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Optimization of Finishing Process in Denim Fabric Manufacturing Plant

Enamul Haque[1]*, Suja Uddin Kaiser[1], Rajib Kabiraj[1], Bokthier Rahman[1], Al-Amin[2] and Abu Hanif[3]

[1]Department of Textile Technology, University of Engineering & Technology (KUET), Khulna, Bangladesh
[2]Department of Textile Technology, University of Textiles (BUTEX), Dhaka, Bangladesh
[3]Department of Textile Technology, University of Bangabandhu Textile Engineering, Tangail, Bangladesh

Abstract

The main factors affecting consumers when selecting denim garments are aesthetics, appearance, and fashion. In addition to these aspects, denim clothing's comfort and functionality while being worn are crucial. In order to maximize the production of cotton-elastane denim fabrics, the goal of this article is to optimize various finishing methods. This study's research design comprises of an experimental investigation. Two different types of fabrics were chosen for analysis in order to determine the potential savings of finishing on the performance characteristics of fabrics. Using chemicals and modifying the basic materials, the finishing process can be made more efficient. The study's findings unmistakably demonstrated that the improved method is effective for producing denim fabric. The literature study revealed that there were few research examining denim materials' finishing procedures all at once. This study examined the impacts of finishing process optimization on the mechanical, thermal, and mechanical comfort parameters of drape, stiffness, and tear strength.

Keywords: Finishing process • Denim fabrics • Potential savings • Process optimization • Cotton elastane fabric

Introduction

Asian nations, particularly Bangladesh, are ideal for the textile industry. In a global survey, Bangladesh ranked fourth in the textile category [1]. Denim is typically a robust and long-lasting cotton fabric made with a 2/1 or 3/1 twill weave construction, in which the weft yarns are white and the warp threads are dyed with a blue pigment derived from indigo dye. It is used to create a variety of clothing items for kids as well as for adults and women of all ages, including jeans, jackets, shirts, and skirts. Because they combine a number of qualities that customers find to be highly desirable, denim fabrics are frequently employed in the apparel business. All age groups can wear denim clothing since it is comfortable, long-lasting, adaptable, inexpensive, and always in style [2-4]. Physical or chemical treatments are utilized in textile finishing operations, which are primarily employed to improve the texture and look of materials. This modernization of clothing increases market sales. A variety of frequently utilized treatment processes, including enzymatic treatment, bleaching treatment, acid treatment, silicone treatment, singeing treatment, heat set, ozone finish, etc., are included in the finishing process for denim fabric. It is important to evaluate how these processes affect the performance and thermal comfort of denim materials [5]. Further chemical processing steps, such as de-sizing, overdyeing, coating, retro dyeing, pigment dyeing, reverse dyeing, non-uniform dyeing, or multi-coloured dyeing, may be added on top of these process stages and depending on the desired outcome. Chemical finishing is used to alter or enhance a fabric's appearance, hand feel, and distinctive practical qualities, such as water- and oil-repellency, wrinkle resistance, and flame resistance, as well as to make the fabric easier to stitch [6]. The purpose was to study the optimization of the denim fabric finishing process by altering the raw materials and chemicals.

***Address for Correspondence:** Enamul Haque, Department of Textile Technology, University of Engineering & Technology (KUET), Khulna, Bangladesh, E-mail: enamulte@yahoo.com*

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Objective

Broad objective: This report's major goal is to lower process costs through the optimization of processes and workflows. There are many elements that affect process costs, but I am focusing on the main ones: the decreased process by altering raw material and chemical utilization. This report, which demonstrates the assignment I was given during my research work, is presented as an experiential report. My results in this report are consistent with what I discovered throughout my research.

Specific objective

To reduce the singeing process in denim fabric

To minimize the heat set process by altering raw material

To calculate the potential savings due to optimizing the process

Materials

In this research work, we used two types of denim greige fabric which are shown in (Figures 1 and 2). After manufacturing, denim fabrics are often subjected to finishing processes to obtain a wide variety of aesthetic and tactile

Figure 1. Fabric sample E0001.

effects. The research has been carried out using stretch denim fabrics with a composition of around 78% Cotton, 2% EL and 3/1 Z twill weave, fabric width is 78 inch, produced on PICANOL OMNI PLUS 800- air jet weaving machines. Structural characteristics of greige denim fabric are displayed in (Table 1).

Methodology

Finishing processes

Singeing: Singeing is a process that uses a gas flame to burn off the fluff or tiny hairs on the surface of denim fabric. This process burns away surface material that makes the fabric look fuzzy. It is carried out to obtain a cleaner and smoother appearance of denim fabrics. This process enhances the color, and the fabric wettability is also increased [6].

Heat setting: Heat-setting is the most important one, since it gives the product the desired characteristics to make it suitable for further processing and use by the consumer [7]. Karmakar explained heat-setting as a heat treatment by which shape retention, crease resistance, resilience and elasticity are imparted to the fibers. It also brings changes in strength, stretchability, softness, dyeability and sometimes on the color of the material. According to Gacen J, et al. [8] heat-setting improves the properties of the textile substrate (improves shrinkage resistance, removes any creases, guarantees level dyeing and improves the fabric handle) [8].

Mercerizing: Mercerization is an industrial process involving sodium hydroxide for cotton yarns or fabrics to increase luster and dyeability. But the mercerization of denim is usually carried out after the denim is woven, so it is different from the more common method of mercerized cotton yarn. Mercerization of denim may be used for achieving ring dyeing, thus keeping the dye on the surface of the yarns or fabrics and preventing dyes from fully penetrating the fibers. In addition to increasing the fabric's luster, it also improves its strength. As it significantly increases the cost and lead times of denim production, at present, it is a relatively rare process [6].

Figure 2. Fabric sample E0002.

Softening: Due to the removal of impurities such as wax, paraffin, and oil after pretreatment processes, denim fabric loses its natural hand feel and therefore it is necessary to regain its softness. Softeners improve abrasion resistance, increase tearing strength and diminish the risk of stitching thread and needle breakage during garment sewing. A wide range of softeners is used in the after-treatment of denim fabrics. The major softener types are cationic, anionic, nonionic, silicones and special softeners [6].

Foam finishing: Foam finishing of denim fabric is an environmentally friendly and energy-saving finishing and shrinking method for meeting the highest quality demands. In this method, the required finishing agents are added to the foam, where the moisture content is minimum. The foam is usually laid on a rubber conveyor, evenly across the width of the conveyor by an oscillating feed pipe system, and a doctor's blade ensures a uniform layer of foam across the width. Foam finishing can result in an 80% savings in water and energy compared with the traditional denim finishing methods [6].

Overdyeing: Traditional indigo-dyed denim fabric can be overdyed as part of a finishing process. Overdyeing can take place between desizing and the addition of softeners. The best results, however, are achieved after stone washing and subsequent bleaching. The preparation requirements for overdyeing are the same as for any other dyeing process [6].

Experimental area: We have completed our research work in a renowned denim plant in Bangladesh where there are so many departments from raw materials to final inspection such as Materials Testing, Yarn Processing, Fabric Manufacturing, Fabric Finishing, Fabric Dyeing, Fabric Washing, Fabric Testing, and Fabric Inspection. Among these departments, we have completed our work in the Fabric Finishing section. The purpose of this work is to reduce fabric process costs by altering materials and process routes. Various factors are involved to reduce process costs but We were working with process optimization of Singeing and Heat-setting.

Process flow chart of denim fabric finishing

(Figure 3)

Experimental work

Experimental details: The main function of the singeing machine is to remove hairiness from the fabric surface by using a flame burner. It can increase the wettability of fabric also. We can rule out this process by using a biopolishing enzyme during de-sizing and before the mercerizing process. This enzyme can be used as a de-sizing agent in this process box. Previously a de-size chemical is used to complete this process. The purpose of the process is to eliminate protruding micro hairs of cotton by an interaction of cellulase. Biopolishing (Figure 4) involves the use of cellulase enzymes, owing to their capability of hydrolyzing cellulosic micro-fibrils (hairs or fuzz) bulging out of the yarn surface as they are vulnerable to enzymatic attack [9]. Heat-setting is a heat treatment by which shape retention, crease resistance, resilience, and elasticity are imparted to the fibers. It also brings changes in strength, stretchability, softness, dyeability, and sometimes on the color of the material. All these changes are connected with the structural and chemical modifications occurring in the fiber. Denim woven fabrics, from unset yams, may be expected to shrink by approximately 5% in warp and weft during the scouring process, and their residual potential shrinkage range from 4.5% to about 11% over the temperature range of 150 to 220°C Staple fiber fabrics shrink less than filament fabrics and stability adequate for apparel fabrics is conferred by setting at 170 to 180°C Polyester fabrics are effectively dimensionally stable if it is set at a temperature of 30 to 40°C higher

Table 1. Greige fabric specification.

Fabric Name	Construction	Composition	Weight (oz/yd²)	Weight (GSM)	Weave	Weaving Machine
E0001	10 OE + 12 OE × 150L40D/71 x 57	Elastane 1.80%, Polyester	8.25	280	3/1 RHT	Picanol Omniplus 800
E0002	10RSL+10R × 16L40D/60 x 48	1%elastane,9%Rayan, 22%polyester,68%cotton	9.25	314	3/1 RHT	Picanol Omniplus 800

Table 2. Regular process time & cost for specific fabric.

		Singeing Process		Heat-Setting Process		Total	
Fabric Name	Fabric Length (m)	Process Time (Hour)	Process Cost (Per 100 m)	Process Time (Hour)	Process Cost (Per 100 m)	Time (Hour)	Cost ($)
E0001	5000	2.08	$3	2.38	$5	-	-
E0002	5000	2.08	$3	2.38	$5	8.92	$800

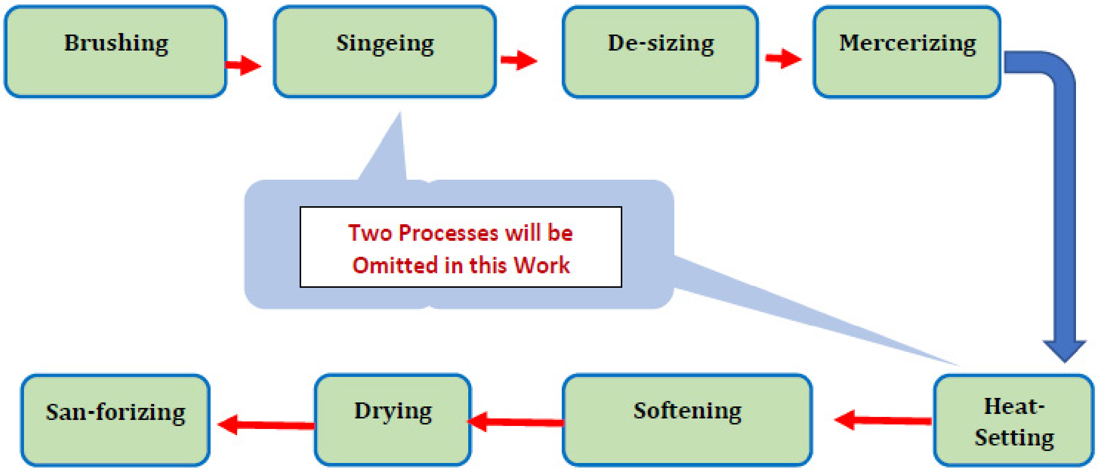

Figure 3. Flow chart of denim fabric finishing.

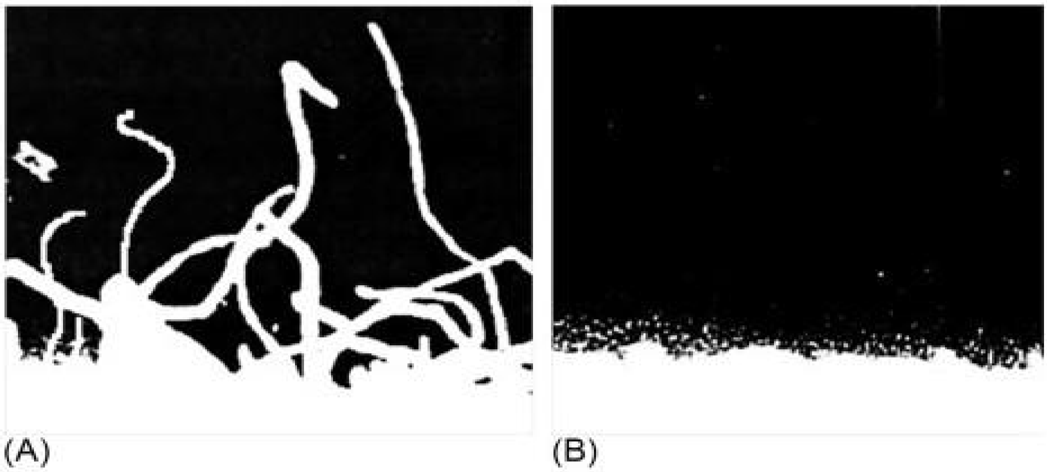

Figure 4. (A) Cotton fabric surface before and after and **(B)** Biopolishing treatment using cellulase enzyme.

Table 3. Fabric test report of regular process & experimental process.

Finishing Process	Fabric Name	Fabric Wt (oz/yd²)	EPI × PPI	Shrinkage (%) (Warp × Weft)	Stiffness (KG)	Skew Movement (%)	Spirality (%)	Stretch (%)	Rubing (Dry × Wet)	Tensile Strength (KG)(Warp × Weft)	Tear Strength (KG) (WARP × Weft)
Regular Process (Brushing- Singeing- Designing- Mercerizing-a Heat set- Softening- Drying- Sanforizing)	E0001	9.17	91 × 65	(-1.42) × (-11.40)	1.24	-0.4	(-1) × (- 1.6)	35.2	3.5 × 1	80.93 × 71.05	3.67 × 5.40
	E0002	10.21	78 × 51	(-1.42) × (-11.40)	1.2	-0.6	(-0.2) × (- 1)	46.2	3.5 × 1	99.03 × 70.12	5.55 × 9.09
Experimental Process (Brushing- Desiging-Mercerizing- Softening- Drying- Sanforizing)	E0001	9.11	91 × 65	(-1.49) × (-11.68)	1.2	-0.4	(-0.2) × (- 2.8)	36.4	3.5 × 1	88.53 × 77.16	3.10 × 4.87
	E0002	10.54	78 × 51	(-0.28) × (-10.83	1.16	-0.6	(-0.2) × (- 1.4)	46.8	3.5 × 1	107.13 × 86.72	4.95 × 8.19

than the temperature to which the fiber is subjected to expose during subsequent processes [10]. We can deduce this process by altering raw materials. Previously, we used 2.8 drafts of spandex yarn for this given fabric (shown in Table 1), where a heat setting is required to achieve fabric stability. In this work, we used 2.0-draft spandex yarn to bypass this process. By doing this work, we can save a lot of time and money. Our final time savings and cost calculations are shown in our results.

Experimental data: For this experimental work, we have taken two different fabric construction for the length of 5000 meters. Firstly, we run these fabrics with regular processes where we found our process time and cost which is shown in (Table 2). For Regular Process- Secondly, we have run our experimental process with the same length of the fabric where singeing and heat set process can be deducted. We have completed this stage by using a biopolishing enzyme instead of singeing process and in the initial stage of fabric manufacturing we replaced our weft yarn to avoid the heat set process. Due to this development, we can omit these two processes and save a lot of time & cost which is calculated in the next step. After completing this stage, we tested our fabric of two different routes to achieve our experimental result.

Test and analysis: Denim fabric samples were conditioned under the standard atmospheric conditions which are 20±2°C temperature and 65±2 percent relative humidity for 24 h. Statistical analyses were conducted using IBM SPSS 23 statistic program. Tear strength tests of all the fabrics in warp and weft courses were performed on James Heal Tensile Tester according to TS EN ISO 13937-2. Drape tests were conducted using the SDL-Atlas fabric drape tester according to the test standard BS 5058 [11]. Stiffness tests were applied on the SDL-Atlas stiffness tester, and test standard ASTM D4032 was used for testing circular bending stiffness values of fabrics [12]. The Alambeta instrument was used to test the thermal comfort properties of denim fabrics. Alambeta is a computer-controlled instrument designed for the measurement of the basic static and dynamic thermal characteristics of textiles [13]. It measures thermal conductivity, thermal diffusion, thermal absorptivity, thermal resistance, and material thickness. The Permetest instrument was used to measure water vapor resistance and water vapor permeability according to ISO 11092:2014 standard [14]. Fabrics' mechanical and surface properties were measured by the KES-F and FAST systems [15,16]. KES-FB1 tensile-shear tester, KES-FB2 bending tester, KES-FB3 compression tester, and KES-FB4 surface tester were used to test denim fabrics. FAST-2 measures the fabric bending length according to BS 3356-1961. Fabric test results of two different routes are shown in (Table 3).

Potential savings: For Singeing Process- We can save 4.16 hours and $300 for 10K meters of fabric to omit this process where we used bio-polishing enzyme during the de-sizing process. Previously we used a normal desizing agent such as Bactasol whose cost is $3.3 per KG. The cost of the bio-polishing enzyme is $4.5 per KG. For the first 5K fabric, we require 30 KG of Bio-polishing enzyme, and for the second 5K fabric, we require an additional 30 KG. Additional Cost due to Bio-polishing enzyme is 60 x $1.2=$72. So, our potential savings to optimize this process is ($300-$72) or $228 and 4.16 hours. For Heat-setting Process- We used 2.0 draft of weft yarn to omit this process instead of 2.8 draft of yarn. Here cost of 2.0 draft of yarn is slightly higher than the 2.8 draft of yarn and the variation is $0.1 per KG of yarn. From fabric E0001, for producing 5000 meters of fabric we need 397 KG of weft yarn. Hence, this fabric can have an additional cost and that is 397 x $0.1=$39.7. In a similar vein, fabric E0002 requires 667 KG of weft yarn for 5000 meters of fabric. Here the additional cost is 667 x $0.1=$66.7. So, our potential savings to optimize this process is ($500-$106.4) or $393.6 and 4.76 hours.

Results and Discussion

The fabric test results for both processing routes are similar and have been approved by an ITS-accredited laboratory in Bangladesh, as shown in Table 3. We got the experimental result that we can save a lot of process time and process costs. We can save $393.6, $228, or $621.6 and approximately 9 hours of processing time based on the number of fabric samples taken. We can calculate the cost on a monthly basis. A denim plant with 400 looms can produce 5 million meters of fabric in a month. Our chosen construction method yields approximately 1 million meters of fabric, as shown in Table 1. So, we can get our monthly savings by optimizing these two processes. We can save $62,160 and a processing time of around 890 hours per month by producing the same construction for 1 million meters of fabric.

Conclusion

In this research work, raw material changes and a bio-polishing enzyme were used to optimize the procedure. The outcome demonstrates that the modified process's fabric properties are superior to those of the current method. Additionally, it was found that the modified process outperformed the original process in terms of cost reductions and process speed. By analyzing this value, we can conclude that by using this modified method, we increase the profit from our product. It should be stated that the results of this study may only apply to the fabrics used in this study. In the future, more work is needed to verify these conclusions with different fabric structures.

Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Disclosure Statement

No potential conflict of interest was reported by the authors

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