Results and Analysis of Achieved Joint Research and Activities Between Rezekne Academy of Technology and Vasil Levski National Military University

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Abstract. **In 2018, the first group of teachers and students from Vasil Levski National University conducted experiments on laser marking in Rezekne Academy Of Technology, Latvia. Since then, joint research has been increasing every year and better results have been achieved not only in the field of laser technologies, but also in other areas of joint interest. A pilot study group is even being formed in a master's program in laser technology. As a result, the interest in laser technologies and in Latvia at Vasil Levski National University increased significantly. Research has been done on the impact of the exchange between the two institutions on the learners and their motivation to learn.**

Keywords: collaborative research; experiment; laser; laser marking; result; 3D printer.

I. INTRODUCTION

Joint research in the field of laser technologies between the Rezekne Academy of Technology, as a leading partner, and the National Military University "Vasyl Levski" has been starting since 2018. The partnership between educational institutions is even older, with the first cooperation framework agreements and Erasmus contracts being signed more than 10 years ago. Over the years, the former rector of the Rezekne Academy of Technology, Prof. Edmunds Teirumnieks, and the dean of the Faculty of Engineering, Erika Teirumnieka, have visited the military university many times, Prof. Lubomir Lazov has also visited the university and delivered public lectures to the academic staff. The National Military University was also attended by trainees from the Academy in Rezekne.

Teachers and students from the educational institution from Bulgaria have also repeatedly visited the Latvian university. During practicals, students from the National University under the guidance of Prof. Lazov carried out research and data processing from experimental and theoretical studies of various materials at the laser center in Rezekne.

Teachers and students from both universities participated in scientific conferences held in the partner country. Representatives of our educational institution from Veliko Tarnovo and Shumen are regular participants in the conference in Rezekne. Professor Lazov has delivered more than 6 plenary reports at conferences in Veliko Tarnovo and Shumen. Students from the Academy in Rezekne also regularly participate in conferences in Veliko Tarnovo. This contributes to closer ties between the two universities, exchange of information and students, and enrichment of the institutions.

II. MATERIALS AND METHODS

In 2018, a group of 5 cadets and students and 2 teachers led by me conducted the first research at the laser center in Rezekne. The group was part of project no and a two-week mobility was carried out. During the visit to the laser center at the Academy, a rich program of research and analysis of the obtained results was carried out. During this half-month period, laser marking, laser cutting and finding the optimal values of the laser beam to perform these activities were carried out. The experiments were performed with a CO_2

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laser on plexiglass, textile and felt. In the study, colorless plexiglass with different sample thicknesses, 4 types of textiles and 2 types of felt were used. As a result of the conducted experiments, the optimal parameters of the laser beam for marking on the samples were found, and the minimum values of the beam power and its speed were determined for performing quality cutting on the samples. Based on the research on plexiglass, we reached the following conclusions. When the laser beam power is constant (10 W, 20 W, 30 W, 40 W or 50 W), as the beam speed increases from 5 mm/s to 30 mm/s, the measured effective perforation depth decreases. The maximum effective perforation depth is 8.324 mm for 50 W and a speed of 5 mm/s. The minimum effective perforation depth is 0.188 mm for 10 W and a speed of 30 mm/s. Furthermore, as the linear energy density decreases, the perforation depth of the efficiency also decreases [1], [2].

Laser marking and cutting can be used for artistic decoration and unique design on any surface of textile products in the fashion industry [3].

Marking, engraving and cutting can be successfully applied to all textile materials and leather materials. The choice of laser process is determined by the desired end result.

III. RESULTS AND DISCUSSION

Marking and engraving on fabric with a composition of 65/35% CO / polyester ± 3% determined according to EN ISO 1833 quantitative chemical standard with a CO_2 laser was investigated and analyzed. For this purpose, an experimental methodology has been developed, which consists of the following [4]:

A matrix of 9 squares with 1x1 cm is created. The power of the laser beam is in the range of 2x26W, and its speed is in the range of 100x350 mm/s. After the experiments conducted and the analysis done, we came to the conclusion that a good cutting of the material is obtained with the following parameters: a constant power of 26 watts and a speed in the range of 100-200 mm/s, with linear energy densities of 0.26, 0.17 and 0 respectively .13 J/mm [5].

A quality mark is obtained in the range of LED values $5*10^{-2}$ x $3.8*10^{-2}$ J/mm for a power of 10 W, where the speed varies in the range 200-260 mm/s. The remaining highlight areas have a slight contrast that is between 5% and 10%.

The felt can be used in different directions and spheres. Most often, useful household products are made from this material, for example, for sealing in various branches of industry - mechanical engineering, paper-pulp industry, also as an insulating material, for polishing, etc. Often felt also serves as upholstery on various surfaces. After doing research, we found that a major factor in the difference in laser cutting of white and red felt is the difference in the color of the material. Another factor is its thickness – which for the white felt is 0.63mm and for the red felt is 0.67mm. Quality cutting of the material is obtained with the following parameters: for white and red felt - constant power 26 W (9%) and speed in the range 100, 150 and 200 mm/s and LEDs are 0.26 J/mm , 0.17 J /mm 0.13 J/mm [6].

The obtained results were reported at the conference in Rezekne in 2019 and at the conference of the Scientific and Technical Unions in Borovets, Bulgaria.

In the summer of 2019, part of the group continued their research in Erasmus summer mobility at the Academy of Technology in Rezekne for 2 or 3 months. The obtained results were consolidated and the range of research was expanded. Few studies were conducted in the winter of 2020 due to the onset of the Covid epidemic. This did not allow us to conduct full-fledged research throughout 2020 [7], [8].

In 2021, the next group of trainees from Vasil Levski National University expanded the research, which was already carried out on metal plates and attention was paid to chrome-nickel alloys. For this purpose, an AISI 304 color palette consisting of fifteen colors was developed and executed. After the practical experiments, the dependence of the obtained colors on the various parameters of the laser processing was analyzed. The resulting colors were then tested using optical, scanning electron and atomic force microscopy, and the configuration of the oxide films was determined by Raman spectroscopy. The resulting colors are of appropriate uniformity, brightness and cover almost all spectral zones, and the resulting colors are of many times better quality than other metallic bases. A color standardization and palette repeatability test was also performed by evaluating the reflectance spectra of the formed colors. The color palette demonstrated high repeatability for all but one particular color. In parallel, the stability of the color markings was studied in terms of environmental, mechanical and chemical resistance. The resulting colors show high resistance to most environmental conditions; however, exposure to very high temperatures and extreme humidity (100 °C, 90%) and to low temperatures and extreme humidity (-40 °C, 90%) results in degradation of several colors. Colored brands show high hardness and excellent mechanical resistance to external influences and exceptional resistance to various chemicals, except for acid solutions and salts [9].

The result shows that with increasing power the colors do not change significantly and only the parametric window moves to higher values of the scan rate for each color. Given that greater performance can be obtained at higher intensities, the next step was to investigate the dependence of color on scan rate with a maximum continuous power of 20 W available at the same parameters of frequency, hatch spacing and duration of the impulse. Initially, the scanning speed was changed from 450 to 850 mm/s with a step of 10 mm/s, and then from 50 to 150 mm/s with the same step.

The test result revealed that specific colors such as light pink, aquamarine or bright purple can be obtained with higher frequency modes. At f=1000 kHz, only silver colors are formed for the entire scan rate range; hence, the parametric color window could not be produced at the mentioned frequency, although it could be assimilated into a final palette to produce white or silver due to its fast production speed [10].

The experiment to study the dependence of colors on the pulse duration was carried out with two different power densities I0=0.8-107 and I0=1.6-107 W/cm2 and two different pulse durations r=4 and r=8 ns with scan speed Vsc=50- 200 mm/s with step 10 mm/s and H=0.01 mm.

Product coatings and markings must withstand various environmental conditions and must not change during the period of use of the product [1], [9]. In this study, environmental testing was performed in a chamber based on four different operating conditions. Experiments are regularly conducted under temperature and humidity conditions that are not actually expected, such as a combination of extremely low or high temperatures (-40, -20, 40, 100 °C) with high humidity (70%, 90%). This ensures the stability of the samples under normal conditions and also compensates for the short duration of the test exposure (24 hours) compared to the actual operating time. The first test was conducted under ambient conditions with a temperature of -20 °C and a humidity of 70%. The result shows no change in colors or materials after 24 hours in the environmental test chamber. Optical microscope analyzes did not reveal any damage or defects in the oxide layers [11], [12], [13], [14], [15], [16], [17], [18].

The research of our cadets and students continued in 2022 under the leadership of Professor Lazov and the staff at the laser center at the Technological Academy in Rezekne.

In 2021, a pilot program for training in the master's degree in laser technologies was also launched, in which graduates and teachers from the National Military University participated. The training is within 4 semesters in a distance form of training during 2 academic years. Experiments were conducted in Rezekne, Gabrovo and Ruse again under the leadership of Prof. Lazov, and the trainees are currently working on their diploma theses. This master's program has proven to be working, and it will be thought about accrediting an already joint such program in the field of the application of laser technologies in military work. The head of the laser center in Rezekne has already been included in a master's training team at the military university [14], [19].

IV. CONCLUSIONS

Over the years, the two educational institutions have developed joint projects under the program "Horizon 2020", "Peter Beron" and others, and we should continue this tradition by involving more participants in joint events and research.

Over the past years, the cooperation between the Rezekne Academy of Technology and the National Military University has been constantly developing and deepening. Many mobilities took place between faculty and trainees from the two universities, research was carried out on laser marking and cutting on common and dual-purpose materials, including Plexiglas, textiles, felt, steel, chrome-nickel, specialized metal alloys and others [2] As a result of the conducted trainings and practices, the interest of the trainees increased and as a result many of them specialize in this field and in the field of 3D printers. After the practices, 5 people bought personal 3D printers and use them rationally. With our own developments, we have participated in 3 international exhibitions with 6 exhibits, which are a consequence of the training at the Academy in Rezekne.

These studies may also be conducted with materials that may have an impact on raising the defense capabilities and combat capability of the armed forces of both countries.

In the future, we hope to increase students' interest in laser technology and 3D printers and to equip our laboratory and open a joint master's program.

V. ACKNOWLEDGMENTS

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