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Research of Laser Marking and Engraving on Brass Alloy 260

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***Abstract*—Brass Alloy 260 is widely used in mechanical engineering (odometer contacts, radiator cores), electrical engineering (electrical connectors, screw shells), plumbing (bathroom fixtures), consumers (watch parts, buttons, lamps) etc. The paper presents an analysis of the laser marking and engraving process. The ability Rofin powerline f20 laser system to engrave on Brass Alloy 260 is described. Recommendations are given on choosing the right parameters for laser marking and engraving of Brass Alloy 260 products.**

Keywords— laser engraving, laser marking, Brass Alloy 260, Brass Alloy laser marking, laser marking analysis.

I. INTRODUCTION

The need for different types of information to be placed on different products has increased in recent years. The most common information on products is related to the manufacturer. A serial number of the product or item, information about the manufacturer, manufacturer's logo, etc. Specific material for marking is brass alloy which is widely used in many areas including military area, where the need for marking has increased. Ammunition marking is necessary for public safety and stronger ammunition control. [2],[4]

Information can be placed in direct text (letters, numbers, and images) or encrypted (barcode or QR code). Different marking methods are used based on the type of material used and production needs. Manufacturing companies devote their efforts and resources to the development of different marking methods for specific needs.

Various marking methods are widely used in industries and fields: shock-mechanical; electro erosion; electrochemical; screen printing; pad printing; anodizing; thermal painting; powder coating; ink printing; labeling; laser marking etc. Each of them has its own place in different specific productions. As the materials used in production change, the requirements for their marking change.

Historically used marking methods become unprofitable or unusable. Like shock-mechanical marking method can't be used on brittle materials.[1] Laser marking successfully replace older marking methods and provide the following benefits:

- the ability to mark various types of materials - metals, semiconductors and dielectrics;
- contactless method;
- minimal heat-affected zone;
- high wear resistance;
- accuracy;
- high contrast;
- high labor productivity;
- high information density;
- flexibility; marking of hard-to-reach places;
- no additional processing;
- the possibility of marking in the movement; integration into automated lines;
- ensuring high protection of information; environmentally friendly process.
- possibility of marking on assembled products, like ammunition cartridges (Fig.1). [5], [6]

Fig. 1. Brass ammunition cartridge laser marking. [2]

As we have many different materials used in production, we must choose the right laser system that meets our marking needs. There are different types of laser systems on the market that have a wide range of applications:

- Gas laser – Helium-Neon, Argon, Krypton, Carbon dioxide, Nitrogen.
- Solid-state laser – Rubin, Neodymium: Glass, Neodymium, Alexandrite.
- Diode laser – GaAlAs/GaAs, InGaAsP/InP, InGaAlAs. [3]

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II. OBJECTIVE OF THE STUDY

The objective of the paper is to analyze marking possibilities on Brass Alloy 260 using the 20W fiber laser system *Rofin powerline f20*.

Research is made for company that manufactures several types of Brass Alloy 260 products. Goal is to create a system and marking technology and integrate it in one of the production stages with the following requirements:

- The mark should be clear and legible;
- After chemical treatment, the mark can’t be significantly damaged;
- The marking area is up to 10x50 mm;
- Up to 16 symbols are placed in the marking area;
- Marking speed should be at least 2 products per second.

III. MATERIALS AND EQUIPMENT

A. MATHERIALS

Brass alloy has been used for many centuries for locks, plumbing valves (Fig.2), bearings and musical instruments. [A7]. Brass is an alloy of copper and zinc. Changes in proportions of zinc and copper leads to different material properties.

There are 3 types of commonly used brass alloys:

- Cartridge Brass (Brass alloy 260) – areas of application: plumbing tools, automotive manufacturing, ammunition (Fig.1) components etc.
- Brass C330 – wide usage in plumbing for good bending and welding ability.
- Brass C360 - Leaded brasses are known for resistance to atmospheric corrosion. [A7]

Fig. 2. Brass Laser Marking with Fiber Laser [A8]

Brass alloy 260 consist of copper and zinc. Where Coper is approx. 70%, zinc is approx. 30% and other components are less than 0.15%.

TABLE I. COMPONENT ELEMENTS PROPERTIES [A9]

Copper, Cu	68.5 - 71.5 %
Iron, Fe	<= 0.050 %
Lead, Pb	<= 0.070 %
Other, total	<= 0.15 %
Zinc, Zn	28.5 - 31.5 %

Brass alloy is a highly reflective material. Therefore, many laser systems are not suitable for marking this material (Fig.3).

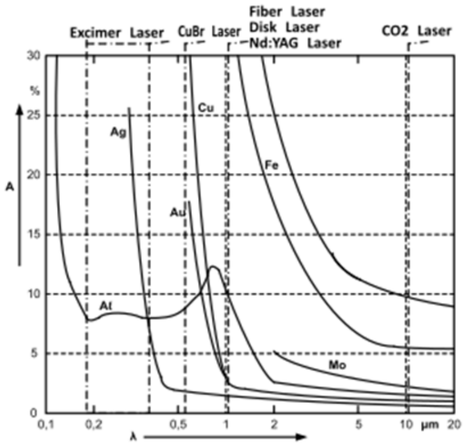

Fig. 3. Various material electromagnetic radiation absobrtion [%] depending on emited wavelength [μm].

B. LASER SYSTEM

The fiber laser system *Rofin powerline f20* was used in the study.

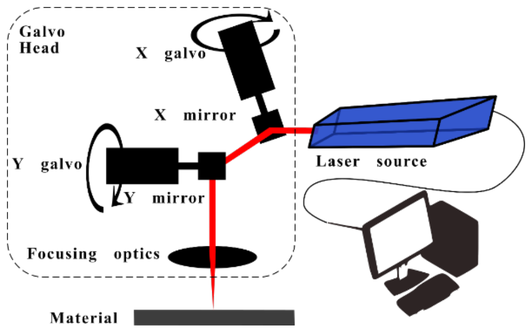

Fig. 4. Schematic view of *Rofin powerline f20* experimental set-up

Rofin powerline f20 laser system technical parameters can be observed in Table II. and schematic view of experimental set-up could be observed in Fig.4

TABLE II. *ROFIN POWERLINE F20* TECHNICAL PARAMETERS

Symbol	Name	Values range	Units
v	Scan speed	1 — 20000	mm/s
Δf	Defocus	-10 — +10	mm
P	Avarege power	0 — 20	W
f	Impulse frequency	20 — 50	kHz
τ	Impulse length	4 - 200	ns
	Working range	300x300	mm
	Focal spot size	20	μm
λ	Wavelength	1064	nm
Laser type		diode pumped fiber Yb;	
Operating mode		impulse	

C. MESUREMENT DEVICES

In the beginning of experiments laser system adjustments were made in pulse mode. The average output power was measured on an OPHIR F150A-BB-26 instrument (Table 3). Results are represented as power as a function from k_p (Fig5). This graph is important as in laser system software must be defined coefficient k_p not power directly.

TABLE III. POWER MEASUREMENT SENSOR OPHIR F150A-BB-26 SPECIFICATIONS

Absorber Type	Broadband
Spectral Range [μm]	0.19 - 20
Aperture diameter [mm]	26
Power Range [W]	0,05 - 150
Power Noise Level [mW]	3
Max Average Power Density [kW/cm2]	12
Max Energy Desnity [J/cm2]	10
Power Accuracy [+/-%]	3
Cooling	fan

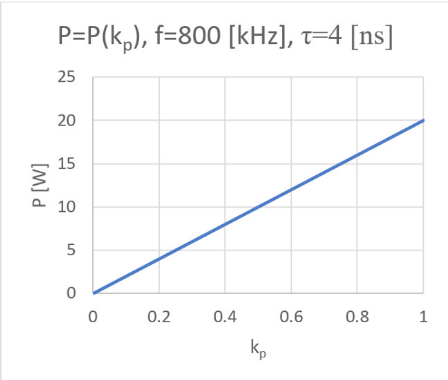

Fig. 5. Mapping of values of power regulation coefficient k_p [%] to laser mean power P [W] with a constant pulse repetition frequency f = 800 [kHz].

"Lext" 3D Laser Measuring Microscope OLS 5000 was used in this study for laser processing impact on the material e.g. in this case after laser processing we measured the width and depth of laser beam influence on the material.

Measurements were made using MPLFNN10XLEXT lens with 236x zoom and following technical data was given from manufacturer:

- Z measurement pitch: 2μm
- Z axis measurement accuracy: 0.15+L/20μm
- X and Y axis resolution: +/- 1.5%

IV. METHODS OF MEASUREMENT

Effects on area of laser impact - heating, melting or evaporation depends on the energy that is absorbed by material. For understanding Energy absorption in more detail following formulas was used:

- Linear Pulse Energy

$$LPE = \frac{P}{v}, [J/mm] \tag{1}$$

The LPE dimension is numerically equal to the absorbed energy per unit length in the laser marking area.

- Linear Pulse Density

$$LPD = \frac{f}{v}, \tag{2}$$

The LPD dimension is numerically equal to the number of pulses fallen to a unit length.

- Effective energy

$$E_{ef} = LPE \ \ LPD, \tag{3}$$

The E_{ef} dimension gives the amount of absorbed energy of the laser radiation per unit area of the laser impact area. From formulas (1), (2) and (3) formula a shorter version could be obtained (4).

$$E_{ef} = \frac{Pf}{v^2}, \tag{4}$$

V. RESULTS AND DISCUSSIONS

The experiments in this study were grouped in three main directions:

- Investigation of the duration of laser pulses on the width and depth of the lines marked on the samples;
- Investigation of the effect of the processing speed on the geometry of the marked line (width, depth);
- Examination of the influence of the power density on the marking (width and line depth)

During each of these series of experiments, the remaining technological parameters were kept constant.

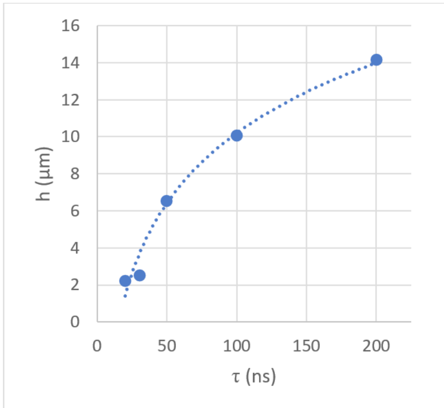

Fig. 6. Graph shows depth changes as a function from impulse length h=h(τ). Variable parameter is τ. All other parameters are constant: f= 2 [kHz], k_p = 80 [%], v=20 [mm/s]. k_p – mean power [%]; τ – pulse duration [ns]; f – pulse frequency [kHz]; v – marking speed [mm/s]

A nonlinear increase in the depth of the mark is observed for the entire investigated pulse duration range (Fig.6). The curve is part of a parabola. The rate of increase in depth is:

- 0.10 μm/ns for the range τ ∈ [20, 100] ns;
- 0.04 μm/ns for the range τ ∈ [100, 200] ns.

In the first pulse duration range, the marking depth is changing significantly faster than in the second.

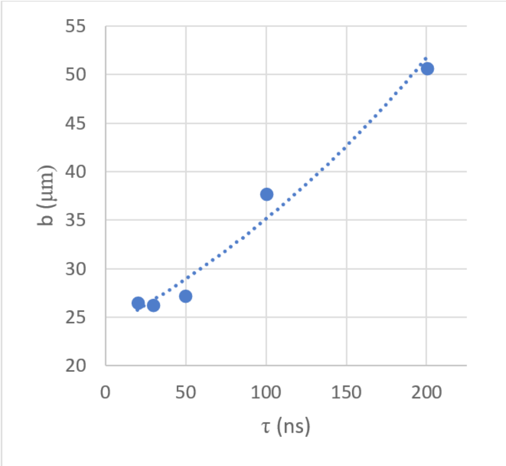

Fig. 7. Graph shows width changes as a function from impulse length b=b(τ). Variable parameter is τ. All other parameters are constant: f= 2 [kHz], k_p = 80 [%], v=20 [mm/s].

A nonlinear increase in the width of the mark is observed for the entire investigated pulse duration range (Fig. 7). The curve is part of a concave parabola. The rate of increase in width is:

- 0.023 µm/ns for the range τ Є [20, 50] ns
- 0.13 µm/ns for the range τ Є [50, 200] ns.

In the first pulse duration range, the marking width is changing significantly faster than in the second.

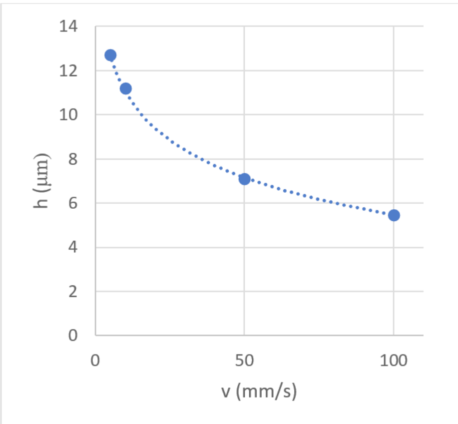

Fig. 8. Graph shows depth changes as a function from marking speed h=h(v). Variable parameter is τ. All other parameters are constant: f= 2 [kHz], k_p = 80 [%], τ=200 [ns].

The depth of the marking decreases non-linearly with increasing the span speed v Є [5, 100] mm / s (Fig.8). The rate of decrease in depth is:

- 0.139 µm/(mm/s) for the range v Є [5, 50] mm/s;
- 0.026 µm/(mm/s) for the range v Є [50, 100] mm/s.

The results are in line with the theory of speed influence on the laser marking process of metals.
The same non-linearity is observed for marking width changes as a function from marking speed (Fig.9).
The rate of decrease in width is:

- 0.93 µm/(mm/s) for the range v Є [5, 50] mm/s;
- 0.033 µm/(mm/s) for the range v Є [50, 100] mm/s.

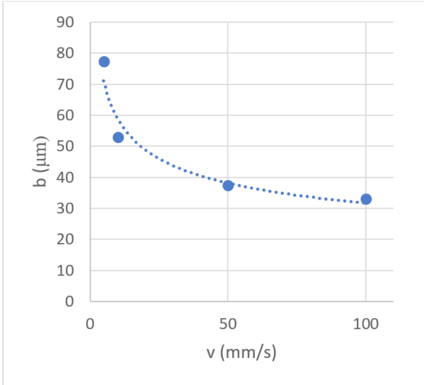

Fig. 9. Graph shows width changes as a function from marking speed b=b(v). Variable parameter is τ. All other parameters are constant: f= 2 [kHz], k_p = 80 [%], τ=200 [ns].

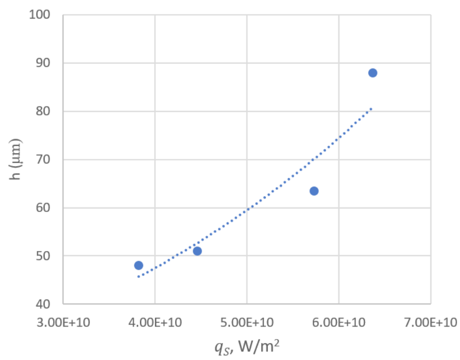

Fig. 10. Graph shows depth changes as a function from power density h=h(q_S). All other parameters are constant: f= 2 [kHz], v = 5 [mm/s], τ=200 [ns].

A nonlinear increase in the depth of the mark is observed for the entire investigated power density range (Fig.10).

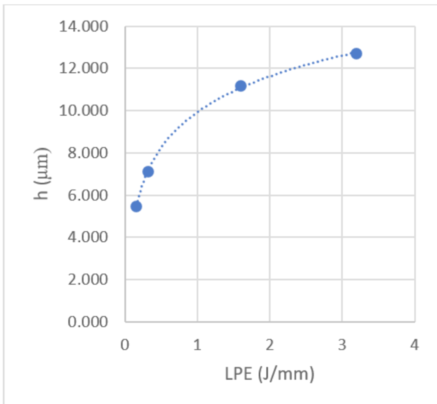

Fig. 11. Graph shows depth changes as a function from linear pulse energy. All other parameters are constant: f= 2 [kHz], v = 5 [mm/s], τ=200 [ns], P=18 [W].

A nonlinear increase in the depth of the mark is observed for the entire investigated linear pulse energy range (Fig.11). The rate of increase in depth is:

- 3.984 µm/(J/mm) for the range LPE ∈ [0.16, 1.6] J/mm;
- 0.925 µm/(J/mm) for the range LPE ∈ [1.6, 3.2] J/mm.

In the first pulse duration range, the marking depth is changing significantly faster than in the second.

VI. CONCLUSION

More and more companies and manufacturers need to mark new materials where classical marking methods become more difficult to apply. Laser marking provides new opportunities to process different materials. Each material has its own specific characteristics, so it is necessary for each technology to choose the most optimal and efficient laser system.

The need for our research is new requirements for the manufacturer to mark each product by including the marking system in the production line. The material used in the production is Brass Alloy 260.

With our chosen F20 fiber laser system, samples with variable parameters of the laser system were marked. The depth and width of the mark were analyzed.

The depth and width of the marking lines were analyzed as a function of the laser parameters, the results obtained were good and meet the user requirements.

Further research will focus on analyzing other parameters related to markup quality, such as contrast, and more. Their dependence on changing laser parameters. Research will also be done with other laser systems having a variable wavelength. It will also assess the performance and economic efficiency of the new technology.

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