Journal of Textile Science and Technology, 2026, 12(2), 19-29
https://www.scirp.org/journal/jtst
ISSN Online: 2379-1551
ISSN Print: 2379-1543

Exploring CO_2 Laser Treatment for Distressed Effects on Knit Fabrics: A Study of Aesthetic and Durability Impacts

Md. Monirul Islam Rajib, Md. Nurul Haque Samdany, Shadman Quamar Mahir, Mahbuba Sultana Mukta

Department of Apparel Manufacturing & Technology, BGMEA University of Fashion & Technology (BUFT), Dhaka, Bangladesh
Email: monirulislam@buft.edu.bd

How to cite this paper: Rajib, M.I., Samdany, N.H., Mahir, S.Q. and Mukta, M.S. (2026) Exploring CO_2 Laser Treatment for Distressed Effects on Knit Fabrics: A Study of Aesthetic and Durability Impacts. *Journal of Textile Science and Technology*, **12**, 19-29.
https://doi.org/10.4236/jtst.2026.122002

Received: February 1, 2026
Accepted: April 4, 2026
Published: April 7, 2026

Abstract

This study investigates whether CO_2 laser distressing can create acceptable distressed aesthetics on multiple knitted fabric structures while maintaining durability after washing. The primary aim was to evaluate the performance of CO_2 laser technology under laundering conditions, with the long-term objective of establishing it as a standard, environmentally sustainable process in garment manufacturing. Thirteen knitted fabric samples were subjected to CO_2 laser treatment followed by washing tests to assess changes in appearance, structural integrity, and shrinkage behavior. The results indicate that most knit structures did not retain satisfactory distressed effects after laundering. However, French terry fabric emerged as the only substrate that maintained a controlled distressed appearance with acceptable shrinkage and structural integrity. The findings position CO_2 laser finishing as a more sustainable alternative to conventional distressing processes such as sandblasting and acid washing, which are associated with significant environmental and health hazards. While CO_2 laser technology demonstrates strong potential for sustainable textile production and fashion design, challenges remain in ensuring garment durability and long-term aesthetic retention, as demanded by consumers. Given that the fashion industry contributes approximately 10% of global carbon emissions, adopting cleaner technologies such as CO_2 laser processing could significantly reduce environmental impact while supporting innovation and new employment opportunities in sustainable manufacturing.

Keywords

CO_2 Laser Treatment, Knit Fabrics, Laser Distressing, Washing Durability, Aesthetic Performance, Sustainable Textile Processing, Eco-Friendly Garment Manufacturing

1. Introduction

In recent years, knitted fabrics have gained prominence in contemporary fashion. Their applications now extend from casual everyday clothing to garments designed for sports and injury recovery. Due to their high extensibility and smooth, flowing lines, knitted structures provide a second-skin effect that does not restrict movement. Consequently, knitted fabrics are commonly used in the production of T-shirts, polo shirts, leggings, and sportswear. Their structural adaptability also makes them well suited to designs and treatments that emphasize fashion over fabric [1].

A widely used effect in the fashion industry is the distressed or "destroyed" appearance, which imparts a worn or antique look to garments. Traditionally, such effects have been achieved through techniques including sandblasting, acid washing, stone washing, and mechanical abrasion. However, several studies have indicated that while these methods effectively produce an aged appearance, they also pose significant environmental and occupational health risks. These risks include the release of chemical toxins into water, excessive water consumption, dust emissions, and unsafe living conditions [1]-[4]. As a result, environmentally friendly alternatives to these processes have become a major focus in textile engineering and fashion technology [5].

In recent years, CO_2 laser technology has emerged as a potential non-contact, digitally regulated method for textile surface treatment [6] [7]. Previous studies have demonstrated that CO_2 laser finishing techniques can effectively replicate traditional damage on denim while achieving significant savings in water, chemical, and energy consumption [8]. However, most research has concentrated on woven fabrics, as denim remains the most treated substrate, with limited attention given to the application of laser technology on knitted products [9] [10]. Knitted structures, characterized by their loop-shaped geometry, higher porosity, and elastic recovery, respond differently to thermal and photonic energy compared to woven textiles [11]. These differences can impact surface morphology, coloration, shrinkage patterns, and fastness.

The objective of this research is to systematically explore the feasibility of using CO_2 laser treatment to produce controlled distressed effects on selected knitted structures without compromising their functional performance [1] [3] [6] [12]-[20]. This study aims to evaluate the aesthetic appeal, physical properties (surface characterization), and post-wash durability of laser-treated knitted fabrics. It will also compare different knit structures subjected to identical laser settings and investigate the ecological benefits of this technique as an alternative to conventional distressing methods [4] [9] [15] [21]. By addressing this gap, this research provides both practical and scientific insights into the development of environmentally friendly garment finishing processes that strike the right balance between visual aesthetics, fabric integrity, and minimal environmental impact.

2. Methodology

2.1. Materials

In this research paper, we have selected a total of thirteen knit fabric samples of different types in order to assess the CO_2 laser outcomes on both aesthetics and durability. These fabrics are regularly utilized in the garment sector to manufacture garments, such as but not limited to t-shirts, pants, and so on. Fabric samples were used, and their respective (GSM) values, which are the weight of the fabric and its density, are given below:

a) Single Jersey (180 GSM) (Figure 1)
b) Heavy Jersey (170 GSM) (Figure 2)
c) 2 × 2 Rib (300 GSM) (Figure 3)
d) 4 × 2 Lycra Rib (200 GSM) (Figure 4)
e) Design Rib (400 GSM) (Figure 5)
f) Mesh (180 GSM) (Figure 6)
g) Pique (210 GSM) (Figure 7)
h) Interlock (330 GSM) (Figure 8)
i) Design Fabric (240 GSM) (Figure 9)
j) Ponte Fabric (280 GSM) (Figure 10)
k) Waffle (320 GSM) (Figure 11)
l) Fleece (300 GSM) (Figure 12)
m) French terry (280 GSM) (Figure 13)

Such pieces of fabric were obtained from one of the textile factories, where they received washing services after laser treatment. Various types of fabrics were selected to offer a wide range of outcomes regarding feel and extent of wear during laser distressing.

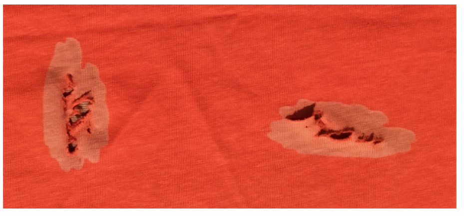

Figure 1. Single jersey fabric.

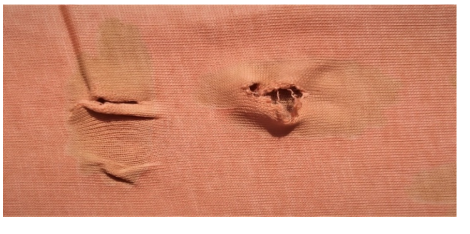

Figure 2. Heavy jersey fabric.

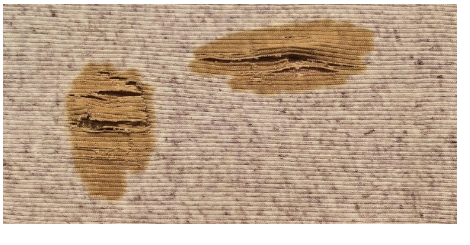

Figure 3. 2 × 2 rib fabric.

Figure 4. 4 × 2 lycra rib fabric.

Figure 5. Design of rib fabric.

Figure 6. Mesh fabric.

Figure 7. Pique fabric.

Figure 8. Interlock fabric.

Figure 9. Design fabric.

Figure 10. Ponte fabric.

Figure 11. Waffle fabric.

Figure 12. Fleece fabric.

Figure 13. French terry fabric (Before wash).

2.2. Equipment

The laser treatment was performed using the JEANOLOGIA Laser System: a CO_2 laser machine that is commonly used in the textile industry to modify the surface [22]. The system is used with the high specification CO_2 RF Metal Lasers in the following way:

a) Laser Power: Average of 600 W, maximum of 1800 W

b) Working Area: 1500 mm × 1500 mm

c) Wavelength: 9 - 12 μm

d) Positioning Accuracy: ±0.1 mm

e) Cooling System: Chiller System

The JEANOLOGIA laser decouples the high-accuracy topographical alterations on textile without destroying bulk characteristics, which in this manner has a less adverse effect on the mechanical and photochemical degradation of fabrics. The capability of this machine to provide a high degree of control in terms of the heat input on the fabric is also relevant to the provision of appealing aesthetic effects with a relatively minimal amount of damage to the integrity of the fabric overall.

2.3. Laser Treatment Procedure

In this technology, laser treatment is carried out using a laser to ensure that the surface properties of the materials are altered by melting or vaporizing the material, using the focused light source (e.g., an improved laser). A distressed look in knit fabric samples was acquired with a laser in the current work. The exposure time of the laser was well controlled because each piece of fabric was not exposed to the treatment for more than 2 s. The intensity of the laser power was absorbed on the surface of a piece of fabric, vaporizing and melting locally so as to achieve a special aesthetic effect. Laser treatment is also chosen over traditional abrasive methods, such as sand blasting or chemical etching, due to its gentle impact on the environment and extremely low chances of damaging the garments.

The thought was to understand the response of each fabric to the heat of the laser, and whether she could manage to create an unpleasant effect without excessive weakening of the fabric. The other goal was to test the feasibility of laser use in the trim fabric sector, which was previously dominated by manual acidic killing techniques.

2.4. Washing Process

The French terry fabric sample that resulted from the improved performance using the laser process was chosen to be further investigated by washing. The wear and appearance of the laser-treated cloth were intended to be tested after washing. A Miele washing machine (Germany) was used under the following conditions:

a) Liquor Ratio: 1:10 (fabric-to-water ratio)

b) Wash Ingredients:

i. Hydrogen Peroxide (H_2O_2, Figure 14): 1.5 g/l

ii. Caustic: 1.5 g/l

iii. Detergent: 0.5 g/l

iv. Stabilizer: 0.5 g/l

c) Temperature: 90˚C

d) Wash Time: 20 minutes

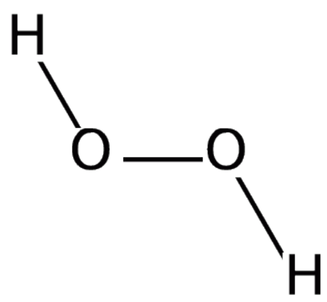

Figure 14. Chemical structure of Hydrogen Peroxide (H_2O_2) [23].

The washing procedure was formulated to reflect general post-treatment patterns in the textile sector. Hot water wash and cold-water wash were conducted after washing and tumble drying of the fabrics. This test was performed with the aim of determining whether or not a fabric that was treated with the laser would preserve its structural integrity and/or design effect when subjected to regular laundering.

2.5. Shrinkage Test

The shrinkage test was performed to assess whether the laser treatment and washing process caused any significant dimensional changes in the fabric. The following steps were taken:

i. The pre-wash measurement of the French terry fabric was recorded as 20 cm.

ii. After washing, the post-wash measurement was taken, and the shrinkage percentage was calculated using the formula:

Shrinkage Percentage = [(Before wash measurement − After wash measurement)/Before wash measurement] × 100

a) Pre-Wash Measurement: 20 cm

b) Post-Wash Measurement: 19.5 cm

c) Shrinkage: 2.5%

The shrinkage observed (2.5%) was well within the acceptable range for most commercial fabrics, where a maximum shrinkage of 5% is typically considered acceptable.

3. Data Analysis

Aesthetic assessment of every fabric was done through naked eyes also after lasing and washing had been done. The aim of the research, though, was pegged on whether the laser distressing 10 effect was even and acceptable using the varied knit fabrics. The properties of strength of fabric were also tested, which include slippage of the yarn and durability of the fabric after treatment.

It was observed that a good number of the fabric samples did not react well or rather reacted anew; French terry sustained an equal measure of distressing with a small amount of fraying (**Figure 15**). The cloth did not lose its strength, form, and appearance following washing and would be applicable to additional applications in fashion designing/the clothing industry.

Figure 15. French terry fabric (After washing) [2].

4. Results and Discussion

4.1. Laser Treatment on Knit Fabrics

A difference in outcome was observed in the treatment of the thirteen fabric samples with the CO_2 laser. The aim of the laser process was to achieve a destroyed or distressed appearance that is popular in the fashion industry for creating clothes that look old and worn. It was also established that among the fabrics sampled, French terry fabrics were the most useful when it came to laser distressing because most of the samples gave poor results despite being in the majority.

French Terrycloth—This came out best. The distressing caused by the laser was controlled, and it looked good. French terry also did not unravel to a great extent as the yarns did but remained in good condition during distress, unlike other types of fabric. The processing of the fabric did not compromise its strength, and it showed a smooth surface finish. The fabric had been preserved even after washing, but it appeared slightly modified, not heavily damaged, and did not lose its color. This renders knitted French terry a good candidate for fashion design since the aesthetic properties and utilitarian functions of a fine finishing cloth were maintained. Other Fabrics The remaining fabric samples, *i.e.*, Single Jersey, Heavy Jersey, and 2 × 2 Rib, appeared to be in different forms of damage. But in the main, that scalded too far away and left irregular fraying or weakened the cloth. As an example, when Pique and Mesh fabrics were subjected to damage, they became unusable (which implies that not all fabrics can be subjected to laser treatment as efficiently). This concurs with other publications that have reported structures and the composition of fabrics to be a critical bias factor to their distressing with laser.

4.2. Impact of Laser Treatment on Fabric Durability

CO_2 laser treatment process provides local heat to the fabric, which is converted to solid-liquid-gas transformation. The resulting effects are the desired appearance effects, but the strength of the fabric and its durability are causes of concern.

Shrinkage: The test on the shrinkage of the French terry fabric was conducted following the laser treatment and washing. The cloth had a contraction of 2.5%, which is reasonable in textile machinery, and a maximum shrinkage of 5 percent can be obtained. In other words, laser treatment did not appear to affect the dimensional stability of the fabric post-washing in a negative way.

Fabric Strength: The strength of the fabric after it was distressed with laser was determined by observing the slippage of the yarns in different directions on the plane of the fabric. It was found that some unraveling was towards course-wise, but none unraveled towards wales-wise. This implies that the architecture of the French terry was mostly retained in some of the directions by the laser-treated fabric, which is critical in the tensile properties and durability of garments.

4.3. Environmental Impact and Sustainability

CO_2 laser technology (environmentally friendly) Above all, the CO_2 technology of laser technology has numerous environmental advantages over other fabric treatments like sandblasting and acid washing, which also result in by-products that are both environmentally hazardous, such as toxic fumes and millions of pounds of waste. The CO_2 laser procedure does not create any chemical waste and is a relatively green procedure as far as the environment is concerned. The precision and efficiency of the laser similarly reduce the overall quantity of energy consumed during distressing, which is a more eco-friendly option for the textile industry [24]-[27].

5. Conclusions

It has been revealed in this research that CO_2 laser treatment is a green and new technology used in distressing knit fabrics. When an experiment was conducted to test the impact of such laser technology on various cloths, significant differences were discovered between the results. Among the 13 samples of fabric that were tested, French terry was identified as the most appropriate fabric that could be laser distressed in terms of aesthetic appearance, low shrinkage, and good fabric durability post-treatment.

It was discovered that CO_2 laser ablation is a cost-effective technique of controlled distressing and is better than other techniques such as sandblasting, acid washing, and hand sanding methods, which are less precise and also have a negative impact on the environment. French Terry, even when washed, would not have its remaining power and appearance revealed by damaging the fabric structure adequately with the laser material during the treatment.

To make the fabrics durable, the laser treatment did not result in any severe shrinkage of the French terry fabrics, which had an attractive percentage of 2.5% at maximum, which was less than the required percentage to make commercial garments. Also, the fabric strength was significantly maintained with minimal tension of backbone destruction in the course wise direction, therefore proving further that laser could be used to maintain the fabric integrity.

Such findings have great industry application, particularly in the textile and sustainable fashion industry. Findings have shown that CO_2 laser could be a viable substitute for chemical or traditional distressing, which will assist the industry not only in minimizing its effects on the environment but also in advancing the quality of fabric finishes. Laser may also reduce the level of noxious emissions as well as water usage, which are required by the new trends of ecological manufacturing in the textile industry. Future research would consider the maximization of the laser settings with various fabric types to expand the range of applications throughout the textile sector.

Overall, the CO_2 laser represents a prospective technique for distressing fabric in a stable and sustainable way. The accuracy and the fact that it does not cause significant environmental damage, coupled with the delicate manner in which it maintains the integrity of garments, make it a tremendous instrument in contemporary clothes manufacturing, as fashion designs will not only be extra-long lasting but also stylish.

Acknowledgements

This research was conducted without any financial support from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Atav, R. and Çolakoğlu, Ö. (2024) Investigation of the Effect of Laser Technology on the Color of Polyester Fabrics. *International Journal of Clothing Science and Technology*, **36**, 417-433. https://doi.org/10.1108/ijcst-06-2023-0089

[2] Farhana, K., Mamun, A., Hosen, S., Abhisheke, A., Hasan, H. and Faisal Mahamude, A.S. (2024) Effect of Acid Wash on Appearance and Physical Properties of Terry and Interlock Knitted Dyed Garment. *International Journal of Textile Engineering and Management*, **1**, Article 18. https://doi.org/10.63261/ijtem114

[3] Hung, O.N., Chan, C.K., Kan, C.W. and Yuen, C.W.M. (2017) Effect of the CO_2 Laser Treatment on Properties of 100% Cotton Knitted Fabrics. *Cellulose*, **24**, 1915-1926. https://doi.org/10.1007/s10570-017-1224-y

[4] Hung, O., Chan, C., Kan, C. and Yuen, C.M. (2017) Microscopic Study of the Surface Morphology of CO_2 Laser-Treated Cotton and Cotton/Polyester Blended Fabric. *Textile Research Journal*, **87**, 1107-1120. https://doi.org/10.1177/0040517516648511

[5] Shamsuzzaman, M., Kashem, M.A., Muhammad Sayem, A.S., Khan, A.M., Shamsuddin, S.M. and Islam, M.M. (2021) Quantifying Environmental Sustainability of Denim Garments Washing Factories through Effluent Analysis: A Case Study in Bangladesh. *Journal of Cleaner Production*, **290**, Article 125740. https://doi.org/10.1016/j.jclepro.2020.125740

[6] Hung, O.N., Chan, C.K., Kan, C.W. and Yuen, C.W.M. (2017) An Analysis of Some Physical and Chemical Properties of CO_2 Laser-Treated Cotton-Based Fabrics. *Cellulose*, **24**, 363-381. https://doi.org/10.1007/s10570-016-1090-z

[7] Ahmad, S., Ashraf, M., Abid, S., Jabbar, M., Shafiq, F. and Siddique, A. (2022) Recent Developments in Laser Fading of Denim: A Critical Review. *Journal of Natural Fibers*, **19**, 11621-11631. https://doi.org/10.1080/15440478.2022.2029793

[8] Khan, M.K.R. and Jintun, S. (2021) Sustainability Issues of Various Denim Washing Methods. *Textile & Leather Review*, **4**, 96-110.

[9] Hung, O. and Kan, C. (2017) Effect of CO_2 Laser Treatment on the Fabric Hand of Cotton and Cotton/Polyester Blended Fabric. *Polymers*, **9**, Article 609. https://doi.org/10.3390/polym9110609

[10] Ahmed, F., Rahman, A.N.M.M., Islam, M.R., Hossain, M.A. and Aabrar, I. (2022) Influence of Laser Treatment and Chemical Washing on the Performance Attributes of Cotton Woven Denim Fabrics. *Journal of Natural Fibers*, **19**, 13876-13889. https://doi.org/10.1080/15440478.2022.2110549

[11] Hecht, J. (2010) A Short History of Laser Development. *Applied Optics*, **49**, F99. https://doi.org/10.1364/ao.49.000f99

[12] Ortiz-Morales, M., Poterasu, M., Acosta-Ortiz, S.E., Compean, I. and Hernandez-Alvarado, M.R. (2003) A Comparison between Characteristics of Various Laser-Based Denim Fading Processes. *Optics and Lasers in Engineering*, **39**, 15-24. https://doi.org/10.1016/s0143-8166(02)00073-8

[13] Hung, O.N. (2016) A Technological Study of Computer-Aided Laser Finishing on Cotton-Based Fabrics. https://theses.lib.polyu.edu.hk/handle/200/8443

[14] Luan, X. (2022) Application of Sustainable Power and Laser Washing Device in Garment Design. *International Journal of Emerging Electric Power Systems*, **23**, 793-805. https://doi.org/10.1515/ijeeps-2022-0106

[15] Kan, C. (2014) CO_2 Laser Treatment as a Clean Process for Treating Denim Fabric. *Journal of Cleaner Production*, **66**, 624-631. https://doi.org/10.1016/j.jclepro.2013.11.054

[16] Kim, I.I., McArthur, B. and Korevaar, E.J. (2001) Comparison of Laser Beam Propagation at 785 nm and 1550 nm in Fog and Haze for Optical Wireless Communications. *SPIE Proceedings*, Boston, 5-8 November 2000, 1. https://doi.org/10.1117/12.417512

[17] Chow, Y.L., Chan, C.K. and Kan, C.W. (2011) Effect of CO_2 Laser Treatment on Cotton Surface. *Cellulose*, **18**, 1635-1641. https://doi.org/10.1007/s10570-011-9603-2

[18] Angelova, Y.P. (2020) Factors Influencing the Laser Treatment of Textile Materials: An Overview. *Journal of Engineered Fibers and Fabrics*, **15**, 1-16.

[19] Hitz, C.B., Ewing, J. and Hecht, J. (2012) Introduction to Laser Technology. Wiley. https://doi.org/10.1002/9781118219492

[20] Gupta, S., Gupta, P., Jakhar, D. and Pabla, G.S. (2020) Laser-Light Amplification by Stimulated Emission of Radiation. *International Journal of Contemporary Medical Research*, **7**, 1.

[21] Gulino, M., Bruzzi, M., Caron, J.N. and Vangi, D. (2022) Non-Contact Ultrasonic Inspection by Gas-Coupled Laser Acoustic Detection (GCLAD). *Scientific Reports*, **12**, Article No. 87. https://doi.org/10.1038/s41598-021-04191-x

[22] Nahid-Ull-Islam, M., Hasan, S.M.M., Chowdhury, M.K.H., Sakib, S.I., Ahamed, S., Abu Sayeed, M., *et al.* (2024) Sustainable Approaches of Ozone Wash and Laser Fading over Conventional Denim Wash. *Tekstilec*, **20**, 104-118.

[23] Wikipedia (2025) Hydrogen Peroxide. https://simple.wikipedia.org/w/index.php?title=Hydrogen_peroxide&oldid=10679093

[24] Angelova, Y., Mežinska, S. and Lazov, L. (2017) Innovative Laser Technology in Textile Industry: Marking and Engraving. *Environment. Technology. Resources. Proceedings of the International Scientific and Practical Conference*, **3**, 15-21. https://doi.org/10.17770/etr2017vol3.2610

[25] Unal, F., Yavas, A. and Avinc, O. (2020) Sustainability in Textile Design with Laser Technology. In: Muthu, S. and Gardetti, M., Eds., *Sustainable Textiles: Production, Processing, Manufacturing & Chemistry*, Springer International Publishing, 263-287. https://doi.org/10.1007/978-3-030-37929-2_11

[26] Rahaman, M.T., Khan, M.S.H. and Pranta, A.D. (2025) Sustainable Approaches to Fashionable Denim Fading: New Perspectives on Conventional and Modern Garment Washing Techniques. *Coloration Technology*, 1-48. https://doi.org/10.1111/cote.70043

[27] Tong, Y., Wang, Q., Wang, Z., Liang, Z., Xu, Q., Zuo, D., *et al.* (2023) Prediction of Parameters in the Laser Fading Process of Denim Using Convolutional Neural Networks. *Textile Research Journal*, **93**, 3790-3801. https://doi.org/10.1177/00405175231162643