Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

# LASER ENHANCED SUSTAINABLE SURFACE TREATMENT FOR TEXTILE DESIGN ON WOOL AND POLYESTER BLENDED FABRIC

[1,2]Guoxiang Yuan

*[1]College of Fashion and Design, Donghua University, [2]Tongji University Shanghai Institute of Design and Innovation, Shanghai, China. vogue@126.com*

## *ABSTRACT*

This paper explores laser engraving as a sustainable surface treatment technique for textile design on wool and polyester blended fabric. As a contactless processing, the laser beam could melt, evaporate and engrave textile surface without the application of water and chemicals. With computer aided design process, unique pattern appearances on the blended fabric with shade changing effects were achieved after laser treatment. Blended fabric of wool and polyester is popular in textile industry and market due to its excellent warmth and elasticity. During laser processing, the parameters of the resolution (dpi) and the pixel time (μs) have been modified and optimized for different application requirement. The results indicated that digital laser surface processing is an environmental, cost-effective and higher quality option for textile design. With lower resolutions, engraved vague patterns with small laser beam dots can be achieved. While the treatment resolution increased, clear patterns could be performed. Based on the same resolution, the higher pixel time can export more energy, which makes the pattern look more clearly. As a feasible and environmentally friendly surface treatment approach, laser engraving has potential application in textile industry as a design tool for textile processing without involving water, dyestuff and solvents.

Keywords: Laser, Surface treatment, Textile, Sustainability

## *INTRODUCTION*

Science and technology play a key role in the development of sustainable design and manufacturing. Nowadays, consumers are becoming more concerned with the environmental impacts of products with sustainable design associated with the production processes. Some environmental problems are arising in textile industry due to the related dyeing and finishing processes have created a huge pollution problem which use more than 8000 chemicals in various processes of textile manufacture. During the processes, many chemicals are toxic and persist in the environment that include heavy-metal-rich dyes and fixing agents, bleaches, solvents, and detergents. Most of these applied chemicals could cause environmental and health problems directly or indirectly. Water is the principal medium for the application of dyes and other chemicals for textile processing, dyeing and printing, so large quantities of water are required in the industry. In recent years, there are some techniques are applied to reduce the impact of pollution from dyeing and printing processes which could carry out more responsible and sustainable approaches for textile manufacture. Digitalized processing has become a popular approach to treat textiles for

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

function or embellishment purpose. Laser surface treatment, as a contactless processing, has various advantages, such as no physical contact, a high degree of automation and fast and precise cutting and engraving (Yam, 2010). It has been increasingly applied in textile industry to generate simple or complex graphics and patterns onto fabric surface through laser beam scanning. Laser treatments can be achieved by using different sources such as carbon dioxide gas laser ($CO_2$ laser), neodymium-doped yttrium aluminium garnet laser (Nd: YAG) and diodes lasers (Brichtová, 2007; Roux, 1989). Of all the various types of lasers, $CO_2$ laser is the most efficient and suitable for engraving materials that are not good conductors of heat and electricity because at its wavelength of 10.6 microns the laser can easily be absorbed by most organics that absorb 10 micron light (Rajagopal, 2008; Ready, 1997; Yuan et al., 2016). Although many researches have applied laser treatment onto fabrics, most of the studies focused on the laser cutting method. Despite the fact that decolor indigo-dye on fabrics has carried out using laser engraving pattern on denim fabric or the cotton finishing process (Chow, Chan & Kan, 2011; Kan, Yuen & Cheng, 2010; Ondogan et al., 2005; Pezelj, Cunko & Andrassy, 2004; Štěpánková, Wiener & Dembický, 2014; Tarhan & Sarıışık, 2009; Tortora & Johnson, 2013; Yuan, 2018). Nowadays, laser has been applied in denim industry as a bleaching tool to create patterns on the denim fabric with color fading, worn appearance or printing effect which can instead of conventional chemical treatment (Dascalu et al., 2000; Jiang, 2015). The laser engraving exploration is insufficient to use various materials such as polyester and wool blended fabric.

In this study, laser technique is combined with different design processes to create unique patterns on wool and polyester blended fabric. The fundamental factors that affect the quality of fabric and changes in the fabric surface are physical and mechanical properties. To assess the performances of the original and technically treated fabrics, some measurements such as weight, air resistance, surface observation, thermal conductivity, color appearance, tear strength and low-stress mechanical properties were investigated. Appropriate design processes including graphic method and resist method are applied to create patterns for textile design by using the laser engraving approach. All the results demonstrate that the integration of the technique, fabric and design method is an effective way to create innovative and environmentally friendly fabric designs.

## *METHODOLOGY*

Laser surface treatment

In this study, laser engraving is carried out by using a FLEXI DENIM 2T, a commercially designed pulsed $CO_2$ laser machine (SEI, Italy) coupled to a computer-controlled table under controlled atmospheric conditions. The experimental parameters for the resolution - intensity of laser spot (20, 30 and 40 dpi), and the pixel time - the time of the laser head positioning on each image point (120 and 270 μs), were varied to investigate the laser engraving effects on wool/polyester blended fabric.

## Process

The process of laser engraving on fabrics for textile design is shown as follows: (1) create graphics in software, (2) convert the graphics to gray scale, (3) send graphics and patterns to laser system, (4) set engraving parameters of pixel time and resolution, (5) place the textile on a honeycomb cutting table in a cabinet, (6) location identification of the laser engraving area, (7) conduct laser engraving.

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

## Material

Fabric for laser surface treatment should meet end user expectations such as comfort, drape, comfort handle, easy care and performance. Wool/polyester blends have a wool-like feel and appearance with some wool-like feel and appearance, and some of the easy-care aspects of polyester (Collier & Tortora, 2001). It also may enhance the abrasion resistance and easy-care properties such as crease retention and wrinkle resistance, and this also can prevent bagging, sagging and stretching (Mendelson, 1999). In this study, 45 % wool and 55 % polyester blended plain weave fabric (density: 48 ends/inch & 40 picks/inch) with fabric weight of 80.35g/m2 and thickness of 1.35 mm under 5 g/cm2 pressure was applied for laser engraving. The fabric was conditioned at 21±1 ºC and 65±5 % relative humidity for 24h before experiments and evaluations.

Physical and mechanical properties

*Fabric weight*

The weight (g/m2) of the square fabric samples sized 200mm×200mm was measured by using an electronic weight meter (GR200, A&D Company Ltd., Japan) in accordance with the ASTM D 3776-07 "Standard Test Methods for Mass Per Unit Area (Weight) of Fabric".

**Air resistance**

The air resistance of the fabric samples was measured based on the constant rate of air flow at 0.04m/s generated by the piston motion/cylinder mechanism and passed through a specimen into atmosphere using Kawabata Evaluation System (KES-F8-AP1) under air flow resistance tester (Kato Tech Co., Ltd., Japan) following the Kawabata specifications. It can measure air pressure loss and calculate air resistance in kiloPascals times second per meter (kPa·s/m) when air flows through the transverse section of fabric samples

*Observation of the fabric surface*

The weight ($g/m^2$) of the square fabric samples sized 200 mm × 200 mm was measured by using an electronic.

**Tear strength**

The tear strength of the fabrics before and after laser engraving was measured by an Elmatear digital tear tester (James H. Heal & Co Ltd, England) in accordance with ASTM D 1424-07a "Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus". Five samples per fabric type with dimensions of 80mm×100 mm for both the warp (for tearing across the weft) and the weft (for tearing across the warp) directions were evaluated. The results of the tear strength are represented in gram-force (gf).

**Thermal conductivity**

Thermal conductivity K is a property that indicates the ability of a material to conduct heat. K was obtained by using a Thermo Lab II (KES-F-TL 2C & D, KATO Tech Co., Japan) following the Kawabata specifications [20]. The temperatures of the base and the heat source plate were set at 30.3 °C and 30.0 °C, respectively. The water box was kept at a constant temperature of $T_w$ (20 °C) by using a water circulation device. The heat contact area of the bottom temperature (BT)-box was 25 ($cm^2$). The temperature gradient $\Delta T$ ($=T_B-T_W$) between the BT box ($T_B$ °C) and the water box ($T_W$ °C) was 10 °C. Five measurements for every sample before and after laser engraving were taken and the average values of the measured parameters were calculated. K was calculated by using the following equation with respect to the thickness of the sample:

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

$$K = \frac{W \cdot D}{\left(A \cdot \Delta T\right) \times 10^2}$$

(1)

where, $K$ is the thermal conductivity (W/m·K); W is the power loss from the plate (without the fabric cover) in watts; D is the thickness of the sample (cm); A is the area of heat contact of the BT-box ($cm^2$); and $\Delta T$ is the temperature difference between the heat source plate and an ambient temperature (°C).

Results and discussion

Physical and mechanical properties

*Fabric weight*

The changes in unit weight of original and laser engraved fabric samples were measured and the results are shown in Figure 1.

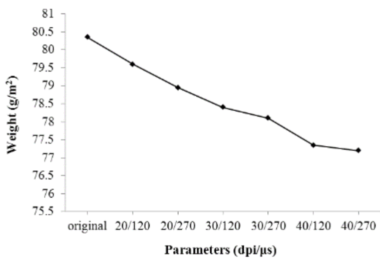


Figure 1 - Weight of original and laser engraved fabric samples

The results show the weight of the engraved fabrics decreases from 0.9 % (20 dpi/120 μs) to 3.9 % (40 dpi/270 μs) which due to the reason that high resolution and long pixel time can engrave, melt and evaporate some of the wool and polyester fibers on the surface of the fabrics. As a consequence, the unit fabric weight decreases and the fabrics become lighter when compared with original fabric.

**Air resistance**

Air resistance is one of the major properties of textile materials and an important factor that influences the wearer's comfort of textile materials. It is governed by factors such as fabric thickness, density, structure, and surface characteristics. The results of air resistance tests of the original and laser engraved fabrics are shown in Figure 2.

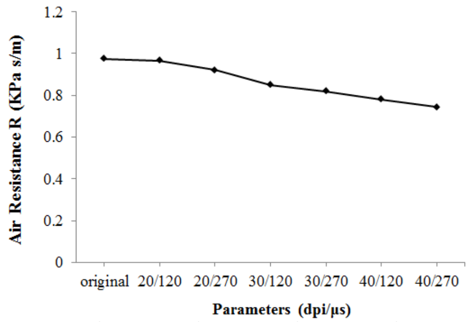


Figure 2 - Air resistance of original and laser engraved fabric samples

A higher air resistance means that a smaller amount of air could flow through. The values presented in Figure 2 represent the air resistance property of original and laser engraving treated samples. There was a decrease from about 0.71 % (20 dpi/120 μs) to 23.7 % (40 dpi/270 μs) in air resistance of the treated fabrics compared with the original one. The value changes of air resistance are related to the fabric thickness and surface characteristics. It is clear that there are only slight changes between the air resistance of original and engraved samples when the resolution at 20 dpi from 120 μs to 270 μs were used because only a minimal amount of fibers were affected by the laser beams. The greater changes in air resistance were possibly due to the melting and evaporation of the surface fibers by laser thermal engraving. The decrease in air resistance was possibly due to the surface fibers were

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

etched away by laser beams and more air spaces between the fibers and fabrics resulted. It became therefore possible for more air to pass through the fabric, resulting in lower air resistance.

Surface observation

Figure 3 show surface micrograph images of the fabrics before and after laser engraving with different resolutions and pixel times.

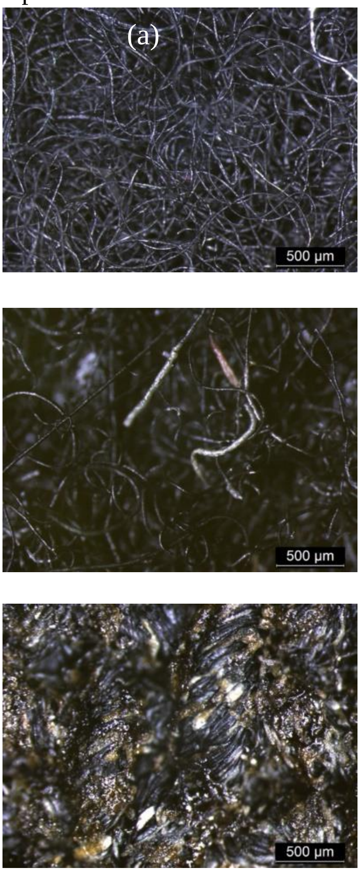


Figure 3 - Surface micrographs of original and laser engraved fabric samples

With reference to the micrograph images of the original and laser engraved fabric samples as shown in Figure 3, different surface morphology images of wool/polyester blended fabric is observed. With the application of thermal laser energy, the wool fabrics show different engraved effects. Figure 3(a) shows an original micrograph image of wool fabric with naturally wavy wool fibers. Through laser engraving with a lower resolution and shorter pixel time, a few fibers become burned as shown in Figure 3(b). When the pixel time is prolonged, the wool fibers turn yellow and melt with polyester fibers as shown in Figure 3(c). The results clearly show that with higher resolutions and longer pixel times, the laser energy was increased, so some of the surface fibers form burnt, bubbled and etched effects on the fabrics and this could also affect the color appearance.

**Thermal conductivity**

The thermal conductivities of the fabric with different pixel times and resolutions are shown in Figure 4.

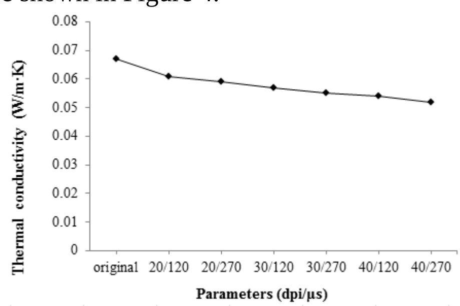


Figure 4 - Thermal conductivity of original and laser engraved fabric samples

The values of conductivity depend on different factors, such as fabric constitution, and include both surface smoothness and apparent density. The laser engraved fabric samples decrease from 8.9 % (20 dpi/120 µs) to 24.2 % (40 dpi/270 µs), respectively, at different

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

parameters. A lower value means a more warmth feeling from the fabric, so it implies that the heat transfer from the skin to the fabric surface becomes slower. The greater changes in thermal conductivity from 20 dpi/120 µs to 40 dpi/270 µs are possibly due to the melting and evaporation of the surface fibers by laser engraving. After treatment, some surface fibers were etched away and melted, and more air spaces between the fibers and fabrics resulted. The surface of the fabric becomes rougher and some spaces are created which trap air between the yarns and fibers, so the value of *K* is reduced with increases in the treatment parameters and results in more warmth compared with the original fabrics.

### *Tear strength*

The tearing strengths of the fabrics in both the weft and warp directions were evaluated and the results are shown in Figure 5.

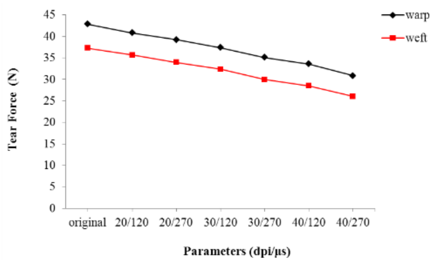


Figure 5 - Tear strength of original and laser engraved fabric samples

The results show that there is a decrease in the tearing strength from about 5 % (20 dpi/120 µs) to 28 % (40 dpi/270 µs) in the warp direction and 4 % (20 dpi/120 µs) to 30 % (40 dpi/270 µs) in the weft direction for the treated fabrics. This is due to the reason that some fibers are engraved and melted by the laser beams, so that the strength of the fabrics decreases.

Design application

*Graphic method.* This method involves the use of a computer with graphic software to design, edit and process images which make the design process faster and permit ideas and designs to be easily changed. After the patterns were designed, the fabrics were placed in a laser treatment cabinet for engraving after confirming the position and size of patterns.


*Figure 6 - Laser engraved wool/polyester fabric with graphic method*

The wool and polyester blended fabric shown in Figure 6(b) was designed and engraved by laser at 30 dpi/270 µs in accordance with the designed patterns. The pattern shown in Figure 6(a) was

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

made using computer-aided design method. Some wool fibers on the fabric surface were ablated and burnt which resulted in different degrees of lightness of yellow. The un-engraved areas retained the original color against the engraved areas. This design demonstrates the effect of laser engraving on the wool and polyester blended fabrics by means of graphic pattern design methods. As a result of design pattern and laser engraving, the fabrics with novel textures and patterns are made possible.

## Resist method

Resist method is used in textile design for decoration. Based on resist method, some imagery, intricate patterning and interesting effects could be achieved. There are many types of resist method such as in tie-dye by use of tying, stitching, folding or clamping the cloth to prevent the dyestuff affect the inner areas. In this research, the resist method of stitching and tying were applied for textile design by using laser engraving. After engraving, some vivid changes in the color shade with tie-dye patterns were achieved as shown in Figure 7.


Figure 7 - Laser engraved wool/polyester fabric with resist method

The treatment result shows the laser treated brown fabrics engraved at 40 dpi/270 μs. According to the resist pattern design method, the fabric was tied and stitched with thread as shown in Figure 7(a) for engraving treatment. This design was explored to study the effects of laser engraving on the wool and polyester blended fabric in combination with the resist method of tying and stitching. After laser treatment, some fibers on the fabric surface burned and melted, the resisted areas retained their original color whereas the engraved areas show a different shade

Author: - Dr. Guoxiang Yuan
College of Fashion and Design, Donghua University, China
GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

of brown according to the intensity of the treatment in Figure 7(b).

## *CONCLUSION*

Laser surface treatment for textile design on wool and polyester blended fabric is carried out in this paper. The characterizations of original and laser treated wool and polyester blended fabrics are assessed and analyzed. The results indicate that the physical and mechanical properties such as weight, air resistance, surface observation, thermal conductivity and tear strength are modified after laser engraving. The appearances of the laser treated fabrics turned yellow compared with the original fabric and the yellowness was enhanced with the increase of the laser treatment parameters. All the changes are related to the reason that the fibers on the surface of the laser engraved fabrics have ablated, burnt, engraved and evaporated in accordance with an increased pixel time and resolution in each case. After laser surface treatment, desired laser engraving effects on wool and polyester blended fabrics were obtained and indicate this technique is suitable for pattern creation and surface embellishment of textile because of its practical value such as: (i) flexibility; (ii) better quality; (iii) production efficiency; (iv) accuracy; (v) more perfection in the finishing of the final products; and (vi) environmental friendliness.

The application of laser engraving for textile design shows that various aesthetic designs could be created and developed by combining laser engraving and developed design methods such as graphic method and resist methods. In accordance with the design results, the benefits are (i) a design process of surface laser treatment could be applied in textile design; (ii) convenience for creative fabric embellishment with computer-aided design method; (iii) a selection of unique laser engraved textile effects could be achieved with the selected parameters on wool and polyester blended fabric; and (iv) flexibility of orders and small batch customization production. The application of laser engraving surface treatment technique for textile designs could also cater to the demand for green products and manufacturing for sustainable development in the fabric industry and flexible responses on the part of designers to market needs.

## *ACKNOWLEDGMENTS*

This research was supported by “the Fundamental Research Funds for the Central Universities”.

## *REFERENCES*

Yam, K. (2010). The Wiley Encyclopedia of Packaging Technology. New York: John Wiley & Sons.

Brichtová, L. (2007). The diode laser system development for the cutting of the textile materials. In: TEXSCI 2007, *Proceedings of the Sixth International Conference*. Liberec: Technical University of Liberec.

Roux, R. (1989). The laser in the French clothing industry. In: D. Belforte and M. R. Levitt, ed., *The Industrial Laser Annual Handbook*. Tulsa: PennWell Books.

Rajagopal, K. (2008). Textbook of Engineering Physics. New Dehli: Prentice-Hall of India Pvt. Ltd., p.45.

Ready, J. (1997). Industrial applications of lasers. San Diego: Academic Press, p.412.

Yuan, G., Jiang, S., Newton, E., Fan, J. and Au, W. (2012). Embellishment of Fashion Design via Laser Engraving.

GARI Publisher | Sustainable Design | Volume: 04 | Issue: 04
Article ID: IN/GARI/ICATFD/2018/128 | Pages: 01-09 (09)
ISSN 2424-6492 | ISBN 978-955-7153-00-1
Edit: GARI Editorial Team | Received: 28.09.2018 | Publish: 05.11.2018

Research Journal of Textile and Apparel, 16(4), pp.106-111.

Chow, Y., Chan, A. and Kan, C. (2011). Effect of CO2 laser irradiation on the properties of cotton fabric. Textile Research Journal, 82(12), pp.1220-1234.

Kan, C., Yuen, C. and Cheng, C. (2010). Technical study of the effect of CO2 laser surface engraving on the colour properties of denim fabric. Coloration Technology, 126(6), pp.365-371.

Ondogan, Z., Pamuk, O., Ondogan, E. and Ozguney, A. (2005). Improving the appearance of all textile products from clothing to home textile using laser technology. Optics & Laser Technology, 37(8), pp.631-637.

Pezelj, E. Cunko, R. and Andrassy, M. (2004). Modification of denim surface using laser. In: world textile conference, 4th AUTEX conference, Roubaix.

Štěpánková, M., Wiener, J. and Dembický, J. (2014). Properties of cotton fabric after irradiation with infrared CO2 laser. Fibers and Polymers, 15(10), pp.2072-2076.

Tarhan, M. and Sarıışık, M. (2009). A Comparison Among Performance Characteristics of Various Denim Fading Processes. Textile Research Journal, 79(4), pp.301-309.

Tortora, G. and Johnson, I. (2013) *The Fairchild Books Dictionary of Textiles*. London: A&C Black, p.243.

Yuan, G. (2018). Sustainable garment design by using laser surface processing for polyester fabric. In: The 20th IFFTI Annual Conference Proceeding. Shanghai: Donghua University, pp.71-77

Dascalu, T., E Acosta-Ortiz, S., Ortiz-Morales, M. and Compean, I. (2000). Removal of the indigo color by laser beam–denim interaction. Optics and Lasers in Engineering, 34(3), pp.179-189.

Jiang, S., Yuan, G., Huang, J., Peng, Q. and Liu, Y. (2015). The effect of laser engraving on aluminum foil-laminated denim fabric. Textile Research Journal, 86(9), pp.919-932.

Collier, J. and Tortora, G. (2001). Understanding textiles. New Jersey: Prentice Hall, pp.97, 144, 179, 181.

Mendelson, C. (1999). *Home comforts: The art and science of keeping house.* New York: Scribner, pp.245, 254, 263.