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Use of CO_2 Laser for Marking and Clearing of Textile Materials for Manufacture of Military Equipment

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***Abstract*— In the last decades, a large application has been found by lasers in marking and cutting on textiles, plexiglass, wood, metals and other materials. These items apply to both the military and the economy of the countries of the world. A group of Bulgarian students from the National Military University Vasil Levski, led by Dr. Nikolay Dolchinkov, conducted a research with a group of TAR under the leadership of Prof. Lubomir Lazov at the Laser Center in Rezekne at the end of 2018. The report shows the achieved results and the relevant analyzes. Graphically and tabularly, the dependence of the depth of the markings and the cut-off of the power and speed of the used CO_2 laser are presented.**

***Keywords*— cutting, laser, marking, research, textil.**

I. Introduction

Laser technologies are one of the most widespread these days. In the early 1960s, the first laser was discovered and its practical application in the industry began to develop. Over time, laser technology has become increasingly important in many sectors of the economy, both in the European Union and in the world.

The advent of laser technology in textiles industry has established a new innovative solution, which successfully prevents some of the weaknesses in the conventional technologies. Lasers are being used in Laser Marking (Only the surface of fabric is processed, fading), Laser Engraving (Controlled cutting to depth). It has been used extensively as the replacement of some conventional dry processes like sand blasting, hand sanding, destroying, and grinding etc., which are potentially harmful and disadvantageous for the environment [2].

Since the practical opening of the laser in the early 1960s, it has continuously improved and contributed to the development of industrial production - automotive, aircraft construction, shipbuilding, machine building in Bulgaria and the world. Swallowing is the most important parameter of the material being processed when it interacts with the laser. For each configuration, swallowing is given as a combination of the following laser parameters: wavelength, drop angle, polarization of laser radiation, and material emission (shape), surface geometry and temperature. The greater the ultimate intake, the greater the laser radiation used in the laser marking process.There is a many ways in which laser cutting technology can be used within the field of textiles too [6]. In this we presente some results from this area.

The aim of the experiments at the Technological Academy Resets, on the basis of analyzing the parameters (velocity and power) change, is to improve the marking and cutting of polymethylmethacrylate (PMMA) products, to obtain data that would be useful in optimizing the production lines using laser technologies for processing PMMA. The studies conducted show the application of laser marking and cutting. The optimal parameters of the laser device were found to perform a 9.5 mm thick PMMA quality cut. At the same time, results were obtained for making markings by removing a certain volume of material.

II. Equipment And Experimental Establishment

Our study examines the dependencies of the technological parameters of cutting and marking for the quality of the processes. Laser marking is an important process in modern production [4]. The last few years have become increasingly popular. Marking is a process of impacting the laser on the surface layer of the material. During the marking, a process of absorption of the laser radiation from the material takes place. Unlike marking, the energy absorbed at the cut is many times larger and leads to ablation by ablation.

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There are various factors that affect the quality of the markings. Some of them are: contrast, homogeneity, clarity and sharpness of the image contour, positioning accuracy, wear resistance, lack of additional products around the impact area. In laser cutting, the factors that affect it are divided into three main groups:

- parameters related to the laser source
- parameters related to the properties of the material
- parameters related to the technological process.

The common advantages of all laser marking techniques are [1]:

- permanent, high quality marks;
- high efficiency and low operation cost;
- good accessibility, even to irregular surface;
- non-contact marking and no special working environmental needed;
- easy to automate and integrate (using computer-controlled movement of the beam or sample);
- precise beam positioning and a beam highly localised energy transfer to the workpiece;
- high reproducibility and high speed ;
- contamination - free.

The quality of a mark is assessed by its legibility characteristics such as mark contrast, mark width, mark depth, and microstructures. The characteristics are usually evaluated using complementary techniques such as optical microscopy, ultrosonics microscopy, electron microscopy, surface roughness measurement. In beam deflected marking, the line width is mainly determined by the focused beam spot size, which varies between 20 - 100 µm. Other parameters: scanning speed, power density and material properties also affect the line width. [1].

The main factors that influence the contrast of laser marking are [7,8,10]:

- 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.

The marking and engraving on fabric with a composition of 65/35% CO / polyester ± 3% determined according to EN ISO 1833 quantitative chemical standard with CO_2 laser was investigated and analysed [8, 9]. For this purpose, an experimental methodology was developed, which concludes in the following:

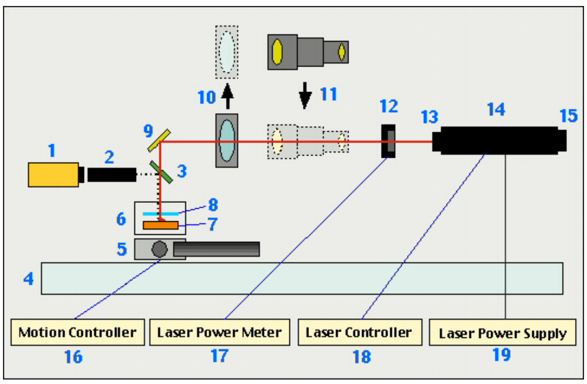

Fig.1. Scheme of the experimental setting[14]

Fig. 1 shows more precisely the schematic diagram of CO_2 laser. It includes also the working area, fully reflecting mirror, intransperant mirror, then anodes and cathodes, the lens and the focus point [15].

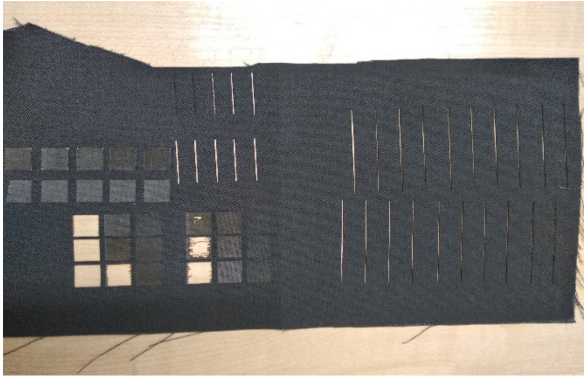

Fig.2. Scheme of the matrix

The marking and engraving on fabric with a composition of 65/35% CO / polyester ± 3% determined according to EN ISO 1833 quantitative chemical standard with CO_2 laser was investigated and analysed [8]. For this purpose, an experimental methodology was developed, which concludes in the following: a matrix of 9 squares with 1x1 cm is created. The power of the laser beam is in the range of 2-26W and its speed is in the range of 100x350 mm/s. A schematic of the six-square matrix after experiments is shown in Fig. 2 and 3.

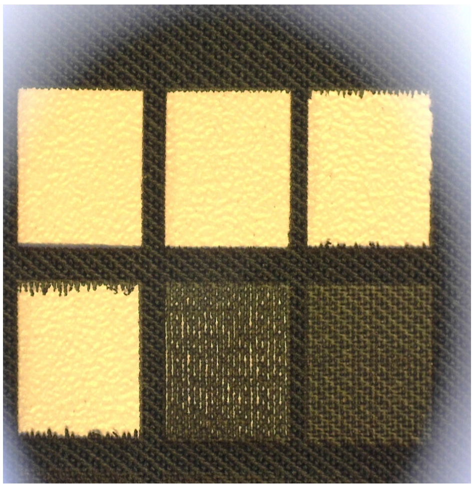

Fig.3. Scheme of the matrix

We investigate the possibility of marking and engraving on CO_2 laser plates. For this purpose, an experimental methodology was developed, which concludes in the following:

- a matrix of 9 squares with dimensions 1: 1 cm was created. Speed and power range in the range of 2-26 Watts and 100-350mm/sec. The scheme of the matrix is shown in Fig. 2

Experimental data were obtained using a Dino-lite AM4515ZTL digital microscope having the following 1.3 MPx result, 10-140X magnification and polarization.

Fig. 5 shows the variation of speed and power P for 2 W, 10 W and 26 W and the resulting linear energy density.

Each processing area (each square) is implemented with the raster scan method [13]. The line-to-line step is 0.1mm. The processing areas and the processing quality were analyzed by means of a AM4515ZTL digital microscope manufactured by DINO-LITE:

https://www.dino-lite.eu/index.php/en/products/microscopes/long-working-distance with 1.3 MPx resolution, 10-140X zoom and polarizer. Total 28 treatment zones were investigated. From all the experiments we can draw the following conclusions [12]:

- a good cutting of the material is obtained with the following parameters: constant power 26 watts and speed ranging from 100-200 mm/s, with linear energy densities correspondingly 0.26, 0.17 and 0.13 J/mm.
- the quality marking is obtained in the range of LED values of $5*10^{-2}$, $3,8*10^{-2}$ J/mm for a power of 10 W where the velocity varies in the range of 200-260 mm/s. The remaining marking areas have a slight contrast that is between 5% and 10%. Contrast measurements are performed using the Color Contrast Analyzer version: 2.5.0.0. [11,12]. On Figure 4 are given photo of marked areas with good contrast.

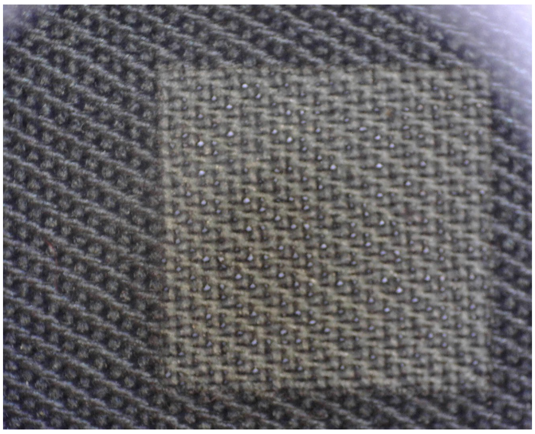

Fig. 4 Photo of marked areas with good contrast.

The main factors that influence the contrast of laser marking are [3,7]:

Each processing area is implemented by the raster scan method. The line-to-line step is 0.1mm. Processing areas and processing quality were analyzed with the help of a digital microscope AM4515ZTL Total 50 processing areas were analyzed.

III. LASER CUTTING

The possibility of laser cutting on a CO_2 laser is investigated [5]. For this purpose, an experimental methodology has been developed which consists of the following:

Lines of length 4 cm are applied to the textile at different speeds and power processing. Power ranges from 2-20 W, and the speed is 10-55 mm/s. Two sets of experiments with 10 lines were made. In one series the power was maintained constant - 10 W, and the speed varied in the range of 10-55 mm/s. In the second series the speed is constant 10 mm/s and the power varies in the range of 2-20 W – fig. 2. The thickness of the textile is 0.41 mm [9].

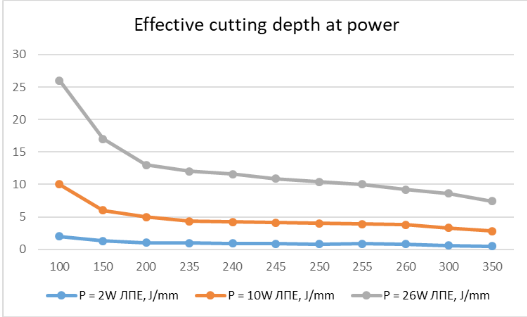

Fig 5: Effective cutting depth at power

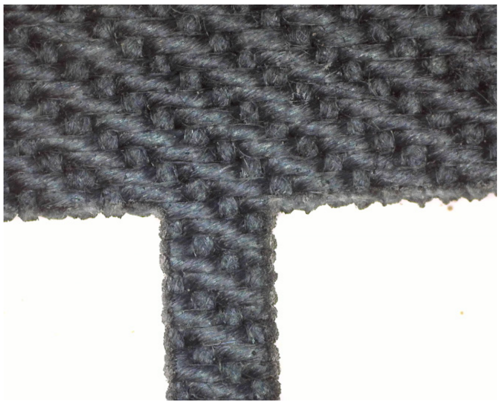

Fig 6. Cutting with good contrast quality

The microscopic analysis of the shear lines shows that a good shear of the fabric is present on all 18 incisions in the range of LED (0.2-2 J/mm for a constant rate of 10 mm/s and 1-0.22 J/mm for a constant power 10 W) - Fig. 5. Quality cutting of the textile, and for two of the experiments at 0.2 J/mm and 0.18 J/m LED for a constant power of 10 W, a shear limit was found. The threshold of destruction is shown on Fig. 6.

The experimental data obtained at the laser beam power at 10 w are shown in Table 1. In which the width of the hole in the material is shown, the heat-affected zone (COP), the Line Energy Density (LED), and the Effective Shear Depth (ESD).

Power density is a function of the focused laser size (laser power per unit area, W/cm^2). This is different from the raw output power of the laser. Focused laser beam size for each focal length lens and laser wavelength is a function of laser beam bias controlled by the laser configuration, the size of the aperture for mode selection, and the magnification of the expansion beam (collimator beam expander).

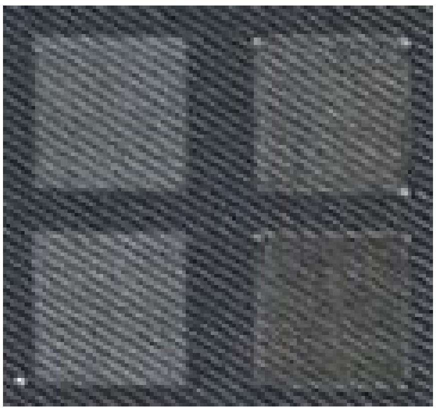

Fig 7. Marked areas with good contrast quality

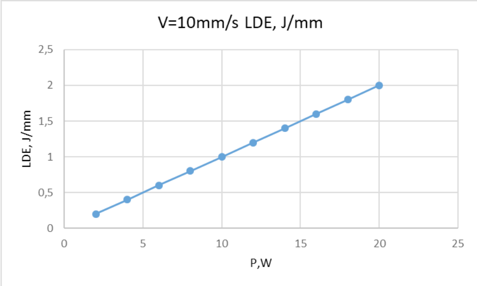

Fig 8: Laser marking parameters

Frequency of repetition of pulses (by acoustic-optical Q switch) and peak power density are critical parameters in forming the markings and achieving optimal contrast and velocity. High peak power at low frequency rapidly increases surface temperature, evaporates material while minimizing heat in the substrate. As the pulse repetition increases, lower peak power results in minimal evaporation, but generates more heat. The beam speed (the laser beam speed through the work surface) is also a critical factor.

Fig 8 and 9 gives the optimal laser marking parameters.

Good marking of the material (nearly 50%) is obtained with the following technological parameters: power 10-20-30 watts at a speed of 25-30 mm/s

Good marking through the material is obtained with the following technological parameters: power 10W 20W 30W 40W at a speed of 30-10mm/s.

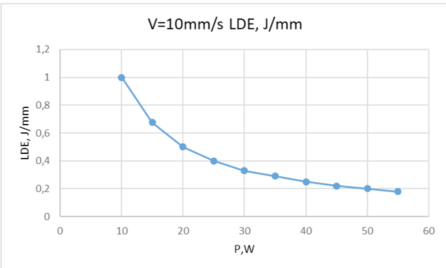

Fig 9: Laser marking parameters

The possibility of laser cutting on a CO_2 laser is also studied. For this purpose several cuts were made with different parameters. A 4 cm (4 cm) line has been placed on the fabric at various processing capacities and speeds. Power ranges from 2 to 20W and speeds from 10 to 55mm / sec. Two series of experiments with 10 lines were made. In the first series the power was maintained constant - 10W, and the speed varied in the range of 20 to 50mm / s. In the second series the speed was preserved - 10mm / s, and the power varies from 2 to 20W.

Microscopic analysis of shear lines shows that a good shear of the fabric is obtained in 18 of the experiments conducted.

V. CONCLUSION

From the conducted study and the analyzed experimental data, the following conclusions can be drawn:

1. A good shear of the material is obtained with the following parameters: constant power 26 watts (9%) and speed ranging from 100-200mm / s. In the first zone, the LPE is 0,1; in the second zone - 0.06 and in the third zone is 0.05
2. Good marking by lightening of the material (nearly 50%) is obtained with the following process parameters: these are shown in Table 2 (with blue color). The rest have a slight contrast that is between 5% and 10%. The quality mark is obtained in the range of 5 * 10^{-2} to 3.8 * 10^{-2}. The speed changes in the range of 200-260mm / s and the power is retained.
3. Microscopic analysis of the shear lines shows that a good shear of the fabric was obtained in 18 of the 50 experiments conducted.
4. The data obtained will serve as a basis for further research on dual-use fabrics. In further studies, similar experiments will be made on fabrics with other content and thickness of matter, comparisons will be made and the best choice will be made for making different purpose clothing.
5. The data obtained can be analyzed and, on the basis of the results obtained, estimates will be made for the possibility of laser cutting and marking of these articles.

For all textile materials and for leather materials, marking, engraving and cutting can be successfully applied. The choice of laser process is determined by the desired final result.

In this research, the laser applications for and textile processing are analyzed. The advantages of laser technology in textile fields were pointed. The linear energy density during marking and cutting by the laser beam was introduce.

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