Practical research of marking and cutting of textiles with increased resistance, using CO₂ laser

Dolchinkov Nikolay Todorov
National Military University „Vasil Levski“, Veliko Tarnovo, Bulgaria;
National Research University "Moscow Power Engineering Institute", Moscow, Russia
Veliko Tarnovo, Bulgaria;
n_dolchinkov@abv.bg

Abstract. During the experiment we do practical research for cutting, marking and engraving on materials made of fabrics, textiles and synthetic bases with the help of a CO₂ laser device. During the experiments, the team created a science-based methodology, which can be presented as the formation of an experimental base of 6 or 9 squares with dimensions of 10:10 mm. The experiment was performed by changing the speed in the range of 100-350 mm/sec and changing the power of the laser beam in the range of 2-26 watts.

1. Introduction
The laser was discovered 60 years ago and since then it has been constantly improved and helps the development of the economy - mechanical engineering, instrument making, car production, self-propelled equipment, airplanes, vessels and others both in Bulgaria and in many other countries around the world. The laser beam sources operate in a wide spectral wavelength range, both in the ultraviolet spectrum and in the visible and infrared light field. The laser units operate in continuous and pulsed modes. Most often, lasers are used for laser cutting, engraving, marking and others. The laser marking systems using different lasers delivery systems can be used to mark too many materials including such as textile, plastics, metals, ceramics, glass, wood and leather [1,2]. Modern technology for laser marking and laser cutting is currently widely used in the textile and clothing industry [3].

2. Experimental setting
The CO₂ laser used is brand CHANXAN CW 1325 CO₂, operating power 1-150 watts, the wavelength of this laser beam is in the range from 1 to 400 mm/s, maximum marking area: 2.5 x 1.3 m and water system cooling of the working fluid – Figure 1. On the figure "Materials" indicates the location where the sample is placed.

The practical research was conducted at the Rēzekne Academy of Technology, Latvia on high-strength fabrics that are used to make protective clothing and work in extreme conditions. These studies are the beginning of more in-depth research on textiles. The experimental data were processed using an AM4515ZTL digital microscope manufactured by Dino-lite having the following characteristics 1.3 MPx resolution, 10-140X magnification and polarization.
3. Laser Marking

Laser marking is a unique and very promising method of marking. Research shows that it will be increasingly used in industry. Classifications of laser marking can be made on various grounds - type of laser source, marking method, production needs, marking method, etc. Two classifications have been implemented - according to the needs of the production and according to the method of laser marking.

The main factors that influence the contrast of laser marking are [4,5]:
- optical characteristics: power density, pulse energy (pulse lasers only), pulse duration of the laser beam, frequency, overlap factor;
- thermophysical characteristics: marking speed, laser beam pitch, laser beam defocus, number of repetitions, volumetric density of the absorbed energy [6].

![Schematic of the experimental setup](image)

**Figure 1:** Schematic of the experimental setup [1].

| № | \(v, \text{[mm/s]}\) | \(P = 2W\) | \(P = 10W\) | \(P = 26W\) |
|----|-----------------|-------------|-------------|-------------|
| 1. | 100             | 0.02        | 0.095       | 0.26        |
| 2. | 150             | 0.013       | 0.066       | 0.17        |
| 3. | 200             | 0.011       | 0.054       | 0.13        |
| 4. | 235             | 0.01        | 0.048       | 0.12        |
| 5. | 240             | 0.0096      | 0.046       | 0.116       |
| 6. | 245             | 0.0088      | 0.042       | 0.11        |
| 7. | 250             | 0.0082      | 0.041       | 0.095       |
| 8. | 255             | 0.007       | 0.039       | 0.091       |
| 9. | 260             | 0.0062      | 0.038       | 0.088       |
| 10.| 300             | 0.0058      | 0.033       | 0.086       |
| 11.| 350             | 0.0048      | 0.025       | 0.077       |

The laser marking and engraving is performed on textiles with a composition of 65/35% CO / polyester ± 5% determined in accordance with EN ISO 1833 and is made with a CO2 laser and the obtained practical results are investigated and analyzed. For this purpose, together with the Academy
of Technology in Rezekne, an experimental methodology has been developed, which can be described as follows:
A matrix of 6 squares with dimensions 10x10 mm is formed. The power of the laser beam varies from 2 to 26 W, and its speed varies in the range from 100 to 350 mm / s. The schematic diagram of the six-square matrix used in our work is shown in Figure 2.

![Figure 2](image)

**Figure 2:** Location of the fabricated matrix with 6 experimental fields.

Table 1 shows the data obtained from the studies of the dependence of the change in speed and power P for 2 W, 10 W and 26 W and the obtained linear energy density at marking.

![Figure 3](image)

**Figure 3:** Good marking on fabric with increased strength.

Each part of the marking matrix used is carried out by the raster scanning method. The step from the stroke of the laser to the next stroke is 0.1 mm. Each processed element of the manufactured matrix and its quality were analyzed, examined and photographed by DINO-LITE: with a resolution of 1.3 MPx, 10-140X magnification and a polarizer. More than 60 areas were surveyed, but half of the best quality were selected for detailed analysis. From the experiments performed in TAP we can draw the following important conclusions for this type of textile:

- The best cutting of the material is obtained with the following parameters: constant power of the laser beam 26 watts and speed of 50 mm / s, with linear energy densities, respectively 0.26, 0.17 and 0.13 J / mm.
- The best quality marking is obtained in the range $5 \times 10^{-2} \times 3.8 \times 10^{-2} J / mm$ for power 10 W, where the speed varies in the range 200-260 mm / s. The other marked areas have a slight contrast, which is between 5% and 10%. Contrast measurements are performed using Color Contrast Analyzer version: 2.5.0.0. [5]. Figure 3 shows two photos of highlighted areas with good contrast.
4. Laser cutting

When very high power is required for drilling and cutting, an Nd-YAG laser is used. They are also used for welding [7].

In our study, the possibility of laser cutting of CO2 laser is evaluated. An experimental methodology has been developed for its implementation, which can be described as follows:

Straight lines with a length of 40 mm are applied to the textile at different speeds of the laser beam and is carried out at different values of power. It is in the range of 2 to 20 W and the speed is 10 mm / s. Two different variants of the experiment were made, each with 10 rows. In the first series of cuts, the power is maintained unchanged - 10 W, and the speed varies in the range from 10 to 55 mm / s. In the next series, the speed does not change and is 50 mm / s, and the power changes in the range from 2 to 20 W. This is illustrated by the data in Table 2. The thickness of the studied textile is 0.41 mm.

Table 2: Results of fabric cutting at changed speeds and powers.

| №  | P, [W] | V=10mm/s  | P, [W] | V=50mm/s |
|----|--------|-----------|--------|----------|
|    |        | LDE, [J/mm]|        | LDE, [J/mm] |
| 1  | 2      | 0.2       | 10     | 1.0      |
| 2  | 4      | 0.4       | 15     | 0.75     |
| 3  | 6      | 0.6       | 20     | 0.60     |
| 4  | 8      | 0.8       | 25     | 0.45     |
| 5  | 10     | 1.0       | 30     | 0.35     |
| 6  | 12     | 1.2       | 35     | 0.31     |
| 7  | 14     | 1.4       | 40     | 0.26     |
| 8  | 16     | 1.6       | 45     | 0.23     |
| 9  | 18     | 1.8       | 50     | 0.21     |
| 10 | 20     | 2.0       | 55     | 0.20     |

To analyze the studies performed, microscopic analysis is used, which can show the quality of the obtained experimental data. The detailed microscopic analysis of the lines shows that there is a good section of the textile in 18 sections in the range of LED (0.2-2 J / mm for a constant speed of 10 mm / s and 1-0.20 J / mm for a constant power 10-55 W) – Figure 4.

Figure 4: Textile cutting at the lowest good quality laser values.

The best cutting of this textile after microscopic analysis was found at 0.2 J / mm and 0.18 J / m LED for a constant power of 10 W. This cut is on the verge of full cutting and maximum economical use of this type of laser. The most good section is shown in Figure 5.
Based on the performed experiments it can be stated that a stable marking of the material is obtained (nearly 50%) at the following main technological parameters: power from 10 to 30 watts at a speed of the laser beam in the range of 20-30 mm / sec
This type of textile has excellent marking of the material with the following technological parameters: power 10W, 20W, 30W, 40W and at a speed in the range from 30 to 100 mm / s.

Figure 5: Partial tearing of the fabric without quality cutting.

5. Conclusion
Laser marking, engraving, cutting and other manipulations are complex physical processes that we know recently, but have great scientific and practical application. Apart from the economy and industry, they are also used for artistic decoration and unique modern design of various surfaces of textile products in the fashion and sewing industry.
Marking, engraving and cutting can be successfully applied to most textile, polyester and leather materials. Depending on the desired result, different forms of laser exposure to the specific material can be selected.
In this study, specific markings and cutting of textiles are made and the obtained results are analyzed. The experiments performed gave optimal results for marking and cutting on this material, which is used in the garment industry.

References
[1] Dolchinkov N., Shterev Y., St. Lilianova, D. Boganova, M. Peneva, L. Linkov, D. Nedialkov, Exploring the possibility of laser cutting with CO₂ laser on felt in the range from 1W to 26W power, International scientific journal: Industry 4.0 Issue 1/2019, ISBN 2534-8582, crp. 29-31;
[2] Lazov L., E. Teirumnieks, Application of laser technology in the army, Proceedings of International Scientific Conference “Defense Technologies”, Faculty of Artillery, Air Defense and Communication and Information Systems, Shumen, Bulgaria, 2018;
[3] Lazov L., H. Deneva, E. Teirumnieka, Study of Auxiliary Gas Pressure on Laser Cutting Technology, Environment. Technology. Resources, Rezekne, Latvia Proceedings of the 11th International Scientific and Practical Conference. Volume III, 159-162;
[4] Lazov L., Angelov N., Scanning the contrast in function of velocity in laser marking of samples of steel, International Scientific Conference, Gabrovo, 2010;
[5] Shterev Y., N. Dolchinkov, St. Lilianova, D. Boganova, M. Peneva, L. Linkov, D. Nedialkov, Examining the possibility Of marking and engraving of textiel using CO₂ laser, International journal for science Machines, Technologies, Materials 12/2018 crp 491-493;
[6] Dolchinkov N., Lazov L., Shterev Y., Lilianova St., Pacejs A., Use of CO₂ laser for marking and clearing of textile materials for manufacture of military equipment, 12th International Scientific and Practical conference Environment. Technology. Resources. ISBN 1691-5402, Vol 3, 20-22.06.2019, Rezekne, Latvia p. 32-36;
[7] Dolchinkov N., The laser - creation, development and prospects, Annual Scientific Conference of Vasil Levski National High School - June 27-28, 2019, pp. 456-465;