



INVESTIGATION OF INFLUENCE OF DEFOCUSING AND PULSE DURATION FOR MARKING ON SAMPLES OF STEEL HS18-0-1 WITH FIBER LASER

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Abstract: The studies relate to process raster laser marking of samples of tool steel H18-0-1 with fiber laser. The dependences of the contrast of marking from defocusing and pulse duration were obtained. Working intervals for the investigated magnitudes in visual perception of the marking are determined.

Keywords: laser marking, tool steel, fiber laser, defocusing, pulse duration, working intervals.

I. Introduction

Laser marking of products from metals and alloys is a complex technological process. The realization depends on a number of factors [1] – [4], relating to:

- the thermo-physical and optical properties of materials – reflection coefficient, absorptance, absorption coefficient, penetration depth, thermal conductivity, thermal diffusivity, specific heat capacity, thermal diffusion length;
- the parameters of the laser – power, power density, pulse power, pulse energy, frequency, pulse duration, beam quality;
- the parameters of the process – speed, step, defocusing, number of repetition.

Defocusing and pulse duration are the basic parameters, influencing of studies process. To assist the operator of laser technological systems is need to define working intervals for them.

II. Presentation

The purpose of the work is the study of the influence of defocusing and pulse duration onto the process of laser marking by melting for samples of tool steel H18-0-1 with fiber laser and receiving the working intervals of the defocusing and the pulse duration.

When working with defocusing, the quality of resulting marking depends on the length of Raleigh z_R . It is a characteristic of each type of laser. It is defined by the expression

$$z_R = \frac{\pi r_0^2}{\lambda}, \quad (1)$$

where λ is the wavelength of the laser, r_0 is the minimum radius of the working spot.

When the condition $\Delta f < z_R$ is satisfied, the diameter of the opening spot almost does not change, and therefore power density of laser radiation reduces very little in comparison with that focus.

When is satisfied the condition $\Delta f < z_R$, the diameter of the working spot almost does not change, and therefore power density of laser radiation reduces very little in comparison with that at focus.

In defocusing Δf power density of laser radiation reduces very quickly compared to operating mode at focus. The diameter d of the working spot for defocusing Δf (Fig. 1) greater than the distance of the Rayleigh z_R is given by the formula

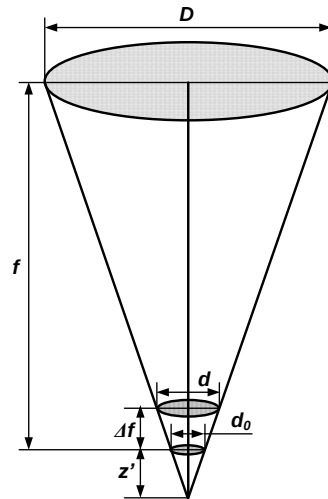
$$d = \frac{D(z' + \Delta f)}{f + z'}, \quad (2)$$

where D is the diameter of the laser beam, falling on the lens, f – focal length of the lens, and the parameter z' is defined from similarity of triangles (Fig. 1) by the expression

$$z' = \frac{d_f f}{D - d_f}, \quad (3)$$

where d_f is the diameter of the working spot at focus.

Figure 1



When $\Delta f > z_R$ from formula (2) follows, that with increasing defocusing Δf increases the diameter d of working spot also, as the dependency is linear. The power density q_s of laser radiation is inversely proportional to the diameter d of the working spot of the second degree. It follows, that the power density q_s rapidly decreases with increasing defocusing Δf . This leads to the exit from the technological mode of marking and inability to obtain marking with requisite contrast.

As is known, the basic modes of the lasers are continuous and pulsed mode. Preferably is, the lasers for marking to work in pulse mode. In this mode are essential pulse power P_p , pulse energy E_p , pulse duration τ and frequency ν . They are connected to the average power P of the laser with the expressions

$$P = P_p \tau \nu. \quad (4)$$

$$P = E_p \nu. \quad (5)$$

Steel H18-0-1 is used widely in industry. Its basic thermo-physical characteristics are presented in Table I [5], [6].

Table I. Certain thermo-physical characteristics on steel H18-0-1

Parameter	Value
Thermal conductivity k , W/(m.K)	26
Specific heat capacity c , J/(kg.K)	420
Density ρ , kg/m ³	8770
Thermal diffusivity a , m ² /s	$7,06 \cdot 10^{-6}$

The experiments were made with the laser technology system with fiber laser. It is a modern laser, operating in the near infrared region and is suitable for the investigated process. The basic parameters of laser technological system for marking with this laser are shown in Table II [7] – [10].

Table III. Basic parameters of laser technological system for marking and used laser

Parameter	Value
Wavelength λ , nm	1064
Power P , W	40
Frequency ν , kHz	$1 \div 250$
Pulse duration τ , ns	$8 \div 250$
Pulse energy E_p , mJ	$0,16 \div 1,33$
Pulse power P_p , kW	$5,32 \div 17,8$
Beam quality M^2	1,05
Positioning accuracy, μm	2,5
Efficiency, %	40

Tasks:

1. Investigation of the dependence of the contrast k^* of marking from the defocusing Δf

Onto samples of investigated steel are marked raster fields with sizes 5 mm x 5 mm. Used is a method of marking with immersed focus. Parameters, that are kept constant during the experiments are given in Table III. The defocusing vary in the interval $\Delta f \in [0; 4,00]$ mm.

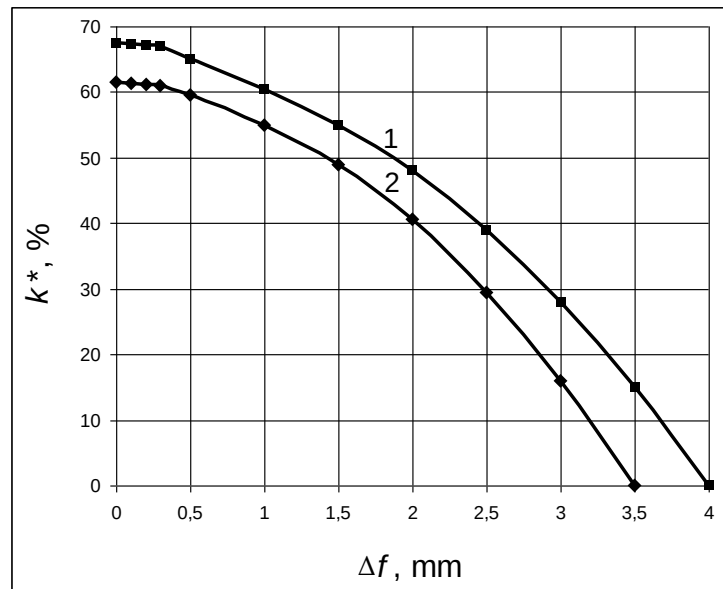
Table IIIII. Parameters, that are kept constant

Parameter	Value
Speed v_1 , mm/s	40
Speed v_2 , mm/s	60
Frequency ν , kHz	30,0
Pulse duration τ , ns	100
Step Δx , μm	50
Number of repetition N	1

On Fig. 2 are shown graphs of the experimental dependence $k^* = k^*(\Delta f)$ for two speeds of marking: $v_1 = 40$ mm/s; $v_2 = 60$ mm/s. From their analysis can draw the following conclusions:

- In the interval $0 < \Delta f < 0,30$ mm contrast of marking almost aren't changed for both speeds. The result is consistent with the theory. It is worked in the area of Raleigh and the power density of laser radiation reduces very slightly;
- In the interval $0,30 \text{ mm} < \Delta f < 4,00$ mm the contrast of marking quickly reduced. The rate of decrease the contrast of the marking:
18,1 %/mm from speed $v_1 = 40$ mm/s;
16,5 %/mm from speed $v_2 = 60$ mm/s;
- The working intervals of defocusing for marking with fiber laser for its visual perception are:
 $\Delta f \in [0; 1,80]$ mm for speed $v_1 = 40$ mm/s;
 $\Delta f \in [0; 1,40]$ mm for speed $v_2 = 60$ mm/s;

Figure 2. Graphs of the dependence $k^* = k^*(\Delta f)$ for marking with fiber laser on samples of steel H18-0-1 with speeds : 1 – $v_1 = 40$ mm/s; 2 – $v_2 = 60$ mm/s



2. Investigation of the dependence of the contrast k^* of marking from the pulse duration τ

Parameters, that are kept constant during the experiments are given in Table IV.

Table IVV. Parameters, that are kept constant

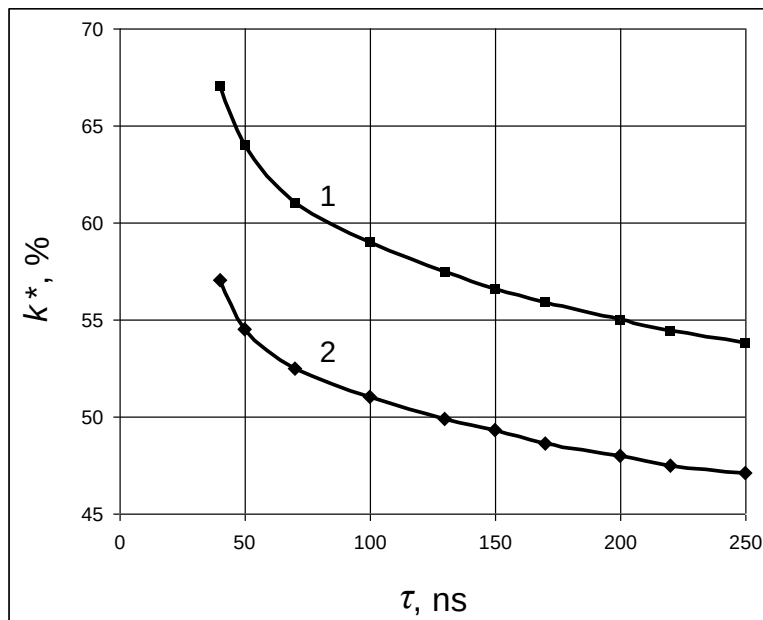
Parameter	Value
Speed v_1 , mm/s	40
Speed v_2 , mm/s	60
Power density q_s , W/m^2	$2,39 \cdot 10^{10}$
Diameter d , μm	40,0
Step Δx , μm	50
Defocusing Δf , mm	0
Number of repetition N	1

On Fig. 2 are shown graphs of the experimental dependence $k^* = k^*(\tau)$ for two speeds of marking: $v_1 = 40$ mm/s; $v_2 = 60$ mm/s. From their analysis follows:

- By increasing the pulse duration was observed slight decrease on contrast of marking for both speeds. The reason for this is, that slightly are increased loss of thermal conductivity and heat affected zone are increased only slightly;

- The rate of decrease the contrast of the marking in the interval $\tau \in [40; 70]$ ns is:
0,20 %/ns for speed $v_1 = 40$ mm/s;
0,15 %/ns for speed $v_2 = 60$ mm/s;
- The rate of decrease the contrast of the marking in the interval $\tau \in [70; 250]$ ns is:
0,040 %/ns for speed $v_1 = 40$ mm/s;
0,030 %/ns for speed $v_2 = 60$ mm/s;
- The working intervals of pulse duration for marking with fiber laser for its visual perception are:
 $\tau \in [40; 250]$ ns for speed $v_1 = 40$ mm/s;
 $\tau \in [40; 125]$ ns for speed $v_2 = 60$ mm/s.

Figure 2. Graphs of the dependence $k^* = k^*(\tau)$ for marking with fiber laser on samples of steel H18-0-1 with speeds: 1 – $v_1 = 40$ mm/s; 2 – $v_2 = 60$ mm/s



III. Conclusion

The received the results of experimental studies allow the formulation of the following statements:

- Work in the mode of defocusing greater than the length of Raleigh hampers greatly the realization on the process of laser marking of tool steels;
- The influence of the pulse duration onto the contrast of the marking for studied speeds is less.

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