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IMPROVEMENT OF THE PHYSICOMECHANICAL PROPERTIES OF GASTHERMAL COATINGS OF AN Fe–Cr–B–Si SYSTEM BY LASER DOPING

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The influence of the regimes of laser treatment of gasthermal coatings of iron-based powders after fusion with modifying dopes on their microhardness and microstructure has been investigated. The conditions of production of coatings with the most uniform distribution of dopants have been revealed.

Working out new methods of surface hardening with the use of laser radiation is a promising trend in the development of modern technologies. The appearance of new mass-produced, high-power laser units has created prerequisites for a wide application of lasers in production.

The existing methods of improvement of the wear resistance of working surfaces in many cases solve the problem of ensuring the required level of service properties. However a number of problems in this field, as previously, remain topical for hardening and restoration of bulk and long-dimension components and components of complex shape.

Traditional nickel-based self-fluxing alloys are widely used as the materials of coatings subjected to laser fusion [1, 2]. The coatings obtained possess high physicomechanical and service characteristics which allow reliable operation of the hardened or restored components under the conditions of wear in boundary friction or lubricated friction, but a substantial drawback of such coatings is their high cost. Therefore, it has been proposed that iron-based self-fluxing powders be used.

The composite character of the structure is responsible for its high wear resistance [3]. The alloys of an Fe–Cr–B–Si system possess structural sensitivity to energy action and alloying additives. Laser modification enables one to accurately measure the supply of energy and dopants, while the character of the structure obtained determines the quality of the hardened layer. Not only does additional introduction of borides and carbides into the alloy help improve to a large extent the service characteristics but it also helps vary the physicochemical properties of the coatings obtained [4].

This work seeks to study the influence of the parameters of laser treatment and additional doping on the formation of the structure and the microhardness of powders of an Fe–Cr–B–Si system.

Investigation Procedure. We carried out investigation on ∅ 50 mm specimens of 40Kh steel. A self-fluxing alloy of PR-Kh4G2R4S2F powder (the basic components of the chemical composition are given in Table 1) was used as the material for spraying.

The sublayer was applied to the surface by the method of plasma spraying with the use of a UPU-3D unit with an IPN-160/600 power supply and a PP-25 plasmatron in the regimes I = 250 A, U = 80 V, and p = 0.6 MPa. The layer thickness was 0.6 mm.

The doping elements were applied to the surface of plasma-sprayed coatings in the form of B_4C, TaB, and MoB powder dopes on adhesive binder (3% AGO adhesive in acetone) [5]. The thickness of the dope layer was 0.09–0.11 mm and it was monitored by an MT-40NTs thickness gauge. Fusion was carried out with an LGN-702 continuous laser of power N = 800 W for a diameter of the laser beam of $d = 3.0 \cdot 10^{-3}$ m with velocities of travel of $V_1 = 0.83 \cdot 10^{-3}$ m/sec, $V_2 = 1.67 \cdot 10^{-3}$ m/sec, $V_3 = 3.33 \cdot 10^{-3}$ m/sec, and $V_4 = 5 \cdot 10^{-3}$ m/sec with an overlap coefficient of 0.8 for obtaining a single phase composition and prescribed properties over the entire thickness of the coating.

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TABLE 1. Chemical Composition of the Sublayer

Grade of powder	Chemical Composition, %								
	Fe	B	Cr	Si	Mn	C	V	Al	Cu
PR-Kh4G2R4S2F	83.1–87.6	3.3–4.3	3.5–4.5	2.0–2.5	2.0–2.5	1.0–1.2	0.5–0.9	0.05–0.5	0.05–0.5

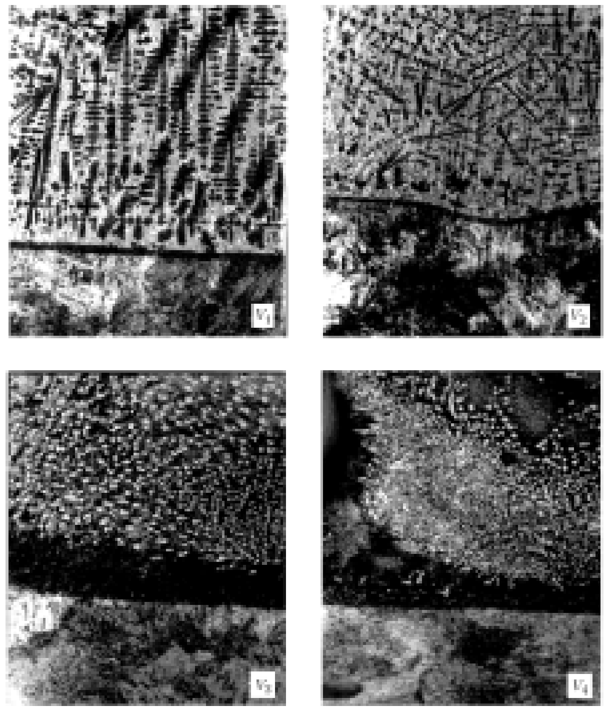

Fig. 1. Microstructure of coatings obtained by fusion of PR-Kh4G2R4S2F powder without a dope for different velocities of motion of the laser beam.

After the spraying and fusion the specimens were cut across the laser tracks so as to eliminate the influence of the instability of temperature conditions of heating and cooling at the edges of a specimen.

The microsections were etched in a 5% alcohol solution of picric acid and then in a 5% alcohol solution of nitric acid.

The specimens etched were studied with a Unimet light metallurgical microscope (Japan) with a ×400 magnification.

Investigation Results and Their Discussion. The presence of the iron matrix in all the specimens was responsible for the same regularities of the influence of laser-treatment regimes on the character of formation of the structure for all the compositions.

Figure 1 shows the structures of laser-fused coatings without dopes for different velocities of motion of the laser beam.

The coatings obtained possess mainly a cast structure with the axes of dendrites of first, second, and third orders. As the time of stay in the melt increases, the structure becomes larger. The increase in the velocity of motion of the laser beam decreases the crystallization time of the coatings; the carbide-boride phase is isolated in the form of a quasieutectic.

The same tendency has been established in the coatings without dopes and TaB-, MoB-, and B_4C-doped coatings.

Variation of the velocities of motion of the laser beam in B_4C doping of a coating leads to such structural changes as V_1 (a cast equilibrium structure is observed) and V_2 (a dendrite structure is formed). As the velocity increases to V_3, we observe a supersaturated boride and carbide-boride structure which is reduced in size for V_4.

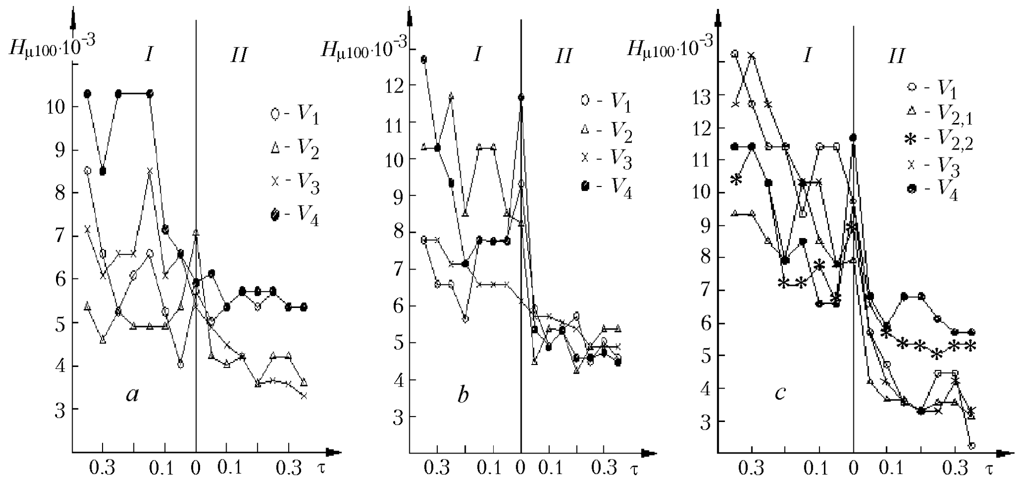

Fig. 2. Microhardness of coatings (I) and base (II) fused by a laser beam for N = 800 W and d = $3.0 \cdot 10^{-3}$ m with different velocities of its travel and doped with MoB (a), TaB (b), and B_4C (c) ($V_{2,1}$ and $V_{2,2}$ are respectively for the microhardness measured at the edges of the B_4C-doped layer and at the center of it).

The increase in the laser-beam velocity influenced the structure of the TaB-doped coating in the following manner: a cast equilibrium structure with individual patches of the dendrites of a solid solution is noted for V_1; for V_2, we have a dendrite structure which is reduced in size with increase in the velocity to V_3; a supersaturated boride structure is formed for V_4. As the laser-beam velocity increases, the melting time of the coating decreases. As a result, a supersaturated solution is formed out of which the borides precipitate when the coating cools down.

In the MoB-doped coating, a large dendrite structure is formed for V_1; this structure is reduced in size as the laser-beam velocity increases. The finest dendrite structure is observed when the velocity of motion of the laser beam attains V_4. The presence of the dendrite skeleton in the structure of the coatings must, apparently, contribute to an improvement of their wear resistance. We have established a regularity shared by the three kinds of dopes. When the laser-beam velocity V_1 is the lowest, the coating is under the conditions of laser heating over a fairly long period. This leads to the equalization of the rate of crystallization of the carbide and boride phases of the α solid iron solution. The coating is totally melted to form a cast structure.

The increase in the velocity to V_2 in the B_4C-doped coatings causes the formation of a dendrite structure, while in the TaB- and MoB-doped coatings the dendrite structure is reduced in size.

In all the coatings in question, the increase in the laser-beam velocity to V_3 leads to further reduction of the dendrites in size.

Further increase in the laser-beam velocity to V_4 reduces the melting time of a coating. A supersaturated solid solution is formed out of which borides and carbides precipitate.

Doping with TaB, MoB, and B_4C does not, in fact, change the picture of a bimetallic coating. This suggests that additional introduction of dopes apparently dopes the iron-based solid solution and to a lesser extent influences the amount of the carbide-boride phase.

Microhardness was measured with a PMT-3 microhardness gauge on etched cross microsections in the coatings, the transition zone, and in the base material.

The analysis of the change in the microhardness as a function of the velocity of travel of the laser beam (Fig. 2) has shown the following dependences.

For the MoB-doped coatings the microhardness increases with the velocity of motion of the laser beam and attains its maximum (10.3 GPa) for V_4. It ranges from 5.72 to 10.3 GPa. The large spread in microhardness suggests the heterogeneity of the structure. As the velocity of motion of the laser beam increases to V_3, the microhardness distribution becomes more uniform and is 6.1–8.51 GPa. Fine dendrites thread the entire surface of the coating all the way through, which suggests the improved wear resistance.

In the TaB-doped coatings, the tendency toward changing the microhardness is preserved, and it attains its maximum (17.2 GPa) for V_4. At the same time, we have noted a large spread in microhardness (7.15–12.72 GPa) for this velocity. This suggests a nonuniform distribution of the doping elements over the coating area. For the velocity V_3 we observe a dendrite structure with a more uniform distribution of the microhardness (6.6–7.2 GPa).

For the B_4C-doped coatings the largest microhardness is attained for the velocity V_1, and it ranges from 9.74 to 14.26 GPa. The carbides have the shape of needles threading the entire coating. Optimum for this kind of coatings is the velocity V_2, for which a spread in microhardness of 6.57–9.34 GPa is observed; the microstructure is represented by fine dendrites.

CONCLUSIONS

1. The parameters of the laser beam and the introduction of dopes exert a large influence on the microhardness and structure of the coatings obtained. The structure of the modified coatings changes from the cast equilibrium type to a fine quasieutectic structure.

2. The strongest influence on the increase in the microhardness is exerted by doping of the coatings with boron carbide.

NOTATION

d, diameter of the laser beam, m; $H_{\mu 100}$, microhardness of the coatings, which is measured with a load of 100 g on the indenter, GPa; I, arc current in plasma spraying of coatings, A; U, electric arc voltage in plasma spraying, V; p, pressure of plasma-forming gases in spraying, MPa; N, power of the LGN-702 laser unit, V; V_1–V_4, velocities of motion of the laser beam, m/sec; τ, length of the coating and the substrate, μm.

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