APPLICATION OF CO_2 LASER TECHNOLOGY IN CREATING WHISKER AND HANDSAND EFFECTS ON DENIM WASH

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ABSTRACT

Garment wash is a new field in Vietnam, particularly whisker and handsand technique applied to create many effects on denim fabric. Currently, laser technique for whiskers and handsand has had limited documents and has been a focus of research in the world. In this research, the conventional method was replaced by the application of CO_2 laser technology at many values of intensity, with a number of radiating times, and radiating duration in order to give several special effects on denim. The research results were to produce better quality by using laser, and to provide sensory evaluation that was as real as the conventional method. Besides, the results were verified by colorimetric method using Chroma meter CS100A from Konica Minolta.

Keywords: Laser CO_2, whiskers & handsand, denim garments, intensity, color properties.

1. INTRODUCTION

Today, Jeans made of Denim have been people's favorite, especially the young's because of its beautiful design, and diverse styles with many effects expressing through durable, comfortable, and modern material. Jeans need to undergo many processes to be completely formed, importantly at washing process that is a decisive factor in the appearance of the product.

Wash technology is an important process of sewing industry applied into denim material. Denim wash is a terminology used to indicate the last process in order to produce complete jeans. There are many kinds of wash, such as dry wash (scraping, spraying, whisker, spotting, rubbing, damaging), and wet wash (dyeing, silicon, enzyme, icing, acid) [1]. After washed, the products change appearance, and become soft, and comfortable. However, washing in a wrong way makes the product fade and lose form of interest.

Wash technology seems to be a new field in Vietnam, especially using Whisker and Handsand technique to create many effects on denim fabrics [2,3]. However, worker have to work manually, which is toxic to them and badly affects their health. CO_2 laser has been worldwide applied in wash technology of sewing industry, but there is no further research on the interaction of laser with variables such as intensity, duration, times of radiation on material, and effects produced on material such that meet aesthetic requirements.

In the extent of this research, in the replace of the mechanic method, laser CO_2 [4-6] was used to create effects such as whisker, fading, wearing out, tearing, etc [7]. A laser is a device

that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for "light amplification by stimulated emission of radiation". The laser works by creating extensive heat. Within the focused region, the material is subject to 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. The laser provides the user with a "hot" beam that can be applied on a controlled basis to heat or burn the surface of certain materials, like a very narrow blowtorch. Some materials break down chemically when they are heated and can emit dangerous vapours in the form of gases or particles. Laser was radiated at many values of intensity, and several radiating times in many durations. The research results were to produce better quality by using laser, and to provide sensory evaluation that is as real as the conventional method [8-17]. Besides, the results were verified by colorimetric method using Chroma meter CS100A from Konica Minolta [18].

2. MATERIALS AND METHODS

2.1. Materials

Denim imported from HeBei Hanlin Co., LTD (China) was research material. The weight of the fabric was 681.2 g/m^2 and the thickness was 0.16 cm with the density of the vertical thread which was 38 threads/cm and the density of the horinzontal thread which was 20 threads/cm. Laser machine was imported from Jeanologia Company (Spain). The laser equipment has been specially designed for industrial use, so restrictions on its installation or additional measures may be necessary to prevent disturbance. Its design and size make the laser a product that is easy to install, with minimum requirements. The CO_2 laser is a Class IV laser product. For this reason, users are recommended to follow all safety precautions meticulously when handling the laser. All samples were stored in the standard environment of $20,5 \pm 0,5^0C$ and humidity was $64 \pm 1\%$ in one hour before treatment [19]. The place of research was Wash Factory – TPG, Can Duoc, Long An Province.

2.2. Method of comparison between mechanic method and laser

The flowcharts and the figures above are processes of whisker by manual method and laser method. The manual method included five main steps. From a health perspective, scrubbing by sandpaper produces a lot of dust causing harm to workers. Performing whisker and handsand by laser method will tackle this problem. Figure 1 and Figure 2 describe basic steps of the two flowcharts that we researched.

Mechanic Method

Step 1
Design embossed whisker patterns on rubber (mould)

Step 2
Insert the patterns under the place where there are needed effects

Step 3
Use balloons pumping to create Handsand effects

Step 4
Use sandpaper to carefully scrub the embossed patterns of the mould

Step 5
Wash to eliminate dust and brighten design

Laser Method

Step 1
Design was drawn graphically on eMark 2.0

Step 2
Set up laser intensity depending on design

Step 3
Start beaming process on required place

Step 4
Wash the denim to eliminate dust and brighten the designs

Figure 1. Whisker by mechanic method

Figure 2. Whisker by CO_2 laser

2.3. Design and Operation of CO_2 laser on samples

The CO_2 laser Flexi-HR3D machine was a model MM0478 from Jeanologia Company, Spain. Technical Parameters included: wavelength was from 9.3 µm to 11.5 µm; maximum power was 10 mW; laser diodes operated in visible spectrum; and 400V-460V/AC three-phase. Available designs were scanned and saved to the memory of the laser machine. The effects of the products were designed virtually by the software eMark 2.0. The laser beam from the tube blasted directly the products based on the parameters established before. The laser beam was used at wavelength of 10.6 µm for all experiments because at its wavelength of 10.6 µm the laser can easily be absorbed by most organics. In the first part of this study, we changed intensity of 36 W/m^2, 46 W/m^2 and 52 W/m^2 and these intensities ware kept constant with one-time radiation, and two-time radiation before and after wash. In the second part of this study, we changed radiating durations, which were 2.081s, 4.088s, and 7.038s at a constant intensity of 36 W/m^2.

The machine had three main parts: Cooling source, laser system (main part), and blasting chamber.

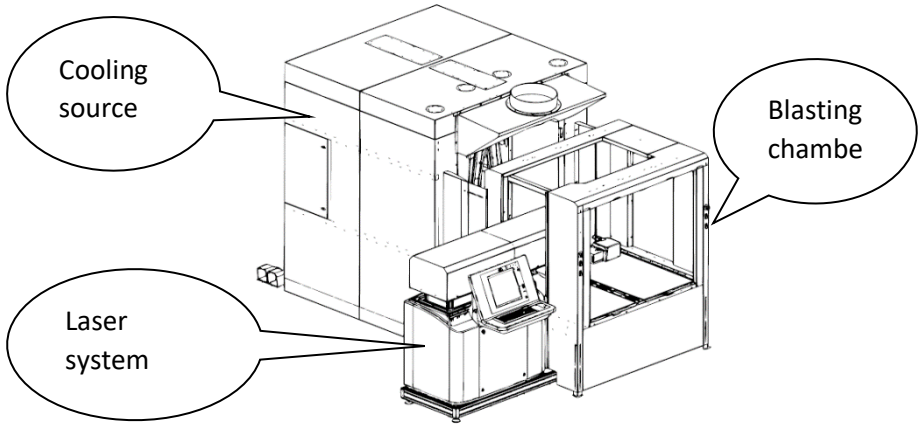


Figure 3. CO_2 laser machine

2.4. Colorimetric method

The color of the denim fabric changed after radiated by CO_2 laser. The color was measured by colorimetric machine Chroma meter CS100A from Konica Minolta.

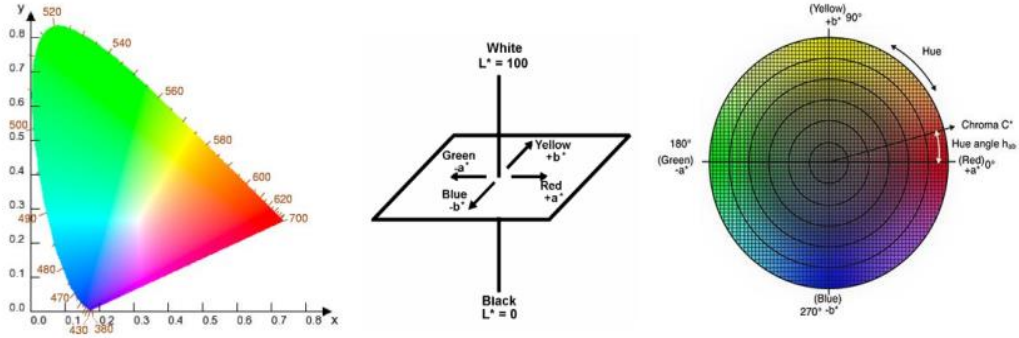


Figure 4. CIE XYZ diagram, CIE Lab and CIE Lch color space

For two colors to match, three quantities defining these colors must be identical. These three quantities are called tristimulus value X, Y, and Z as determined by the CIE (Commission Internationale de l'Eclairage) in 1931. Color as perceived has three dimensions: hue, chroma, and brightness. Chromaticity includes hue and chroma (saturation), specified by the x and y coordinates in the CIE Chromaticity Diagram. Since the two dimensional diagrams cannot describe a specific color completely, a brightness factor must also include to identify a sample precisely. Y is the luminance expressed in terms of cd/m^2 of fL; x and y are chromatically coordinated of the CIE x, y Chromaticity Diagram, defined by the equations below:

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

X, Y, Z tristimulus values may be calculated from Y, x, y values by using the equations below:

$$X = \frac{x}{y} Y$$

$$Z = \frac{1 - x - y}{y} Y$$

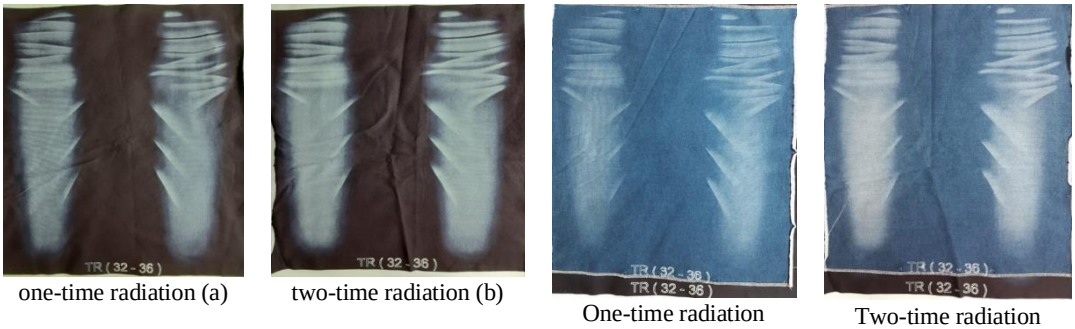
The CIELab space (or CIEL*a*b* or simply "Lab") is a refinement defined in 1976. CIELab is intended to be perceptually uniform, meaning that the space between mapped colors corresponds to their visual differences. CIELab expresses colors according to three values: L - Lightness, from black (0) to white (100); a - Amount of green (-) to red (+); b - Amount of blue (-) to yellow (+). In the diagram, visible colors extend equally along the two hue axes, making chromatic properties relatively easy to see. As a theoretical model, CIELab includes "imaginary" colors that are outside the range of human perception.

Because CIELAB has many advantages over CIE Color System, parameters such as x and y from Chroma meter CS100A were then converted into CIELAB parameters. CIELAB parameters such as a and b were considered, whereas L parameter were neglected because L parameter expresses luminosity, which was not necessary in the study.

3. RESULTS AND DISCUSSION

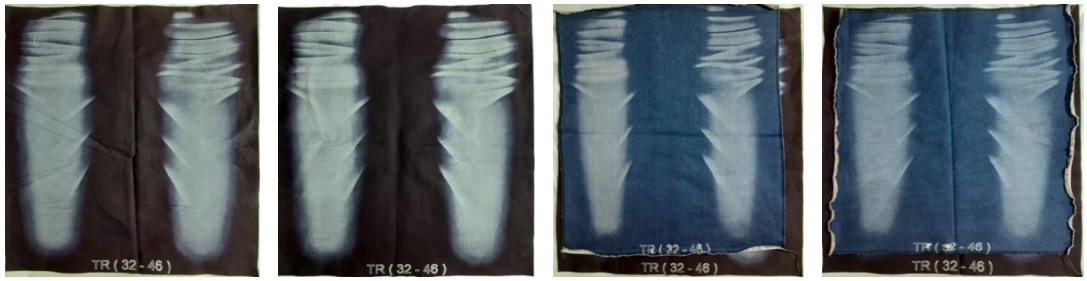
3.1. Comparison between one-time radiation and two-time radiation at the same intensity

Figure 5a, b, c, and d are the samples radiated at the intensity of 36 W/m^2 and this intensity was kept constant with one-time radiation, and two-time radiation before and after wash. The experiments were replicated similarly at intensity of 46 W/m^2 illustrated by figure 6a, b, c, and d, and at intensity of 52 W/m^2 illustrated by figure 7a, b, c, and d.



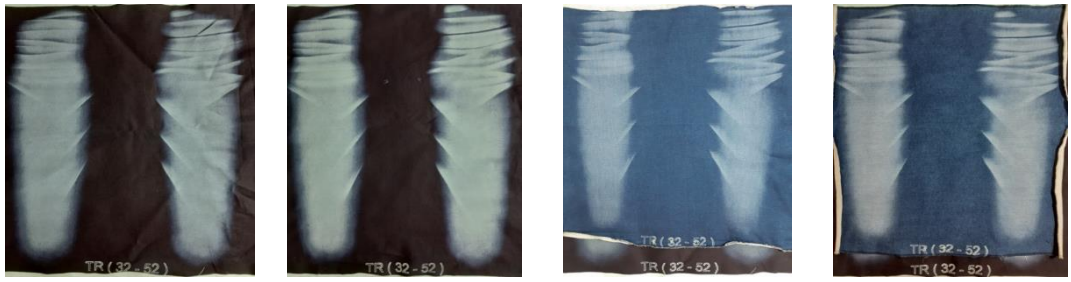
one-time radiation (a) | two-time radiation (b) | One-time radiation after wash (c) | Two-time radiation after wash (d)

Figure 5. Samples radiated at the intensity of 36 W/m^2



one-time radiation (a) | two-time radiation (b) | One-time radiation after wash (c) | Two-time radiation after wash (d)

Figure 6. Samples radiated at the intensity of 46 W/m^2



One-time radiation (a) | Two-time radiation (b) | One-time radiation after wash (c) | Two-time radiation after wash (d)

Figure 7. Samples radiated at the intensity of 46 W/m^2

3.2. Comparison in radiating durations at the same intensity of 36 W/m^2

In the second part of this study, we changed radiating durations, which were 2.081s, 4.088s, and 7.038s at a constant intensity of 36W/m^2. Changing the duration was to assess the extent of color change on denim under the impact of laser beam with respect to time.

(a) (b) (c)

Figure 8. Three figures indicated radiating durations: (a) 2.081s; (b) 4.088s; and (c) 7.038s.

3.3. Evaluation

In all experiments, the results of third-time radiations failed because the size of whisker expanded and the whiskers overlapped one another, not meeting aesthetic requirements and design requirements. Therefore, those samples failed. In comparison between one-time radiation and two-time radiation and in comparison between material before wash and material after wash, white spots had size increased when radiated by two-time laser, and the radiated area became brighter because of more vaporization of dye materials. As a result, the surface was seen blur, and there was a loss of sharpness and a loss of the obvious edges.

Table 1. Comparison in intensities and in radiating times

Intensity	36 W/m^2	46 W/m^2	52 W/m^2
One time	Sharp whisker. Meet aesthetic requirement	Sharp whisker but the size of the whiskers expanded. Not meet aesthetic requirements and design requirements	Sharp whisker but the size of the whiskers expanded. Not meet aesthetic requirements and design requirements
Two times	Sharp whisker but the size of the whiskers expanded. Not meet aesthetic requirements	Whisker was blur on the edge. The size of the whiskers expanded and whiskers overlapped one another.	Whisker was blur on the edge. The size of the whiskers expanded and whiskers overlapped one another.
Three times	Not meet design requirements	Not meet design requirements	Not meet design requirements

Table 2. Comparison among radiating times

Duration	2.081s	4.088s	7.038s
Intensity (36 W/m^2)	Sharp whisker. Meet aesthetic requirement	Sharp whisker but the size of the whiskers expanded. Not meet aesthetic requirements and design requirements	Whisker was blur on the edge. The size of the whiskers expanded and whiskers overlapped one another.

The increase in radiating durations and the increase in radiating times gave the same level of vaporization of dyes as the increase in intensity. On average, it took a worker 60 seconds to perform one pair of jeans by manual method, whereas it took a worker 6 seconds to perform them by laser method. Laser can remove dyes fast because laser beam is designed to provide energy for the surface by converting optical energy to heat. The change of color intensity of multilayer denim treated by laser depends on the different combinations of laser intensity and radiating duration. The physical phenomenon involved in the laser was that the dyes were removed from the denim fabric surface, which is vaporization process. Materials were removed by laser in a simple vaporization process, with laser energy absorption of the denim samples treated continuously on the surface. When laser energy rises, materials can vaporize fast. Therefore, vaporized materials can diffuse into the ambient environment and have no interaction with the beam.

3.4. Verification

Verified by colorimetric machine Chroma meter CS100A from Konica Minolta (Japan). Laser beam acted on the samples with the same intensity and with the same duration, so the change of color was similar. Therefore, during color verification, we measured at the place where there was the change of color. The results of measured parameters were shown below:

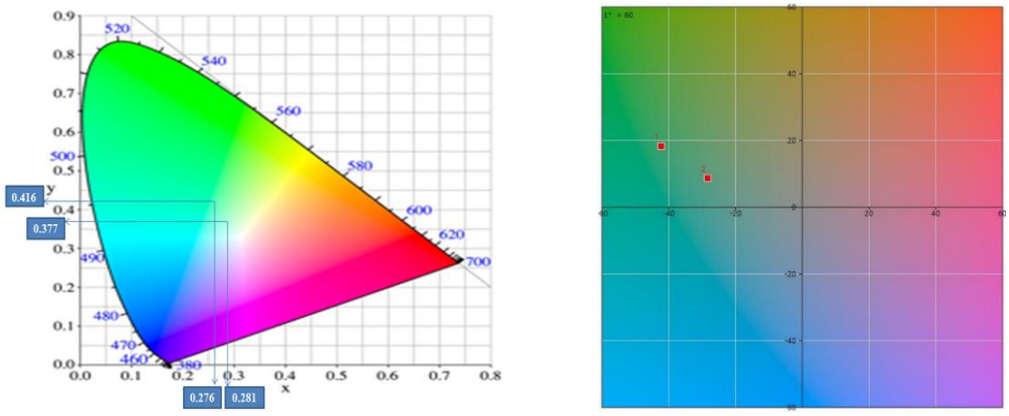
Table 3. x and y values when materials were measured by the colorimetric machine

	Intensity (W/m^2)	x	y
Before wash		0.276	0.416
One-time radiation (after wash)	36	0.241	0.405
Two-time radiation (after wash)	36	0.262	0.375
One-time radiation (after wash)	46	0.244	0.412
Two-time radiation (after wash)	46	0.268	0.382
One-time radiation (after wash)	52	0.245	0.409
Two-time radiation (after wash)	52	0.281	0.377

Table 4. Changed X, Y, Z values of CIE Yxy to L, a, b values

	X	Y	Z	L	a	b
Before wash	0.276	0.416	0.308	70.59	-42.15	18.01
Two-time radiation at 52 W/m^2 (after wash)	0.281	0.377	0.342	67.8	-28.11	8.53

As can be seen from Figure 9, the color changed from green area (before wash) to whiter area (after wash) (x increased and y decreased) based on intensity, duration, and times. Samples treated by laser with different parameters showed different effects. Table 3 showed change of coordinates of color of the denim samples when they were treated by laser, leading to the change of color from green to white when laser power rose or when radiating duration increased. Figure 9 indicated the difference in color value. Color intensity and the complete difference in color of the denim samples are the example.



CIE Yxy color space (a) Lab color space (b)

Figure 9. The plot indicates the coordinates of the point of "before wash" and the point "two-time radiation (after wash) at intensity of 52 W/m^2" with a - CIE Yxy color space and b - Lab color space.

The colour difference ΔE was calculated according to the following equations and the values from Table 4.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} = 17.169$$

In three difference intensities, 36W/m^2, 46W/m^2, and 52 W/m^2, dyes were eliminated out of fabric surface, leading to surface fading. For instance, x coordinate of 36 W/m^2 one-time radiation and x coordinate of 36 W/m^2 two-time radiation were 0.241 and 0.262, respectively. Respective y coordinates were 0.405 and 0.375. As a result, they showed that radiating laser is a process of fading denim effectively. When laser power increased, denim faded as a trend. This is because the increase in laser power resulted in fast and more vaporization of dye. To illustrate the change, Figure 9 showed the difference between before and after wash when denim was treated with the highest intensity. Moreover, color difference (ΔE) was used in determining color change, ΔE is an equally weighted combination of the coordinate (L, a, b) differences. It represents the magnitude of the difference in color but does not indicate the direction of the color difference.

4. CONCLUSION

In this study, characteristics of denim after radiated by laser including surface, physical characters and some characters after wash were evaluated effectively. The results showed that denim had whisker and handsand by laser in different durations and with different intensities. The material fades only where the beam impacts on the fabric. The desired degree of fading depends upon the wavelength, power density, and pulse width of the laser beam. The laser action can be compared with the focusing of sunlight through magnifying glass. This focused light forms a high-density beam which decomposes the dye with the resulting vapours being vented away.

The images of the surface of denim radiated by laser showed that the threads on the surface lost dyes through vaporization by changing the energy of the laser beam with increasing intensity and prolonged exposure. Therefore, using CO_2 laser with wavelength of 10.6 µm, intensity of 36 W/m^2, and one-time radiation in 2.081 second gave high-quality products with the best aesthetics. However, based on design, and aesthetic requirements, parameters such as intensity, and radiating duration can vary depending on material character, thickness, and elasticity of fabric.

There are a lot of benefits when laser method replaces manual method. In terms of work, laser method has comparatively lower strength loss than other manual fading processes. Laser method is environmentally friendly and has no water waste. Especially, laser method requires no chemicals, so there are no harmful substances left on jeans. As to electricity, other mechanic method needs 1.5 kW/h, whereas the laser method utilizes 1 kW/h, which means costing less electricity to produce the same quantity of jeans.

The overall results showed that based on fundamental physics of interaction of laser and fabric, by selecting a type of laser with suitable intensity, suitable radiating duration, and suitable radiating times, CO_2 laser can be applied into Whisker & Handsand in the replace of manual method, but still give equivalently good products in shorter time.

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TÓM TẮT

ỨNG DỤNG KỸ THUẬT LASER CO_2 ĐỂ TẠO HIỆU ỨNG WHISKER VÀ HANDSAND TRONG CÔNG NGHỆ GIẶT VẢI DENIM

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Garment wash là một lĩnh vực còn khá mới mẻ ở Việt Nam, đặc biệt là kỹ thuật whisker và handsand để tạo các hiệu ứng trên chất liệu vải denim. Hiện nay, kỹ thuật whisker và handsand vẫn còn ít tài liệu và đang là trọng tâm nghiên cứu trên thế giới. Trong nghiên cứu này, chúng tôi thực hiện việc thay thế phương pháp thủ công trong việc tạo hiệu ứng cho hàng denim bằng phương pháp ứng dụng laser CO_2 ở nhiều cường độ, nhiều lần chiếu và nhiều mức thời gian chiếu trong kỹ thuật whisker và handsand để tạo ra nhiều hiệu ứng trên denim. Kết quả nghiên cứu là tạo ra chất lượng tốt hơn bằng cách sử dụng tia laser và cung cấp đánh giá cảm quan giống như phương pháp thông thường. Ngoài ra, kết quả còn được kiểm chứng bằng phương pháp so màu sử dụng máy đo Chroma CS100A của Konica Minolta.

Từ khóa: Laser CO_2, whiskers & handsand, vải denim, cường độ, thuộc tính màu.