Effect of laser engraving and cellulase enzyme treatment on jeans trousers

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Abstract:
A new trend of jeans trousers fashion is giving faded and worn out look to new jeans trousers for attracting the attention. In this study, effect of CO_2 laser engraving and cellulase enzyme together were studied on the tensile strength of denim fabrics of jeans. This study detected which the best sequence of processes for treating jeans trousers. Different samples of denim trousers were engraved by CO_2 laser at different laser power and resolution before and after cellulase treatment. Then the tensile strength of all samples was measured. This study concluded that, Co_2 laser engraving process after cellulase treatment in high laser power is more suitable for denim fabrics. This sequence of processes decreases the loss of tensile strength of denim fabrics and save fabrics from damage. This study concluded that the loss of tensile strength by laser engraving in high laser power, more than the loss of tensile strength by cellulases treatment. So, when samples were treated by laser engraving in high laser power before treated by cellulases enzyme, that caused more damage for denim fabrics.

Keywords:
Denim fabrics, Jeans trousers, CO_2 Laser engraving, Cellulase enzyme, enzymatic treatment, Tensile strength, Processes sequence.

ملخص البحث:
الإتجاه الجديد في موضة البنطلون الجينز هي إعطاء البنطلون الجديد مظهر وتأثيرات البنطلون المستعمل لجذب الإنتباه. هذا البحث يقوم بدراسة تاثير كلاً من النقش بالليزر والمعالجات الإنزيمية بإستخدام إنزيم السليولاز على متانة وقوة شد أقمشة الدنيم المستخدمة في البنطلون الجينز. حيث يحدد البحث الترتيب الأمثل للمعالجات الخاصة بالبنطلون الجينز. ويتبع هذا البحث المنهج التجريبي حيث تم تعريض العديد من البنطلونات الجينز للمعالجة بالليزر قبل وبعد المعالجة الإنزيمية بإنزيم السيلولاز. وبعد ذلك تم قياس قوة شد أقمشة الدينم لكل العينات. توصل البحث إلى أن معالجة خامة الدينم بالليزر بعد المعالجة الإنزيمية بإستخدام إنزيم السليولاز أفضل وأنسب للخامة. حيث أن هذا الترتيب للمعالجات يقلل من الفقد في قوة شد الخامة ويحميها من التلف. إستتنج البحث أن الفقد في قوة الشد الناتج عن المعالجة بالليزر أكثر من الفقد في قوة الشد الناتج عن تأثير إنزيم السليولاز. لذلك فإن معالجة خامة الدينم بالليزر أولاً قبل المعالجة بالإنزيم يساعد على تعرض الخامة للتلف.

الكلمات المفتاحية:
خامات الدينم، البنطلون الجينز، النقش بالليزر، إنزيم السليولاز، المعالجات الإنزيمية، قوة الشد، ترتيب العمليات.

1- Introduction:

Denim fabrics are constructed from cotton twill weave 2/1 or 3/1. Weft yarns is undyed and warp yarns is dyed by indigo dyes. Indigo dyestuffs have very low rub fastness properties and can be stripped by different methods (A.T. Ozguney, 2007). A new trend of jeans trousers fashion is giving faded and worn out look to new jeans trousers for attracting the attention. Faded jeans trousers became very popular among young consumer than bright jeans (Z. Ondogana, O. Pamuka, E. N. Ondoganb, & A. Ozguney., 2005). Many traditional methods of textile and clothing finishing consume significant energy amount, water and other supplies (Ferrero F, Testore F, Innocenti R, & Tonin C., 2002). Fading surface of denim fabric by conventional chemical and mechanical processes (sand blasting, stone washing, bleach washing, grinding, etc.) cause environmental pollution (Ferrero F, Testore F, Innocenti R, & Tonin C., 2002, Esterves, F, & Alonso H., 2007, Belforte, D., 2015). Moreover, these method cause time- consumption, difficulty of application, less quality, and less accuracy. All of these factors increase the cost of product and decrease the competitive advantages in the market (Z. Ondogana, O. Pamuka, E. N. Ondoganb, & A. Ozguney., 2005). In recent years, the use of laser for textile materials marking and engraving became interesting and increasing because of its speed, accuracy and flexibility of this modern technique. (Overton, G.D., Belforte, A., Nogee, C., & Holto N, 2015).

Compared with other traditional methods, the laser technology is adequate to achieve good results at low cost. The laser technology is used extensively and as a replacement of some conventional process which are consider potentially harmful and disadvantageous for environment. (Csanák, E., 2014, Nayak, R., & R.Padhye, 2016, Solaiman. Md., & J. Saha, 2015). Laser textile treatments depend on the fallowing characteristics of laser source: wavelength λ, the diameter of the minimum focal spot, average power, pulse duration, pulse frequency, and power density of the laser beam. One of the most workable textile lasers treatment is bleaching. (Juciene, M., V. Urbelis, Ž. Juchnevičienė, & L.Čepukonė, 2013). By controlling laser parameters, such as amount of energy which applied on the fabric, the color is changed on the surface without unacceptance damage to the material surface. The laser technology also reduces water consumption by 80% and removes toxic chemicals which used for treatment of denim fabrics in traditional method**.** Moreover, it reduces the cost of energy consumption at three-times higher performance relative to conventional methods-160 pair of Jeans per hour. Currently decorating clothes by using laser technology is the most economical and creative technology which allows create truly unusual complicated designs in many ways and certainly completely unique models in fashion design. (Yordanka Angelova, Lyubomir Lazov, & Silvija Mezinska, 2017). Some denim treatments are also environmentally friendly such as cellulase treatment. Cellulase treatment is very important for improving fashionable look of denim wear. Cellulase treatment improves softness, worn look and bio-polishing of denim wear by hydrolysis of cellulose molecules. (Mondal, M.I.H., & Khan, M.M.R., 2014)

The advantages of laser engraving on denim wear can be summarize as following:

1- It is less harmful to environment because it reduces the use of chemicals and water. (C. W. Kan, 2014, Akihiro, S., & Mochiduki, N., 2001, Akihiro, S., & Ishihara, M., 2002, Akihiro, S., & Mochiduki, N., 2003).
2- It is short-time process for creating designs and drawing geometrical models of the design texture. (C. W. Kan, 2014).
3- It can be applied in both completed denim wear and raw denim fabrics. (Akihiro, S., & Narusue, S., 2004)
4- The CO_2 laser engraving machine has a safe usage and an easy maintenance.
5- The cost of product which is made by laser engraving, is lower than the product which is made by traditional processes. (Dascalu, T., Acosta-Ortiz, S.E., Ortiz-Morales, & M., Compean, I., 2000).
6- It creates pictures, letters, figures, designs, special logos and characters onto jeans trousers with the desired appearance, density and two or three dimensions. (C. W. Kan, 2014).
7- It creates different layers of the same color shade on the denim fabric, which is very difficult by manual treatments (Z. Ondogana, O. Pamuka, E. N. Ondoganb, & A. Ozguney., 2005, C. W. Kan, C. W. M.Yuen, & C. W. Cheng, 2010)

In the last years, laser engraving process field became very interested for many researchers, but still needs a lot of work to understand the physical changes in fabrics surface. A lot of studies were reported the effects of CO_2 laser engraving on some properties of denim fabrics, but a few of them were reported the effect of both Co_2 laser engraving treatment and cellulase enzyme treatment on the tensile strength of denim wear. In practice, some of denim trousers factories apply CO_2 laser engraving process on denim fabric before cellulase enzyme treatment, and others apply this process after cellulase enzyme treatment. In this study, the effect of CO_2 laser engraving treatment and cellulase enzyme treatment were studied on the tensile strength of enzyme treated denim fabric to detect the best treatments sequence of denim wear. Different samples of denim fabric were irradiated using CO_2 laser at different laser power and resolution before and after cellulase treatment. Tensile strength of all samples was measured to detect the best sequence of process.

2- Experimental work

2-1- Materials

Denim fabrics specifications

100% Cotton denim fabric with 3/1 twill weave were obtained from Fortex Textiles company, Egypt. Warp yarns were dyed by indigo dyes, weft yarns were undyed. Fabrics are fully described in Table 1.

Table 1. Specifications of Denim fabrics

Fabric	**Weave**	**Thread per cm**		**Weight/ area (g/m^2)**	**Warp tensile strength (kg)**	Thickness (mm)
		Warp	**weft**			
Denim	**Twill 3/1**	**30**	**24**	**360**	**195**	**0.68**

Chemicals

- Amylase enzyme (Amylase AGO 40), Asutex, Spain.
- Neutral enzyme (Stone Wash GN 140), Asutex, Spain.
- Anti-back staining (Asumin wash), Asutex, spain.

Washing machine

- Brand name: Yilmak;
- Capacity: 5 kg;
- RPM (Revolution per minute)—30 - 33 rpm;
- Origin: Turkey.

Laser engraving machine

The laser engraving process was conducted with a CO_2 source laser engraving machine (2000 Laser, Multicam, America) with specifications as shown in Table 2.

Table 2. Specifications of laser engraving machine.

Manufacturer/model:	**2000 Laser, Multicam**
laser frequency	10000 Hz
Laser medium	CO_2
Wavelength	10.6μm
Wave mode	Pulsed

The intensity of the beam gun is readjusted by means of the mechanical device developed to adjust the dimension of the image. The optical device is used for focusing according to the intensity that has been selected [2] as shown in Figure 1.

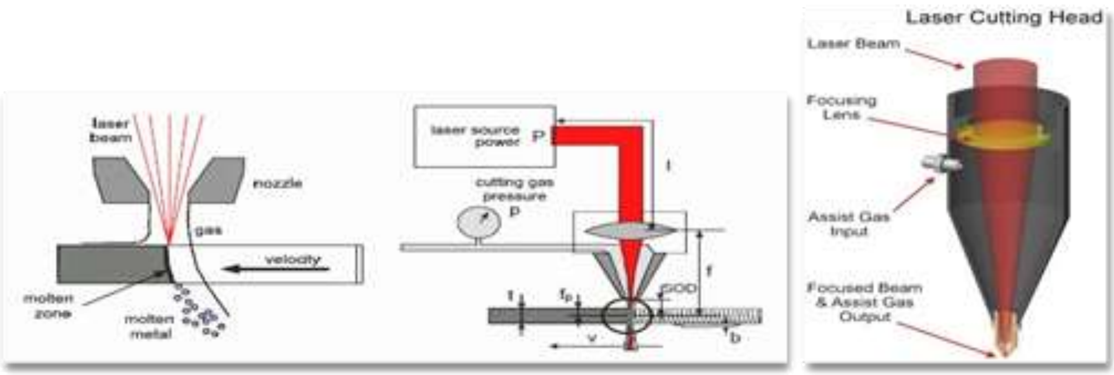

Figure 1. Laser engraving system.

2-2- Methods

32 pieces of denim samples were sewn as trousers legs. All samples were desized by amylase enzyme. Half of denim samples were treated with neutral cellulase enzyme firstly, then samples were engraved with CO_2 laser. Other half of samples were engraved with CO_2 laser firstly, then were treated by neutral cellulase enzyme.

Enzymatic treatments

Desizing

Amylase enzyme (Amylase AGO 40)	1% (w.o.g)
Anti-back staining agent (Asumin wash)	1 g/l
pH	7
Temperature	50- 55 ^{o}C.
Time	10 min.
L: R	1: 10

Samples were rinsed by cold water in a bath for 10 minutes.

Cellulase treatment

Neutral Cellulases enzyme (Stone wash	1 % (w.o.g)
140)	1 g/l
Anti-back staining agent (Asumin wash)	7
pH	50- 55 ^{o}C.
Temperature	30 min.
Time	1: 10
L: R	

After the treatment was finished, the temperature was raised up to 70-80^{o}C for 10 min. to stop the enzyme activity. Then samples were rinsed by cold water in a bath for 10 minutes.

Laser engraving process

The laser engraving process was conducted with a CO_2 source laser engraving machine (2000 Laser, Multicam, America) in Furniture Technology Center in Damietta with specifications as shown in Table 2. During the laser treatment, the resolution of the laser beam set was 40, 60, 80 and 120 dots per inch (dpi) with Laser power of 100, 80, and 60 Watt.

Resolution (expressed in dpi) is defined as a parameter that controls the intensity of laser spots per unit area. Laser power (expressed in W) and is defined as a parameter that is equal amount of energy, measured in joules. Divided by the duration of exposure, measured in seconds.

Watts (W) =$\frac{Jouls(J)}{Second(s)}$

Hence, the laser power density is the amount of power that is concentrated into a spot, or W/cm^2.

Power Density =$\frac{Watts}{Spot\ size\ (cm^2)}$

The spot size of the laser beam depends on several variables, including the focal lens, the wavelength of the laser, and transverse electromagnetic mode of the laser beam.

Square patterns with dimensions of 10 cm x 10 cm were engraved according to various combinations of resolution and Laser power (four square pattern fabric samples were prepared for each combination) as shown in Figure 2 engraved square pattern of samples at different irradiated CO_2 laser powers. Figure 3. shows the application of laser engraving on the complete denim trousers.

Figure 2. shows engraved square pattern of samples

Figure 3. application of laser engraving on complete denim trousers

2-3- Tensile strength measurements

The tensile strength is the amount of the greatest stress that a sample can take Without breaking. This test is intended for use in determination the changes of the weft tensile strength of samples.

This test was carried out at national researches center .Tensile strength in weft direction was determined by the grab method according to ASTM D 5034.

3- Results and discussion

Tensile strength values of samples are shown in Table 3 and Figure 4

Table 3. tensile strength of denim samples

Sample No.	Laser power (W)	Resolution (dpi)	Tensile strength (Kgf)	
			Laser engraving after enzymatic treatments	Laser engraving before enzymatic treatment
1	100	120	12	6
2		80	14	6
3		60	20	12
4		40	25	15
5	80	120	19	15
6		80	20	15
7		60	21	20
8		40	27	20
9	60	120	28	27
10		80	27	27
11		60	29	28
12		40	34	33
13	120	120	Damaged	Damaged
14		80		
15		60		
16		40		

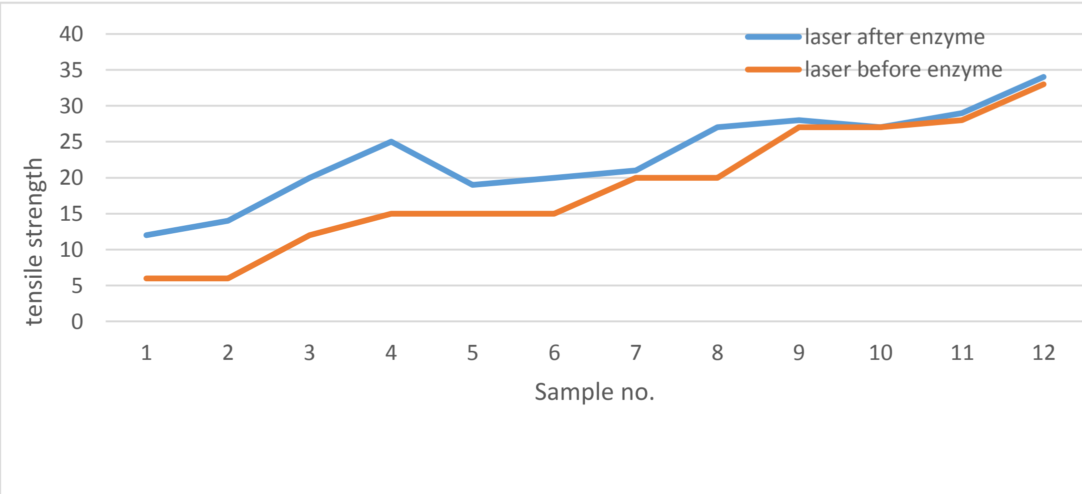

Figure 4. tensile strength of denim samples.

3-1- Effect of laser power

Table 3 Shows the samples of denim fabric in laser power 120 W were, damaged in all resolution values. This damage effect was needed in jeans fashion. So that is important to know in which laser power, the denim fabric was damaged.

Table 3 and figure 4 show that if the laser power was increased, the tensile strength of denim fabric was decreased. That is due to denim fabric absorbs the laser beam photons energy. The laser power of laser beam increases the temperature of absorbed cellulosic denim fabric surface. The high temperature of cellulosic denim fabric surface decreases the physical and mechanical properties of the fabric, so it decreases the tensile strength of denim fabric.

3-2- Effect of laser resolution

Table 3 and figure 4 Show that if the resolution of laser beam was increased, the tensile strength of denim fabric was decreased, especially in high laser power such as 100 W. That is due to the resolution of laser beam increase the laser intensity onto the surface of cellulosic denim fabric, so it increases the temperature of fabric surface. The high temperature of denim fabric surface decreases the physical and mechanical properties of the fabric, so it decreases the tensile strength of denim fabric.

3-3- Effect of cellulase treatment and laser engraving

There are two groups of samples: The first group of samples were applied by laser engraving before cellulase treatment. The second group of samples applied by laser engraving after cellulase treatment. Table 3 and Figure 3 Show the tensile strength of the first group of samples, is less than the tensile strength of the second group of samples high laser power. In laser power 100 W, the difference in tensile strength between two groups of samples about 40-60%. In laser power 80 W, the difference in tensile strength between two groups of samples about 25%. In laser power 40 W, no significant difference in tensile strength between two groups of samples. Laser engraving in high laser power decreases the tensile strength of cellulosic denim fabric, due to the laser beam increases the temperature of fabric as we explained before. Cellulases enzyme treatment decreases the tensile strength of cellulosic fabrics such as denim, due to cellulases enzyme hydrolysis cellulases fibers to soluble products such as glucose. This study concluded that the loss of tensile strength by laser engraving in high laser power, more than the loss of tensile strength by cellulases treatment. So, when samples were treated by laser engraving in high laser power before treated by cellulases enzyme, that caused more damage for denim fabrics.

So, we recommend in this study to treat denim fabrics by laser in high power after cellulases treatment to decrease the loss of tensile strength and save the fabric from damage.

4- Conclusions

In this study, Different samples of denim fabrics were engraved by CO_2 laser at different laser power and resolution before and after cellulase treatment. Then the tensile strength of all samples was measured. The tensile strength of denim fabric was decreased, if the laser power was increased. In laser power 120 W, samples of denim fabric were damaged in all resolution values. The tensile strength of denim fabric was decreased, if the resolution of laser beam was increased, especially in high laser power such as 100 W.

CO_2 laser engraving process after cellulase treatment in high laser power is more suitable for denim fabrics. This sequence of processes decreases the loss of tensile strength of denim fabrics and save fabrics from damage.

This study concluded that the loss of tensile strength by laser engraving in high laser power, more than the loss of tensile strength by cellulases treatment. So, when samples were treated by laser engraving in high laser power before treated by cellulases enzyme, that caused more damage for denim fabrics.

So, we recommend in this study to treat denim fabrics by laser in high power after cellulases treatment to decrease the loss of tensile strength and save the fabric from damage.

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References:

Akihiro, S.; Ishihara, M., "Application of CO_2 laser heating zone drawing and zone annealing to nylon 6 fibers". J. Appl. Polym. Sci. 83, (2002): p. 1711-171.

Akihiro, S.; Mochiduki, N., "Mechanical properties and microstructure of poly (ethylene trephthalate) microfibers prepared by carbon dioxide laser heating."J. Appl. Polym. Sci. 90, (2003): p.1955-1958.

Akihiro, S.; Mochiduki, N., "Mechanical properties and superstructure of poly (ethylene trephthalate) fibers zone-drawn and zone-annealed by CO2 laser heating". J. Appl. Polym. Sci. 82, (2001): p. 2775-2783.

Akihiro, S.; Narusue, S., "Isotactic polypropylene microfiber prepared by carbon dioxide laser heating". J. Appl. Polym. Sci. 92, (2004): p.1534-1539.

Belforte, D., "Industrial laser market outperforms global manufacturing instability", Industrial lasers Solutions. (2015).

Csanák, E., *Sustainable Concepts and Eco-Friendly Technologies in The Denim Industry*, Budapest, Hungary. (2014).

Dascalu, T.; Acosta-Ortiz, S.E.; Ortiz-Morales, M.; Compean, I., "Removal of the indigo color by laser beam denim interaction". Opt. Laser. Eng. 34, (2000): p.179-189.

Esterves, F; Alonso H., "Effect of CO_2 laser radiation on surface properties of synoptics fibers". Research Journal of Textile and Apparel, 11(3). (2007).

Ferrero, F.; Testore, F.; Innocenti, R; Tonin, C., "Surface degradation of linen textiles induced by laser treatment: comparison with electron beam and heat source", AUTEX Research Journal. Vol.2(3). (2002).

Juciene, M.; Urbelis,V.; Juchnevičienė,Ž.; Čepukonė,L. "The effect of laser technological parameters on the color and structure of denim fabric", TRJ. (2013).

Kan, C. W. "CO_2, laser treatment as a clean process for treating denim fabric", Cleaner production, Elsevier, 66, (2014): p 624-631.

Kan, C. W.; Yuen, M.; Cheng, C. W. "Technical study of the effect of CO_2 laser surface engraving on the color properties of denim fabric", Coloration technology,126, (2010): p. 365–371.

Mondal, M.I.H., & Khan, M.M.R., "Characterization and Process Optimization of Indigo Dyed Cotton Denim Garments by Enzymatic Wash". Fashion and Textiles, (2014): p 1-19.

Nayak, R.; Padhye, R., "The use of laser in garment manufacturing": A review, Fashion and Textiles, Springer Open Journal. (2016).

Overton, G.D.; Belforte, A.; Nogee, C.; Holto N, *Laser Marketplace: Lasers surround us in the Year of Light*, Tulsa. (2015).

Ozguney, A.; Ondogana,Z.; Pamuka,,O.; Ondoganb,E. N., "Improving the appearance of all textile products from clothing to home textile using laser technology", optics and laser technology, (2005): p 631–637.

Ozguney, A.T., "The comparison of laser surface designing and pigment printing methods for the product quality", optics and laser technology, (2007): p1054–1058.

Solaiman. Md.; J. Saha, Comparative Analysis of Manual Fading and Laser Fading Process on Denim Fabric, Science Discovery, Vol.3(6), (2015): pp 44-49.

Yordanka Angelova; Lyubomir Lazov; Silvija Mezinska, "Innovative Laser Technology in Textile Industry: Marking and Engraving". Proceedings of the 11th International Scientific and Practical Conference, Rezekne, Latvia. Volume III, (2017): p15-21.