International Conference on Mechanical, Industrial and Materials Engineering 2015 (ICMIME2015)
11-13 December, 2015, RUET, Rajshahi, Bangladesh.

Paper ID: IE-09

Technical study of the effect of CO_2 Laser surface engraving on the physical properties of denim fabric

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Abstract

Laser engraving is a technology used to design various patterns on fabric surface within a very short time. Laser engraving has successfully replaced some conventional dry processes which were used to make the fabric look faded and worn out. These dry processes were time consuming, health hazardous for both the worker and the end user and with a high rejection rate whereas the laser engraving technology is fast and very much accurate. But controlling the process parameters in laser engraving is very important. If the process parameters are not set and controlled correctly, the physical properties of the fabric can be changed drastically and can result in rejection of the fabric. Present study aims to study the effect of CO_2 laser parameters on 100% cotton denim fabric. Leg panels were formed from the fabric pieces and then the leg panels were exposed to different DPI (Dots per Inch) and Pixel time. The leg panels were treated using 20 DPI and 100 µS, 20 DPI and 150 µS, 20 DPI and 200 µS, 25 DPI and 100 µS, 25 DPI and 150 µS, 25 DPI and 200 µS. The treated panels were then washed with detergent and softener by following standard recipe. The physical properties of the treated denim leg panels were analyzed using standard test methods. The properties that were analyzed are hand feel, tearing strength, fabric weight, EPI (Ends per Inch), PPI (Picks per Inch) and crease recovery angle. The laser intensity has a great effect on the physical properties especially on the strength of the denim. The treated leg panels exhibits a significant difference in the properties than the untreated samples.

Keywords: CO_2 Laser, Laser intensity, Denim, Physical property of denim.

1. Introduction

In Bangladesh ready-made garments are the top export item and among which the share of woven item is maximum [1]. Among woven items, the denim garments possess a significant share. This denim is processed with several of wet washes [2] and dry processes [3]. Some of the dry processes are used to make the denim look like faded and worn out. But these conventional processes of dry processing are time consuming. Health hazardous for both the worker and the end user and their rejection rate is notably high [4]. The laser engraving is the best suited solution of this problem in terms of speed of the production and accuracy [4]. Apart from this, laser systems are also used in fashion design, pleating, cutting, modification of fabric surface [5] and to impart some special finish like antimicrobial finish [6]. The application of laser engraving technique can create unique appearances of textiles without chemical applications and is environmentally friendly compared to other conventional methods employed for creating the same effect [7]. Different types of laser treatments can be achieved by using different machines such as carbon dioxide laser (CO2 laser), neodymium-doped yttrium aluminium garnet laser (Nd: YAG) and diodes lasers [8]. Laser engraving is a subtractive method and can engrave simple or complex patterns and designs through laser beam scanning. CO2 laser is the most efficient and suitable for engraving materials that are not good conductors of heat and electricity because its wavelength can easily be absorbed by textiles [7]. A laser system generates monochromatic, coherent photons in a low-divergent beam. The beam is focused on the desired area of the fabric and within the focused region, the material is subject to a very intensive heating within a very small region. Laser energy is absorbed as heat and the material rapidly heats leading to melting as a phase change from solid to liquid takes place. Some of the molten liquid tries to move, driven by surface tension of the liquid. The remaining liquid heats very rapidly, boiling and releasing vapors another phase change takes place from liquid to gas [9]. Despite of having some safety issues [10] in laser processing, the process is very useful in textile cutting [11] and engraving [12].

2. Materials and methods

Materials

100% cotton denim leg panels were used. These comprised sized indigo dip-dyed denim fabric, GSM (Grams per Square Meter) 481, 3/1 warp faced twill, construction 76 x 57 / 12 x 11, fabric width 57 inch. The leg panels were treated in a laser system (VAV Technology) according to the intended DPI (Dots Per Inch) and Pixel Time (µs). Then the samples were washed with detergent (Hostapur WCTH, Germany) and softener (Resil AOEC, Resil, India) following standard recipe.

Methods

At first, the samples (leg panels) were treated in a laser system (VAV Technology) for 100 µs, 150 µs and 200 µs in 20 DPI and for 100 µs, 150 µs and 200 µs in 25 DPI. The design was developed with Photoshop software and then the leg panels were 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 leg panels. At first twill leg panels were desized using desizing agent. This pretreatment was conducted in liquor containing desizing agent, Luzyme (1 g/l). Material to liquor ratio was 1:10 and the process was performed in a small scale front loading industrial washing machine (Sutlick, Singapore). This treatment was carried out at temperature 60°C for 10 min and the pH of the bath was 7. Then the panels were washed using detergent, Hostapur WCTH (1 g/l) in the same machine for 5 minutes at 30º C. Then the panels were rinsed twice with cold water. After treating with detergent, the panels were softened with a softener. This treatment was conducted in a bath with a liquor ration of 1:10, containing Resil AOEC (2 g/l), acetic acid (40 gm.) to maintain pH 5.5 in room temperature for 7 minutes.

Washed and softened denim leg panels were squeezed to a wet pick-up of 70% at 200 rpm for 3- 4 min in laboratory scale hydro-extractor machine (Zanussi, Roaches International Limited, England), then dried at 70-74 °C for 18 min. in a steam dryer (fabcare, India). Treated denim leg panels were then analyzed to determine and compare their physical properties.

Testing and analysis

Treated denim leg panels were conditioned in 65% RH and 20°C for 24 hour before testing according to BS EN 20139 and ASTM D1776. Hand feel of the fabric was determined by holding the fabric between the thumbs and compared with the untreated sample. Tearing strength was determined according to ASTM D1424 - 09(2013). Fabric weight (GSM) was determined according to ASTM D 3776 and the weight change (%) was calculated from the difference in fabric weight before and after the treatment. Crease recovery angle of the treated fabric has been determined according to AATCC Test Method 66- 2014.

3. Results and discussion

Effect of laser treatment on feel of fabric

The handle of the fabric improves a lot after performing the laser engraving and normal washing process. But it is notable that, the hand feeling improves significantly with the increment in the DPI or pixel time of laser. For 25 DPI and 100 µs, the best feeling is achieved.

Effect of laser treatment on general fabric property

Effects of laser engraving treatment on EPI, PPI, Warp count, Weft count and GSM (Grams per square meter) are presented in the table below-

Table 1. Effect of laser treatment on the general specification of denim fabric

Treating Conditions	EPI (Ends/Inch)	PPI (Picks/ Inch)	Warp Count (Ne)	Weft Count (Ne)	Fabric Weight (GSM)
Control	76	57	12	11	481
20 DPIX100 µs	77	57	13	11	391 (-18.7%)
20 DPIX150 µs	78	58	14	12	368 (-23.5%)
20 DPIX200 µs	77	57	14	11	364 (-24.3%)
25 DPIX100 µs	77	57	14	12	350 (-27.2%)
25 DPIX150 µs	78	57	15	12	336 (-30.1%)
25 DPIX200 µs	77	58	15	12	318 (-33.9%)

Here (-) means decrement and (+) means increment in fabric weight

It is clear from table 1 that, the laser engraving imparts significant change in the fabric properties. The fabric weight (GSM) has been found reduced up to 33.9% as the laser melts and evaporates the surface materials and a part of the fiber from the denim fabric. The effect of decreasing of GSM is more prominent in case of increased DPI than increased pixel time. High DPI damages the higher portion of denim surface and that causes rapid decrement in the GSM of the fabric. But a very long pixel time may cause severe damage to the fabric which can result the burning of the fabric.

The changes in EPI, PPI, Warp count and Weft count are not so prominent. The weft count remains either same or increases a little as the laser ray burns a part away from the yarn and their weight per unit length reduces. This change of count is more prominent in warp way as the fabric is warp faced twill and the laser acts direct upon the warp yarns and thus the count of warp yarns are found increasing with the increment of laser intensity (DPI and pixel time).

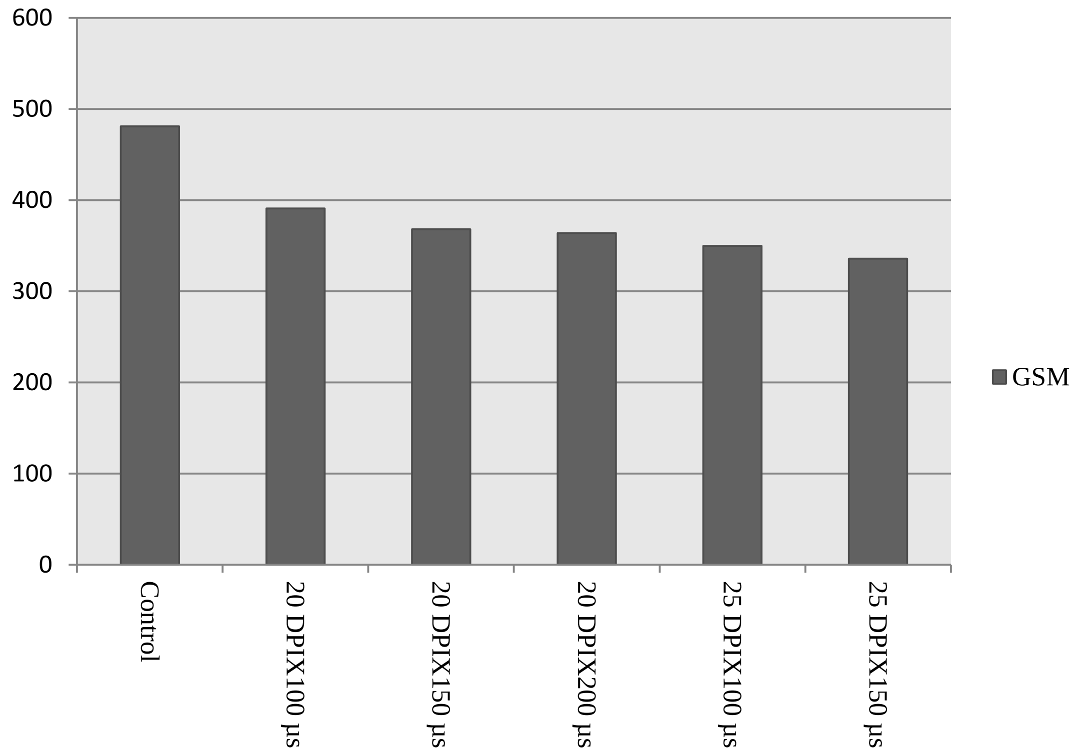

Fig. 1. Change in fabric GSM (Grams per Square Meter) in different process conditions

Effect of laser treatment on tearing strength of the fabric

Effects of laser engraving treatment on the tearing strength of the denim fabric are presented in the table below-

Table 2. Effect of laser treatment on the tearing strength of denim fabric

Treating Conditions	Tearing Strength (lb)	
	Warp	Weft
Control	8.78	9.16
20 DPIX100 µs	5.19	5.54
20 DPIX150 µs	5.15	5.36
20 DPIX200 µs	4.75	4.94
25 DPIX100 µs	3.55	3.80
25 DPIX150 µs	3.14	3.38
25 DPIX200 µs	2.99	3.07

Gradual increment in laser intensity (DPI and pixel time) causes gradual decrement in tearing strength of denim fabric. Increased pixel time and DPI causes damage to the fabric and thus the strength of the fabric falls. In 25 DPI and 150 µs the strength of the denim fabric is found minimum and which is 65.94% less than control in warp way and 66.48 % less than control in weft way. In case of 20 DPI and 100 µs the tearing strength experiences a huge decrement (40.89% in warp way and 39.48% in weft way) compared to the control sample. Then the tearing strength falls gradually in increasing laser intensity.

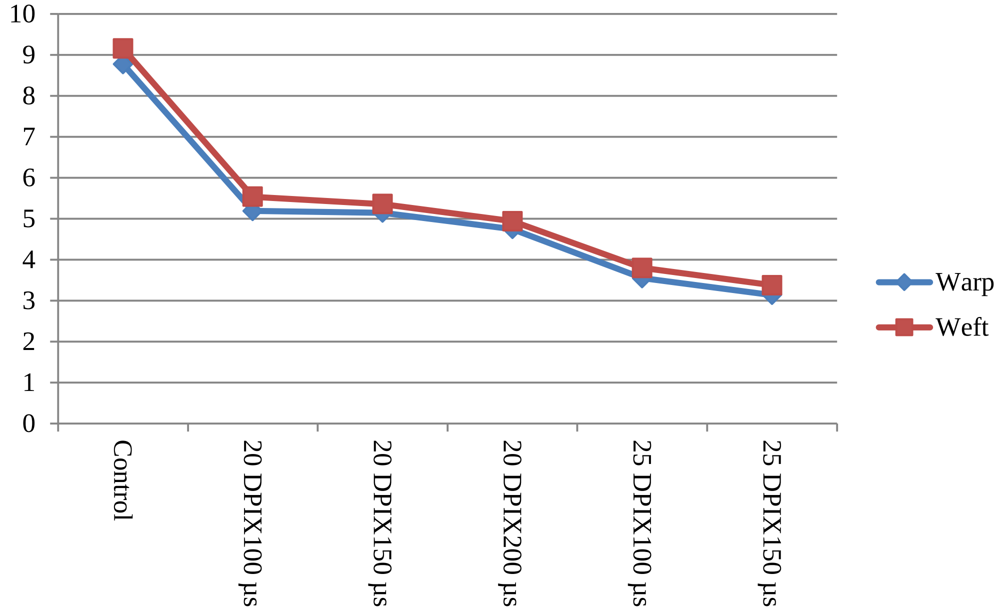

Fig. 2. Changes in warp way and weft way tearing strength of denim fabric in different process conditions

Effect of laser treatment on crease recovery angle of the fabric

Effects of laser engraving treatment on the crease recovery angle of the denim fabric are presented in the table below-

Table 3. Effect of laser treatment on the crease recovery angle of denim fabric

Treating Conditions	Crease recovery angle (Degree)	
	Warp	Weft
Control	70	65
20 DPIX100 µs	69	62
20 DPIX150 µs	67	61
20 DPIX200 µs	65	60
25 DPIX100 µs	60	57
25 DPIX150 µs	55	50
25 DPIX200 µs	52	48

In both warp and weft way, the crease recovery angle is found decreasing with the increasing laser intensity. A reduced crease recovery angle means the fabric becomes softer and more prone to crease. Thus in case of 25 DPI and 150 µs the crease recovery angle is minimum in both warp and weft way.

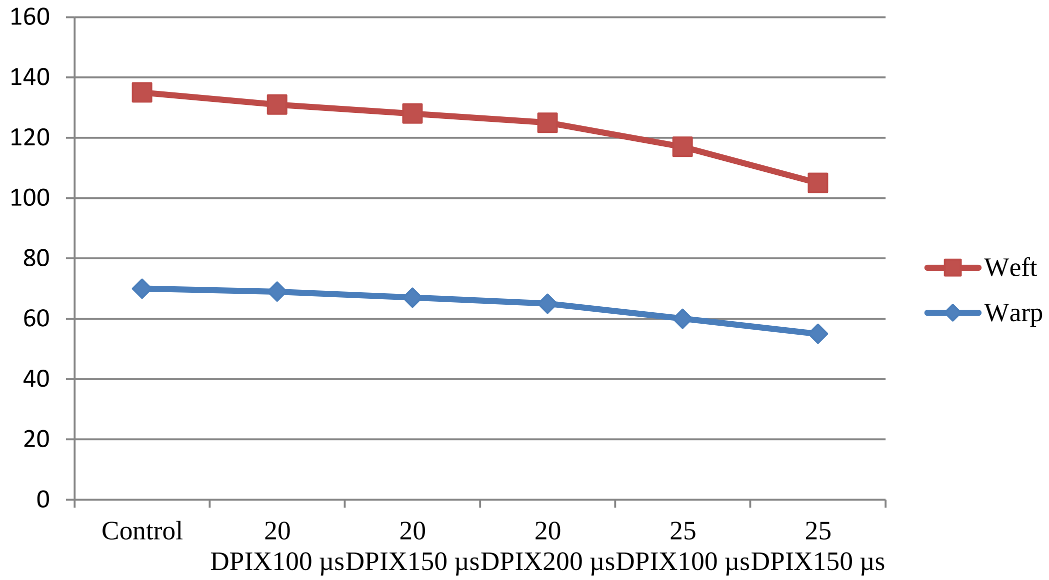

Fig. 3. Changes in warp way and weft way crease recovery angle of denim fabric in different process condition

4. Conclusion

The laser engraving treatment has a distinct effect on the physical properties of the denim fabric. Fabric appearance, crease resistance and more importantly, the strength of the fabric are significantly changed as a result of the treatment. The weight (GSM) of the fabric also changed in a notable extent. The decrement in GSM of the fabric makes the fabric light, comparatively dimensionally unstable as well as the strength of the fabric falls. We can see that, the tearing strength of the fabric is 65.94% and 66.48% less than the raw sample in warp and weft way respectively in the highest laser intensity. This also affects the crease recovery angle of the fabric. Of course the increasing intensity of the laser makes the fabric soft but, it makes the fabric weak and more prone to crease. So, it is eminent that, the increased laser intensity is required for a more prominent design on the surface of the fabric but, the increasing laser intensity makes the fabric weak, dimensionally unstable and more prone to crease. So a balance needs to be drawn. An optimum condition should be chosen to engrave the denim with laser without hampering the strength, GSM, crease recovery angle in large extent. The best condition should be chosen depending on the required performance of the end product.
Considering all the requirements and serviceability of the end product it can be said that, 20 DPI with 100, 150 and 200 µs can be used for this particular fabric. But increasing laser intensity than these conditions will reduce the serviceability of the end product in a large extent which is not acceptable.

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