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APPLICATION OF LASER ALLOYING AND THERMOCYCLING AS MEANS OF FORMATION OF WEAR RESISTANT BORIDE COATINGS

The paper focuses on the investigation of formation of boron-based coatings using methods of laser alloying and laser thermocycling as a surface heat treatment method. The results of investigation of borated diffusion coating phase composition are listed. It was investigated the microhardness distribution in the coating from the top to the bottom. The results of tribotests using disc-on-disc method promise high reliability of the coating.

Key words: *laser treatment, alloying, wear resistance, hardness, thermocycling*

Introduction. Recent years developments in the area of surface modification propose a great variety of coatings, including DLC, with high wear resistance and service life. This is good for advanced engineering products, and is also cost efficient. But, if it concerns to restoration of conventional products, and reinforcing of working surfaces of general quality metallurgical equipment, the newest methods are not so effective.

A very good serviceability is demonstrated by steel products with diffusion-saturated strengthening by boron. But, the results of previous investigations do not give any universal answer on the question about phase composition of borides in steel surface. Especially of it concerns the application of laser-aided methods for technology improvement.

The task of investigation. At recent times the laser alloying becomes a very promising method of surface treatment and modification. It allows to broadly changing chemical composition, structure and the properties of the surface layer [1; 2]. Significant strengthening effect is achieved after the surface layer is diffusion saturated by boron atoms, as far as chemical compounds with high hardness FeB and Fe_2B are formed. This also provides high wear resistance [3; 4].

Current work is devoted to investigation of forming of wear resistant surface layers by introduction into them of Boron-contained components at laser remelting and following laser thermal cycling. This technology includes the preparation of the surface, application of a special paste with carefully balanced composition, and remelting of thin surface layer by laser beam. The treatment was done for two materials: high carbon eutectoid steel AISI 1080 and steel type 321. The used pastes contained one or a combination of the following components: amorphous boron, boron carbide.

Equipment and procedure. Laser treatment and thermal cycling was done in a temperature range 1273 ↔ 873 K, which includes the region of polymorphic transformation. For this porpoise we used the «LATUS-31» installation. The laser beam power –1,2 kW.

Metallographic investigation was done by the use of «Neophot-32» microscope with magnification ×240…1000 in dark and light fields. The microsections etching was done using 3%-solution of Iodine in water, and also the electrolytic etching in 10% water solution of chromic acid. The phase composition was investigated by the x-ray analyses using diffractometer «DRON-3» in the irradiation of cobalt anode. The distribution of alloying elements in the surface layer was analysed with the help of microanalyzer «Camebax SX50».

To determine the microhardness and microbrittleness of the coating we used the hardness tester M-400 of «Leco Corporation» with auromatic loading mechanism. The indenter loading varied in a range of 0,2…1,0N. For tribotests we used the ring-on-ring method with no lubrication. The specific loading was 1-3 MPa, sliding speed 0,1—1,9 m/sec, temperature 293K. Friction path 1000 m. As counterbody material we used carburized AISI 5115 alloy steel with hardness HV 650-700.

Results and discussion. Studies have shown that as a result of laser alloying on the surface of the samples in all cases the following areas are formed: alloyed area, heat-affected zone and base material. The alloyed layers have eutectic structure on the basis of system Fe – B – C. The nature of this structure, the degree of non-equilibrium depends on the mode of laser processing. Thus, changing the processing modes we can set a coarse dendritic structure and structure representing extrafine differentiated eutectic-reinforced phase mixed with supersaturated solution of boron in iron (Fig. 1). The reinforced region consists of two zones: a bottom with crystallized columnar structure of borides, and the upper, formed by fine constituents, which are usually can't be etched by common etchants. This structure is capable to uniformly distribution of frictional load in the volume of viscoelastic matrix and localizes plastic deformation in the surface layers.

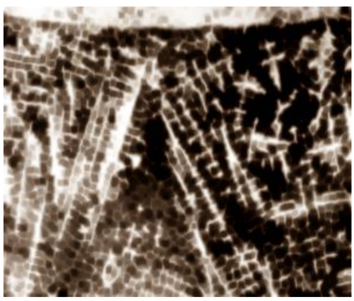

Fig. 1. The microstructure of AISI 1080 steel after laser-aided borating and thermocycling (4 times), ×500

Proceeding from the analysis of the components of the paste and the phase diagram of Fe-B-C system, in the hardened layer we can expect the presence of mainly borides, carboborides and iron-based solid solutions. Since the conditions of alloying are not equilibrium, the formation of met stable phases is possible. As follows from the results of X-ray analyses of surface layers of steel 1080, the additional thermal cycling eliminates the $Fe_{23}(C,B)_6$ phase and instead of it a boride Fe_2B appears.

The character of change of concentration of chemical elements in-depth of the coating makes it evident thet the concentration of carbon and boron increases in the surface layer (1,5% and 2,2 % respectively) and gradually decrease in lower layers. The pure iron content is about 86%. It is determined, that the boron is present only in alloyed region, which was fully melted at treatment of the steel. In the thermal affected zone boron is not detected. We also have discovered that thermal cycling increases the uniformity of boron distribution in the steel, the layer thickness is increased. This high intensity of diffusion processes is assisted by polymorphic transformations α-γ-α [5; 6]. The modes of treatment and the phase composition of surface layers is shown it table.

Table

The modes of laser treatment

Surface treatment	Phase composition
Alloying	α-Fe, FeO, $Fe_{23}(C,B)_6$, $Fe_3(C,B)$, FeB
Alloying + thermocycling	α-Fe, FeO, $Fe_3(C,B)$, FeB, Fe_2,B

The microhardness if modified zones may vary in a wide range (9000-12000 MPa), what is shown on fig. 2.

It should be noted that after thermocycling microhardness increased somewhat, and its depth distribution layer is of a uniform character with plasticity of hardened zone increases. This is indirectly confirmed by the fact that to measure microbrittleness of boron-containing layer after thermal cycling (four times) by a standard method failed because of cracks near the indenter were not observed even at a load of 10N. The reason for this, apparently, is accompanying thermal cycling processes of stress relaxation and refining of phase components

This combination of properties and structural peculiarities makes material much more wear resistant. Also, gradual decrease of hardness in depth of diffusion coating decreases the probability of its exfoliation under variable external loading and especially in the impact mode. The lower zone is an effective dumper of external energy. The surface layer of the steel after four times reheating without melting in the range of temperatures, that are in the range of temperatures of polymorphic transformation increases the tribological properties of modified surface layer.

The results of wear test under described test conditions (fig. 3) it is clearly seen that the wear resistance of steel after laser treatment and diffusion coatings which were deposited with the help of laser beam. The analysis of the wear track shows the absence of deep irregularities on the surface. It is fully covered by the thin and dence oxide film. This is the evidence of mechano-oxidation normal mode of wear. The microwelding was not detected by the analyses.

This figure demonstrates the advances of laser-aided alloying against the conventional diffusion saturation of steel by boron. The best result is achieved when the surface is laser-aid alloyed by boron with subsequent laser thermal cycling in a range of temperatures of polymorphic transformations.

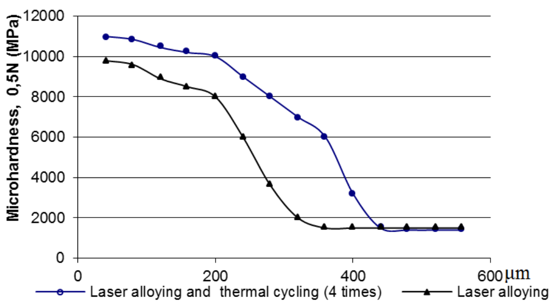

Fig. 2. Change of microhardness of the modified layer

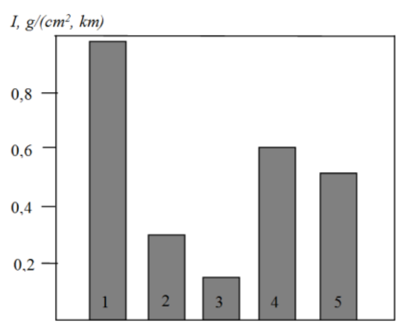

Fig. 3. The intensity of wear of various hardened coatings: *1* – hardened steel; *2* – borating; *3* – borating+ laser melting; *4* – boron alloying; *5* – boron alloying + thermocycling

Conclusions. It was experimentally proved that laser alloying by boron significantly increases wear resistance of alloy and carbon steels. The additional laser-aided thermal cycling increases the microhardness of surface layer, increases the thickness of strengthened metal, and allows getting more uniform distribution of boron in the steel. Together with good tribological properties these coatings are not subjected to cracking and fallout and may be recommended to wear application for elements working at sliding friction with no lubricant.

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МЕЙСАМ ХАГЕРІЗАДЕ

ЗАСТОСУВАННЯ ЛАЗЕРНОГО ЛЕГУВАННЯ І ТЕРМОЦИКЛЮВАННЯ ДЛЯ ОТРИМАННЯ ЗНОСОСТІЙКИХ БОРИДНИХ ПОКРИТТІВ

Наведені результати досліджень особливостей формування покриттів на основі бору методами лазерного легуванні і термоциклювання. Досліджено фазовий і хімічний склади зміцнених шарів, наведено оцінку їх мікротвердості і зносостійкості.

Ключовы слова: лазерна обробка, легування, зносостійкість, твердість, термоциклювання.

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