage is more pronounced in the warp direction for both standard wash and enzyme-stone wash. Notably, the enzyme-stone wash process results in considerably greater shrinkage. 4.2. Weight loss Enzyme-stone wash results in a greater weight loss compared to bleach wash, mainly due to increased abrasion with pumice stone. In this experiment, garments underwent a weight loss of 17g with enzyme-stone wash, whereas only 11.6g weight loss was observed with bleach wash. Enzymes specifically target the surface area of the garment, removing protruding fibers and dye substances. Weight loss 20 15 Weight loss 10 5 0 Enzyme Stone wash Bleach wash Graph 4.2: Graphical representation of weight loss over time for enzyme-stone wash and bleach wash. During denim weaving, cotton fabrics experience tension primarily in the warp direction. Subsequently, during calendaring in the finishing section [11], additional stretching is applied to render the fabric dimensionally stable. However, when the fabric is cut and sewn for garments and undergoes washing, particularly in bleach, it tends to revert to it less stable dimensions, causing yarn contraction. This contraction is more noticeable in the warp direction than in the weft direction, leading to relaxation shrinkage. Consequently, the PPI (Pores Per Inch) increases, contributing to weight loss. Weight loss improves the fabric's hand feel and enhances abrasion resistance. 4.3. EPI & PPI As understood, changes in EPI and PPI can occur due to shrinkage. In our investigation, we observed average EPI variations of 3.6 for enzyme-stone wash and 3 for bleach wash. Similarly, the average PPI variations were approximately 2 and 1.2 for enzyme-stone wash and bleach wash, respectively. Since enzyme-stone wash induces more shrinkage than bleach wash, it leads to more significant changes in both EPI and PPI variations. Notably, the variation in EPI is higher than that in PPI. 4 3.5 3 2.5 2 1.5 1 0.5 0 Bleach wash Enzyme-stone wash Enzyme-stone wash Bleach wash EPI PPI Graph 4.3: Variation of EPI & PPI for Enzyme-stone wash and Bleach wash During enzyme washing, cellulose undergoes hydrolysis with the help of enzymes. Initially, these enzymes target the protruding fibers, breaking them down. Subsequently, they penetrate the yarn portion within the fabric, undergoing partial hydrolysis, which leads to a faded appearance. The addition of stones during the washing process causes uneven fading and increased weight loss, as they rub against the garments during washing, resulting in heightened abrasion and subsequent reduction in weight is gained for the using for pumice stone in enzyme wash then the bleach wash. And better hand feel provided by compact position of warp and yarn as they shrink or EPI & PPI increased. 28 | P a g e Chapter-5 Conclusion The quality of denim garments is predominantly influenced by the finishing process, particularly the washing stage. This report provides analytical insights into shrinkage, EPI & PPI, and weight loss of denim garments: • Enzyme stone washing results in a noticeable reduction in garment length post-washing. • Both bleach wash and enzyme stone wash contribute to decreased garment weight due to abrasion. • EPI and PPI exhibit more significant increases in enzyme stone wash, although it diminishes the pilling tendency in garments. • Shrinkage during bleach washing leads to elevated EPI and PPI values in garments. • The alteration in garment width is mitigated as shrinkage intensifies. Throughout my internship, I diligently gathered original data to complete this report. References 1. https://www.researchgate.net/publication/303205771_MNF_Technology_of_industr ial_denim_washing_review 2. https://textilelearner.net/bleach-wash-of-woven-denim/ 3. https://garmentsmerchandising.com/flow-chart-of-enzyme-washing-process/ 4. https://www.textileblog.com/stone-washing-process-an-overview/ 31|Page Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone - Enzyme Wash on the characteristics of Denim fabric 2024 Studies on the effect of Bleaching and Stone -

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