

# INVESTIGATION OF THE BULK, SURFACE AND TRANSFER PROPERTIES OF CHLORINE BLEACHED DENIM APPAREL AT DIFFERENT CONDITION

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## Abstract

Oxidizing bleaching agent (calcium hypochlorite or bleaching powder) is widely used in the apparel washing plant as a color removing and cost effective finishing chemical. As the faded denim or old look denim is preferred by the today's youth it has become a crucial issue for the technologists to modify denim apparel to fulfill the demand of existing trend. Calcium hypochlorite ( $\text{Ca}(\text{OCl})\text{Cl}$ ) fades the denim effectively but a significant changes are happened in the properties of the denim apparel. The main objective of this paper was to investigate the changes of bulk, surface and transfer properties of denim apparel after the chlorine bleach action at varying length of washing time (10,15 and 30 min) with fixed concentration and temperature ( $50^{\circ}\text{C}$ ). These properties are related to the performance of the end product. 100% cotton indigo dyed 2/1 twill denim apparel was treated with 5gm/l ( $\text{Ca}(\text{OCl})\text{Cl}$ ). To determine the end use performance of the modified denim the changes of tensile strength, stiffness, dimensional stability (bulk properties), hand roughness, rubbing fastness (surface properties), air permeability, water repellency (transfer properties) of the modified denim apparel were evaluated. It has been monitored from the experimental data that the bulk properties play down but the surface properties have a noticeable improvement after the chlorine bleach action. It is also noticed that washing time has a significant effect on air permeability of the treated denim apparel.

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**Keywords:** Denim, calcium hypochlorite, tensile strength, air permeability

## Introduction

A popular conception of the etymology of the word denim is that it is a contraction or derivative of the French term, serge de Nîmes. Denim was traditionally colored blue with indigo dye to make blue "jeans," though "jean" then denoted a different, lighter cotton textile (Shalini). In general denim is cotton and twill weave stiff fabric where the warp yarns are dyed with indigo which remains on the surface (Khan,Mondal,2012). It is used for jeans, work clothes and casual wear.

Now-a-days different types of techniques are applied in weaving for denim modification. Dramatic changes have occurred in the function and design of jean garments since the first pairs of jeans were created for gold miners during the California Gold Rush. The evolution of the jeans' market led to the development of some unique and creative methods for the processing of denim garments (Cotton incorporated, 2000). The present day trend indicates that consumer is interested to wear denim and feels that denim is comfortable dress material (Arjun, Hiranmayee & Farheen, 2013). When jeans were discovered and appreciated by consumers as general casual wear, new techniques were developed to enhance denim garments and make them more unique. Conventional technologies involve creating designs by fading the color of fabric by making the use of enzymatic treatment and bleach washing (Kan, Wong, Song & Law, 2013).

Denim garment (Jeans) washing is known as one of the widely used finishing treatment that has vast usage in textile sectors because of creating special appearance and making fashionable and wear comfortable garments of the present day world (Khan, Mondal & Uddin, 2011). The most common industrial bleaching agent for cotton is hydrogen peroxide which removes natural color of cotton and increased whiteness. But hydrogen peroxide is fairly effective in denim washing, because it is applied under boiling conditions and increased fiber damage and high temperature bleaching leads to higher energy consumption (Gursoy, Lim, Hinks & Hauser, 2004),(Buschle-Diller, Yang & Yamato, 2001).

Bleaching powder ( $\text{Ca}(\text{OCl})\text{Cl}$ ) has wider applications in our daily life for both disinfectant and to bleach color. Textile industry is using bleaching powder as an effective oxidant for denim washing although chlorine is a harsh chemical, harmful to human health and destructive to cotton (Khan, Mondal, Alam & Hossain, 2012). Without washing, denim garment is uncomfortable to wear, because denim is produced using very coarser yarns in both warp and weft. In addition, the warp yarns are mostly dyed with indigo and sized, as a result, denim is very stiff fabric and hard (Razzaque, 2004).

Recently some research papers have published on bleach wash of denim apparels for modification. The aim of this study was to analysis of the

bulk (tensile strength, bending behavior, dimensional stability), surface (hand roughness and rubbing fastness) and transfer properties (air permeability and water repellency) (Goswami, Martindale & Scardino, 1995) of the chlorine (calcium hypochlorite) bleached denim apparel at different condition (fixed parameter was concentration, 5gm/l and temperature, 50°C; variable parameter was duration of washing). The findings of this research work will help the technologists to explore the consequence of chlorine bleach wash on 100% cotton denim apparel at different washing time while the concentration and temperature remain same.

## **Materials and Methods**

### **Materials**

For investigation 100% cotton indigo dyed 2/1 warp faced twill denim apparel (jeans) was selected which was produced in the Apparel Manufacturing lab of Bangladesh University of Business and Technology (BUBT, Dhaka, Bangladesh). The specification of the denim fabric was (75×45)/(10×9) when the fabric weight in gram per square meter was 343. The samples were desized by desizing agent (Desizol) following the standard recipe (Islam,2010). Anti- staining agent (RM) was used for avoiding back staining during treatment. The bleaching operation was carried out by the calcium hypochlorite ( $\text{Ca}(\text{OCl})\text{Cl}$ ) which acts as a color removing agent. Soda ash ( $\text{Na}_2\text{CO}_3$ ) was used for maintaining the alkaline medium. To neutralize the chlorine from the samples a reducing agent, sodium hyposulphite ( $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ ) was applied. Softening process was carried out by a cationic softener (Rongsong, Malaysia). All the chemicals used for this experiment were collected from Jamuna Washing Plant (Dhaka, Bangladesh).

### **Methods**

#### **Desizing procedure**

The initial treatment of chlorine bleach wash was desizing process which was carried out by desizing agent (Desizol) (1gm/l) and anti-staining agent (4gm/l) at material to liquor ratio (M:L) 1:25. The duration of the process was 25 minute at 60°C. The treatment was conducted in a sample washing machine (Dongel, Korea). The purpose of desizing process was to remove the sizing material which was adhered in the warp yarn (Khan, 2011).

Then a hot wash of 5 minute at 70°C following a cold wash of 3 minute at room temperature was processed.

### **Bleaching procedure**

The oxidant calcium hypochlorite ( $\text{Ca}(\text{OCl})\text{Cl}$ ) (5gm/l) at 50°C was applied for varying length of time (10,15,30 minute) for the bleaching treatment. 4gm/l soda ash was applied for each time of washing to make the solution alkaline (pH 10.5). The M:L was 1:20 during bleaching treatment and the process was carried out in the same sample washing machine with RPM 35. After the beaching treatment the neutral wash was completed by the reducing agent sodium hyposulphite (4gm/l) for 5 min at 40°C and a rinsed wash with distilled water.

### **Softening process**

To improve fabric handle and other valuable properties, softeners are widely used in the finishing process (Mazumder, 2010). At the end of neutralizing process, a softening process was followed with a cationic softener (1.5gm/l) with acetic acid (0.5gm/l) to give soft hand feel of the chlorine bleached sample. This was the last wet treatment of the bleach wash.

### **Hydro-extracting and drying process**

The process of hydro-extracting was carried out in an Industrial hydro-extracting machine (Dongel, Korea) at 250 RPM for 3 min to remove excess water from the sample. Then the samples were dried in an industrial gas drier (Dongel, Korea) at 75°C for 20 min following a cold dry of 5 min to return the apparel in normal position.

### **Experimental investigation**

A variety of testing was conducted to chlorine bleached denim apparel to investigate the bulk, transfer and surface properties. The treated samples were conditioned to moisture equilibrium with reference ASTM D1776 (American Society for Testing and Materials, 2008). To investigate the properties of the chlorine treated denim five observations of each testing were conducted and the properties of the samples were characterized. The tensile strength of the denim apparel was determined according to ASTM D5034 (Grab test principle) (American Society for Testing and Materials, 2009). Bending behavior of the treated samples was measured from the bending length of fabric by Shirley stiffness tester according to BS 3356 ("Method for determination of bending length", 1990). Dimensional stability (shrinkage or growth percentage) of treated sample was measured according to AATCC test method 96 (American Association of Textile Chemists and Colorists, 2009). Color fastness to rubbing of denim apparel was assessed according to BS 1006:1990 (British Standard, 1990). Water repellency test of the treated sample was evaluated according to AATCC Test Method 22 -

2005. The air permeability of the treated sample was measured according to IS 11056 (Bureau of Indian Standards, 1984).

## **Results and discussion**

### **Bulk properties**

#### **Measurement of tensile strength**



Figure 1. Horizontal tensile strength tester

The cotton polymer is a linear, cellulose polymer. The strength of a cotton fibre is attributed to the good alignment of its long polymer. Cotton has a well developed primary and secondary wall (Gohl & Vilensky, 2005). During the bleaching treatment the calcium hypochlorite decomposed cotton under the alkaline condition. Bleaching powder first attacked on dyed yarn portion, decomposed them slowly and fibers are partly degraded from the yarn chain and step by step penetrated inside fabric. Therefore, the chemical bonds of primary wall are broken by the decomposition of the aqueous solution of hypochlorite bleach. As a result the primary wall of the cotton fibre loosened and broken down quickly (Khan et al., 2011). This reaction was accelerated due to the rotating motion of the washing machine. As a result the strength of the warp yarn decreased after the bleaching treatment. But the reduction in strength also depends on the duration of washing.

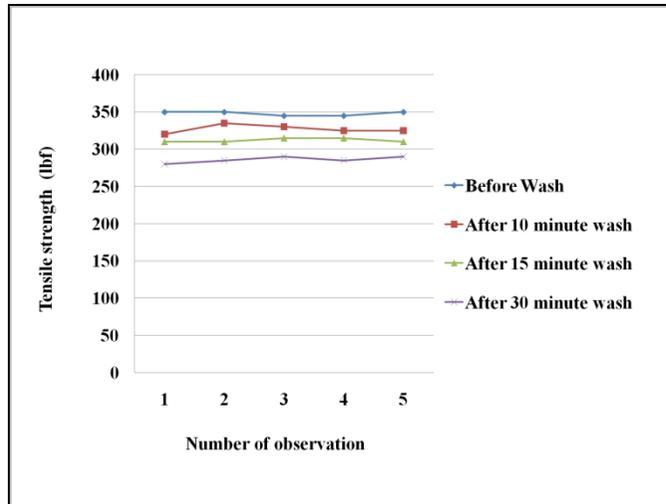


Figure 2. Graphical presentation of tensile strength (lbf) in warp way

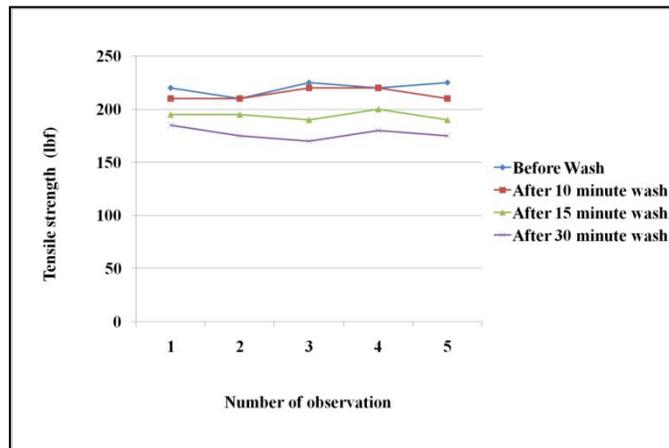


Figure 3. Graphical presentation of tensile strength (lbf) in weft way

From the result it has been explored that the duration of washing negatively relates with tensile strength. Higher duration of washing fades the color more but lessens the tensile strength. So duration of washing is an effective process control parameter to control the limit of cellulose degradation during bleaching action.

### Measurement of stiffness:

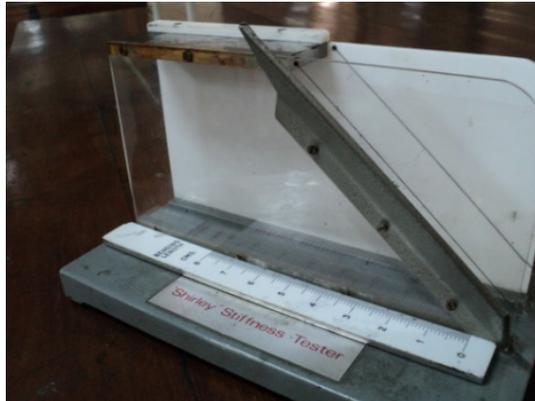


Figure 4. Shirley stiffness tester

Stiffness (bending length) of the treated sample was calculated by the Shirley stiffness tester.

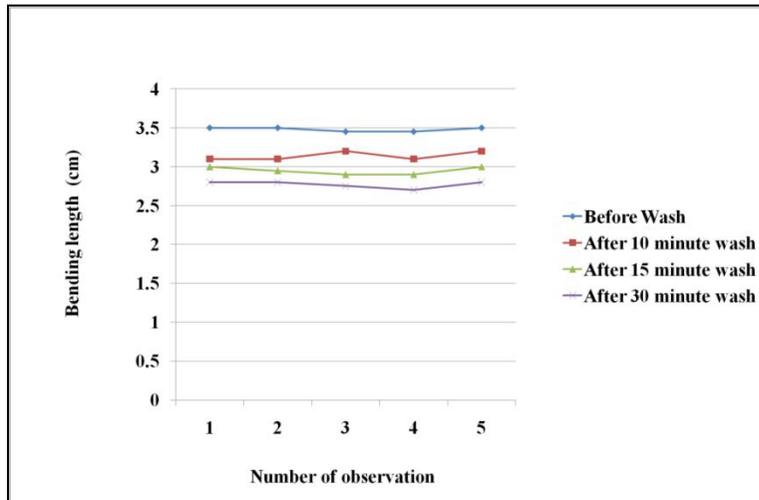


Figure 5. Graphical presentation of bending length (cm) in warp way

From the experimental data it has been observed that the stiffness of the denim was decreased both in the warp and weft way after chlorine bleach wash as the sizing materials were removed from the fabric due to desizing following several times washing. During the manufacturing of woven fabric size material is applied to the warp yarn to make it strong, stiff for facilitating the weaving process (Siddique, Begum, Islam & Ahmed, 2013). Softening is another basis of decreasing the bending length or stiffness.

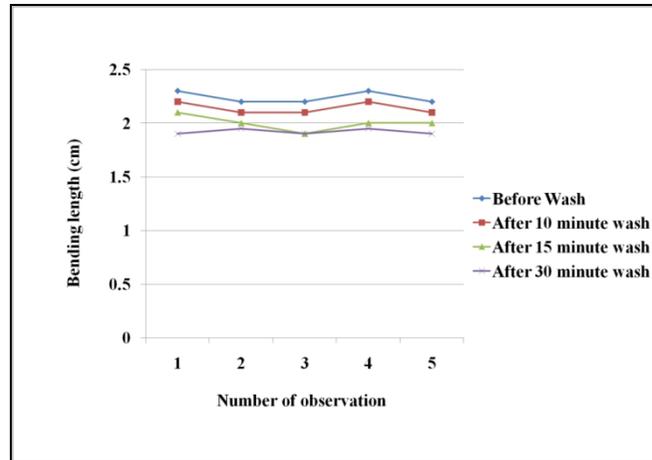


Figure 6. Graphical presentation of bending length (cm) in weft way

### **Dimensional stability (Shrinkage %):**

Relaxation shrinkage is a result of the stretching that occurs in the manufacture. It is difficult to avoid stretching the fabric during manufacture and finishing. This stretch becomes set in the fabric when it is finally dried after finishing, but at the first opportunity the fabric will relax and returns to its most stable, that is most natural state. This change will occur completely only if the cloth is washed several times with agitation in hot water which is the basic principle of apparel washing (Taylor, 1990). From the observation it was revealed that the bleach wash treatment shrinks of denim apparel both in the length and width wise direction here, as the width wise shrinkage percentage was more than the length wise shrinkage percentage. During manufacture, fabrics and their component yarns are subjected to applied tension under varying conditions of temperature and moisture content. In the finished state the fabric may be temporarily 'set' in a stretched condition. Such stretching upsets the balance of warp and weft way crimp percentages. The hot and wet conditions of washing allow the strains to relax and therefore the denim shrinks both in the warp and weft way (Booth, 2008).

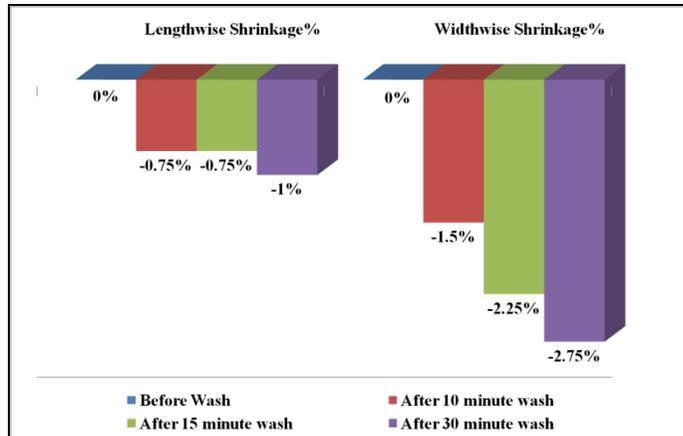


Figure 7. Graphical comparison of shrinkage %

## Surface properties

### Color fastness to rubbing

Color fastness is a measure of how permanent a color is on the fabric. Color fastness to rubbing is a basic test used by customers to determine the quality of a colored fabric and has been an area of concern for processors for many years.



Figure 8. Crock master



Figure9. : Assessment of color fastness to rubbing

To measure the color fastness to rubbing we followed the BS 1006-1990 where downward force was 9N and number of cycles/ turns was 10 times in 10 seconds. For visual assessment the James Heal grey scale assessing for staining was used.

Table 1. Effect of bleach wash on the color fastness to rubbing of the denim apparel

Observation no.	Before Wash		After 10 minute wash		After 15 minute wash		After 30 minute wash	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
1.	2/3	1	3	2	3/4	2/3	4	3
2.	2/3	1	3	2	3/4	2/3	4	3
3.	2/3	1	3	2	3/4	2/3	4	3
4.	2/3	1	3	2	3/4	2/3	4	3
5.	2/3	1	3	2	3/4	2/3	4	3

Denim is a surface dyeing fabric remaining a white core and from the investigation we have found that the color fastness to rubbing of denim apparel is not satisfactory. Graphical presentation shows that the bleaching treatment improves the fastness of the denim both in wet and dry condition and a satisfactory level was achieved to color fastness to rubbing.

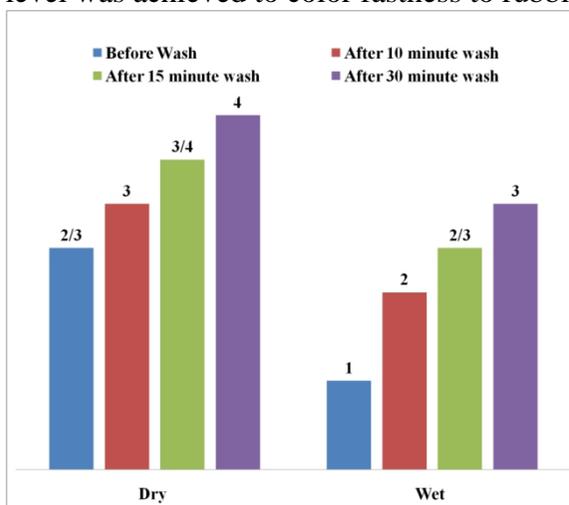


Figure 10. Graphical presentation of Color fastness to rubbing

### Hand roughness of denim apparel

Hand roughness of the chlorine bleached denim apparel was assessed by feel of touch. It has been explored that the raw denim achieved a soft hand feel after the bleach wash treatment. Because softening agent render the surface of the fibre smoother, resulting in a supple handle of the materials. The cationic softener produces an oily film on the negative sites of the fibre which produces a soft handle, a pliable and well lubricated surface (Shenai, 1995).

**Transfer properties:  
Air permeability:**

Air permeability is an important factor in the performance of textile material and provides an indication of the breathability of a garment (Maryan, Montazer, & Rashidi, 2013).



Figure 11. MAG Air Permeability Tester

Data in the graph is clearly revealed that the air permeability of chlorine bleached samples was higher than the raw (unwashed) sample when the duration of the treatment was 10 and 15 minute. But the value was decreased to some extent when treatment time was 30 minute. The base of this happening is that the surface density (ends per inch and picks per inch) had increased due to relaxation shrinkage which decreased the air permeability of denim apparel to some extent.

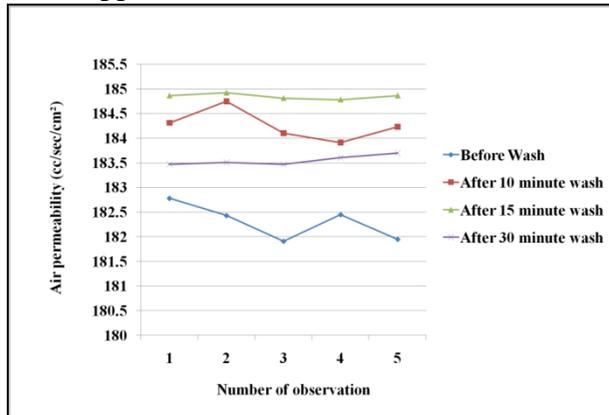


Figure 12. Graphical presentation of air permeability (cc/sec/cm<sup>2</sup>)

**Water repellency (AATCC 22-2005):**

Water repellency is a transfer property of denim fabric. It is the characteristic of textile to resist surface wetting. This test was conducted for treated denim to observe whether the fabrics resist wetting similarly. Test method AATCC 22-2005 was followed and a little difference between the

raw and treated sample was found. The water repellency rating of the raw sample was 70 (partial wetting of whole of upper surface) and the processed sample was 50 (the complete wetting of whole of upper surface).

Table2. Effects of bleach wash on the water repellency

No of Observation	Before Wash	After 10 minute wash	After 15 minute wash	After 30 minute wash
1.	Grade 70	Grade 50	Grade 50	Grade 50
2.	Grade 70	Grade 50	Grade 50	Grade 50
3.	Grade 70	Grade 50	Grade 50	Grade 50
4.	Grade 70	Grade 50	Grade 50	Grade 50
5.	Grade 70	Grade 50	Grade 50	Grade 50

### STANDARD SPRAY TEST RATINGS

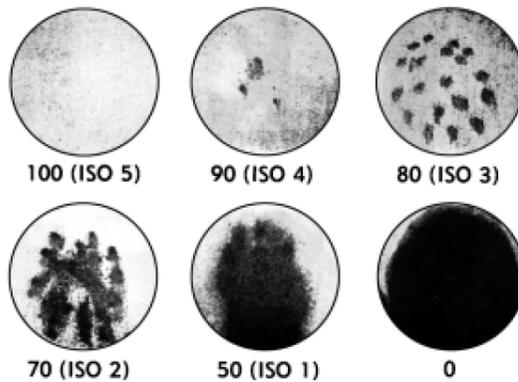


Figure 13. Standard Spray test ratings according to AATCC 22-2005



Figure 14. Photographic view of raw sample after water repellency test



Figure 15. Photographic view of chlorine bleached samples after water repellency test

The cuticle (very outside) of cotton fibre is composed of a waxy layer (cotton wax). The waxy nature of the cuticle enables it to adhere tenaciously to the primary wall of the fibre (Gohl & Vilensky, 2005). During the bleach wash the primary wall decomposed due to bleaching action. Sizing is the warp surface coating process. Sizing materials were removed after desizing. Both of these occurrences were responsible for the reduction of water repellency performance of the denim.

### **Conclusion**

To achieve a required faded look of the denim apparel, calcium hypochlorite can be an effective oxidant for washing treatment. It has been explored from this investigation that duration of washing is a significant process parameter of bleach wash to control the effect of chlorine bleach. The effect could be realized under investigation by evaluating the bulk, surface and transfer properties between the raw and treated sample. Though the required light color could be found by increasing the washing time, it decreases the tensile strength of denim. The chlorine bleach treatment improves the hand roughness, color fastness to rubbing of the denim apparel. Though bleach treatment assist the technologists to produce a fashion item, within a limited cost its effect on the properties of denim need to be controlled to maintain the required performance and conformance of the end product.

### **References:**

- Shalini, N., Fabric and garment finishing: Basic washes in denim fabric, National Institute of Fashion Technology Hyderabad.
- M. Mashiur Rahman Khan and M. Ibrahim H. Mondal, Bleach Washing Combined with Pumice Stone for the Modification of Denim Garments, Oriental Journal of Chemistry, Vol. 28, Issue 3, 2012 pp. 1241-1247
- Cotton incorporated, Garment Washing Techniques for Cotton Apparel, Technical bulletin, 6399 Weston Parkway, Cary, North Carolina, 27513.

- Arjun.D., Hiranmayee . J. Farheen. M. N., Technology of Industrial Denim Washing: Review, International Journal of Industrial Engineering & Technology (IJIET), Vol. 3, Issue 4, Oct 2013, pp-25-34
- Kan, C. W., Wong, W. Y., Song, L. J., & Law, M. C., Prediction of Color Properties of Cellulase-Treated 100% Cotton Denim Fabric, Journal of Textiles Volume 2013, Article ID 962751, 10 pages, Hindawi Publishing Corporation, <http://dx.doi.org/10.1155/2013/962751>
- Md. Mashiur Rahman Khan, Md. Ibrahim H. Mondal and Md. Zulhash Uddin, Effect of Bleach Wash on The Physical and Mechanical Properties of Denim Garments, International Conference on Mechanical Engineering 2011 (ICME2011) 18-20 December 2011, Dhaka, Bangladesh ICME11-FL-022.
- Gursoy, N. C., Lim, S., Hinks, D. and Hauser, P., Evaluating Hydrogen Peroxide Bleaching with Cationic Bleach Activators in A Cold Pad-Batch Process, Textile Research Journal, 74(11), pp. 970-976, 2004.
- Buschle-Diller, G., Yang, X. D. and Yamato, R., Enzymatic bleaching of cotton fabric with glucose oxidase, Textile Research Journal, 71(5), pp. 388-394,2001.
- Md. Mashiur Rahman Khan, Md. Ibrahim H. Mondal, A.B.M. Fakrul Alam and Md. Mohsin Hossain, Modification of Denim Garment with the Treatment of Bleaching Powder, Canadian Journal on Chemical Engineering & Technology Vol. 3 No. 2, March 2012,pp-30-36.
- M. A. Razzaque, “Garment & Textile Merchandising”, (1<sup>st</sup> ed.), Popular Publications, Dhaka, 2004, pp. 223-226.
- Goswami, B.C., Martindale, J.G., Scardino, F.L., Textile Yarns Technology, Structure and Application, (1<sup>st</sup> ed), Mahajan Book Distributors, India, 1995, pp: 137-143.
- Islam, M.T., “Garments Washing and Dyeing”, (1<sup>st</sup> ed), Brother’s publication, Dhaka,2010, pp:56-63.
- Khan, M.E., “Technology of Denim Manufacturing”, (1<sup>st</sup> ed), Books fair Publication, Bangladesh, 2011, pp-1-109.
- Mazumder, S., Effects of Sand Blasting with Industrial Enzyme silicon wash on Denim apparel Characteristics, Daffodil International University Journal of Science and Technology, vol.5, Issue 4, January 2010, pp.6-10.
- ASTM D 1776 “Standard practice for conditioning textiles for testing” American Society for testing and materials, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, vol. 7(1), 2008.
- ASTM D 5034, “Standard test method for breaking force and elongation of textile fabrics (Grab test)”, American Society for testing and materials, Annual Book of ASTM Standards, ASTM International, West Conshohocken, PA, USA, vol. 7(1), 2009.

- BS 3356, “Method for determination of bending length and flexural rigidity of fabrics”, BSI Publisher, Chiswick High Road, London, UK, (1990).
- AATCC Test method 96, “Dimensional changes in commercial laundering of woven and knitted fabrics except wool”, American Association of Textile Chemists and colorists, 2009.
- British Standard BS 1006-1990 “Color fastness to rubbing”
- AATCC Test Method 22 -2005 “Water repellency: Spray test.”
- IS 11056: Method for determination of air permeability of fabrics, Bureau of Indian Standards (1984)
- Gohl, E.P.G., Vilensky, L.D., Textile Science, (2<sup>nd</sup> ed), CBS Publisher and Distributors ,India, pp. 43-45, 2005
- Khan, M.M.R., Mondal, M.I.H., Uddin, M.Z., Effects of Bleach Wash on the physical & mechanical properties of denim Garments, *ICME 14-FL-022(2011)*.
- Siddique, A.B., Begum, H.A, Islam, M.R., Ahmed, M.S., “Introduction to Textile Engineering”, (1<sup>st</sup> ed) , Siddique Book House Publisher, Bangladesh, pp.114-116, 2013.
- Taylor,M.A., Technology of Textile Properties,(3<sup>rd</sup> ed) Forbes Publications,London,pp 168-172,1990
- Booth, J.E., “Principles of Textile Testing”, (3<sup>rd</sup> ed) CBS Publishers and Distributors ,India.pp.333-335 2008.
- Shenai, V.A., “Chemistry of Organic Textile Chemicals”, (2<sup>nd</sup> ed), Sevak Publishers, Bombay-400031, 1995, pp. 180-183, 1995.
- Maryan, A. S., Montazer, M., Rashidi, A., Introducing Old-look, Soft Handle, Flame Retardant, and Anti-bacterial Properties to Denim Garments Using Nano Clay, *Journal of Engineered Fibers and Fabrics*, 8( 4) 2013.