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BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 10

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BOOK 5

"MATHEMATICS, INFORMATICS AND PHYSICS"

VOLUME 10

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INVESTIGATION OF THE INFLUENCE OF THE TYPE OF SURFACE ON THE QUALITY OF LASER MARKING

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***Abstract**: The possibility of marking tools have been examined with three types of surfaces: brushed, nickel-plated and oxidized. The change of the contrast has also been analyzed according to two technological parameters - power density and speed of marking. The intervals of power density and speed of marking for optimal contrast have been defined. Experiments were made with two types of lasers - Nd: YAG disc laser D16 and CuBr laser, in purpose to assess the influence of the wavelength on the marking process. Moreover, the physical mechanism for marking on the three surfaces is discussed further.*
***Keywords:** laser marking, surface, optimal contrast, power density, speed.*

INTRODUCTION

Under modern requirements of production standards on cutting tools, offered on the market, there should be marking such as: company logos, serial numbers or lately matrix and barcode containing important technical information etc [1, 8, 9]. In the final stage of the manufacturing process on the instruments, coatings must be applied with purpose to protect from both weathering and aggressive environments during their operation. Without damage significantly of these coatings, the affixed marking should also be durable and should have good readability both visually and by automated control systems. In the study of the process of marking is established that these two criteria for quality are significantly influenced by many factors, and also choosing a suitable method of marking [2, 3]. In many instruments such as taps, dies, drills, lathe tools, main background is dark in result of the final operation on their oxidation. In this case, the method of marking should ensure maximum contrast by removing the top layer and revealing a bright surface of the base material from which the instrument has been made. In the nickel-plated tools, the surface is bright and should be selected a method for marking, that ensures respectively darker marked area to ensure required contrast. Compliance with these requirements in conjunction with the complex relationships that exist between the various thermo-physical and optical properties of the materials of which the instruments on the one hand and the technological parameters related to the laser source and system technologies such as wavelength, power, speed of processing and others required to perform preliminary experimental research in each case in order to establish the optimum process parameters.

EXPERIMENT

In the paper are studied the real products (knives, drills, cutters, taps, dies) from rapid tool steel P6M5 with standard coatings [10, 11]. In purpose to monitor the influence of the wavelength of laser radiation on the process of absorption from the surface of the article for laser marking, the experiments were made with two types of lasers - Nd: YAG disc laser D16 [12] and laser CuBr [13] (see Table 1).

Table 1

Laser Parameters	Nd:YAG disc laser D16	CuBr laser
Wavelength λ, nm	1 064	511 & 578
Power P, W	16,0	10,0
Frequency ν, kHz	5÷50	19,0
Duration of pulses τ, ns	1000 –10000	30
Pulse energy E_p, mJ	0,32 – 3,2	0,51
Pulse power P_p, kW	0,032 – 3,2	17,0

Experimental method provides a research on contrast of the marking k^*, the basic criteria for quality, in:

- a function of power density $k^* = k^*(q_S)$;
- a function of the speed of processing $k^* = k^*(v)$.

Series of experiments are conducted onto:

1. Products with nickel-plated surfaces, as compared are made and control measurements in marking at a polished surface of basic material.

(Method of marking by melting on the surface layer)

2. Products with oxidized surfaces.

(Method of marking by evaporation on the surface layer of the background material)

In both series of experiments the power density of laser radiation q_S is amended in the intervals:

- for disc laser D16 q_S Є [0,91.10^{10}; 2,27.10^{10}] W/m^2 with a step 1,13.10^9 W/m^2;
- for CuBr laser q_S Є [0,72.10^{10}; 1,34.10^{10}] W/m^2 with a step 0,715.10^9 W/m^2.

In experiments related to the study of the influence of technological parameters speed v of processing changes its interval v Є [10, 120] mm/s with a step 10 mm/s.

The criteria for quality contrast, according to the standard for the perception of visual marking and automated readout of information, are indicated in [4, 7, 14].

In order to define more precisely the contrast by the method of comparison with the surrounding surface [5], onto prepared samples perform a marking of areas (squares of side 5 mm) on the faster method, such as the paths are written with step Δx = 50 μm.

1. Investigation of the marking process on a nickel-plated surfaces

The results from study of $k^* = k^*(q_S)$ with disc laser D16 and CuBr laser are presented in graphic form in Fig. 1 (a, b).

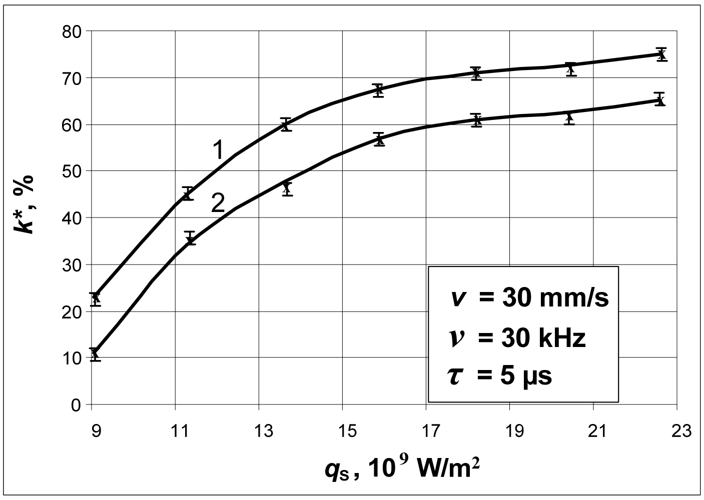


Fig. 1a Amendment of contrast k as a function of power density q_S for marking with disc laser D16 for samples of steel P6M5 with: 1 - brushed surface, 2 - nickel-plated surface.*

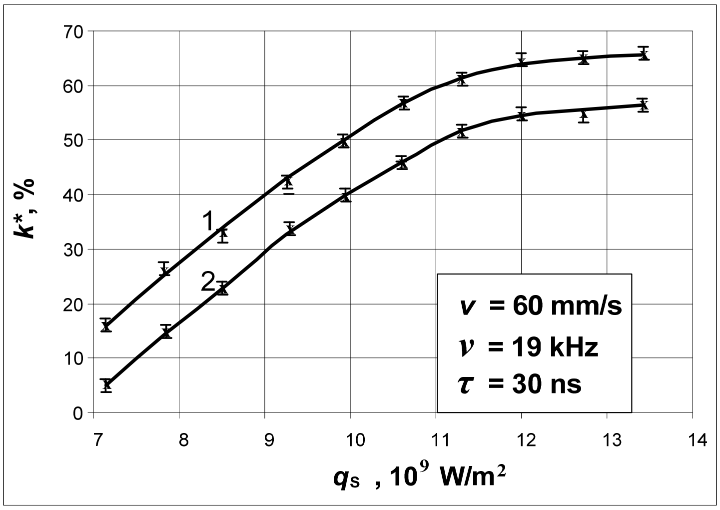


Fig. 1b Amendment of contrast k as a function of power density q_S for marking with CuBr laser for samples of steel P6M5 with: 1 - brushed surface, 2 - nickel-plated surface.*

The following conclusions can be drawn from the analysis of the graphs:

• For polished and nickel-plated surfaces to impact with disc laser D16 and CuBr laser, contrast of marking *k** increases with the increase of surface power density q_S of laser radiation.

• For disc laser the speed of change of contrast is therefore in the interval of power density of laser radiation q_S Є [0,91.10^{10}; 1,36.10^{10}] W/m^2 - 8,2.10^{-9} %/(W/m^2 for both surfaces and in the interval q_S Є [1,36.10^{10}; 2,27.10^{10}] W/m^2 - 1,65.10^{-9} %/(W/m^2).

• For CuBr laser the speed of change of contrast is therefore in the interval of power density of laser radiation q_S Є [0,72.10^{10}; 1,13.10^{10}] W/m^2 - 11,1.10^{-9} %/(W/m^2) for both surfaces and in the interval q_S Є [1,13.10^{10}; 1,34.10^{10}] W/m^2 - 2,4.10^{-9} %/(W/m^2).

• For brushed surface the contrast of marking is with 10-12% higher than that of the nickel-plated surface at impact with disc laser and 10-11% - in impact with CuBr laser. The explanation for this phenomenon can be found in the greater absorbability of the sanded surface than the nickel surface [6].

• Optimal intervals for power density of laser radiation for marking with disc laser D16 at speed v = 30 mm/s.

in the visual perception of the marking	brushed surface nickel-plated surface	q_S Є [1,19.10^{10}; 2,27.10^{10}] W/m^2 q_S Є [1,42.10^{10}; 2,27.10^{10}] W/m^2
in using of special readers	brushed surface nickel-plated surface	q_S Є [0,91.10^{10}; 2,27.10^{10}] W/m^2 q_S Є [1,00.10^{10}; 2,27.10^{10}] W/m^2

• Optimal intervals for power density of laser radiation for marking with CuBr laser at speed *v* = 60 mm/s.

in the visual perception of the marking	brushed surface nickel-plated surface	q_S Є [0,99.10^{10}; 1,34.10^{10}] W/m2 q_S Є [1,11.10^{10}; 1,34.10^{10}] W/m^2
in using of special readers	brushed surface nickel-plated surface	q_S Є [0,75.10^{10}; 1,34.10^{10}] W/m^2 q_S Є [0,83.10^{10}; 1,34.10^{10}] W/m^2

• Due to the higher absorbence of the laser radiation in CuBr (A = 45%) compared with disc laser (*A* = 30%) work with 25-30% less surface power density of laser radiation.

The results of the study of the dependence of the contrast as a function of speed of marking - $k^* = k^*(v)$, with both types of lasers are shown in Fig. 2a and Fig. 2b. The remaining technological parameters for this series of experiments are kept constant.

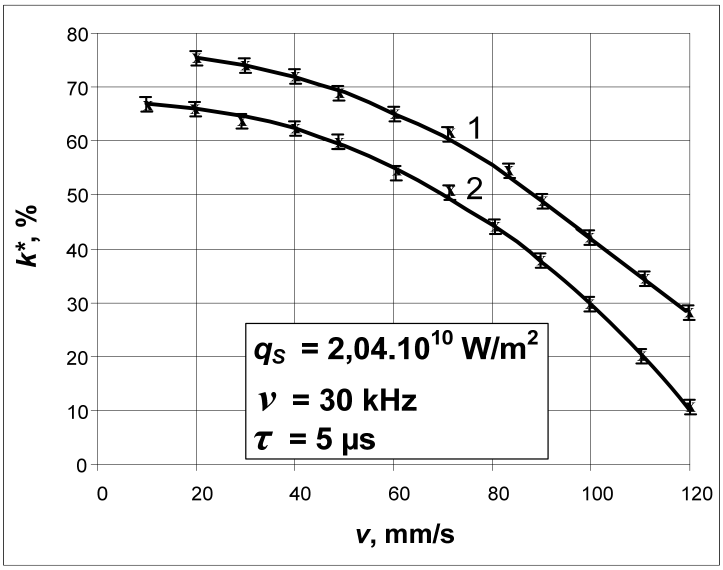


Fig. 2a. Amendment of contrast k as a function of speed v of marking with disc laser D16 for samples of steel P6M5 with: 1 - brushed surface, 2 - nickel-plated surface.*

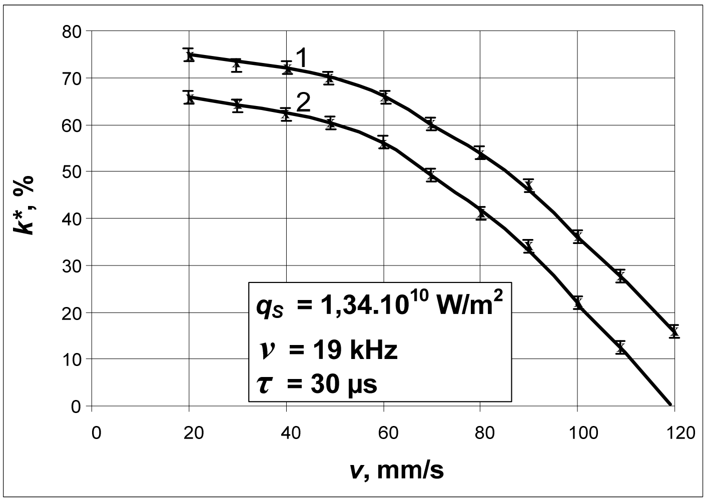


Fig. 2b. Amendment of contrast k as a function of speed v of marking with CuBr laser for samples of steel P6M5 with: 1 - brushed surface, 2 - nickel-plated surface.*

It can be concluded of the constructed graphs of $k^* = k^*(v)$ that:

• For brushed and nickel-plated surface speed steel P6M5 with increasing velocity decreases contrast of marking it with the same speed of change (- 0,41%/(mm/s)) in impact with disc laser and in CuBr laser - speed of change (- 0,5%/(mm/s)).

• Optimal intervals of speed of marking *v* for surface power density of laser radiation $q_S = 2{,}04.10^{10}$ W/m^2 with disc laser.

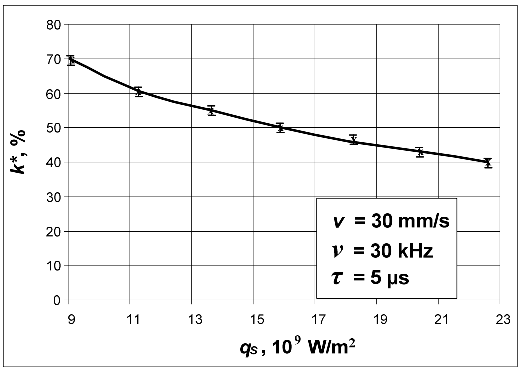
in the visual perception of the marking	brushed surface nickel-plated surface	v Є [20, 88] mm/s v Є [10, 70] mm/s
in using of special readers	brushed surface nickel-plated surface	v Є [20, 120] mm/s v Є [20, 103] mm/s

• Optimal intervals of speed of marking v for surface power density of laser radiation q_S = 1,34.10^{10} W/m^2 with CuBr laser.

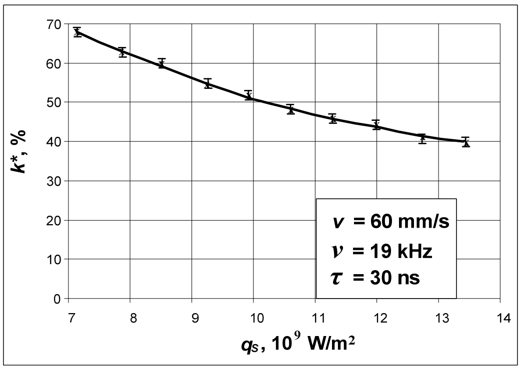
in the visual perception of the marking	brushed surface nickel-plated surface	v Є [20, 85] mm/s v Є [20, 68] mm/s
in using of special readers	brushed surface nickel-plated surface	v Є [20, 116] mm/s v Є [20, 110] mm/s

2. Investigation of the laser marking process on the oxidized surfaces

The results of amendment of the contrast k^* as a function of power density q_S with disc laser and CuBr laser are presented in graphic form in Fig. 3 (a, b).



a)



б)

Fig. 3. Experimental dependence $k^* = k^*(q_S)$ for marking of samples of P6M5 steel with oxidized surfaces for: a) disc laser D16; b) CuBr laser

From the analysis of obtained results the following points can be brought out:

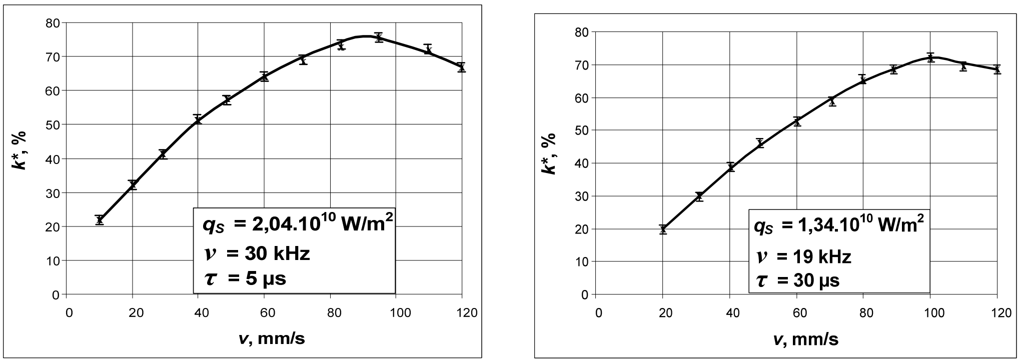
• In the research interval of power density q_S occurs withdrawal of layer and melting of the basic material, which leads to darkening, and thus reduce the contrast.

• There is an almost linear decrease the contrast k^* with increasing power density of laser radiation q_S such as in impact with a disc laser speed of this change is 2,2.10^{-9} %/(W/m^2) and in CuBr laser - 4,4.10^{-9} %/(W/m^2).

• The optimal interval of power density q_S to obtain quality marking.

in the visual perception of the marking	disc laser CuBr laser	v = 30 mm/s v = 60 mm/s	q_S Є [0,91.10^{10}; 1,58.10^{10}] W/m^2 q_S Є [0,72.10^{10}; 1,03.10^{10}] W/m^2
in using of special readers	disc laser CuBr laser	v = 30 mm/s v = 60 mm/s	q_S Є [0,91.10^{10}; 2,27.10^{10}] W/m^2 q_S Є [0,72.10^{10}; 1,34.10^{10}] W/m^2

The results of the study of the dependence of the contrast k^* in a function from velocity v in marking on samples with oxidized surfaces are illustrated in Fig. 4a, b.



а) *б)*

Fig. 4. Experimental dependence k = k* (v) for marking of samples of steel R6M5 with: a) disc laser D16; b) CuBr laser*

From the resulting graphical dependences it can be determined that:

• With increasing of speed v is observed nonlinear increase on the contrast k^* in impact with both laser sources:

- for disc laser the maximum of speed is at v = 90 mm/s;
- for CuBr laser the maximum of speed is at v = 100 mm/s.

• The optimal working intervals of speed v for obtaining of quality marking.

in the visual perception of the marking	disc laser CuBr laser	q_S = 2,04.10^{10} W/m^2 q_S = 1,34.10^{10} W/m^2	v Є [38, 120] mm/s v Є [56, 120] mm/s
in using of special readers	disc laser CuBr laser	q_S = 2,04.10^{10} W/m^2 q_S = 1,34.10^{10} W/m^2	v Є [20, 120] mm/s v Є [20, 120] mm/s.

This amendment of contrast is explained as follows. In speed of marking v = 20 mm/s obtains the withdrawal of the layer and melting of the basic material in the zone of impact. The increase of speed reduces the depth of the melt. At a speed v = 90 mm/s is attained only removal of oxidized layer and so the contrast is maximized. At speeds above v = 90 mm/s to obtain the withdrawal of part of the layer where the greater the speed is, the lower part of it is taken. This leads to reduction of the contrast in this range of speeds.

CONCLUSION

Experimental researches on laser marking process of tool steels can continue for other technological parameters - frequency, pulse duration, step in raster selection, number of repetitions, defocus on one hand, but also for other types of lasers and brands instrumental steel. The results obtained in experimental studies can be laid in the technological tables, building a database of optimal process parameters in each case. For given input data in them the operator can quickly reach optimal technological parameters necessary to obtain quality marking of manufactured product in this moment.

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ИЗСЛЕДВАНЕ НА ВЛИЯНИЕТО НА ВИДА НА ПОВЪРХНОСТТА ВЪРХУ КАЧЕСТВОТО НА ЛАЗЕРНАТА МАРКИРОВКА

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Резюме: *Изследвана е възможността за маркировка на инструменти с три вида повърхности: шлифована, никелирана и оксидирана. Анализира се измененията на контраста в зависимост от два технологични параметъра - плътността на мощността и скоростта на маркиране. Определени са интервали на плътността на мощността и скоростта на маркиране за получаване на оптимален контраст. Експериментите са реализирани с два типа лазери – Nd:YAG шайбов лазер D16 и лазер на CuBr с цел да се оцени и влиянието на дължината на вълната върху процеса на маркиране. Дискутира се и физическия механизъм при маркиране върху трите повърхности.*

Ключови думи: *лазерно маркиране,оптимален контраст, повърхност, плътност на мощността, скорост.*

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