Influence of Power Density on Laser Marking of Copper Samples

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Abstract. Numerical experiments were conducted to study the influence of power density on laser marking of copper samples. Software TEMPERATURFELD3D, working in MATLAB, was used. The research concerns a disc laser, operating in the near infrared range and a CuBr laser, operating in the visible range. Temperature dependence on power density for both lasers were analyzed and corresponding graphics were drawn. The obtained results were analyzed.

Keywords: laser marking, copper, software TEMPERATURFELD3D, numerical experiments, temperature, power density.

1. INTRODUCTION

Marking of articles and details is one of the important processes in modern industry. The absence of marking makes it difficult and in some cases impossible to control the quality and volume of production. The marking is needed to the manufacturer to promote the brand and to the user as a guarantee of quality and source of information about the product parameters. All this requires obtaining of a marking on the product with good contrast and quality (Valiulin et al., 2007).

There are different methods of marking – impact-mechanical, electro-chemical, electro-erosion, screen printing, tampon printing, sticking labels, laser marking. The laser method is an innovative, high-tech and flexible method. Because of its advantages over traditional methods, it has gradually shifted to a number of proceedings.

The main difficulties are that you have to choose the appropriate laser for each material from which the product is made. A next step is to determine the appropriate working parameters for realization of the process. This requires a wide range of experimental research to obtain the required parameters (Dinev, 1993; Sobotova et al., 2015; Angelov, 2011; Valiulin et al., 2007).

One of the most widely used applications of laser marking is for products from metals and alloys.

The purpose of this work is to investigate the influence of the power density onto the laser marking process of copper samples with a disc laser and CuBr laser and to define the preliminary working intervals of power density for the used lasers

2. THEORETICAL BASIS

The upper power limit (and therefore the power density) of each laser source is predetermined and it is necessary to determine the optimal interval of the variation to achieve good quality of the marking.

In order to make the marking, the laser power density must be sufficient for melting of the material in the processing area and/or for its partial evaporation. In the studies it is necessary to take into account the fact that with its increase steels absorption increases, too.

3. DATA

Software

The numerical experiments were carried out by applying the Temperaturfeld3D software

(Belev, 2009). It specializes in calculating temperature fields for laser impact on various materials. It is suitable for technological processes laser marking, laser engraving, laser cutting, laser welding, laser drilling and others. The dynamic model of the program is chosen for the laser marking process. The main program window is revealed on Fig. 1. There is a possibility to store data and results from previous numerical experiments.

When performing a specific numerical experiment input data is entered, which includes:

- Program parameters;
- Geometric parameters;
- Laser parameters and process parameters;
- Material parameters.

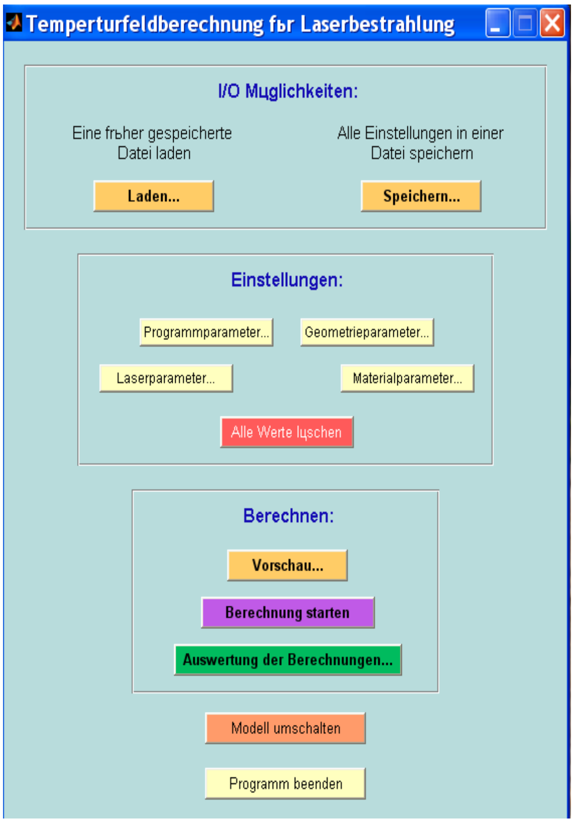

Fig. 1 Basic window of the Temperaturfeld3D software

The next step is to perform the calculation. The obtained results can be displayed after opening the „Output Data" window. It includes (Fig. 2):

- Approximating the results;
- Animation of the whole process;
- Temperature profile of the material at a time;
- Profile of maximum temperature;
- Dependence of temperature from time;
- Temperature change in depth of the material.

Fig. 2 „Output Data" window of the Temperaturfeld3D software

Laser system

The experiments relate to laser technology systems with a disc laser and a CuBr laser.

The disc laser consists of a thin crystal disc of yttrium-aluminum garnet with Nd, Yb or Er atoms introduced (Fig. 3). It uses a very thin crystal disc with a low surface-to-volume ratio as a laser medium instead of crystalline rod (as with most solid-state lasers). The crystal can be pumped at a constant intensity regardless of the power level, which further improves the beam quality (www.spie.org/publications/fg12_p62_thin-disk_lasers?SSO=1).

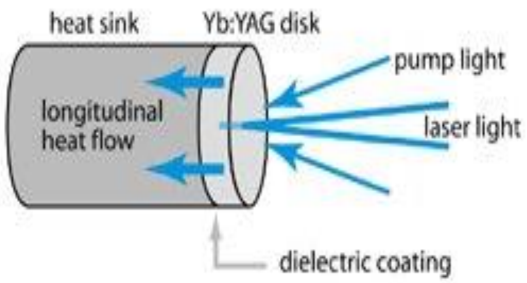

Fig. 3 General appearance of a disc laser (www.spie.org/publications/fg12_p62_thin-disk_lasers?SSO=1)

Some basic parameters of the system are given in Table 1. The disc laser operates in pulse mode and has wavelength λ = 1062 nm.

The steel has a good absorption of the laser radiation. The laser has a high frequency of pulses repetition and the pulse duration is relatively high. It has a relatively high efficiency. The laser system has very high positioning accuracy and good repeatability.

The CuBr laser is working in the visible range. It emits in two wavelengths and is a pulse laser. It has a small pulse duration, high impulse power and good beam quality. The CuBr laser is used for marking, research and in medicine (www.pulsligth.com).

TABLE 1. Basic parameters of the technological systems with disc laser and CuBr laser

Laser Parameter	Disc laser	CuBr laser
Wavelength λ, nm	1062	511 & 578
Power P, W	16	10,0
Diameter of working spot d, µm	35	30
Frequency ν, kHz	5-50	20,0
Pulses duration τ, ns	1000 –10000	30
Pulse energy E_p, mJ	0,32 – 3,2	0,50
Pulse power P_p, kW	0,032 – 3,2	16,7
Speed v, mm/s	0 ÷ 6000	0 ÷ 5000
Beam quality M^2	< 1,2	< 1,7
Positioning accuracy, µm	2,5	2,5
Efficiency, %	35	1,5

4. EXPERIMENTAL RESULTS

Through the TEMPERATURFELD3D software, series of numerical experiments were carried out. The research concerns laser marking by melting. A geometric model of samples was created. Two-dimensional temperature fields were obtained in and around the impact area for different power density values.

Graphics of temperature dependence on power density for the disc laser (Fig. 4) and for the CuBr laser (Fig. 5) are drawn. From the analysis of the graphics, the following conclusions can be done:

- Nonlinear temperature increases with increment power density for both lasers;
- The working intervals of power density are for the disc laser are:
  q_S € [1,08.10^{10}, 2,08.10^{10}] W/m^2 for speed v_1 = 30 mm/s;
  q_S € [1,23.10^{10}, 2,08.10^{10}] W/m^2 for speed v_2 = 40 mm/s;
  for CuBr laser

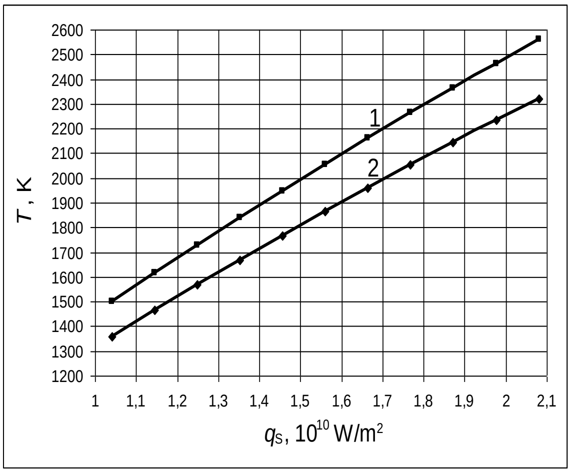

Fig. 4 Graphics of dependence of temperature on power density for disc laser at speeds: 1 – v_1 = 30 mm/s; 2 – v_2 = 40 mm/s.

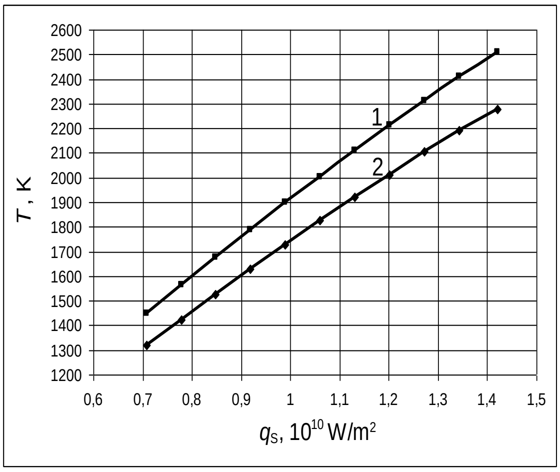

Fig. 5 Graphics of dependence of temperature on power density for CuBr laser at speeds: 1 – v_1 = 30 mm/s; 2 – v_2 = 40 mm/s.

q_S Є [0,77.10^{10}, 1,42.10^{10}] W/m^2 for speed v_1 = 30 mm/s;
q_S Є [0,86.10^{10}, 1,42.10^{10}] W/m^2 for speed v_2 = 40 mm/s;

5. CONCLUSIONS

The resulting working intervals of power density are an important step in optimizing the process of laser marking with a disc laser and a CuBr laser on products of copper. They help operators of laser technology marking systems and contribute to improving the efficiency of production.

Experimental studies for this material should be continued to determine working intervals for other technological parameters such as marking speed, frequency, pulse duration, step, defocus, number of repetitions.

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