



Comparative Performance Analysis Between Potassium Permanganate (KMnO₄) Spray and Alternative PP (KMnO₄) Spray on Various Properties of Denim Fabric

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To cite this article:

Md. Zayedul Hasan, Md. Rokonuzzaman, Abdur Razzaque, Md. Mubashwir Moshwan, Md. Hasan Reza, Sohel Rana, Bristi Basak, A. K. M. Ayatullah Hosne Asif. Comparative Performance Analysis Between Potassium Permanganate (KMnO₄) Spray and Alternative PP (KMnO₄) Spray on Various Properties of Denim Fabric. *International Journal of Industrial and Manufacturing Systems Engineering*. Vol. 6, No. 4, 2021, pp. 59-65. doi: 10.11648/j.ijimse.20210604.11

Received: September 24, 2021; Accepted: October 18, 2021; Published: November 19, 2021

Abstract: The growth of denim items in global market is rising steadily. The aesthetic appearance and design of denim are one of the causes for this increase in demand. This study was attempted to compare the performance relating to potassium permanganate spray and alternative potassium permanganate spray on denim fabric. In this research; after the application of de-sizing, stone enzyme, bleaching, neutralization processes; stretch denim fabric was all over sprayed with potassium permanganate along with alternative potassium permanganate in varying concentration. After neutralization and drying, the different features of denim fabric was explored accordingly. For comparison, industrially performed potassium permanganate concentration solution of 2%, 3%, and 5% were applied as well as alternative potassium permanganate concentration solution of 60%, 80%, and 100% were also utilized. After applying those chemicals, samples were neutralized and dried in a steam dryer. Finally, the mechanical properties like fabric tensile strength, tear strength were determined respectively. All of the tests were carried out according to ISO standards. The physical properties like color fastness to rubbing, color fastness to wash, GSM, pH values were also checked. Specially EIM (environmental impact) was also investigated; in that case, samples treated with potassium permanganate spray exhibited poor performance than the alternative potassium permanganate sprayed sample. In the case of alternative potassium permanganate spray after increasing the concentration of chemical, tensile and tear strength decreasing percentage was observed almost similar, while in the case of potassium permanganate spray, a decrease relating to tensile and tear strength properties were observed after increasing the chemical concentration respectively. On the other hand, the grading related to color-fastness to rubbing was better. But there was no significant change was observed for the grading related to color fastness to washing for samples treated with potassium permanganate and alternative potassium permanganate spray. In terms of EIM investigation, samples treated with alternative potassium permanganate spray showed satisfactory values in accordance with worker and eco-friendly aspects.

Keywords: Denim, Potassium Permanganate Spray, Alternative Potassium Permanganate Spray, Color Fastness, Environmental Impact

1. Introduction

Garments made of denim fabric are very popular nowadays [1-2]. Denim is thought to be one of the world's oldest fashion items. Denim fabric is constructed of 100% cotton twill weave structure and is quite pleasant to wear. Jeans, coats, shirts,

handbags, bags, and a variety of others fashion items for men and women of all ages are made from denim [3-5]. Denim garments provide an aesthetic, attractive look through various washing process, which is one of the reasons to gain popularity among the current fashion worlds than other items [6-8]. There are two types of denim washing process namely wet process

and dry process [9]. These types of washing are done not only for softness but also for comfort.

The aspects of different denim washing process comprise enzyme wash, bleach wash, stone wash, and so on [10]. Studies had been conducted on the effects of bleaching (potassium permanganate) on denim clothing [11]. With the assistance of a regular spray gun, potassium permanganate solution is sprayed on the fading areas of denim clothing while spraying potassium permanganate over denim creates a brilliant appearance on the hand sand area [12]. When this potassium permanganate is sprayed on clothing, it appears pink at first but quickly becomes muddy. After potassium permanganate spray, the garment is hung out to dry in the open, and it is deemed ready for the next procedure when the potassium permanganate becomes entirely muddy [13]. Any chemical which has an effect on the environment, all the chemicals in washing have a detrimental effect on the environment and the body of the workers [14]. While potassium permanganate has a devastating effect on the environment, various studies have shown that people who have worked in this potassium permanganate spray section for a long time suffer from various physical problems (such as asthma, itching, eye irritation) [15-16]. There is no denying of the fact that, contemporary period is well known and well understandable for sustainability and environmental sensitivity, all customers are concerned about the environmental impact of their purchases regarding textile related products with special focus on sustainability [17-20].

Due to the negative consequences of potassium, different chemical firms have been attempting for a long time to develop not only chemical but also process improvement those will perform the same function [21-24]. For that perspective, a new kind of bleaching agent that works in the fading like potassium is necessary relating to mitigate the harmful effects of chemical [25-27]. A liquid supplementary solution specifically intended to decolorize indigo and Sulphur dyestuffs on denim fabric. But so far, no one has yet investigated the application of this chemical how much deviates the physical and mechanical properties of denim garments. According to this current research work, the use of alternative potassium permanganate spray portrayed good performance than potassium permanganate spray, which is both environmentally and health-hazardous. Therefore, the aim of this research was to understand the use of potassium permanganate spray and alternative potassium permanganate spray's effect on different changes of physical and mechanical properties of denim garments.

2. Materials and Method

2.1. Materials

2.1.1. Fabric

For conducting this research work; 99% of cotton, 1% of elastane indigo dyed stretch denim fabric was used. The fabric GSM (gram per square meter) was 374 (Before wash), 3/1 twill fabric; width 57 inch.

2.1.2. Chemicals

Soda ash, NTM (Anti-back staining agent), Pumice stone, Ecozyme V-max, KCI (Calcium Hypochlorite), Hydrogen Peroxide, Potassium Permanganate, Phosphoric Acid, Hydrogen Peroxide, Alternative Potassium Permanganate (Oximagic), Oximagic Activator, Acetic Acid, Sodium Meta Bisulfite were used for this study.

2.1.3. Experimental Instruments

For this experiment; washing machine, hydro extractor machine, tumble dryer machine, spray gun, spray chamber, fabric GSM cutter, tensile strength testing machine, tear strength testing machine, crock-meter for testing the color fastness to perspiration, electronic balance and fabric pH meter were used.

2.2. Methodology

2.2.1. Working Flow Diagram of Washing Process

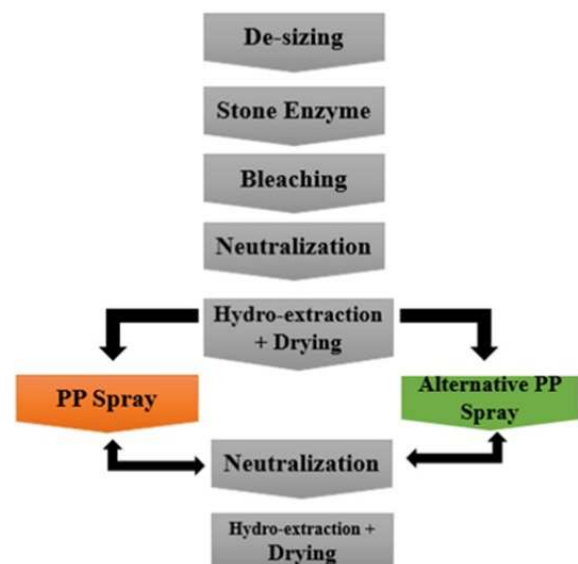


Figure 1. Process flow diagram of denim washing process.

2.2.2. Testing of Tensile Strength

To conduct experimental testing, tensile strength testing was conducted according to ISO 13934 [28]

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.

2.2.3. Testing of Tear Strength

The testing of tear strength of stretch denim fabric samples treated with super white washing process was measured according to the standard of ISO 13937-1 [29].

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.

2.2.4. Measurement of Color Fastness Properties

For this research work, following color fastness tests were done accordingly [30-31]:

- 1) Color fastness to wash (Method: ISO 105 C10);
- 2) Color fastness to rubbing (Method: ISO 105 X12).

2.2.5. GSM Measurement of the Sample

At first, cut the sample with the help of GSM cutter and cut pieces; weight was measured by electronic balance. The cutter allows us to cut out a perfect circle with an area of 100 cm. By using formula

$$\text{GSM} = \frac{\text{weight of the sample in gram} \times 10.000}{\text{area of sample in cm}^2}$$

GSM was calculated accordingly.

2.2.7. Experimental Approach of PP and Alternative PP Spray

Table 1. Experimental Approach of PP and alternative PP spray.

Process	Sample	Concentration	Chemical Composition	Spray N.D	Time
Application of PP spray	Sample-1	2%	100 ml water + 2 gm Potassium+ 2 gm Phosphoric acid	C	10s
	Sample-2	3%	100 ml water + 3gm Potassium+ 2 gm Phosphoric acid	C	10s
	Sample-3	5%	100 ml water + 5gm Potassium+ 2 gm Phosphoric acid	C	10s
Application of alternative PP spray	Sample-1	60%	50 ml Oximagic solution + 33.3 ml water	C	10s
	Sample-2	80%	50 ml Oximagic solution + 12.5 ml water	C	10s
	Sample-3	100%	85 ml Oximagic+ 15 ml Oximagic activator	C	10s

Here, C- means constant.

3. Results and Discussion

3.1. Determination of Tensile Strength for Different Denim Samples in Warp and Weft Direction Treated with PP and Alternative PP Spray

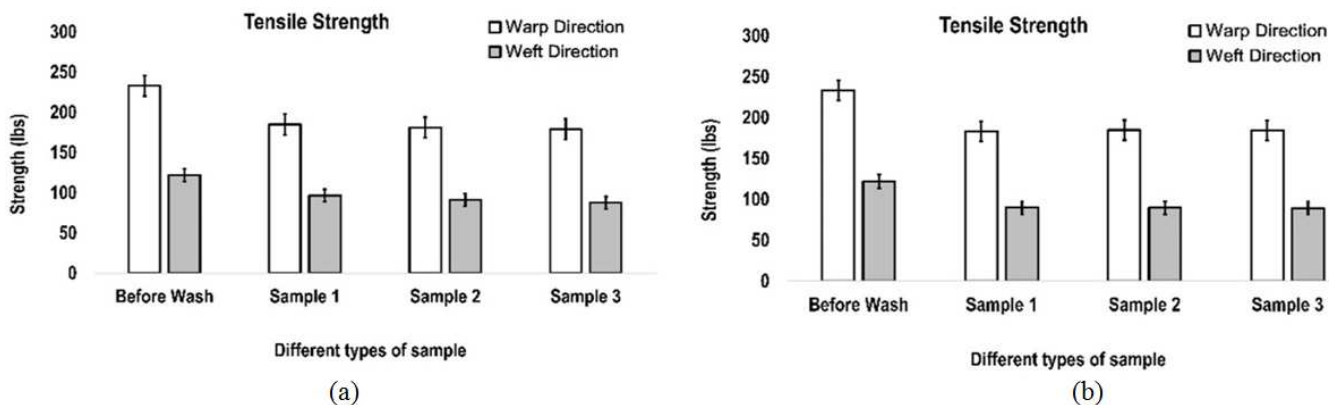


Figure 2. Determination of tensile strength of different denim samples in warp and weft direction treated with PP spray (a) and alternative PP spray (b).

The following figures represent about the effect of concentration variation on tensile strength properties of potassium permanganate spray and alternative potassium permanganate spray treated denim fabric in both warp and weft direction. These bar diagrams reveal that there was a gradual falling of tensile strength in both the warp and weft direction with the increase of solution concentration up to a

2.2.6. Environmental Impact Measurement (EIM)

Environmental sustainability is an essential component of apparel production. Environmental effect in textile manufacturing, particularly in the manufacturing of denims has many different attributes. Through all stages of denim manufacture, from cotton growing to completing wearable garments, all have an influence on the environment. Moreover, the washing of denim has a direct impact on the environment due to its impact on water resources, chemical discharge and many other pollutants. The EIM Software (Environmental Impact Measurement) software from JEANOLOGIA was used in this experiment for better understanding about the environmental impact in the following individual categories:

- 1) Water consumption;
- 2) Energy consumption;
- 3) Chemical product used;
- 4) Worker health.

certain stage. But for alternative potassium permanganate spray, it showed that the gradual decreasing rate was lower according to increasing the concentration. Alternative PP spray contains Sulfuric acid and Ammonium cerium (IV) sulfate which caused less degradation effect on cellulose than the Potassium Permanganate spray which contains the manganese caused highly degradation to cellulose, that's why

though tensile strength decreases in both samples, but decreasing rate of tensile strength for potassium permanganate spray was more significant due to the increase of concentration. Moreover, the denim fabric was manufactured in three-up, one-down structure, which means the warp yarn are more apparent in the front of the fabric and

the weft is less. The chemical was sprayed on the front side of the garment during spraying. As a result, weft yarn had a lower chemical penetration and was less impacted during spraying, resulting in less damage than warp yarns. As a result, the decreasing rate was seen in the weft was comparably lower than the warp.

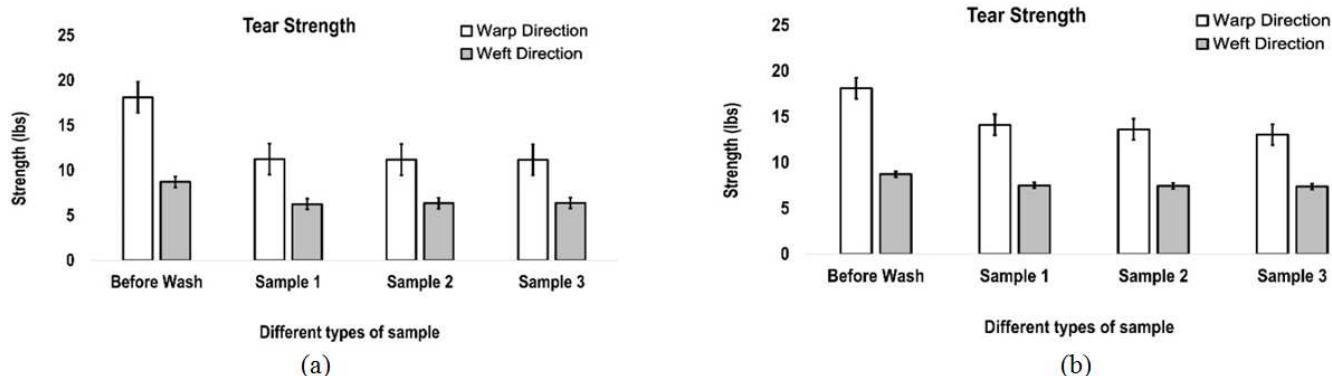


Figure 3. Impact on tear strength for different denim samples in warp and weft direction treated with PP spray (a) and alternative PP spray (b).

3.2. Impact on Tear Strength for Different Denim Samples in Warp and Weft Direction Treated with PP and Alternative PP Spray

The following figures represent about the variation of chemical concentration on tear strength properties of potassium permanganate spray and alternative potassium permanganate spray treated denim fabric in both warp and weft direction. These diagrams reveal that tear strength for PP spray and alternative PP in warp direction was decreasing accordingly, but for alternative potassium permanganate spray; decreasing rate was lower. Potassium permanganate contains manganese which is responsible for the damage of surface of the yarn and more cellulose degradation was occurred during this operation, finally it made fiber weak,

which led to a decrease in tear strength which was almost 37-38% decreasing during increasing the concentration of potassium permanganate. In case of alternative PP spray, sulphuric acid and aluminum cerium (IV) sulfate degraded cellulose less amount; so, tear strength decreasing rate was founded almost 10-15% lower than PP. Although the solution concentration had higher impact on the denim fabric's front side (warp yarns). When potassium permanganate and alternative PP alternative potassium permanganate were sprayed, it degraded the color of these yarns and destroyed the strength of the yarn through cellulose soiling; not only in the warp yarns, but also lower amounts of chemicals entered the weft yarn of the fabric, which reduces also the tear strength of weft yarn.

Table 2. Effect of PP and Alternative PP Spray on Color Fastness to Rubbing.

Parameter	Sample type	Before treatment		After treatment	
		Dry	Wet	Dry	Wet
Application of PP Spray	Sample-1	3-4	2	4	2
	Sample-2			4-5	2-3
	Sample-3			4	3
Application of Alternative PP Spray	Sample-1	3-4	2	4	2
	Sample-2			4	2-3
	Sample-3			4-5	3

3.3. Determination of Color Fastness to Rubbing for Different Denim Samples Treated with PP and Alternative PP Spray

From the above table, it is showed that the colorfastness to rubbing for both samples were almost similar, because potassium permanganate and alternative potassium permanganate are both powerful oxidative agents, spraying

these two on a denim fabric resulted good grading for dry state related to color-fastness to rubbing value. It was determined that after increasing the concentration of potassium permanganate spray on the denim, the color fastness to rubbing grade was continued to improve. In the case of alternative potassium permanganate spray, almost similar grading was observed.

Table 3. Effect of PP and Alternative PP Spray on color fastness to washing.

Parameter	Sample type	Grade (Change in Color)	Grade (Color Staining on Multi Fiber)					
			Acetate	Cotton	Nylon	Polyester	Acrylic	Wool
Application of PP Spray	Sample-1	3	3	3	3-4	3	3	3
	Sample-2	3-4	3	3-4	3	3-4	3-4	3-4
	Sample-3	3-4	3-4	3-4	3-4	3-4	3-4	3-4
Application of Alternative PP Spray	Sample-1	4	3	4	3	4	4	4
	Sample-2	4	3-4	4	3-4	4	4	4
	Sample-3	4	3-4	4	4	4	4-5	4

3.4. Determination of Color Fastness to Washing for Different Denim Samples Treated with PP and Alternative PP Spray

Above table showed that the color fastness to wash for both potassium permanganate and alternative potassium

permanganate spray treated samples were almost similar, because these two compounds are bleaching agents, their color fastness to washing significantly improved from moderate to good. And there was no significant change was observed for color fastness to washing.

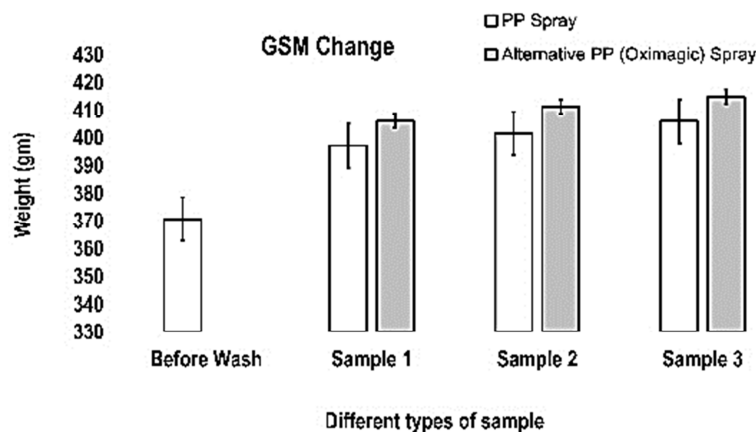
Table 4. Analysis of pH rate fluctuation after application of pp and alternative pp spray.

Parameter	Sample type	Value
Application of PP Spray	Sample-1	5.5
	Sample-2	5.7
	Sample-3	5.8
Application of Alternative PP Spray	Sample-1	5.1
	Sample-2	5.1
	Sample-3	5.2

3.5. Determination of pH for Different Denim Samples Treated with PP and Alternative PP Spray

Above table showed that pH rate was lower for both cases relating to PP and alternative potassium permanganate spray, but in PP spray increasing the concentration, pH rate was

increased accordingly but for alternative potassium permanganate spray; it showed lower rate relating to increasing the concentration. In alternative potassium permanganate spray, it contains sulphuric acid which tends to generate more hydrogen ion, that's why value of the pH was lower than the PP spray.

**Figure 4.** Impact of PP and Alternative PP Spray on GSM Properties.

3.6. Determination of GSM Change for Different Denim Samples Treated with PP and Alternative PP Spray

The following chart denotes that there was a gradual increase of GSM properties, alternative potassium permanganate spray treated sample showed the rate of increasing about GSM was higher than the PP spray. In the case of alternative potassium permanganate spray, the degradation of the fiber was less, resulting in more grams per

square meter. A little bit of color was lost as a result of PP spray and alternative potassium permanganate spray and yarn strength was also reduced, but one thing remained; after washing, the warp and weft yarn were squeezed or stretched. Shrinkage was observed experimentally, which increased the density and the GSM of denim fabric.

3.7. Sustainability Test (EIM Score)

The Environmental Impact Measurement of experimented

sample was determined after potassium permanganate spray and alternative potassium permanganate spray.

The EIM score during a garment washing depends on several processes. Therefore, the individual EIM scores for the two compounds were determined for actual accuracy. The chemical impact and worker impact of potassium

permanganate sprays are almost 40-45 percent greater than the alternative potassium permanganate spray and the EIM for the overall process was significantly higher. Finally, on the basis of whole process the final EIM score for the samples were determined and related explanation are pointed out below:

Sample type	Calculated Impact				Effective Impact				EIM score	Remarks
	Water	Energy	Chemical	Worker	Water	Energy	Chemical	Worker		
Sample pp-1	54	1.3	49.5	61	54	1.3	49.5	61	60	Medium
Sample pp-2	54	1.53	49.5	61	54	1.53	49.5	61	62	Medium
Sample pp-3	54	1.64	76	84.5	54	1.64	76	84.5	67	High
Sample ox-1	54	1.3	42.5	54	54	1.3	42.5	54	54	Medium
Sample ox-2	54	1.3	42.5	54	54	1.3	42.5	54	54	Medium
Sample ox-3	54	1.43	42.5	54	54	1.43	42.5	54	55	Medium

Figure 5. Analyzing the Impact on EIM Score for PP and Alternative PP Spray.

Following figure illustrated that the chemical impact for potassium permanganate spray was increased significantly, but the chemical impact was not increased significantly for using the highest alternative potassium permanganate concentration, because potassium permanganate contains manganese, which is heavy metal and not biodegradable, on the other hand sulfuric acid and ammonium cerium (IV) sulfate has no longer effect to the environment. Therefore, it was determined that alternative potassium permanganate spray was more sustainable than the potassium permanganate spray.

4. Conclusion

This study was carried out to explore the comparative analysis between potassium permanganate spray and alternative potassium permanganate spray. In this study 99% cotton and 1% spandex composition denim fabric was used to determine the performance. Overall, the potassium permanganate spray deteriorated tensile strength more than the alternate potassium permanganate spray in both warp and weft direction. In the case of alternative potassium permanganate spray, when the concentration was increased, the tensile strength was decreased by less amount. After investigating tear strength, it was also observed that alternative potassium permanganate spray resulted less value relating to tear strength decrease than potassium permanganate spray. The usage of alternative potassium permanganate spray resulted lower value of four impact (worker impact, energy impact, chemical impact, water impact) whereas potassium permanganate raised the value. As a result, the impact

of potassium permanganate on the environmental was observed higher than the impact of alternative potassium permanganate. Alternative potassium permanganate spray was performed more sustainable attribute. Alternative potassium permanganate and conventional potassium permanganate spray had no prominent impact on the grading of color stain and change in color relating to color fastness properties. Spraying alternative potassium permanganate spray improved GSM values as compared to conventional PP spray. Based upon the findings, textile manufacturers and technologists will be more cautious about the selection of appropriate materials for the processing of denim fabric.

Compliance with Ethics Requirements

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

Conflict of Interest

The authors have declared no conflict of interest.

Acknowledgements

The authors gratefully acknowledge the Department of Textile Engineering of Mawlana Bhashani Science and Technology University (MBSTU) and Express Washing and Dyeing Limited, Ashulia, Savar, Dhaka for technical support of this work.

References

- [1] Patra, A. K., & Pattanayak, A. K. (2015). Novel varieties of denim fabrics. *Denim*, 483–506.
- [2] Yao, J. M., & Wei, S. N. (2012). Effects of Potassium Permanganate Decoloration on Denim Shade. *Advanced Materials Research*, 627, 190–194.
- [3] Meksi, N., & Mhenni, M. F. (2015). Indigo dyeing technology for denim yarns. *Denim*, 69–105.
- [4] Zayedul Hasan, M., K. M. Ayatullah Hosne Asif, A., Tareque Rahaman, M., & Akter, S. (2021). Effect of Super White Washing Process Temperature and Optical Brightening Agent Concentration on Various Properties of Stretch Denim Fabric. *International Journal of Systems Engineering*, 5 (1), 43–50.
- [5] Khedher, F., Dhouib, S., Msahli, S., & Sakli, F. (2011). Study of the influence of matter and finishing treatments on the denim garment shade. *International Journal of Clothing Science and Technology*, 23 (1), 34–45.
- [6] Shaheen, I. M., Mamun, M. A. A., Siddique, M. A. B., Asif, A. K. M. A. H. (2016). Effect of Finishing Machine Parameters on Dimensional Stability of Single Lacoste Cotton Knitted Fabric. *Advances in Materials*, 5 (5), 35–43.
- [7] Choudhury, A. K. R. (2017). Environmental impacts of denim washing. *Sustainability in Denim*, 49–81.
- [8] Juciene, M., Urbelis, V. V., Juchneviciene, Ž., Saceviciene, V., & Dobilaite, V. (2018). The influence of laser treatment and industrial washing on denim fabric tension properties. *International Journal of Clothing Science and Technology*, 30 (4), 588–596.
- [9] Annapoorani, S. G. (2017). Introduction to denim. *Sustainability in Denim*, 1–26.
- [10] Khedher, F., Dhouib, S., Msahli, S., & Sakli, F. (2011). Study of the influence of matter and finishing treatments on the denim garment shade. *International Journal of Clothing Science and Technology*, 23 (2/3), 107–118.
- [11] Kan, C. W. (2015). Washing techniques for denim jeans. *Denim*, 313–356.
- [12] Siddique, A., Hussain, T., Ibrahim, W., Raza, Z. A., & Abid, S. (2018). Optimization of discharge printing of indigo denim using potassium permanganate via response surface regression. *Pigment & Resin Technology*, 47 (3), 228–235.
- [13] Castañeda Juárez, M., Martínez Miranda, V., Almazán Sánchez, P. T., Linares Hernández, I., & Vázquez Mejía, G. (2020). Electrosynthesis Of Sodium And Potassium Ferrate For The Treatment Of Indigo Blue Aqueous Solutions And Denim Wastewater. *Revista Internacional de Contaminación Ambiental*.
- [14] Gore, J., Leonard, B. R., & Gable, R. (2001). Evaluation Of Denim And Denim Combinations Against Bollworm And Tobacco Budworm, 2000. *Arthropod Management Tests*, 26 (1).
- [15] Samanta, K. K., Basak, S., & Chattopadhyay, S. K. (2017). Environmentally friendly denim processing using water-free technologies. *Sustainability in Denim*, 319–348.
- [16] Mia, R., Ahmed, T., Tanjim, M. N., Waqar, M. A., Hasan, M. M., Das, A., Jahan, K. (2020). An extensive analysis of the health hazards for RMG workers in apparel sector of Bangladesh. *Journal of Textile Engineering & Fashion Technology*, 6 (4), 141–146.
- [17] Sarker, P., Asif, A. K. M. A. H., Rahman, M., Islam, M. M. and Rahman, K. H. (2020). Green Dyeing of Silk Fabric with Turmeric Powder Using Tamarind Seed Coat as Mordant. *Journal of Materials Science and Chemical Engineering*, 8 (2), 65–80.
- [18] Asif, A. K. M. A. H. (2017). An Overview of Sustainability on Apparel Manufacturing Industry in Bangladesh. *Science Journal of Energy Engineering*, 5 (1), 1–12.
- [19] Asif, A. K. M. A. and Hasan, M. Z. (2018). Application of Nanotechnology in Modern Textiles: A Review. *International Journal of Current Engineering and Technology*, 8 (2), 227–231.
- [20] Rahman, M., Asif, A. K. M. A. H., Siddique, M. A. B. and Rokonzaman, M. (2014). Effect of Shade Percentage on Various Properties of Cotton Knitted Fabric Dyed with Reactive Dyes. *International Journal of Research in Engineering and Technology*, 3 (2), 339–343.
- [21] Halim, M. A., & Islam, T. (2021). Washing Defects and Remedial actions of Denim Garments and Statistical Review of Denim Sectors in Emerging Economy. *Journal of Management Science & Engineering Research*, 4 (1).
- [22] Adivarekar, R. V. (2018). Study of Decolouration Effect on Denim by Ceric Sulphate Treatment using Statistical Modeling. *Trends in Textile Engineering & Fashion Technology*, 4 (1), 403–408.
- [23] Hasan, M. Z., Asif, A. A. H., Razzaque, A., Hasan, M. R., Sur, S., and Faruque, M. O. (2021). An Experimental Investigation of Different Washing Processes on Various Properties of Stretch Denim Fabric. *Journal of Materials Science and Chemical Engineering*, 9 (1), 1–15.
- [24] Chen, C., Carrico, M., Riewe, K., Rougeaux-Burnes, L. A., & Drago, S. (2019). Denim Risk: A Case Study by Five Fashion Designers with Nontraditional Seam Placement in a Creative Design Process Using Denim Fabric.
- [25] Hosen, F., Hasan, M. Z., and Asif, A. A. H. (2020). Effect of Different Softeners on Dimensional Stability and Color Fastness Properties of Stretch Denim Fabric. *Advances in Applied Sciences*, 5 (4), 112–119.
- [26] Islam, M. M., Mahmud, K., Faruk, O., & Billah, S. (2011). Assessment of environmental impacts for textile dyeing industries in Bangladesh. *International Conference on Green Technology and Environmental Conservation (GTEC-2011)*.
- [27] Yildirim, N., Üstütağ, S., & Örtlek, H. G. (2014). The Effects of Washing Treatments on Physical Properties of Denim Fabrics. *Tekstil Ve Mühendis*, 16–29.
- [28] ISO 13934-2: 2014; Textiles — Tensile properties of fabrics — Part 2: Determination of maximum force using the grab method.
- [29] ISO 13937-1: 2000; Textiles — Tear properties of fabrics — Part 1: Determination of tear force using ballistic pendulum method (Elmendorf).
- [30] ISO 105-C10: 2006; Textiles -- Tests for color fastness--Part C04: Color fastness to washing: Test 4.
- [31] ISO 105-X12: 2016; Textiles -- Tests for color fastness -- Part X12: Color fastness to rubbing.