RESEARCH OF THE INFLUENCE OF LASER BEAM PARAMETERS ON THE NEOPRENE LASER ENGRAVEMENT AND LASER CUT

LĀZERA STARA PARAMETRU IETEKMES IZPĒTE UZ NEOPRĒNA LĀZERA GRAVĒŠANU UN GRIEŠANU

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Abstract. *The report considers the possibility of using laser technology for neoprene engraving and cutting. This modern material is a type of synthetic rubber with great strain resistance, general durability and excellent temperature insulation properties. This study uses a CO_2 laser system SUNTOP ST-CC 9060 with a wavelength of 10640 nm with a goal to achieve the best engraving and cutting quality of the material and Zwick / Roell machine for testing the samples. As a result of experimental studies, power density and processing speed parameters were optimized for high – quality engraving and cutting of the neoprene.*
Keywords: *CO_2 laser, cutting, engraving, laser processing, neoprene.*

Introduction

Following an increased demand for natural rubber, and therefore the subsequent price rise in the 1920s, scientists set out to create a cheaper synthetic alternative. [1] On April 17, 1930, scientists of the company DuPont invented neoprene after purchasing the patent rights from the University of Notre Dame. Today, more than 90 years later, the material is being used in wide variety of applications, such as civil and automotive engineering, medicine, clothing, home accessories etc. [2] However, the engraving and cutting of the material, as with automated manufacturing processes for neoprene, has not yet been fully optimized. This study discusses laser usage for engraving and cutting as an alternative method to the mechanical processing of the material.

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of radiation differing from other sources of light in that it emits light, which is coherent. Lasers are used in laser printers, laser surgery, processing materials, for entertainment etc. [3]

Laser engraving is the practice of using lasers to engrave an object whether it is a text, picture or something else. On the other hand, it can be defined as a broader category of methods to leave marks on an object, which also includes color change due to chemical/ molecular alteration, charring, foaming, melting, ablation and more. The technique is contactless, as it does not involve the use of inks or tool bits that contact the engraving surface. [4] The main difference form laser marking is that the high heat of the laser beam vaporizes the material thereby cutting into the part's surface and physically removing material. This process leaves a cavity in the surface that is not only visible with a high contrast but is also noticeable by touch. [5],[6]

Laser cutting is a technology that uses laser to slice materials. Laser cutting works by directing the output of a high power laser most commonly through optics. The focused laser beam is directed at the material, which then either melts, burns, vaporizes away or is blown away by a jet of gas, leaving an edge with a high quality surface finish. While typically used for industrial manufacturing applications, it is beginning to be used by schools, small businesses and hobbyists. [7]

Neoprene is usually used as an interlayer between two textile layers therefore, it is hard to cut the material precisely using traditional methods, such as cutting with scissors. [8] Solution

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for post – processing is to cut neoprene with laser. The experiments were conducted in an enclosed cell connected to an exhaust system in order to prevent the operator from being exposed to emissions from the engraving and cutting process.

Equipment for research process

For the experiment and research CO_2 laser system SUNTOP ST-CC9060 and material testing machine Zwick / Roell was used. Technical parameters of laser system are shown in Table 1. Laser system SUNTOP ST-CC9060 shown in Fig. 1.

Table 1. [9]

Technical parameters of laser system SUNTOP ST-CC9060

Laser type	CO2 laser
Working mode	Continuous mode (CW)
Wavelength	10640 nm
Maximal output power	100 W
Working space	900 x 600 mm
Cutting speed	0 – 1000 mm/ s
Positioning precision	0.02 mm
Cooling system	Water cooling

Fig. 1. View from outside.

This laser system is designed for processing non – metals such as wood, bamboo, plastic, fabric, leather etc. Machine is designed for precise engraving and cutting of parts.

Material for research

Neoprene is a type of synthetic rubber produced by polymerization of chloroprene invented by DuPont scientists on April 17, 1930. It resists degradation more than natural or synthetic rubber. In garment manufacturing, neoprene is used as an interlayer between two textile layers making the fabric light, soft, strain resistant and durable in general. Moreover, it has excellent temperature insulation properties and it is effective against shock damages. [2], [10] General characteristics of the neoprene as a material are shown in Table 2.

Table 2. [2]

General characteristics of the neoprene

Hardness (Shore A)	40 – 95
Tensile failure stress, MPa	3.45 – 20.68
Elongation after fracture, %	600
Density, g/ cm^3	1.23

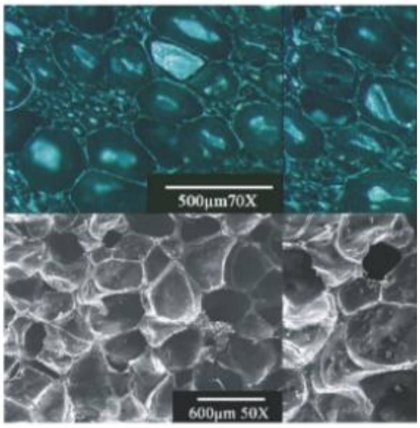


Fig. 2. Micrographs of uncompressed foam neoprene under various magnifications. [11]

Although the material is durable, when used in garment manufacturing, it still needs to be cleaned properly. Since the material has direct contact with the body, it should be washed frequently in low temperatures such as 30° C – 40° C, which means that it should not be exposed to high temperatures. [12] This means that the laser parameters have to be optimized both for engraving and cutting to make sure that the material is not being damaged in working process making engraving and cut quality also an important factor. For the study, the material of thickness of approximately 2.5 mm was used.

Methodology

Before the experiment, the laser output power is measured. The power P adjustment curve is shown in the graph in Fig. 3.

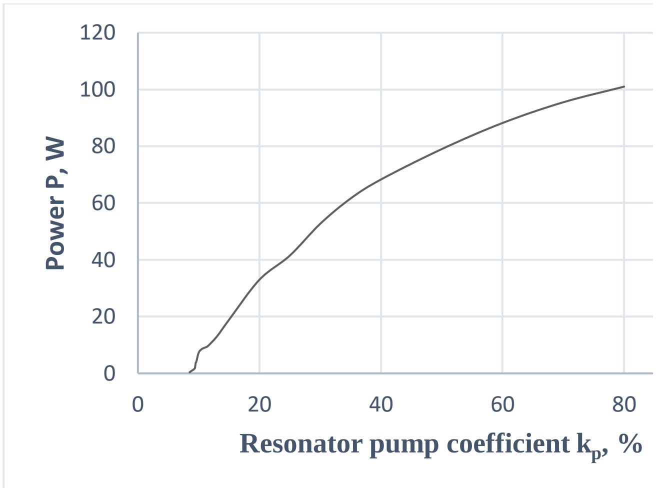


Fig. 3. Output power P (W) dependence on the resonator pump coefficient k_p, %

Three series of experiments were made.

1) In the first series of the experiment, the dependence of the cut geometric and visual parameters depending on the power output *P* and speed *v* is investigated. *P* takes the value of 9.5; 9.8; 10; 10.3; 10.5; 10.8; 11; 13; 15 W. Each power output amount *P* were tested with three different velocity parameters: 50; 70; 90 mm/s.

2) In the second series of the experiment, the dependence of the engraving geometric and visual parameters depending on the power output *P* and speed *v* is investigated. *P* takes the value of 8.5; 8.8; 9; 9.1; 9.2; 9.3; 9.4; 9.5; 9.6 W. Each power output amount *P* were tested with three different velocity parameters: 80; 100; 120 mm/s. The experiment was carried out two times, changing the direction of the thread.
3) In the third series of the experiment, the dependence of the engraving geometric and visual parameters depending on the thread direction and line distance *Δ x* is investigated. *P* takes the value of 8.8 W and velocity v takes the value of 120 mm/s as the best parameters for engraving obtained from the previous experiment.

After the third experiment, six samples were tested for strain resistance using Zwick/ Roell testing machine with the tensile testing speed of 50 mm/ min and constant load. Three samples were made both with the examples with straight thread and slanting thread.

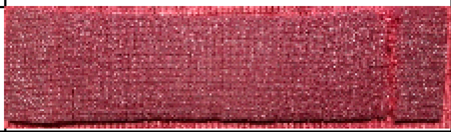
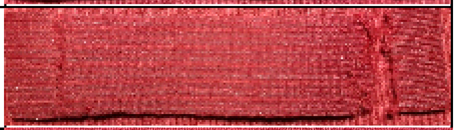
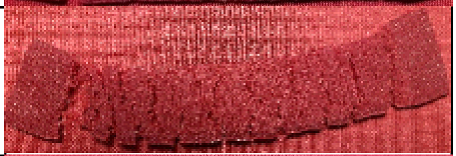
Example No.		P, W	v, mm/s
1		8.8	120
2			
3			
4			
5			
6			

Fig. 4. Summary of data for engraved neoprene (1.-3. straight thread, 4.-6. slanting thread)

Results

Based on the data obtained from the tests, graphs were constructed that show the strain durability dependence on the direction of the thread and line distance *Δ x*. The obtained results were compared to the test results of the non – engraved examples. The most important parameter to be observed after tensile tests was the tensile length *dL* (mm) at the maximum force *F* (N), as the goal of this study is to optimize laser processing parameters to obtain both the best visual quality and durability of the material after laser processing. The results were collected and shown both in graph and table (Fig. 5. and Fig. 6.). As for the cutting parameters, the best output power *P* and speed *v* to be used for cutting neoprene was 11 W and 50 mm/ s, giving the best cutting edge quality.

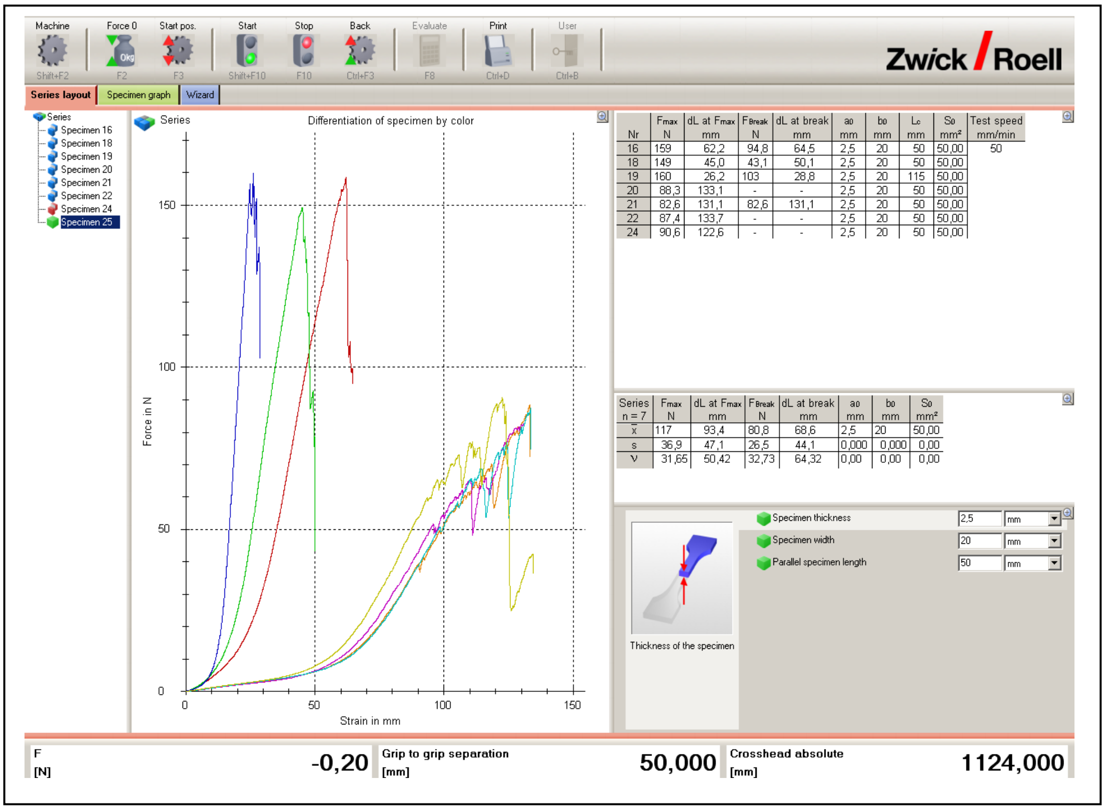


Fig. 5. The tensile test results of non – engraved examples (test speed v = 50 mm/ min).

The graph of examples No. 16; 18; 19 shows test results of examples with straight thread. The average maximum tensile strength F_{max} for these three examples were 156 N. As for the average maximum tensile length, 44.47 mm were obtained while testing the material. Examples No. 20; 21; 22; 24 show the results of the tests carried out with slanting thread. The average maximum tensile strength F_{max} for these four examples were 87.23 N. As for the average maximum tensile length, 130.13 mm were obtained while testing the material. The results of the tests with engraved examples for comparison are given in Fig. 6.

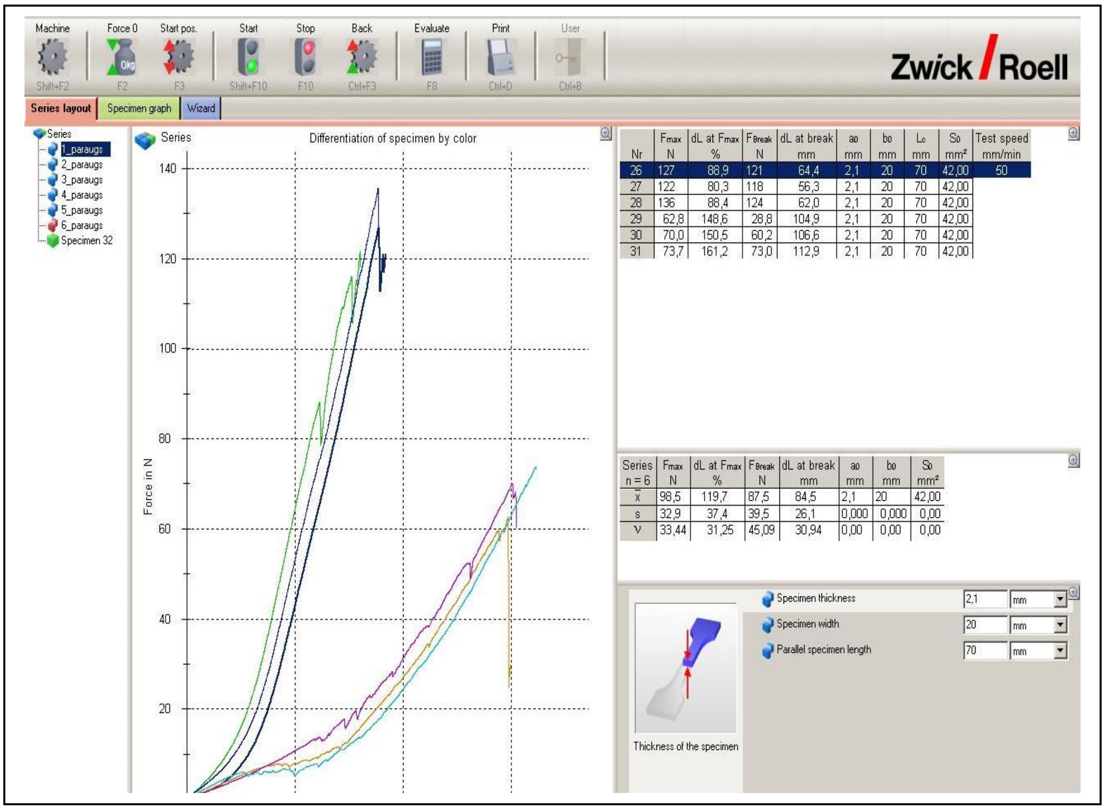


Fig. 6. The tensile test results of engraved examples (test speed v = 50 mm/ min).

The graph of examples No. 26; 27; 28 shows test results of examples with straight thread. The average maximum tensile strength F_{max} for these three examples were 128 N. As for the average maximum tensile length, 85.87 mm were obtained while testing the material. Examples No. 29; 30; 31 show the results of the tests carried out with slanting thread. The average maximum tensile strength F_{max} for these four examples were 68.83 N. As for the average maximum tensile length, 153.43 mm were obtained while testing the material.

The obtained results of both non – engraved and engraved examples show the tensile differences between examples with straight and slanting thread. Better tensile results can be achieved when using material with slanting thread. As for engraving, the best result is also achieved with slanting thread due to less change in length to force ratio.

Summary

1. *As a result, optimal parameters for engraving neoprene with CO_2 laser can be made. So one can say that for engraving approximately 2.5 mm thick neoprene best power P is P = 8.8 W and the best engraving speed to be used is v = 120 mm/ s.*
2. *For cutting approximately 2.5 mm thick neoprene, the best power P is P = 11 W and the best engraving speed to be used is v = 50 mm/ s, because it cuts through the material and leaves the cutting edge with the best quality.*
3. *The direction of the thread also changes the result of engraving. The best results can be achieved, when engraving in the direction of the slanting thread.*
4. *There are many advantages for cutting neoprene with laser, such as more precise cuts, shorter cutting time and less material consumption.*

Bibliography

1. https://www.processindustryforum.com/article/what-is-neoprene-and-why-should-we-use-it (Last opened 18.03.2021)

2. https://en.wikipedia.org/wiki/Neoprene (Last opened 18.03.2021)
3. https://en.wikipedia.org/wiki/Laser (Last opened 18.03.2021)
4. Angelova Y. P., (March 2020) Factors influencing the laser treatment of textile materials: An overview, Journal of Engineered Fiber and Fabrics Volume 15: 1 – 16
5. Dudeja J. P., (September 2018) Laser Application in Apparel Industry, International Journal of Advanced Scientific Technologies in Engineering and Management Sciences Volume. 4, Issue 9.
6. https://www.lasercut4.com/en/articles/textile-laser-cutting (Last opened 18.03.2021)
7. https://en.wikipedia.org/wiki/Laser_cutting (Last opened 18.03.2021)
8. Razumeev K. E., Chreunova I., Tashpulatov S., (January 2021) Neoprene: Application area and prospects for usage, Tashkent Institute of Textile and Light Industry, Tashkent, Uzbekistan
9. https://www.suntoplaser.com/co2-laser-cutting-machine/co2-laser-cutting-machine-1574339975.html (Last opened 18.03.2021)
10. https://blog.zmorph3d.com/neoprene-laser-engraving-cutting/#What_is_Neoprene (Last opened 18.03.2021)
11. Bardy E., Mollendorf J., Pendergast D. R., (September 2005) Thermal conductivity and compressive strain of foam neoprene insulation under hydrostatic pressure, Journal of Physicd D Applied Physics
12. Yoojung H., Jongjun K., (2015) A Study on Changes of Drape Shapes and Physical Properties by Applying Laser – Cutting Technique on Neoprene Materials, 2015 spring Conference of The Korean Society of Fashion Business.