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Innovative And Sustainable Design Development For Denim Fabric Using Laser Techniques, Tie And Dye And Manual Whiskering

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Abstract: Environment friendly method of processing denim garments is utmost important for value addition in the denim apparel business. Diverse methods exist today to carry out denim finishing such as bleaching, stone washing, sand blasting, snow washing, enzyme washing etc., These effects are found to be non-ecofriendly due to high energy and water consumption, more time consuming, health hazardous for both the employees and the consumers and also leads to high rejection rate. This research deals with ecofriendly and sustainable methods of denim finishing such as laser finishing and also encompasses few other innovative design development techniques for denim. Using various laser techniques like laser cut, laser whiskering, torn effect and laser fading, innovative designs (abstract, ethnic, geometric, calligraphy) were developed. Ethnic designs are incorporated by manual whiskering technique using blocks. Tie & Dyed warp yarns and undyed weft yarns were used for the development of tie and dyed denim garments. The treated denim was washed with detergent and then analyzed for weight of the sample, EPI (Ends per Inch), PPI (Picks per Inch), tensile strength, abrasion resistance, pilling resistance, tearing strength, stiffness, crease recovery, wash fastness, colour value and shrinkage. The treated fabrics exhibit a significant difference in the properties compared to the untreated samples. The intensity of laser treatment has a significant effect on the physical properties especially on the strength of the denim materials. Denim garment with innovative designs are expected to gain popularity among the customers.

Keywords: Denim finishing, Laser engraving, Laser technique, Whiskering, Tie and Die, Sustainable finishing.

1. INTRODUCTION

Denim garments play an important role in fashion industry. Among all textile products, no other fabric is as widely recognized as denim. It has been widely used by people of all ages, classes and genders. Jeans can be considered the most commonly used clothing in the fashion industry. Over the years, jeans have evolved from work clothes to casual clothes, and then to high-end functional clothing. Designer jeans and high-end jeans initially affected a small number of luxury consumers, but now consumers of all social and

economic classes adopt them. The challenges facing denim manufacturers and fashion designers include the need to reinvent products for niche markets and meet consumer needs through sustainable and environmentally friendly manufacturing[1].

There are almost innumerable variations in wet and dry processing techniques used by designers and textile chemists to achieve a unique and desirable fashionable appearance [25]. Denim has undergone various types of wet cleaning [6] and dry cleaning [7] treatments, such as pre-wash, rinse, stone wash, sand wash, snow wash, enzyme stone wash and bleached, which are used to make denim appear faded and bleached wear. However, these treatments can harm the health of workers and end users, and can also lead to wastewater contamination [8,10]. Furthermore, the chemical treatment is time consuming and the surface results are inconsistent, making the product quality difficult to control and its rejection rate particularly high [11]. To solve environmental problems, some finishing technologies (laser, ozone and waterjet) have been introduced as an alternative to traditional wet processing [12,16]. In terms of production speed and precision, laser engraving is the best solution to this problem [11]. Laser engraving is a technique used to design various patterns on the surface of fabrics with high precision and repeatability. The application of laser engraving technology can create a unique textile appearance without the application of chemicals and is environmentally friendly compared to other traditional methods used to create the same effect [17].

In the laser-based fading process, the computer directs the laser beam at the material to be marked or faded. The laser system produces coherent, monochromatic photons in a low divergence beam. The beam of light is focused on the desired area of the fabric. In the focused area, the material is heated very strongly in a very small area. The laser beam breaks down the dye and the generated vapor is discharged. The material only fades where the lightning strikes the fabric. The degree of attenuation required depends on the wavelength, power density and pulse width of the laser beam. Compared to stripping or sandblasting, laser marking or bleaching methods are more environmentally friendly. The precision of the results depends on the stability of the laser, the duration of the pulse and the total control of the energy, the dynamic autofocus and the power on demand [18].

Different types of laser treatment can be achieved using different machines, such as carbon dioxide lasers (CO_2 lasers), neodymium doped yttrium-aluminum garnet (Nd: YAG) lasers, and diode lasers [19]. Laser engraving is a subtractive method that can engrave simple or complex patterns and designs through laser beam scanning. The CO_2 laser is the most efficient, suitable for engraving materials that are not good conductors of heat and electricity, because its wavelength is easily absorbed by textiles [17, 20]. The use of computers to develop new designs and transfer the obtained designs onto the textile surface will not only increase and promote production in a more practical way, but will also help to create identical designs. This means the mass production of products with standard quality, thus increasing the added value. But it is very important to control the process parameters of laser engraving. If the process parameters are not properly configured and controlled, the physical properties of the fabric may change dramatically, and the fabric may be scrapped [11,21].

From the laser fading process, it may be observed that the treatment has good results which are similar or better than the denim technique previously recommended [17]. The laser fading process efficiently eliminates indigo from the denim. Changes in Denim diffusion reflectance spectra after laser irradiation were up to 17% at a wavelength of 450

nm in comparison with the reflectivity of 8% unidentified denim [8]. Although the effect of color fading has increased with increased laser output, optimal effects for color fading can be achieved. The color plans of the laser treated denim fabric were good in accordance with quantitative measurement. However, it was found that the direction of laser irradiation did not affect the effect of fading of color and the color level [15]. The laser power density was improved in response to the level of time and resolution of pixels. Due to the influence of the high density of laser power, an appearance of the surface of the thin plate is achieved for the denim fabric that has significantly reduced the value of the denim fabric, indicating that the amount of dye present on denim is significantly reduced. In addition, a green yellow tone was observed in a sample of denim fabric after laser engraving [16]. As the gray scale color increases, color fainting is high, which affects the performance of the fabric along the weight of all fabrics, which in turn affects the performance of the fabric. Based on this, this study recommends a set of optimal laser processing parameters to produce stress or faded effects without sacrificing the performance of the fabric [16]. This study is mainly focusing on developing innovative designs using laser technology, manual mustaches and tie threads and dyed in denim products.

2. METHODOLOGY

This research attempts to bring design variation in denim that can be commercialized. It makes use of laser beams to transfer pictures, figures as well as graphics of desired variety, size and intensity on denim fabric. In the designed system, computer-controlled laser beams are used to change the color of the dye material on the textile surface by directing the laser beams at a desired wavelength and intensity. For this purpose, a laser beam source that can reach the initial level of power and that can be controlled by means of a computer interface; reflecting mirrors that can direct this beam at two axes; a galvanometer which comprised of an optical aperture; and a computer program that can transfer images obtained in standard formats to the galvanometer control card were used.

The laser process was conducted with a CO_2 source laser (wavelength: 10.6μm) engraving machine (GFK, Spain) which is computer-controlled. The design was developed with Photoshop software and the denim fabric was treated in the laser machine in the above mentioned conditions. After laser treatment, a normal washing was performed to remove size particles and other dirt and dusts from the fabric.

In this research, the laser technology is used for producing different style of designs as given below:

- Developing different colored patches using laser techniques.
- Developing whiskering pattern using laser technique.
- Cut motifs using laser.
- Developing torn denim using laser
- Tie & Dye Denim

TESTING

After laser treatment, denim fabrics were subjected to washing according to AATCC Test Method 135: 2004, using a Whirlpool US WTW5905 washing machine and 66.0 ± 1.0 g of detergent to wash denim at 27 ± 3ºC for 12 minutes. After washing, the denim is subjected to hydraulic extraction for 6 minutes and then drum-dried at 66 ± 5 ° C

for 10 minutes. After drying, the denim is conditioned in a standard atmosphere of 65 ± 2% relative humidity and 20 ± 2 ° C before measurement. To study dimensional stability, the denim was washed and dried once, thrice and five times. After each wash and dry, measure the size of the pattern and calculate the dimensional stability of the denim.

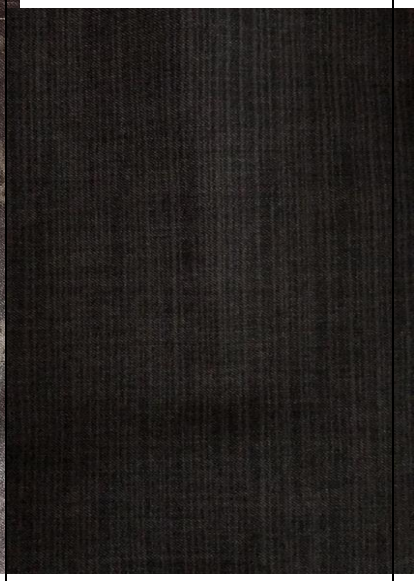
Several performance tests were conducted to see if these samples are marketable. The treated samples are checked for fabric weight, EPI (number of counts per inch), PPI (number of peaks per inch), tensile strength, abrasion resistance, pilling resistance, tear resistance, stiffness, wrinkle recovery, and resistance of the treated samples, color value and shrinkage rate. The standard test methods used are tensile strength ISO 139342, dimensional stability AATCC 135: 2010, color fastness to washing ISO 105 C06, abrasion resistance ASTM D4966, resistance to pilling EN ISO 129451: 2000, color fastness to rub ISO 105x12; 1993, ISO 139372 tear strength and color value using a spectrophotometer.

3. RESULTS AND DISCUSSIONS

Laser Printing /Colour Fading

The designs such as patch, ethnic, striped, checked, geometric, abstract, calligraphy were created using Adobe illustrator software. The designs were then uploaded in the laser machine (KG Denim Pvt Ltd) and the design created was replicated in the samples. The intensity of laser should be appropriate to the thickness of the fabric otherwise the fabric may get damaged. Various designs are developed with different colours in the same motif and in the same fabric sample by adjusting the laser intensity. The variations in designs can be created using different intensities by adjusting the dots per inch (DPI).

The laser power plays an important role in the CO_2 laser treatment on the denim fabric which is closely related to the indigo removal process of textile. The physical phenomena involved in the indigo removal process will be the vaporization process. The material removal by laser may often be a simple vaporization process with absorption of the laser energy at a continually treated surface. As the laser energy increases, the material reaches vaporization conditions more rapidly [8]. It is observed that, the shorter the pixel time, the darker the shade of the laser-engraved fabric. It had been proved that the short pixel time would have a lower laser power for the engraving process such that a fewer amount of dyes could be removed from the denim fabric surface resulting in a darker shade. Similarly, when the resolution was taken into consideration, the reflectance values increased with the enhanced resolution. The higher the resolution, larger the laser power will be, resulting in more dye removal and paler shade. Hence the laser process is an effective tool to transfer a pattern or image from computer to the fabric surface. With the use of laser processing, the engraved pattern could totally match the desired size. Various designs developed on denim is shown in the Fig 1.

Geometric design (25 dpi)	Checked pattern (25 dpi)	Ethnic design (21 dpi)
		
Ethnic design (24 dpi)	Ethnic motif (24 dpi)	Striped pattern (18 dpi)
		
Ethnic design (19 psi)	Checked design (22psi)	Ethnic pattern (21psi)

Abstract design (20-28 psi)	Caligraphy (21 psi)	Abstract design (18 psi)

Figure 1 Designs developed using laser printing/ Colour Fading

Torn denim by laser technique

Torn denim is one of the widely used fashionable denim and it involves high manual task like first grinding and removing of the warp yarns and blowing air to get the required effect in the garment. This can be eliminated by using laser by setting intensity little higher than the actual intensity that the garment can withstand so that the particular part of the garment is damaged but not fully cut. Then by using knife, the top layer that is the warp yarns can be removed to get the torn effect. In this process the intensity is kept at

26 dpi to produce this effect. In laser cut the intensity of the laser is kept as high 29dpi and the fabric is cut according to the developed motif or pattern.

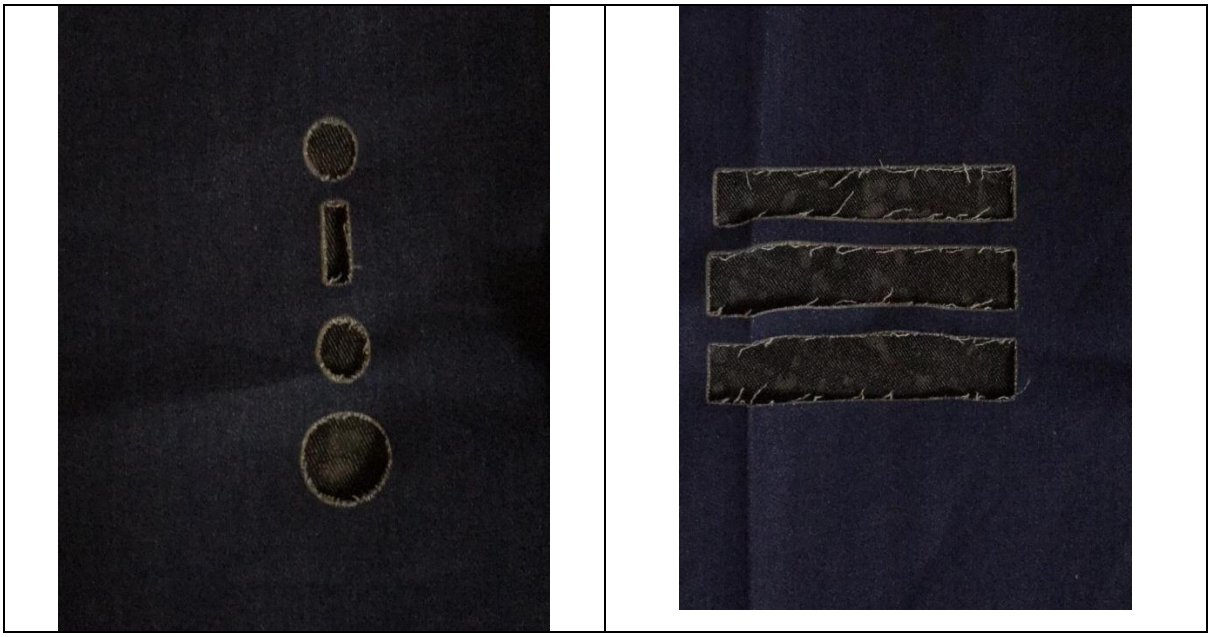


Figure 2 Designs developed using Laser Cut/ Torn Denim

Laser Whiskering

Whiskering in denim is generally done manually. It involves more man power and hence incurs high labor cost. Manual whiskering may also result in health problems like respiratory disorders. Laser whiskering eliminates all these difficulties and productivity is high. One of the disadvantage found in laser whiskering was the effect obtained was not natural and not blended as that of manual whiskering, however this can be avoided by proper brushing. The laser whiskering is highly visible in light weight denim fabrics and if appropriate intensities are maintained, the whiskering effect will be effective in heavy denim fabrics also.19 psi was used to develop whiskering effect and the sample is shown in Fig.3

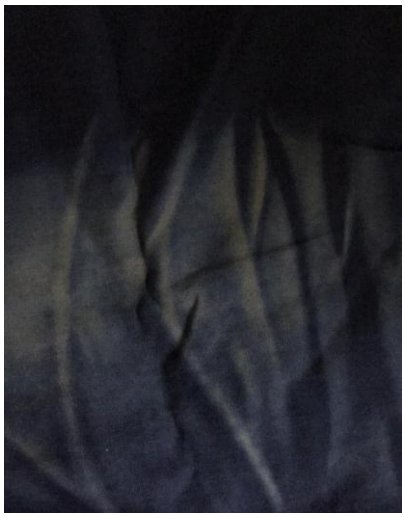


Figure 3 Designs developed using Laser Whiskering

Tie & Dye Denim

To generate a different look and effect on denim, instead of using solid color yarn in warp direction, tie and dyed yarn is used in warp and undyed yarn is used in weft direction. Indigo color is used for tie and dye effect in yarn. The sample developed is shown in Fig.4

Tie and dyed warp yarn	**Tie and dyed denim**
	

Figure 4 Designs developed using Tie & Dye technique

Manual Pattern Whiskering

This technique involves the use of blocks with patterns for whiskering. Instead of normal rubber pad whiskering, the denim garment is placed over the blocks and is rubbed using emery sheet to get the engraved motif design on the garment. Using the whiskering

using wooden blocks, greater aesthetic effect can be achieved, like ethnic, abstract, geometric etc. It also replaces printing technique on denim garment. The Fig. 5 shows the samples developed through manual whiskering technique.

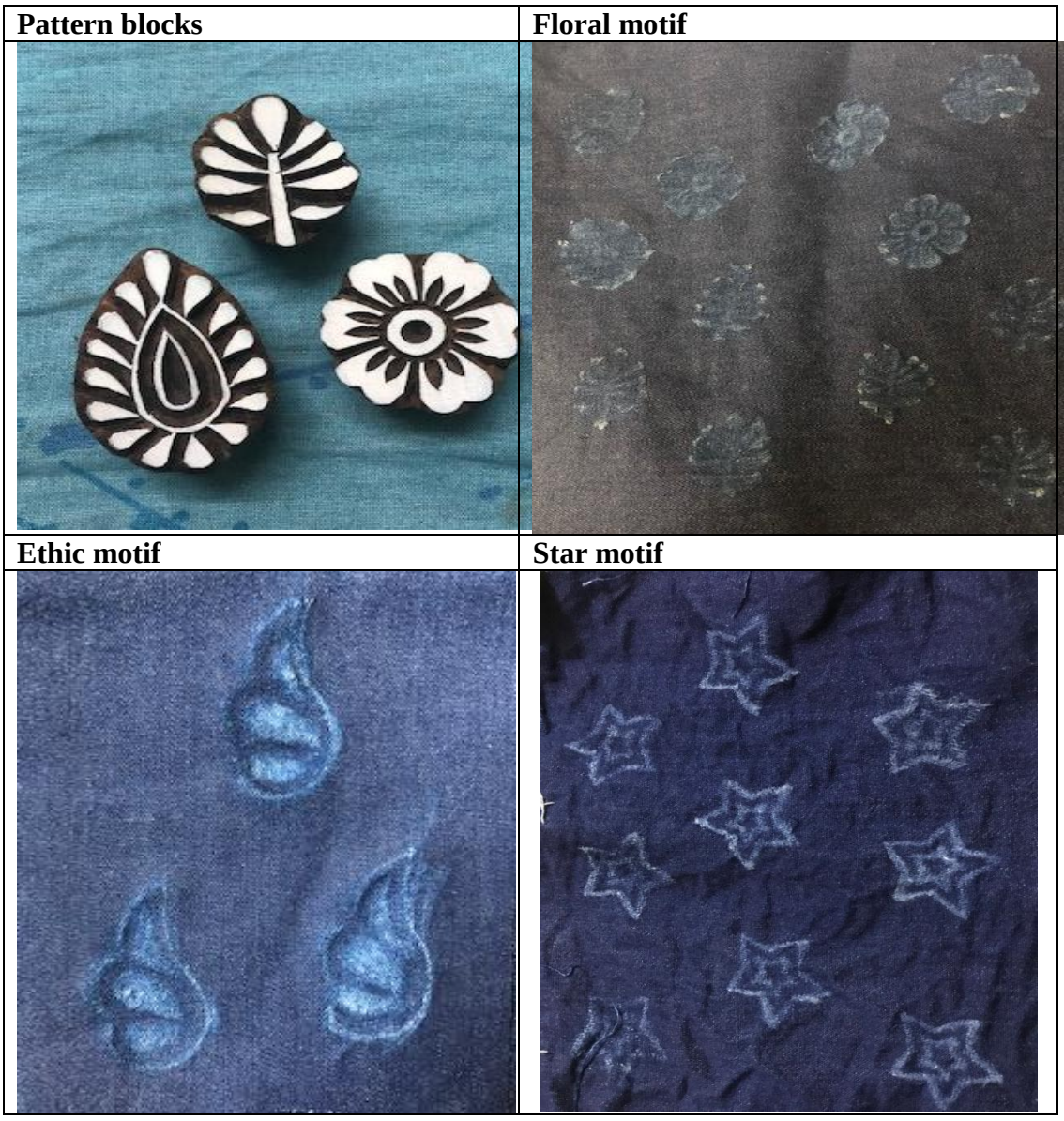


Figure 5 Designs developed using manual whiskering

Effect of washing on manual whiskered sample

Laundry wash is done to test the durability of the developed motifs. The test is carried out using the standard method ISO105C06. In this method, the sample fabric and multifibre fabric (10x4cm) are stitched at one edge and is treated in the soap solution of 4gpl and 1gpl of sodium perborate in the Rotawash machine. The temperature is maintained at 60˚C for 30 minutes and 10 pieces of steel balls are used and the sample is rinsed with hot water and then squeezed with cold water and dried at a temperature not exceeding 60˚C and then the stitch is taken out and the staining of colour and change in colour is noted by the grey scale. It is observed that the motifs withstand even after four washes and hence the fabric is acceptable for usage.

Before wash	After wash
	
	

Figure 6 Effect of washing on manual whiskered samples

Abrasion resistance of manual whiskered sample

The samples are tested for resistance to abrasion. The test is carried out under the standard ASTM D 4966 method. The shade variation 4 was noted by the grey scale under day light D65. Hence the manual whiskered sample has good abrasion resistance and it can be commercially used. It is also noted from the result that the colour change of the sample is 4 and the weight loss percentage is 2.25%. As the shade variation and the weight loss percentage is within the tolerance level the samples are acceptable for usage.

Dimensional Stability

The laser treated denim fabric samples were tested for shrinkage percentage as per ISO 6330 method. The samples were subjected to simulated domestic washing with

different washing cycles and the shrinkage and growth in fabric dimension were noted. The degree of shrinkage and growth depended much on the laser power used. Generally speaking, shrinkage occurred mostly in the lengthwise direction because the yarn in the lengthwise direction is subjected to a higher tension during the fabric production process. So during washing, the relaxation shrinkage occurred severely in the lengthwise direction. It was also important to note that during the washing process, damage of denim fabric occurred when it was treated with very high laser power. As a result, when using laser for creating pattern or design in textile fabric, a careful selection of laser processing parameters was recommended so as to prevent shape deformation without affecting the final result. The laser treated sample shows a vertical measurement of 335 mm and percentage of dimensional change is 0.043% (shrinkage) and the horizontal measurement of 356 mm and percentage of dimensional change is 0.017% (growth). The tolerance limit of acceptance for woven fabrics is ± 3%, and since the shrinkage % is very less for the laser treated fabric, it can be accepted.

Performance of tie and dyed samples

The colour fastness to washing of the tie and dyed samples were tested according to the standard ISO 105 C06. The change in colour of the specimen and the staining of the adjacent fabric are assessed with the grey scales and is given in Table 1

Table 1. Colour fastness to washing of Tie & Dye sample

FABRIC (Staining)	GRADE
Acetate	4
Cotton	4
Nylon	3
Polyester	4
Acrylic	4
Wool	4

The sample which is dyed by tie & dye method is within tolerance limit 4 and hence it is acceptable for usage. The results for the abrasion resistance test shows that after abrasion, the shade variation was 4 under day light D65 and the weight loss % was 1.77%. Hence the sample passed abrasion test and can be commercially used. Similarly, the pilling test was carried out by the standard EN ISO 12945-1:2000 and the fuzziness and pilling was assessed visually after a defined period of tumbling. It is assessed that all the samples are of in the pilling grade of 4.

FINAL GARMENTS DEVELOPED

Garments were developed using the developed fabrics and are shown in the Fig.7

Figure 7 Garments developed

4. CONCLUSION

This project deals with bringing variation in denim that can be commercialized. Implementation of whiskering, torn effect and cut using laser technique reduces hazardous effect on labours than doing it manually. Costing and survey is done to increase the possibility of commercialization. Manual pattern whiskering overcomes the disadvantage of printing and various motifs can be developed. Better appearance is achieved by the use of tie and yarn than top dyed denim garments. The developed designs are new to commercial market and can gain popularity among customers. The developed samples are surveyed and the garments are accepted based on the designs developed.

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