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Union of Scientists - Ruse
16, Konstantin Irechek Street
7000 Ruse
BULGARIA
Phone: (++359 82) 828 135,
(++359 82) 841 634
E-mail: suruse@uni-ruse.bg
web: suruse.uni-ruse.bg

Contacts with Editor
Phone: (++359 82) 888 738
E-mail: zzdravkova@uni-ruse.bg

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BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 12

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"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 12

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DETERMINATION OF WORKING INTERVALS OF POWER DENSITY AND FREQUENCY FOR LASER MARKING ON SAMPLES FROM STEEL HS18-0-1

Nikolay Angelov

Technical University of Gabrovo

Abstract: *The process of laser marking by melting with fiber laser on samples from tool steel H18-0-1 was investigated. In carrying out the experiments the raster method of marking is used. The dependences of the contrast of marking from power density and frequency were obtained. Working intervals are determinited from the experimental results for the investigated magnitudes of this steel.*
Keywords: *laser marking, tool steel, fiber laser, power density, frequency, working intervals*

INTRODUCTION

The process of laser marking products from metals and alloys is influenced by certain factors [1-4]. Due to the different values of the thermo-physical and optical properties of materials and different characteristics and capabilities of lasers for each particular case experiments should be conducted to optimize the process. Two of the basic parameters influencing the process are power density and frequency. Therefore of crucial importance for the operator of laser systems is to determine the working intervals for them.

The purpose of the work is the study of the influence of power density and frequency onto the process of laser marking by melting for samples of tool steel H18-0-1 with fiber laser and receiving the work intervals of the power density of the laser radiation and the frequency.

EXPERIMENT

To obtain marking, the power density of the laser radiation should be sufficient to cause melting of the material in the treatment zone. At research it is necessary to take into account the fact that with power density increase absorption ability of steel increases. The upper limit of power (and thus of power density) of each laser source is predetermined. It is necessary to determine the work interval of its change to achieve good quality of marking.

To determine the power density of the laser radiation it is used the formula

$$q_S = \frac{P}{S}, \qquad (1)$$

where *P* is the power of laser beam, *S* is the surface of the work spot.

Taking into account that $S = \frac{\pi d^2}{4}$ we obtain

$$q_S = \frac{4P}{\pi d^2}, \qquad (2)$$

where *d* is the diameter of the working spot.

H18-0-1 steel is used for making of incisors, drills, cutters, thread cutters, shaping cutters, reamers, countersinks, taps, broaches for the treatment of structural steels and others. Its chemical composition is given in Table 1 due to [7] and its basic thermo-physical characteristics are presented in Table 2 as in [6], [8], [9].

Table 1. Chemical composition on steel H18-0-1

Chemical element	C	Si	Mn	Ni	S	P
Content, %	0,73÷ 0,82	0,2 ÷ 0,5	0,2 ÷ 0,5	< 0,6	< 0,03	< 0,03
Chemical element	Cr	Mo	W	V	Co	Cu
Content, %	3,8÷ 4,4	< 1,0	17÷18,5	1,0÷1,4	< 0,5	< 0,25

Table 2. Certain thermo-physical characteristics on steel H18-0-1: k – thermal conductivity; c – specific heat capacity; ρ – density, a – thermal diffusivity.

Magnitude Temperature t, ^{o}C	k, W/(m.K)	c, J/(kg.K)	ρ, kg/m^3	a, m^2/s
100	26	420	8770	$7{,}06.10^{-6}$
200	27	450	8730	$6{,}87.10^{-6}$
300	28	470	8690	$6{,}86.10^{-6}$
400	29	510	8650	$6{,}57.10^{-6}$
500	28	550	8610	$5{,}91.10^{-6}$
600	27	610	8570	$5{,}16.10^{-6}$
700	27	690	8530	$4{,}59.10^{-6}$

Experiments were made with the laser system with fiber laser (Fig. 1). It is a contemporary laser, operating in the near infrared area and it is suitable for the investigated process.

Fig.1. General view of the laser technological system with fiber laser

The basic parameters of laser technological system for marking with this laser [5], [7] are given in the Table 3:

Table 3

Parameter	Value
Wavelength λ, nm	1064
Power *P*, W	50
Frequency ν, kHz	1 ÷ 250
Pulse duration τ, ns	8 ÷ 250
Pulse energy E_p, mJ	0,16 ÷ 1,66
Pulse power P_p, kW	5,32 ÷ 22,2
Beam quality M^2	1,05
Positioning accuracy, μm	2,5
Efficiency, %	40

Experimental studies were carried out in two directions:

- **Influence of the power density onto the contrast of the marking**
- **Influence of the frequency onto the contrast of the marking**

REALIZED TASKS

1. Investigation of the dependence of the contrast *k of marking from the power density q_S**

Parameters, which are kept constant during the experiments are given in Table 4. The power density of laser radiation varies in the interval q_S Є [1,75.10^{10}; 3,19.10^{10}] W/m^2 with step 1,60.10^9 W/m^2.

Table 4. Parameters, which are kept constant during the experiments

Parameter	Value
Speed v_1, mm/s Speed v_2, mm/s	40 60
Diameter *d*, μm	40,0
Frequency ν, kHz (only for task 1)	30,0
Power density q_S, W/m^2 (only for task 2)	2,30.10^{10}
Pulse duration τ, ns	100
Step Δ*x*, μm	50
Defocusing Δ*f*, mm	0
Number if repetition *N*	1

On Fig. 2 graphs are shown of the experimental dependence $k^* = k^*(q_S)$ for two speeds of marking: 1 – v_1 = 40 mm/s; 2 – v_2 = 60 mm/s. From their analysis one can make the following conclusions:

- By increasing the power density of the laser beam a nonlinear increase in the contrast of the marking for two speeds was observed;

- The rate of increase in the contrast of the marking in the interval q_S Є [1,75.10^{10}; 2,71.10^{10}] W/m^2 is:

3,28.10^{-9} %/(W/m^2) for speed v_1 = 40 mm/s;

3,91.10^{-9} %/(W/m^2) for speed v_2 = 60 mm/s;

- The rate of increase in the contrast of the marking in the interval q_S Є [$2,71.10^{10}$; $3,19.10^{10}$] W/m^2 is:

$1,04.10^{-9}$ %/(W/m^2) for speed v_1 = 40 mm/s;

$0,94.10^{-9}$ %/(W/m^2) for speed v_2 = 60 mm/s.

The working intervals of the power density for marking with fiber laser are:

For visual perception of marking	q_S Є [$2,12.10^{10}$; $3,19.10^{10}$] W/m^2 q_S Є [$2,36.10^{10}$; $3,19.10^{10}$] W/m^2	speed v_1 = 40 mm/s speed v_2 = 60 mm/s
Using a readers	q_S Є [$1,75.10^{10}$; $3,19.10^{10}$] q_S Є [$1,75.10^{10}$; $3,19.10^{10}$] W/m^2	speed v_1 = 40 mm/s speed v_2 = 60 mm/s

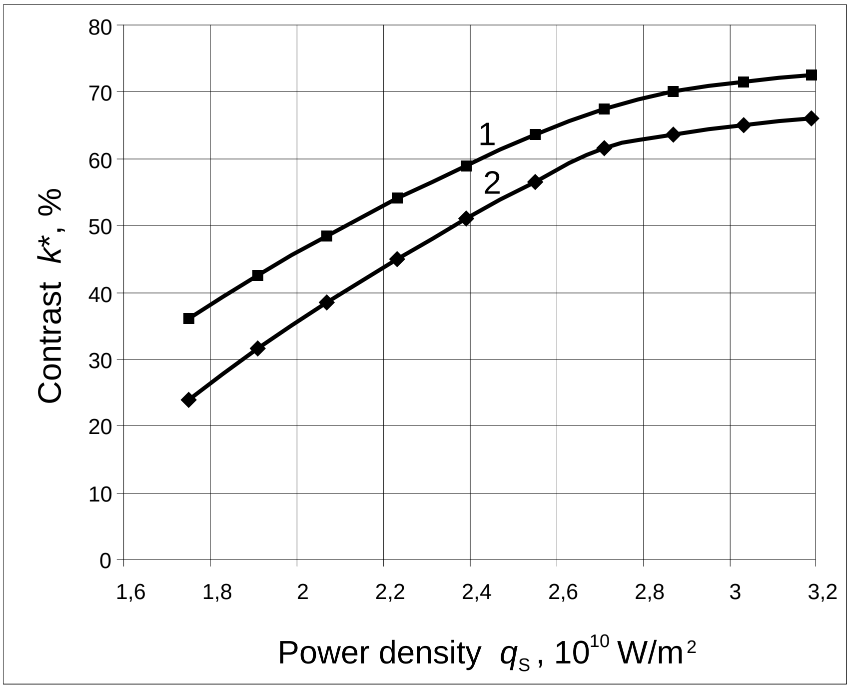

Fig.2.

2. Investigation of the dependence of the contrast *k of marking from the frequency *ν***

Parameters, which are kept constant during the experiments are given in Table 4. The frequency varies in the interval *ν* Є [10; 100] kHz with step 10 kHz.

On Fig. 3 are shown graphs of the experimental dependence *k** = *k**(*ν*) for two speeds of marking: 1 – v_1 = 40 mm/s; 2 – v_2 = 60 mm/s. From their analysis follows:

- By increasing the frequency nonlinear increase in the contrast of the marking for two speeds was observed;

- The working intervals of the frequency for marking with fiber laser are:

For visual perception of marking	*ν* Є [20; 100] kHz *ν* Є [34; 100] kHz	speed v_1 = 40 mm/s speed v_2 = 60 mm/s
Using a readers	*ν* Є [10; 100] kHz *ν* Є [10; 100] kHz	speed v_1 = 40 mm/s speed v_2 = 60 mm/s

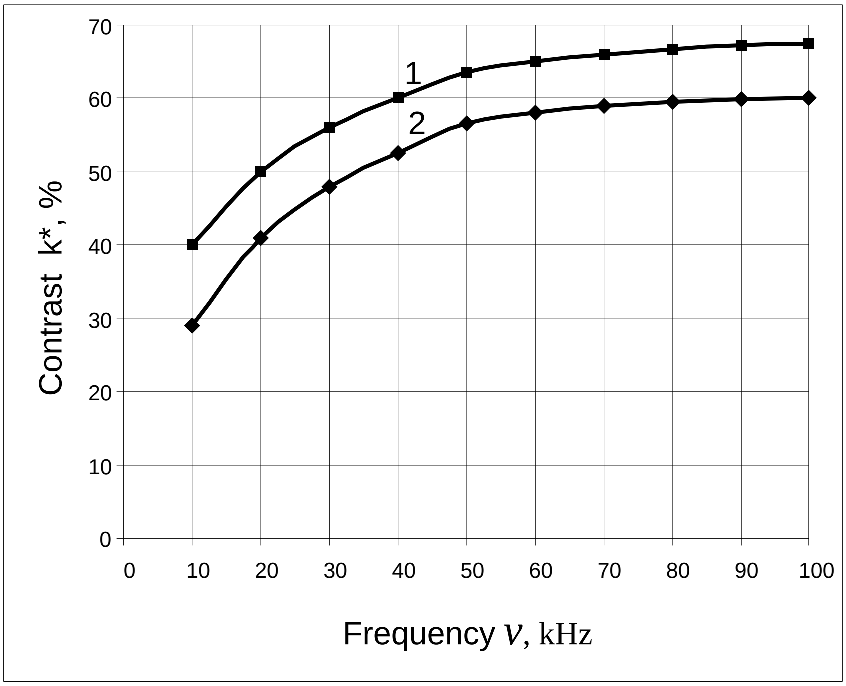

Fig.3.

CONCLUSION

The received results of experimental studies succour the work of the operator of the laser technological system. They shorten the implementation times for the products in production. The investigation can continue for marking with lasers, operating in the visible area. These lasers are also suitable for realizing the process.

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CONTACT ADDRESS
Assist. Prof. Nikolay Angelov Petrov, PhD
Department of Physics, Chemistry and Ecology, Faculty of Economics
Technical University of Gabrovo
4 Hadzhy Dimitar Str., 5300 Gabrovo, Bulgaria
Phone: (++359 66) 827 318
E-mail: angelov_np@abv.bg

ОПРЕДЕЛЯНЕ НА РАБОТНИ ИНТЕРВАЛИ НА ПЛЪТНОСТТА НА МОЩНОСТТА И ЧЕСТОТАТА ПРИ ЛАЗЕРНО МАРКИРАНЕ НА ОБРАЗЦИ ОТ СТОМАНА HS18-0-1

Николай Ангелов

Технически университет - Габрово

Резюме: *Изследван е процеса на лазерно маркиране чрез топене на образци от инструментална стомана Н18-0-1 с влакнесто-оптически лазер. При провеждане на експериментите е използван растерния метод на маркиране. Получени са зависимостите на контраста на маркировката от плътността на мощността и честотата. От получените резултати са определени работни интервали за изследваните величини за тази стомана.*

Ключови думи: *лазерно маркиране, инструментална стомана, влакнесто-оптичен лазер, плътност на мощността, честота, работни интервали.*

The paper is dedicated to **International Year of Light and Light-based Technologies, 2015 (IYL 2015).**

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