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Influence of Pulse Energy on Contrast for Laser Marking of Samples of Steel 15Cr2

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Abstract. Experimental studies have been conducted for the influence of pulse energy on the contrast of the laser marking. They refer to structural alloy steel 15Cr2 with industry wide application. A technological system for marking with fiber laser is used. The impulse energy and speed are changed in the experiments. Contrast dependence on pulse energy for two speeds was analyzed obtained and correspondent graphics were plotted. The results are analyzed and summarized. Working intervals of pulse energy for the studied speeds are determined.

Keywords: laser marking, fiber laser, steel 15Cr2, contrast, pulse energy.

1. INTRODUCTION

Areas of use of laser technology are very diverse – processing of materials (metals and alloys, non-metals), communications, computer science, medicine, research, construction, transport, food industry, military, archeology and many others. Laser processing of metals and alloys involves the technological processes marking, engraving, cutting, welding, sintering, scribing (Dinev, 1993; Grigoryanc at al., 2006; Veiko, 2007).

The purpose of this work is to investigate the influence of impulse energy on the laser marking process of steel 15Cr2 with fiber laser and to define pulse energy working intervals for two speeds of marking.

2. THEORETICAL BASIS

As is known, the main modes of operation of the lasers are continuous and pulse mode. It is preferable that the lasers for the marking work in pulse mode. In these, impulse power P_p, impulse energy E_p, duration τ and frequency ν of impulses are essential. They are related to the average power P of the laser by the expressions

$$P = P_p \tau \nu \ . \tag{1}$$

$$P = E_p \nu \ . \tag{2}$$

Pulse energy can change with an amendment in laser beam power and frequency.

For some lasers there is a connection between laser parameters of a constructive type.

3. DATA

Material

Experimental studies refer to laser marking of samples of structural steel 15Cr2. It is widely used in industry. It is used to make bushings, rings, gears, rollers, pushers, steel pipes. The temperature dependence of the basic parameters of the steel are presented in Table 1 (www.splav-kharkov.com). The coefficients of thermal conductivity and of thermal diffusivity have normal values for steels.

TABLE 1. Temperature dependence of basic physical parameters of structural steel 15Cr2. Here *T* – temperature; *k* – coefficient of thermal conductivity; *ρ* – density; *c* – specific heat capacity; *a* – coefficient of thermal diffusivity.

T, K	*k*, W/(m.K)	*ρ*, kg/m^3	*c*, J/(kg.K)	*a*, m^2/s
293	44	7830	486	1,16.10^{-5}
373	44	7810	496	1,14.10^{-5}
473	43	7780	508	1,09.10^{-5}
573	41	7750	525	1,09.10^{-5}
673	39	7710	538	1,01.10^{-5}
773	36	7670	567	8,28.10^{-6}
873	33	7640	588	6,90.10^{-6}
973	32	7610	626	6,72.10^{-6}
1073	32	7580	706	5,98.10^{-6}

Laser system

The experiments were performed, using a laser technology system with fiber laser (www.spilasers.com). Some of its basic parameters are given in Table 2. The laser operates in pulse mode and has radiation in the near infrared area (wavelength λ = 1064 nm). It has high efficiency, high beam quality and a small diameter of work spot. The laser system is characterized by good positioning accuracy and can provide a wide range of laser beam travel speeds.

TABLE 2. Parameters of the applied laser technological system with fiber laser

Parameter	Value
Wavelength λ, nm	1064
Power *P*, W	20,0
Diameter of working spot *d*, µm	35
Frequency *ν*, kHz	80
Pulses duration *τ*, ns	100
Pulse power P_p, kW	2,50
Speed *v*, mm	0 ÷ 7000
Beam quality M^2	< 1,1
Positioning accuracy, µm	2,5
Efficiency, %	40

4. METHODOLOGY

Samples of the tested steel were prepared. The raster expedient for marking by melting was used. A test field consisting of 100 squares with a 5 mm side, located in ten columns, was created and introduced. The contrast was determined for each marking according to certain methodology (Angelov, 2011).

5. EXPERIMENTAL RESULTS

The experiments were carried out for two speeds of marking – v_1 = 40 mm/s и v_2 = 70 mm/s. Parameters that did not change during the experiments are given in Table 3.

TABLE 3. Parameters that are kept constant during experiments

Parameter	Value
Diameter of working spot *d*, µm	35
Frequency *ν*, kHz	20
Pulses duration *τ*, ns	100
Number of repetition *N*	1
Defocusing Δ*f*, mm	0
Step Δ*x*, µm	50

Graphics of the experimental dependence of the contrast k^* on the pulse energy E_p for two speeds of marking: v_1 = 40 mm/s и v_2 = 70 mm/s were drawn nn Fig. 1 and Fig. 2. From their analysis, the following conclusions can be drawn:

- A non-linear increase of contrast is observed with increment of the impulse energy over the whole range;
- The rate of change of the pulse energy is in interval E_p Є [0,246; 0,400] mJ

23,4 %/mJ at speed v_1 = 40 mm/s;
34,1 %/mJ at speed v_2 = 70 mm/s;
in interval E_p Є [0,400; 0,800] mJ
5,75 %/mJ at speed v_1 = 40 mm/s;
3,50 %/mJ at speed v_2 = 70 mm/s;

- The working intervals of the pulse energy are:

E_p Є [0,246; 0,800] mJ for speed v_1 = 40 mm/s;

E_p Є [0,300; 0,800] mJ for speed v_2 = 70 mm/s;

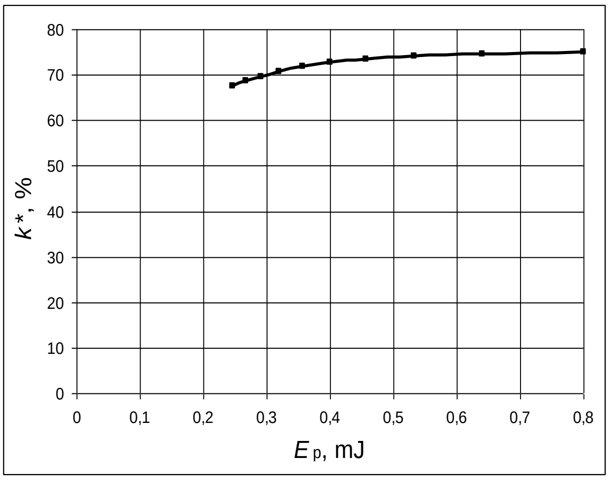

Fig. 1 Graphics of the dependence of contrast on pulse energy at speed v_1 = 40 mm/s

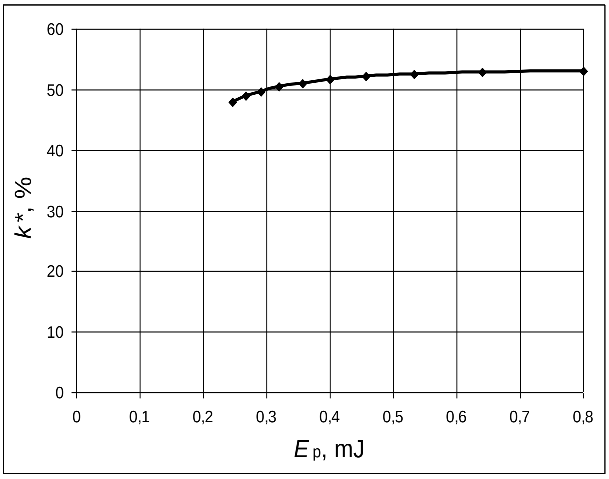

Fig. 2 Graphics of the dependence of contrast on pulse energy at speed v_2 = 70 mm/s.

6. CONCLUSIONS

The following results were obtained:

- The influence of pulse energy on the process of laser marking of samples of structural steel 15Cr2 was studied;
- Working intervals of pulse energy for two marking speeds were obtained.

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