DURABILITY UTILIZING ABRASION OF SEAMED LASER FADED DENIM

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Abstract

Purpose of this work was to study the effect of laser denim wash process onto abrasion of seamed denim. Experimental used a number of three different weight 100% cotton fabrics, all are indigo dyed, fabrics were faded using industrial CO₂ laser beam onto seamed areas. Seams were completed on weft direction for each tested denim fabric. The three seamed denim fabrics, unwashed and laser faded, were tested using Rubtester and abraded denim surface was scanned. Moreover, scanning Electronic Microscopy SEM for the three fabrics was acquired to explore the difference in surface morphology, of the laser fading onto different denim fabrics’ weight. Color hue and ΔE were detected showing the change in color, through comparing unwashed to CO₂ laser faded fabrics. In between all tested denim fabrics, resultant data presented the light weight plain weaved denim fabric to be severely damaged by the fading effect of laser, in terms of abrasion. For industrial use it is advised to use laser fading onto heavy weight twill denim garments, and utilize the superimposed seam instead of topstitched lap-felled seam for anaesthetic durable piece of laser faded garment.

Keywords: Laser types, Seam durability, Denim SEM, Color Hue

1. INTRODUCTION

Durability of denim garments is expected to be higher, by consumers, than any other clothing item. Seam strength is one aspect can be used into identifying garment’s durability. Seam strength is determined through the breaking strength and elongation length of both a woven fabric and its sewn line. Failure at a seam makes a garment unusable even though the fabric may be in good condition. There are a number of possible causes of seam failure; first, the sewing thread wears out before the fabric does, second, the yarns making up the fabric are broken by the needle during sewing process, or third, seam slippage occurs (Saville BP 2004). Abrasion is another aspect predicts the lasting period of time a garment can endure. Fabric quality alone does not fulfil all the criteria for production of high quality garments (Bahere et al. 1997; Dureja 1992).

Sewn seam is the primarily used principal into assembling a three dimensional garment, by joining each two pieces or edges of the same piece together. Sewing is defined as a two or more pieces of fabric are joined using sewing machines, sewing threads and various types of stitching (Eberle H et al. 2002). The simplest seam type of class 1 is formed by superimposing the edge of one piece of material on another; an example of this is the French seam which is completed in two stages. Class 2 of lapped seams is common on jeans; this provides a very strong seam in garments that will take a lot of wear, though there is a possibility that the thread on the surface may suffer abrasion in areas such as inside leg seams (Tyler D. 2005; Carr and Latham 1988). McLoughlin and Hayes 2013 mentioned that when joining materials aesthetic appeal, strength and durability are some factors of others should be considered. Seams should possess durability as much as the fabric assembled, there are known defects such as seam slippage and seam pucker mainly shown onto light weight fabrics, not predicted to appear onto denim garments. Even though denim wash process can degrade seamed areas due to the stresses caused by fading chemicals or mechanical behaviour.

Denim wash process can be identified as the worn off look of the indigo dyed twill textile material. Traditionally is known as stone and super stone wash; where pumice stones are used in washing machines with the intended denim garment, achieving the traditional denim washed look after several hours. Due to the high water and time consumption for those washing methods, new technologies have been applied. Laser is one of those technologies with no water wastage.
Laser fading denim is important as it is not a wet process; precisely controlled faded patterns can be obtained. Removal of indigo color by laser beam from denim garments has some recommended waves, ND: YAG laser with wave length 1064nm, or double ND: YAG 532nm. Also the clean process of laser beam generated from CO₂ at wave length 10600nm (10.6µm). Excimer laser can be used for denim fading utilizing wave length in between 196nm to 235nm (Lockman and Clyson 1996). A research presented by Dascalu et al. 2000 compared between the ND: YAG laser and CO₂ on fading denim; different pulse parameters were applied, conclusion was made that both CO₂and ND:YAG caused fading; CO₂ affected the textile fibers negatively in terms of strength, due to the heat and evaporation phenomena. Laser treatments on textile materials are growing, a recent study by Jiang et al. 2015 the researchers applied an adhesive to textile fabric, followed by that sticking foil and laser CO₂ was applied to give fashionable shades. A higher cost might be a result of denim fading process using laser.

A relatively big number of denim fabrics were tested for laundry effect on pilling and abrasion by Card et al. 2006, denim samples were pre-washed, stone washed, and cellulase enzyme washed. Edge abrasion was evaluated at the bottom cuff and side seam areas of each sample and rated on scale of four or nodamage to one or major damage. The samples were examined using either the human eye or a stereomicroscope. In conclusion, enzyme treated garments experienced more edge abrasion than the pre-washed jeans, but less abrasion than the stone washed jeans after repeated home laundering.

Even though, denim wash using various methods, chemically or mechanically have been used. Durability utilising abrasion of laser faded denim various seams was not investigated before.

II. EXPERIMENTAL

Three different weights 100% cotton denim fabrics specified in Table1 were supplied by the Concrete company for Children’s wear of Egypt, either unwashed and CO₂ laser faded fabric are represented. Abrading surface of silicone paper P1500 was used on the machine, the durability of intended seamed denim fabrics were investigated using abrasion for a constant of 35 rubs of the Rub-tester BS 5690. Color hue K/S, which shows deepness in color, has been examined for all laser treated samples, ∆E was calculated in reference to the control untreated denim sample, using the Optimatch 3100, ISO105-Jo1:1989. SEM using Quanta FEG 250 was done investigating denim surface change due to CO₂ laser fading.

Table1: specification of tested denim fabrics

<table>
<thead>
<tr>
<th>Weight g/m²</th>
<th>Thickness mm</th>
<th>construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>“FH”</td>
<td>376</td>
<td>0.730</td>
</tr>
<tr>
<td>“FM”</td>
<td>296</td>
<td>0.570</td>
</tr>
<tr>
<td>“FL”</td>
<td>155</td>
<td>0.335</td>
</tr>
</tbody>
</table>

Note: FH Heavy weight fabric, FM is for medium weight fabric, while FL represents light weight fabric

Laser fading has been done using scan mode with 500mm/sec speed and interval of 0.1mm, utilizing maximum power 13%. This was stable for all tested denim fabrics of this study.

Two types of seams were assembled, lap-felled seam with a double needle topstitch and superimposed seam resembling both inner and outer side seams respectively, with stitch density of 3.5stitches/cm, 5stitch overlap was used, thread count 40/3 for both seams, while an extra stitch line lock stitch using thread count 20/2, all threads used were 100% polyester.

III. RESULTS AND DISCUSSION

Abrasion Test

Table3 shows the different photos of tested denim fabrics, before and after abrasion for both unwashed and laser faded effects. Images show the FL light weight denim fabric to be severely damaged at seamed areas, causing any constructed garment from such a fabric to a failure in quality requirements; either in terms of durability or aesthetic appeal. This was the case for both sewn types of seams in table 2 below. Seams must withstand loads during wearing and prevent seam breakage or visible damage to the fabric in the seam region (Mukhopadhyay and Midha 2013). Form this context the other two tested fabrics, heavy and medium weight denim, are having problems in terms of durability when assembled using the lap-felled seam; where the top stitched lines have been abraded leaving the garment as if worn out.

On the other hand, for superimposed seams of the heavy weight and medium denim fabrics, showed a
better aesthetic appeal where fading took place but worn out with slippage effect was not present. This confirms the resultant data of this research, superimposed seam is a better resolution when garment is laser faded, either heavy or medium weight. Even though, it was mentioned by Ondogan et al. 2005 it would be possible to transfer certain designs onto the surface of textile material by changing the dye molecules in the fabric and creating alterations in its color quality by directing the laser to the material at reduced intensity; light weight denim plain weave should not be laser faded at seam areas, as shown in this study. Any decrease in tensile strength values indicates damage in fabric structure, laser fading process cause a decrease in tensile strength values. However, the most significant decrease is occurred after 250μs pulse times.

**Color Hue Test**

The color measurements were carried out between 400-700 nm wavelength and the values were taken from the wavelength where reflection values were smallest. The K/S values of the faded samples were calculated using the following formula; K/S = (1-R)² / (2*R), where R: Reflection value in maximum absorption wavelength, K: Absorption coefficient and S: Scattering coefficient (Özguney et al. 2009). The resultant data obtained from this study is shown in Table 2. Light weight fabric has the highest change in color after laser fading, this is shown as from the big ΔE value compared to the other heavy and medium weight denim laser faded ones. The color change (ΔE*) values of the faded samples were calculated by using the following formula ΔE* = [(ΔL*)²+(Δa*)²+(Δb*)²]¹/².

**Table 2: Color Hue and ΔE of the three tested denim fabrics before and after laser fading process**

<table>
<thead>
<tr>
<th></th>
<th>FL</th>
<th>FH</th>
<th>FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>l</td>
<td>30.42</td>
<td>40.43</td>
<td>23.87</td>
</tr>
<tr>
<td>a</td>
<td>1.08</td>
<td>-0.65</td>
<td>1.65</td>
</tr>
<tr>
<td>b</td>
<td>-3.78</td>
<td>-6.44</td>
<td>-1.33</td>
</tr>
<tr>
<td>K/S</td>
<td>5.942</td>
<td>2.67</td>
<td>10.84</td>
</tr>
</tbody>
</table>

Where a: Red (+) – Green (-), b: Yellow (+) – Blue (-), L: White (+) – Black (-).

**Table 3: Surface Morphology of tested denim fabrics**
Superimposed seam for outer denim pants side seam

<table>
<thead>
<tr>
<th></th>
<th>Unwashed Before Abrasion</th>
<th>Abraded</th>
<th>CO₂ Laser Faded before abrasion</th>
<th>CO₂ Laser faded abraded</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FH</strong></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>FM</strong></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td><strong>FL</strong></td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
</tr>
</tbody>
</table>

As a general rule, if there is a total color difference of \( \Delta E \) equal to 0.2 between two samples, these samples can be considered visually different (Mercer H 2014). From table 5 above the “\( l \)” value shows all faded denim fabrics whiter in shade than before CO₂ laser treatment, with highest white effect for the light weight fabric FL. The “\( a \)” value indicates all denim fabrics with reddish shade prior to laser fading, this was changed to green shade for the light weight FL denim after CO₂ laser treatment, in general all tested denim fabrics showed less red effect after being laser faded. The “\( b \)” appears to show all examined denim fabrics with blue shade; again for the light weight FL shade became away for yellow, as well as the other two heavy FH and medium FM weight CO₂ faded denim fabrics. Lower value of \( \Delta E \) is shown for the heavy weight FH denim fabric, then medium weight appeared to get higher differences in shade when CO₂ laser faded, finally the light weight FL is faded intensely when using the CO₂ laser fading technique.

**Scanning Electronic Microscopy SEM**

SEM before and After CO₂ Laser Fading of Different denim weights are shown in table below. Morphology of denim 100% cotton yarns has been studied giving the following scans. Both 150X and 2000X times magnification were observed.

Table 4: SEM of denim fabrics before and after CO₂ laser fading.

<table>
<thead>
<tr>
<th></th>
<th>CO₂ Laser Faded Denim 150X</th>
<th>CO₂ Laser Faded Denim 2000X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FL</strong></td>
<td><img src="image13.png" alt="Image" /></td>
<td><img src="image14.png" alt="Image" /></td>
</tr>
</tbody>
</table>
The laser action on the colored denim fibers is mainly carried out with the indigo color, by thermal effect (Özguney et al. 2009). This was the reason of the SEM shown for the three tested laser faded denim fabrics; the thermal effect of CO$_2$ laser invisible beam attacked the synthetic indigo dye, causing a molten polymer effect shown onto the burnt cotton dyed warp yarns, this was in line with a former work by Gabr B. 2016; onto that earlier investigation not only the SEM presented burnt effect but also air permeability declined for faded 100% cotton indigo dyed denim fabric. Photos above show the effect of laser beam burning effect is minor in case of the heavy weight denim fabric FH, and a sort of a further scattered burning effect at the FM medium weight fabric, while almost the entire surface of light weight fabric was burnt FL.

IV. CONCLUSION

In conclusion, the lap-felled seam is giving a worse effect for the abraded denim garment, when compared to superimposed seamed lines; not only the indigo dye is faded but also the topstitched sewing threads are worn off, degrading the entire garment. The light weight plain weaved denim illustrated damage when laser faded, when time passes on the garment would ruined at seamed areas, giving a low quality piece of garment. On the other hand, in terms of change in color $\Delta E$ showed light weight denim fabric with higher fading effect, which is consistent with the abrasion results and SEM where the damage occurred due to intense fading. The findings illustrate the advantage of using CO$_2$ laser fading technique upon heavy weight to medium denim fabrics, and the use of superimposed seams to eliminate any damage may be caused during the laser processing or while in use by denim garment consumer.

ACKNOWLEDGEMENT

The authors would like to thank, Eng. Moustafa Mahmoud Salman and Eng. Ahmed Farouk managers at Concrete for ready-made garments of Egypt, for supplying materials and assembled specimens used in this study.

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REFERENCES


