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Investigation Of Laser Marking On Chromium-Nickel Samples

Nikolay Todorov Dolchinkov
Vasil Levski National Military University, Veliko Tarnovo, Bulgaria
Veliko Tarnovo, Bulgaria
n_dolchinkov@abv.bg

Milen Krasimirov Tortorikov
Vasil Levski National Military University, Veliko Tarnovo, Bulgaria
Veliko Tarnovo, Bulgaria
milen_tortorikov@abv.bg

Abstract. **In the present century, laser marking on various materials is increasingly used. Very good results are achieved when working on resistant materials and as in our experiment with chrome-nickel samples.**
Chrome-nickel is used in the production of a number of details and products, especially in the military-industrial complex. Experiments were performed on thin chromium-nickel samples and the variation of marking quality with variation of laser speed and power and material roughness was investigated. The results obtained have been analysed and this will enable both the use of the obtained results and the continuation of research. These studies were carried out at the Laser Centre of the Rezekne Academy of Technology during an Erasmus internship.

Keywords: chrome-nickel, laser, marking, power, roughness, speed.

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 [1], [2], [3]. There is a regular exchange of students and teachers between the two educational institutions and joint research projects are developed and research is mainly in the field of laser technology.

Teachers, cadets and students from the military educational institution from Bulgaria have also repeatedly visited the Latvian university. Under the guidance of Prof. Lazov, cadets and students from the National University of Applied Sciences carried out research and data processing from the creation of experimental and theoretical studies of different types of materials at the laser centre in Rezekne.

Marking is an essential part of the production cycle that provides the necessary information about the product and serves as a marketing tool to attract the attention of the consumer to the specified product. Despite the fact that different markings are applied to the types of products, permanent markings that do not lose their qualities over time and are difficult to manipulate are optional [4], [5], [6]. A variety of techniques can be used to create a permanent mark, including etching, electrochemical etching, engraving, dot etching, and laser marking. In the dynamic wide stage of our development, laser marking is widely used in various sections of the production line for a variety of applications to create high-quality permanent prints. The laser marking method is effective, non-contact and applies to both metallic and non-metallic surfaces, and it is also applicable to non-traditional materials. In addition, it requires no additional additives or solvents and produces no waste; thus, it is sustainable for the environment and does not pollute it [1], [7], [8].

II. MATERIALS AND METHODS

Setting and parameters of the laser procedure Stainless steel contains chromium in its composition, which provides chemical stability and high heat resistance of the alloy and makes it suitable for use in the laser process. In this study, 2 mm thick chromium-nickel steel plates with initial roughness Rz = 8.42 µm, reflectivity R (λ=1.06 µm) = 0.75, thermal diffusivity a = 3x10-6 are used. m2/s, thermal conductivity k = 37 W/mK, melting point = 1800 °C and boiling point = 3145 °C. At the initial stage, the surfaces were cleaned with acetone to avoid any contamination or stains. A nanosecond pulse ytterbium fibber laser supplied by IPG Photonics Corporation

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<τ<200 ns at a repetition rate of 1.6 was selected as the source of laser radiation with a wavelength of 1055<λ<1075 nm generating pulses of 4 seconds duration <f<1000 kHz. The configuration of the laser processing system developed for scribing and marking purposes is presented in Fig. 1 and consists of 1) IPG Photonics nanosecond fibber laser, 2) fibber optic transfer, 3) SCANLAB scanning system, 4) 100 mm objective, 5) Neff-Wiesel linear drive for vertical movement, 6) XY coordinate stage, 7) Koll morgen ACD servo drives [9].

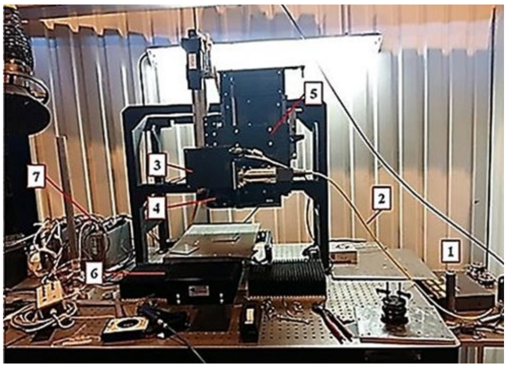

Fig. 1: The configuration of the laser processing system

A fibber pulsed ytterbium laser was emitted and fed into a collimating system via an optical fibber to form a parallel beam output. A dual-axis galvanometer scanning system (hurry SCAN II 14 digital scanning head from SCANLAB corp.) was installed to move along the X and Y axes. A focusing lens with a focal distance 100 mm [10], [11], [12]. Additional horizontal movements and vertical movements can be performed using a multi-axis linear motor coordinate stage, which allows the extension of the working space to 250×250 mm. Laser radiation parameters and scan speed can be changed using the developed lab VIEW code. Also, all vertical and horizontal movements can be controlled by the same code.

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 several different operating conditions. For more complete results, the experiments are conducted under temperature and humidity conditions that are rarely obtained in real conditions, such as a combination of extremely low or high temperatures (-40, -20, 40, 100 °C) with high humidity (70 %, 90%). In this way, the stability of the samples under normal conditions is guaranteed for an extended period. At the same time, this 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 analyses did not reveal any damage or defects in the oxide layers.

III. RESULTS AND DISCUSSION

The process of colour laser marking on chrome-nickel steel involves successive melting and hardening of the material, resulting in oxidation and intruding of the surface of the material. The final surface and oxide film formation is the result of repeated pulsed laser operation, which varies depending on the heat of the laser and the overlap value of the laser pulses [13]. The result of the relief and colour of the surface is affected by almost all parameters of the laser source. In this study, the dependence of the micro hardness of a series of samples on scan speed, laser power, pulse duration, and laser pulse frequency is investigated. The study of the dependence of the obtained colour on the relief of the surface is not the purpose of this study, the purpose of the study was to obtain a qualitative and stable marking on chrome-nickel steel [4], [13].

Due to the impossibility of presenting the entire study due to its large volume, we will emphasize some basic data and graphs that were obtained after measuring the obtained results and analysing them.

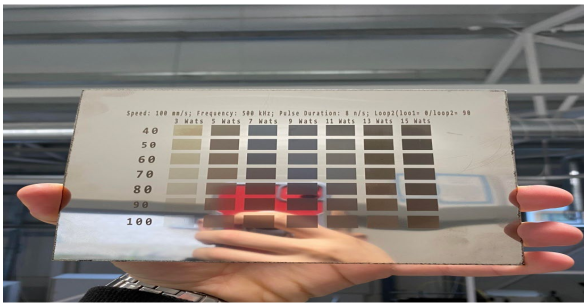

Fig. 2. Sample 1 study matrix

In fig. 2 shows the results obtained for measuring the microhardness of the surface of sample #1. Measurements were made at a constant speed of 100 m/s. of the laser beam and at a laser radiation frequency of 500 kHz. During the measurement, a matrix of 7x7 fields was made, with the variables being the laser power and the marking step. The results of the conducted research are shown in table 1.

TABLE 1 MEASUREMENT OF MICROHARDNESS OF CHROMIUM-NICKEL STEEL, SPECIMEN 1

	Speed: 100m/s ; Frequency: 500 kHz; Pulse duration: 8n/s; Loop1-90° Loop2 0°							
	Power ,W	3	5	7	9	11	13	15
Step	40	173,5	182,2	187,4	193,2	188,5	204,8	205,6
	50	170	182,4	186,7	190,5	194,7	212,5	223,5
	60	171,9	173,9	182,7	174,8	186,7	209,9	214,1
	70	167,5	184,9	181,9	195,3	189,1	210,8	227,9
	80	170,3	178,9	189,5	185,3	181,9	234,4	248,4
	90	172,3	174	187,6	183,7	196,1	223,1	205,5
	100	169,7	187,7	185,8	186,2	187,5	194,5	198,3

The obtained results are also shown in graph 3. It can be clearly seen that at low powers (up to 11 Watts) the change is close to linear with increase. After 11 watts, there is a sharp change in the picture and no dependence of the micro hardness on the power or on the step of the laser beam can be determined.

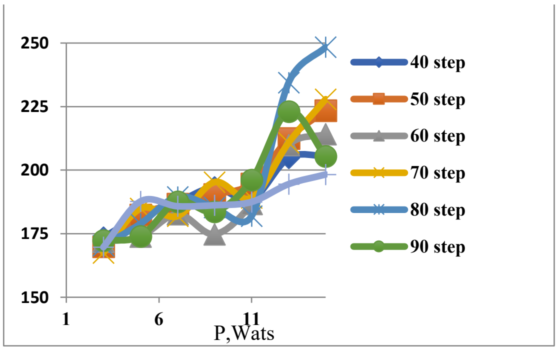

Fig. 3. Dependence of Micro hardness on the power and step of the laser beam for sample 1

Measurements were made on 12 samples, and the results up to 11 watts had a related growth rate, and after 11 watts there was a wear and tear of the indicators and no definite pattern of change could be captured. This means that in order to obtain good indicators of the laser marking of chrome-nickel steel, the laser equipment must work at a low power. The best data was obtained on sample 2 and the graph of the obtained results is shown in fig. 4.

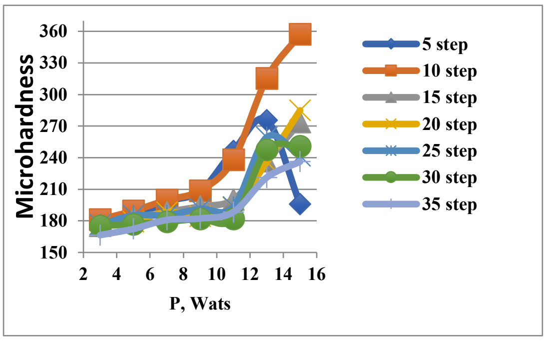

Fig.4 Dependence of the microhardness on the power and step of the laser beam of sample 2

From fig. 4 it is clearly seen that at smaller steps (5, 10) the microhardness is higher and at larger power values it already leaves the zone of linearity of the dependence and there are sharp changes. At larger steps, there is a change in the dependence, as the microhardness increases sharply.

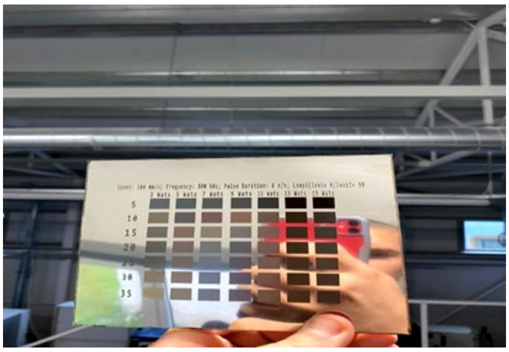

Fig.5. Sample 2

Figure 5 shows the visually obtained results for marking chrome-nickel steel on sample 2, where the best relationships were obtained. Due to the volume of the report, the remaining samples are not presented, but the authors can further analyse the results and present them in a subsequent report.

In parallel with these studies, studies were also made of the achieved marking quality and the micro roughness of the resulting machined surface. Plates of the same chromium-nickel steel samples and the same laser were used, the variables here being speed, power and step of the laser beam. The matrix that was developed and the quality of the images obtained are shown in Fig. 5.

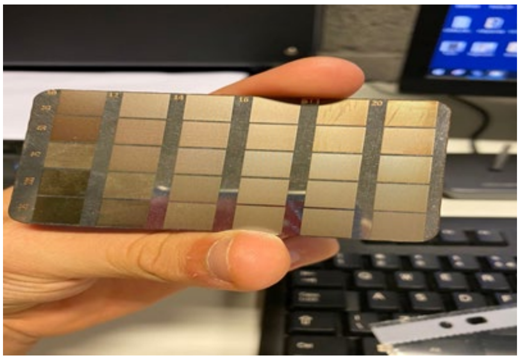

Fig. 6. Plate with a matrix from the quality studies of the roughness of the marking

Accordingly, the obtained results were processed and graphs of the dependences of the 12 measurements made were built. In fig. 7 shows the resulting graph of sample 4.

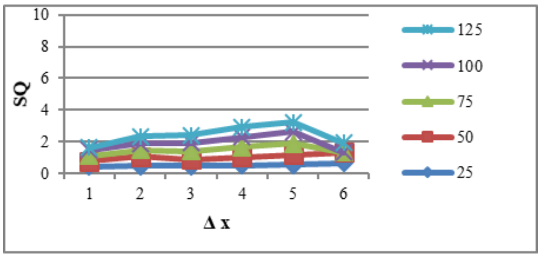

Fig. 7. Graph of the dependence of SQ on the variation of x and the step of the laser beam

What is characteristic of this study is that up to 5 Watts the change is linear and smoothly increasing, and then there is a sharp change and the larger the step, the more SQ decreases. For larger powers, no measurement was made because the results obtained have no practical significance [5], [14], [15], [16].

As the next research that was done was measuring the roughness of the obtained marking depending on the speed of the laser beam and its power. Here too, 12 chrome-nickel steel dies were made and interesting results were obtained. Table 2 shows the obtained numerical values, and fig. 7 the dependence of the roughness on the power and step of the laser beam is plotted.

TABLE 2. DEPENDENCE OF THE ROUGHNESS ON THE POWER AND STEP OF THE LASER BEAM

	P, W	10	12	14	16	18	20
v, mm/s	25	0,389	0,431	0,482	0,535	0,615	0,715
	50	0,307	0,351	0,404	0,461	0,543	0,645
	75	0,231	0,278	0,335	0,395	0,48	0,585
	100	0,161	0,209	0,267	0,328	0,414	0,529
	125	0,101	0,152	0,213	0,277	0,365	0,482

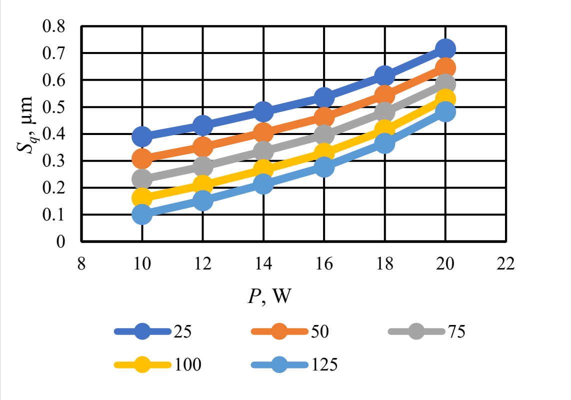

Fig. 8. Graph of the dependence of SQ on the variation of x and the step of the laser beam

From the last 2 measurements, the results of only one sample are shown, due to the limited volume of the report. The results obtained from the comprehensive research, which was carried out within 2 months, are many and could not be presented in such a small volume [7].

IV. Conclusions

The laser processing system developed for the purpose of this research work is based on a nanosecond ytterbium fibre laser on a multi-axis work piece platform and a vertical movement capability of the laser scanning head. In the preliminary phase, the scanning system was calibrated and the specifications of the laser beam at the focal point were determined. To find the appropriate power density value, the distribution of the laser spot on the surface is measured. The dependence of the resulting colours on laser processing parameters, including scan speed, pulse duration, emission power, and pulse repetition rate, was investigated.

Based on the analysis, 12 blanks were prepared for the three trials, and a suitable matrix was developed for each trial. Each blank from the first study consists of 49 squares with different indicators of power and course of the laser beam and dimensions 8×15 mm. The obtained oxide films were examined using optical microscopy and scanning electron microscope (SEM). The surface topology was established using atomic force microscopy (AFM).

In a similar way, the samples for the second and third experiments were prepared, and here the number of fields was 30. The results confirm that the created samples have appropriate consistency, brightness and cover approximately all spectral regions.

In the joint work of the representatives of the Vasil Levski National Military University and the Rezekne Academy of Technology, the algorithms for working and conducting the research to find the optimal parameters for marking different color spectra on chrome-nickel steel were initially compiled. The research was carried out during a practice at the Academy in Rezekne and the obtained matrices were examined with the equipment available in the laser center. The obtained results contributed to finding the optimal mode for marking on this material and obtaining the best quality surface marking. The results obtained so far will be developed in further experiments.

The obtained results are the basis for further research on the marking of chromium-nickel steel, taking into account the operating conditions of the resulting surface. Based on the obtained results, the most suitable speeds and beam travel were selected to obtain an excellent marking with good indicators on the resulting surface. Marking with a laser beam power higher than 11 Watts was excluded from further research, and depending on the desired result, a corresponding step of the laser beam was also selected.

Acknowledgments

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