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RESEARCH ON LASER HARDENING OF AUTOMOTIVE PARTS IN THE AGRICULTURAL INDUSTRY

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During laser hardening of various automobile parts, an important factor influencing their service life is the depth of hardening and microhardness, which depend on the parameters of surface laser treatment. Successful selection of the parameters of the laser hardening process, the use of laser alloying can provide a significant increase in the operational characteristics of the processed automotive parts in the agricultural and industrial complex. The aim of the work was to determine the dependence of the depth and microhardness of the surface zones of the studied samples of iron-carbon alloys on such laser treatment parameters as laser radiation power, processing speed and the use of their laser alloying using strengthening impurities of boron carbide and tungsten carbide in an absorbing coating.

As a result of the research, it was found that with an increase in laser treatment power, the microhardness in the hardening zone increases slightly. Only at P = 1.5 kW and v = 25 mm/s does surface melting occur, and hardening without melting is observed to a depth of up to 0.5 mm. The microhardness of martensite in the lower layers of the HAZ of steel 35 increases continuously with increasing processing speed. In the upper layers of the HAZ, up to a processing speed of more than 40 mm/s, the microhardness also increases to 6900 MPa, and with a further increase in speed, it decreases.

The results of the study of the influence of strengthening impurities of boron carbide and tungsten carbide in the absorbing coating (yellow gouache) showed that the highest microhardness of the surface zones of the processed samples can be achieved by using a tungsten carbide impurity at a processing speed of V=1 mm/s.

It was established that the iron-carbon alloys used by domestic manufacturers of motor vehicles can be effectively subjected to laser processing, which will allow to provide a significant increase in the operational characteristics of the corresponding parts.

Key words: *laser hardening, tempering, microhardness, laser alloying, road transport details in the agro-industrial complex.*

Fig. 5. Ref. 12.

1. Problem formulation

To increase the wear resistance of various parts of motor vehicles in the agricultural sector, it is relevant to use the capabilities of the laser processing method.

For the effective application of this method, it is necessary to study the features of the laser effect on the surface of the processed samples, to determine the dependence of the characteristics obtained by them on the parameters of the laser hardening process.

It is known that as a result of laser hardening of various car parts, an important factor influencing their service life is the depth of hardening and microhardness, which depend on the parameters of surface laser processing.

Successful selection of the parameters of the laser hardening process, the use of laser alloying can provide a significant increase in the operational characteristics of the processed parts of motor vehicles in the agricultural and industrial complex.

Therefore, it is relevant to study the influence of laser processing on such parameters of the processed samples as the depth of hardening and microhardness of their surface zones.

2. Analysis of recent research and publications

From the analysis of publications of recent years, it can be concluded that many scientists and scholars pay their attention to the tasks related to determining the properties of iron-carbon alloys that are amenable to laser processing. For example, this issue was studied by scientists Tokarev A., Afanaseva O.V., Lalazarova N.O., Fedorenko E.P. and others, who analyzed the effect of laser flux on the surface of iron-carbon samples for different materials and in different cases [1-3].

Also, the effect of laser processing on the operational characteristics of various machine parts in recent years was studied by Dobras D., Lesyk D.A., Grushka M., Sidun K.Yu., Aulin V.V., Zavoiko O.S. and others [4-12].

The issue of a more detailed and in-depth study of the effect of laser radiation on the microstructure of surface layers, on the depth of the laser hardening zone and the corresponding microhardness in order to increase the wear resistance of various parts of motor vehicles in the agricultural and industrial complex remains unresolved.

3. The purpose of the article

The aim of the work is to determine the dependence of the depth and microhardness of the surface zones of the studied samples of iron-carbon alloys on such laser processing parameters as laser radiation power, processing speed and the application of their laser alloying using strengthening impurities of boron carbide and tungsten carbide in the absorbing coating.

4. Results of the researches

The effectiveness of laser hardening of automotive parts is influenced by various parameters of this process, including laser radiation power, processing speed and laser doping of the studied samples. Let us consider in more detail the influence of these laser processing parameters on the depth and microhardness of the hardened layers, which are directly related to the wear resistance of the corresponding parts.

Fig. 1 shows graphs of changes in the depth of the HAZ for iron-carbon alloys depending on the radiation power (absorbing coating - yellow gouache). In this case, only at P = 1.5 kW and v = 25 mm/s does surface melting occur, and hardening without melting is observed to a depth of up to 0.5 mm.

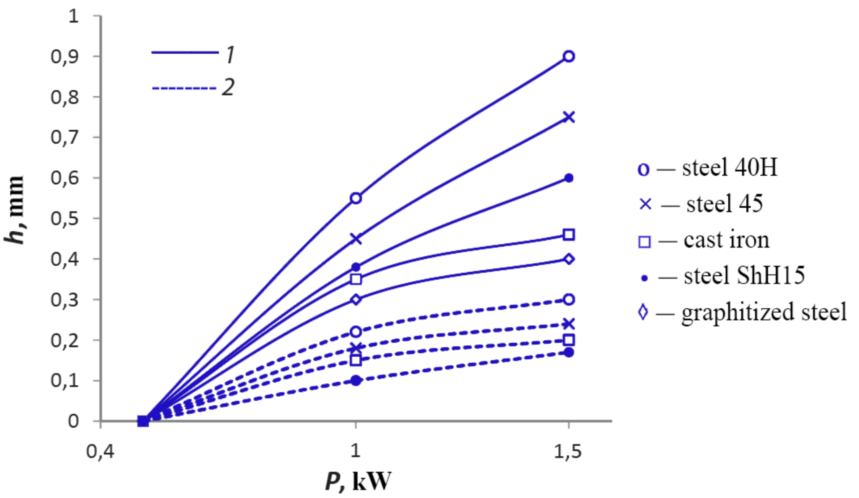

Fig. 1. Dependence of the HAZ depth on the laser radiation power at processing speeds v = 25 mm/s (1) and v = 83 mm/s (2)

With increasing processing power, the microhardness in the HAZ increases slightly (Fig. 2). This may be due to a more complete equalization of the carbon concentration and an increase in the size of the region with homogeneous martensite.

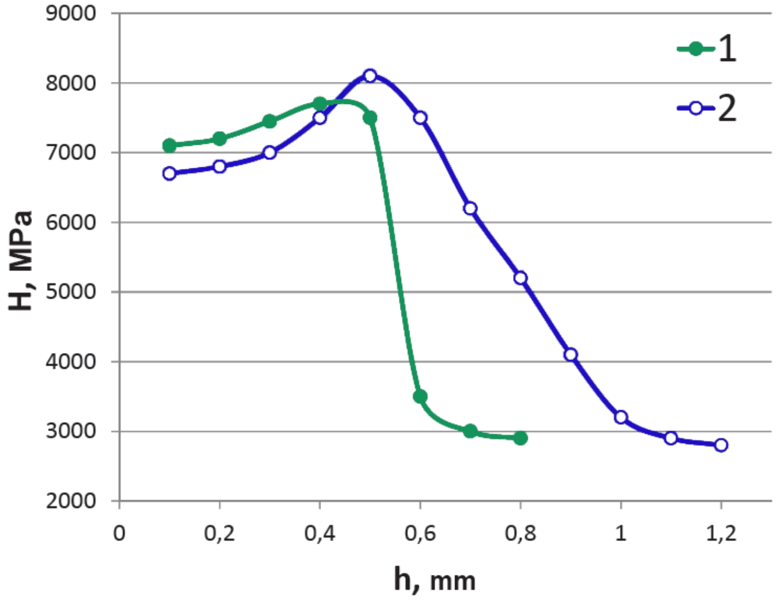

Fig. 2. Dependence of the microhardness of steel 45 on the depth of the HAZ during processing with laser melting with power P = 1 kW (1) and P = 3 kW (2)

The influence of laser processing speed on the microhardness of different layers of the HAZ of steel 35 is shown in Fig. 3. In the upper layers of the HAZ, in the processing speed range from 10 to 40 mm/s, melting of the steel surface occurred, and the microhardness in the melting zone continuously increased. With an increase in the processing speed (over 40 mm/s), melting disappears and the hardness of the steel increases to 6900 MPa. With a further increase in speed, the microhardness of the upper part of the HAZ decreases. In this case, martensite with a troostite network is formed in the surface layer. The microhardness of martensite in the lower layers of the HAZ continuously increases with increasing processing speed.

A particularly noticeable increase in the microhardness of martensitic areas is observed with an increase in speed to 46 mm/s, since with an increase in the processing speed, the diffusion redistribution of carbon between excess ferrite and pearlite slows down. As a result, at a high processing speed, martensite formed in place of pearlite can have a carbon concentration close to the eutectoid, which determines its high hardness.

In the heat-affected zone of pre-hardened and low-tempered steel 45, a homogeneous martensitic structure is formed. In the lower layers of the HAZ, a tempering zone with a size of 50...150 μm is formed on the border with the original structure, which has a reduced microhardness. The grinding of the original structure, which leads to the acceleration of austenitization during heating, is the reason for a significant increase in the homogeneity of the microstructure of the HAZ of hypoeutectoid steel.

It is also advisable to use surface alloying to achieve high wear resistance of the surface layers of automotive parts during their processing with a laser beam.

In the process of microalloying, an alloying substance is fed into the melt zone. In this case, the lower layers of the HAZ are heated without melting. It has been established that the HAZ will have the greatest hardness only after the transformation of martensite in the process of laser alloying. However, when alloying a certain area of the surface of the samples, the HAZ is tempered to the hardness of the original material, that is, under the alloyed layer there is a practically unstrengthened base.

The greatest influence on the process and the quality of the treated surface is exerted by the speed of movement of the laser beam or sample, the power of laser radiation, and the thickness of the coating during laser alloying.

The number of microalloying elements per unit volume of molten metal has a strong influence on the structures of the alloying zone. The content of alloying elements in the laser-affected zone tends to increase with increasing speed of movement of the laser beam or sample and decreasing radiation power. The increase in the content of alloying elements in the laser-affected zone occurs when the absorbing coating layer increases to a certain limit.

With an increase in the graphite concentration in the reflow zone during steel carburizing, the laser alloying zone changes. The surface layers show the structure of white cast iron obtained from the liquid phase.

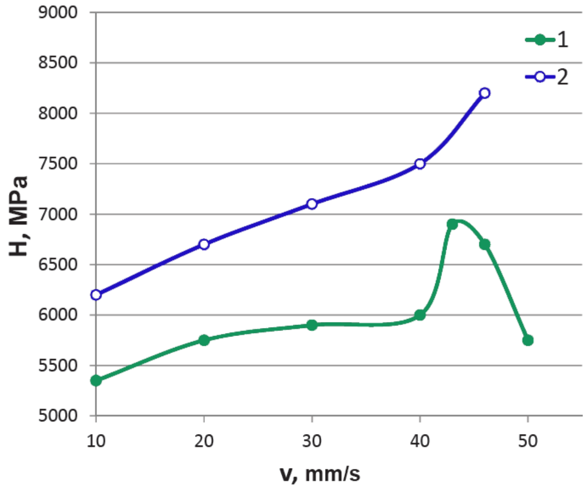

Fig. 3. Dependence of the microhardness of the upper (1) and lower (2) layers of the HAZ of normalized steel 35 on the laser processing speed

The structural components of the hardened layer include martensite and residual austenite. After laser boriding, the hardened zone consists of ferrite and borides Fe_2B and FeB. With an increase in the amount of boron in the alloyed zone, the ferrite content decreases, and the borides increase. A feature of this zone is that these phases are metallographically indistinct, and the needle-like structure characteristic of diffusion boride layers is absent. The alloyed zone has a granular structure. In this case, it is possible to increase the concentration of the alloying substance in the alloying zone in order to obtain new phases. From graphite-based pastes after laser cementation, zones consisting of cementite and inclusions of structurally free graphite were obtained. After laser boridation, the phases consisted of iron boride (FeB) and a phase based on boron.

The results of micro-X-ray spectral, metallographic, and X-ray structural analysis showed that the basis of this phase is one of the modifications of boron. Obtaining alloyed zones containing structurally free graphite, which acts as a solid lubricant, as well as high-hardness compounds based on boron and other metals, should contribute to increasing the wear resistance of the working layers. Phases with a special structure are formed, which determine some features of structural transformations in the laser alloying zones. The specified properties of the obtained surfaces can be obtained due to the removal of heat from the melt in a certain direction during the crystallization process. After laser cementation, the texture of cementite plates, which are located perpendicular to the direction of heat removal, is clearly observed. The texture of laser boride zones differs sharply from the texture of boride coatings obtained by solid-phase diffusion.

As a result of the action of the laser beam on the surface of the samples, their heating occurs with the simultaneous formation of tracks having different thicknesses, and, as a result, the formation of layers with different characteristics. When the surface of the melt is saturated with boron, the thickness of the laser tracks was in the range of 90...140 μm. The scale factor, which characterizes the ratio of the mass, shape of the sample, mode and area of treatment, determines the degree of influence of the surface temperature on the laser alloying process. This proves the need to optimize the laser alloying modes to obtain the required surface properties of a particular steel grade.

There is a need to study not only the distribution of microhardness in metal layers after laser alloying, but also wear resistance in different modes, metal brittleness. The wear resistance of laser boride layers is on average an order of magnitude higher than that of cemented laser layers. The brittleness of laser boride layers in all processing modes is lower than the brittleness of diffusion boride layers. Thus, laser boride should be used for parts subject to wear, with high specific loads and impacts.

Pulsed and continuous lasers can be used to alloy the surface of the part, but continuous laser installations are the most promising for industrial applications, which have higher productivity. These differences determine the peculiarities of the formation of the structure and properties of alloyed zones obtained on continuous lasers.

Thanks to laser microalloying of surface layers with chemical elements and compounds, the effect of strengthening various materials is achieved. Carbide, oxide, boride phases in the composition of absorbing coatings have the highest wear resistance. However, when choosing a laser alloying mode, it is necessary to take into account such factors as the condition of the treated surface, the microstructure of the metal, its composition, as well as the temperature factor. The most promising for this purpose are continuous lasers.

An increase in the microhardness of the laser-affected zone of steels, even with a small filling with alloying elements, is observed in medium-carbon steels. When processing 40H steel, the laser melting zone has a much higher microhardness than in 45 steel. This indicates the feasibility of introducing alloying elements both into the steel base and through the surface layer of the treated sample.

The results of the study of the influence of strengthening impurities of boron carbide and tungsten carbide in the absorbing coating (yellow gouache) are presented in Fig. 4 and Fig. 5.

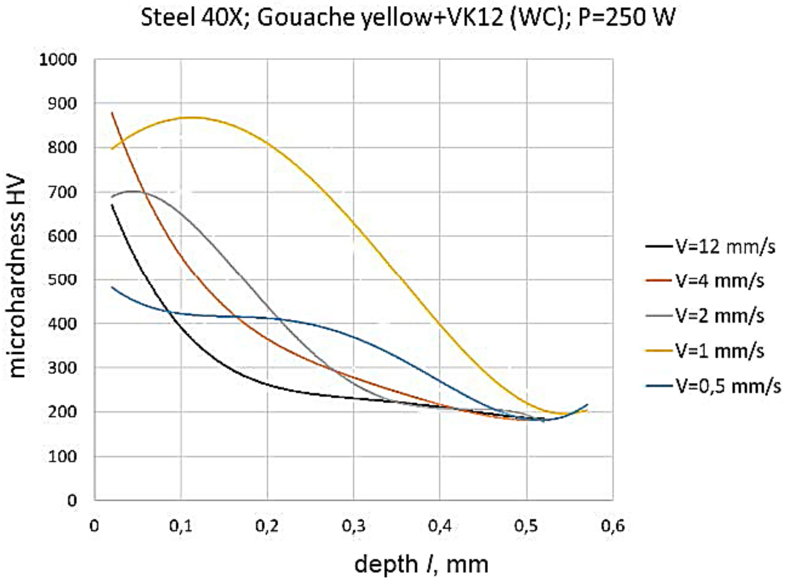

Fig. 4. Change in microhardness HV according to zone depth and laser processing speed when using gouache yellow + VK12 coating

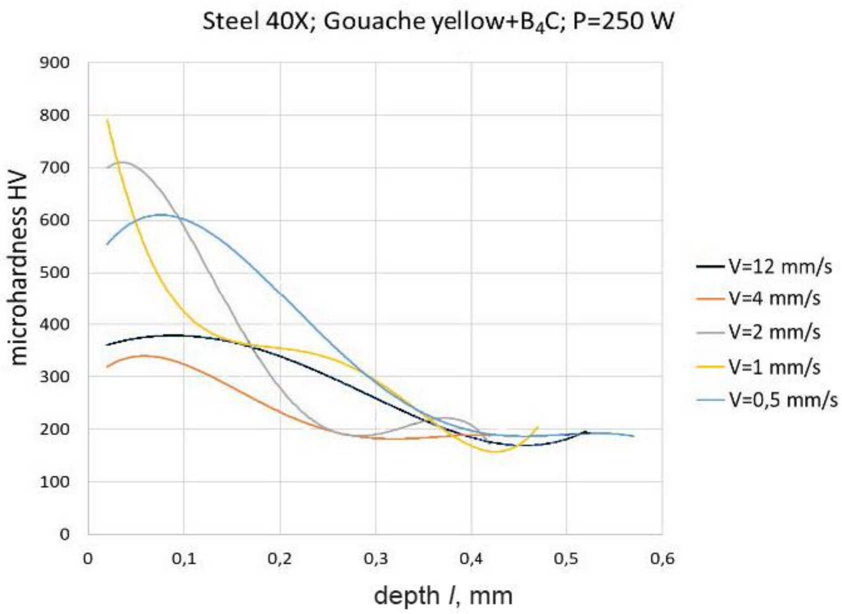

Fig. 5. Change in microhardness HV with zone depth and laser processing speed when using yellow gouache + B_4C coating

The highest microhardness of the surface zones of the processed samples can be achieved by using an admixture of tungsten carbide at a processing speed of V=1 mm/s.

Laser thermal hardening of steels can also be used to increase the wear resistance of the surface of parts operating under friction conditions. Special structures in certain layers during laser processing of the surfaces of parts can be obtained only by using highly concentrated energy sources, which are lasers.

Laser processing of samples made of 40H steel significantly increases wear resistance compared to typical hardening and tempering. Laser processing of samples made of 40H steel with a continuous CO_2 laser without surface melting increases the fatigue strength of the steels.

5. Conclusions and prospects for further research

The results obtained showed that with increasing laser processing power, the microhardness in the hardening zone increases slightly. Only at P = 1.5 kW and v = 25 mm/s does surface melting occur, and quenching without melting is observed to a depth of up to 0.5 mm.

The microhardness of martensite in the lower layers of the HAZ of steel 35 increases continuously with increasing processing speed. In the upper layers of the HAZ, up to a processing speed of more than 40 mm/s, the microhardness also increases to 6900 MPa, and with a further increase in speed, it decreases.

As a result of studying the influence of strengthening impurities of boron carbide and tungsten carbide in the absorbing coating (yellow gouache), it was found that the highest microhardness of the surface zones of the treated samples can be achieved by using a tungsten carbide impurity at a processing speed of V = 1 mm/s.

Therefore, iron-carbon alloys used by domestic manufacturers of motor vehicles can be effectively subjected to laser processing, which will allow for a significant increase in the operational characteristics of the relevant parts.

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ДОСЛІДЖЕННЯ ЛАЗЕРНОГО ЗМІЦНЕННЯ ДЕТАЛЕЙ АВТОМОБІЛЬНОГО ТРАНСПОРТУ В АПК

Під час зміцнення лазером різних деталей автомобілів важливим фактором впливу на їх ресурс виробітку є глибина зміцнення та мікротвердість, які залежать від параметрів поверхневої лазерної обробки. Вдалий підбір параметрів процесу лазерного зміцнення, застосування лазерного легування може забезпечити значне підвищення експлуатаційних характеристик оброблюваних деталей автомобільного транспорту в АПК. Метою роботи було визначення залежності глибини та мікротвердості поверхневих зон досліджуваних зразків із залізовуглецевих сплавів від таких параметрів лазерної обробки, як потужність лазерного випромінювання, швидкість обробки та застосування їх лазерного легування з використанням зміцнюючих домішок карбіду бору і карбіду вольфраму у поглинаючому покритті.

У результаті досліджень встановлено, що при збільшенні потужності лазерної обробки мікротвердість у зоні зміцнення дещо збільшується. Лише при Р = 1,5 кВт і v = 25 мм/с має місце оплавлення поверхні, а гартування без оплавлення спостерігається на глибину до 0,5 мм. Мікротвердість мартенситу у нижніх шарах ЗТВ сталі 35 зі збільшенням швидкості обробки безперервно зростає. У верхніх шарах ЗТВ до швидкості обробки понад 40 мм/с також мікротвердість зростає до 6900 МПа, а при подальшому збільшенні швидкості – знижується.

Отримані результати дослідження впливу зміцнюючих домішок карбіду бору і карбіду вольфраму у поглинаючому покритті (жовта гуаш) показали, що найвищої мікротвердості поверхневих зон оброблюваних зразків можна досягти шляхом використання домішки карбіду вольфраму при швидкості обробки V=1 мм/с.

Встановлено, що використовувані вітчизняними виробниками автомобільного транспорту залізовуглецеві сплави можуть ефективно піддаватись лазерній обробці, що дасть змогу забезпечити значне підвищення експлуатаційних характеристик відповідних деталей.

Ключові слова: *лазерне зміцнення, гартування, мікротвердість, лазерне легування, деталі автомобільного транспорту в АПК.*

Рис. 5. Літ. 12.

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