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STUDYING LASER RADIATION EFFECT ON STEEL STRUCTURE AND PROPERTIES

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Preliminary Note – Prethodno priopćenje

There was studied the effect of laser radiation on the structure and properties of annealed and tempered steel with different content of carbon. For surface hardening there was used a laser complex equipped with Nd: YAG pulse laser with power density up to 30 kW/cm^2. As a result of the carried-out studies there were calculated characteristics of laser, steel microstructure and properties.

Key words: steel, laser surface hardening, thermal treatment, microstructure, microhardness

INTRODUCTION

When manufacturing parts of steel subjected to wear, the main task is obtaining high surface hardness when saving sufficient viscosity permitting to withstand loadings in case of shock without corrupting.

To observe these requirements, steels are subject to different types of surface treatment. There are traditionally used such treatment of the surface as gas-flame and induction hardening, different pad welding with hard alloys. However the traditional methods of the surface treatment possess a number of shortcomings: high time and energy expenditure, a complicated mode of thermal treatment, a wide zone of thermal effect. The use of laser radiation as a heat source for surface treatment permits to exclude the majority of shortcomings of the abovementioned methods of treatment.

Laser radiation permits to affect metal within a short-time period, locally, to treat specific areas of the material, thus excluding the part warping and occurrence of hardening stresses. This number of laser effect advantages speaks of feasibility and prospects of laser application for surface hardening.

At present there are used two types of lasers for carrying out surface hardening: Nd:YAG and CO_2 [1]. However the wavelength of CO_2 laser radiation makes 10,6 microns, and the coefficient of its absorption by metals is low. Therefore the use of solid-state lasers with the radiation wavelength 1,06 microns is more preferable owing to its good absorption by metals, thus the need of using absorbing coverings disappears [2].

In the works carried out before [3, 4] there was studied the use of laser for surface hardening, however a number of questions remains disputable and requires additional studies. The purpose of this work is the study the mode of the laser surface treatment effect on steel microstructure and microhardness with different content of carbon.

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EXPERIMENTAL STUDIES

For studies there were selected steels of C 45 and C 70W2, C 120W grades. In the work there were used steel specimens of 30 x 20 x 10 mm dimensions in the annealed and tempered states. Thermal treatment was carried out according to the standard mode for the steels selected.

As a laser source of radiation there was used a solid body Nd:YAG-laser operating in the pulse mode with the wavelength of radiation 1,064 mcm and the pulse duration 12 msec. For the effect there was used a rectangular pulse with the laser spot diameter 0,35 mm. In the experiment the laser radiation power varied from 15,6 to 31,2 kW/cm^2.

Based on the obtained specimens there were made standard metallographic sections for studying microstructure and microhardness. The surface etching was carried out with 4 % HNO_3 solution in ethyl alcohol. In the course of the experiment there was calculated the temperature in the zone of thermal effect and laser radiation power density. Microhardness was measured using the PMT-3 device with 150 g/mm^2 loading. Metallographic studies were carried out using Axio Observer. A1m microscope.

Changing laser radiation power leads to changing the temperature of the treated surface and the zone of thermal effect that in turn causes the changing of the surface layer structure and mechanical properties [5]. In this connection there was calculated the temperature in the zone of laser radiation effect according to the method indicated in [6]:

$$T = \frac{q_S \sqrt{\alpha \tau_i}}{\lambda_T},$$

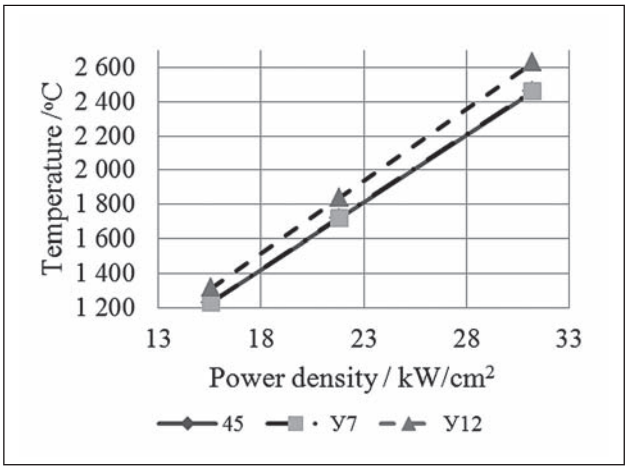


Figure 1 Temperature achieved within the laser effect zone depending on radiation power density

where;
q_S - the flow density that falls on the surface / W/cm^2,
τ_i - the duration of laser pulse / sec,
α - the material temperature conductivity / cm^2/sec,
λ_T - the material heat conductivity / W/(cm*K).

From Figure 1 it is seen that with increasing laser power density the temperature of the surface of all studied specimens increases and reaches its maximum: 2 450…2 650 °C at the power of radiation 31,2 kW/cm^2. The temperature increase on the surface of different steels is manifested ambiguously. In steels with the carbon content 0,45 % and 0,7 % the temperature increase depending on power is manifested almost equally. In steel with the carbon content 1,2 % the dependence has also a rectilinear character but absolute values of changing the temperature have higher values. This fact can be explained by the distinction in the initial microstructure of steel. In У12 steel microstructure there is a large number of secondary cementite that leads to decreasing steel heat conductivity. Therefore, the heat brought in the steel surface extends on a sample much slower that leads to localization of heat in the spot of the light bunch and, as a result, to the temperature increase.

RESULTS AND DISCUSSION

In Figure 2 there are presented steel structures obtained at a single effect of the radiation pulse with power density 31,2 kW/ cm^2. In the pictures there are well seen zones of laser effect and zones of thermal effect. The zone of laser effect represents a light area which dimensions are various for different steel grades. It is obvious that in this zone there was metal melting that is testified to by the absence of marks located in the adjacent area.

In Figure 3 there are presented the dependences of the diameter and depth of epy zone of laser effect laser power density for steels of various structure in the annealed and tempered states. From the diagrams it is seen that increasing the density of power leads to increasing the diameter (a) and the depth (b) of the zone of laser effect. It should be noted that the increase of the carbon content in steel leads to increasing the zone of laser effect on the whole.

In the zone of laser effect steel microhardness changes depending on the initial condition of steel before treatment.

In Figure 4 there are presented the dependences of changing microhardness on the initial state to the center of the treated area in the annealed and tempered states.

Microhardness of steel in the annealed state increases immediately after crossing the boundary between the processed and not processed zones. In 45 steel microhardness increases from 250 to 650 MPa, and in У12 steel from 300 to 1 050 MPa. Such increase of microhardness is connected with steel hardening from the liquid state and forming a very fine structure which yields but poorly to etching.

In tempered steel changing the microhardness happens differently. Microhardness of tempered steel makes about 800 MPa. When approaching the zone of laser effect microhardness at first decreases, then there is observed increase to 1 050 MPa. The decrease in hardness near the zone of laser effect is caused by steel tempering.

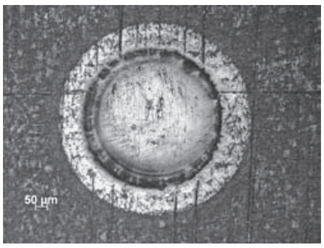
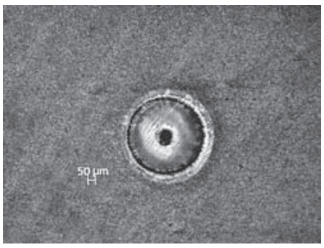
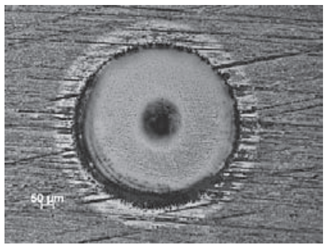
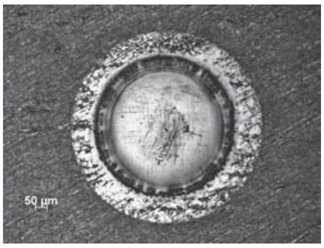
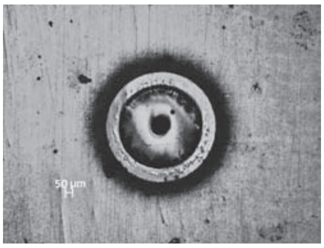
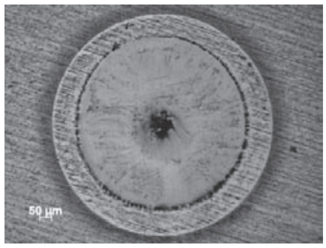
Steel grade	45	У7	У12
Annealed specimen			
Tempered specimen			

Figure 2 Structure of laser-treated specimens with power density 31,2 kW/cm, plane section (001)

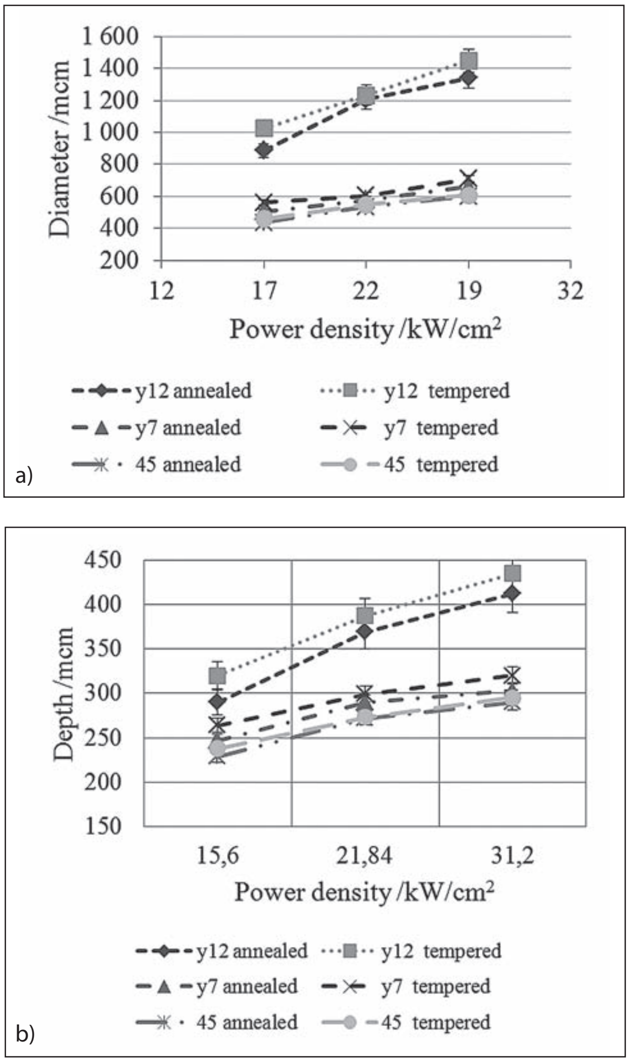


Figure 3 Dependence of the laser effect zone diameter and depth on radiation power density and steel preliminary treatment

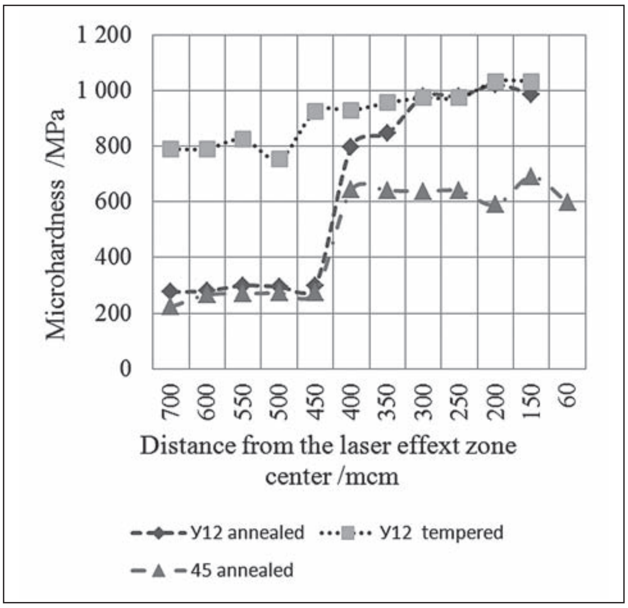


Figure 4 Microhardness changing in the zone subject to laser treatment with power density 21,8 kW/cm^2

CONCLUSIONS

Treating carbon steels with pulse laser showed:

– the zone of laser effect (its diameter and depth) increases with the increase of the carbon content in steel; this effect is manifested in tempered steel stronger than in annealed steel;

– microhardness of steel increases at the distance of 400…450 microns from the center of the laser effect zone, and is manifested stronger in annealed steels than in steels after hardening.

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Note: The responsible for England language is Nataliya Drak, Karaganda Kazakhstan