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SURFACE ALLOYING OF ALLOY AL25 BY LASER

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The literature at present deals fairly extensively with questions of laser alloying of iron-carbon alloys. The special features of strengthening aluminum alloys by introducing alloying elements into the surface layer with the aid of laser radiation were investigated much less. The authors of [1, 2] presented the results of investigations into the possibility of alloying aluminum alloys with the aid of pulsed laser radiation.

The object of the present work is the investigation of the peculiarities of structure formation in the surface layer of alloy AL25 when it is alloyed with wear-resistant compositions with the aid of a continuous CO_2 laser, and the discovery of the basic possibility of carrying out the process of laser alloying of the grooves for the compression rings in pistons of internal combustion engines made of this alloy.

Specimens with 90-mm diameter of alloy AL25 (12% Si, 1.1% Mg, 1.3% Cu, 1.0% Ni) [3] with initial structure of α-solid solution and eutectic (Fig. 1a) were treated by CO_2 lasers with power density $4 \cdot 10^3$–10^4 W/cm²; the specimen was shifted at a speed of 0.1–0.5 m/min. The treatment was carried out in an atmosphere of protective gases. The structure of the alloy in the initial state and after laser alloying was investigated on microscopes MIM-8 and "Neophot." The distribution of the alloying elements was determined on a scanning electron microscope JSM-35 with an attachment for x-ray spectroscopic analysis. Microhardness was measured on an instrument PMT-3 with a load of 0.196 N.

For alloying we used powders on the basis of NiCr, FeCuB, NiCrMo which, in the form of coatings, were applied to the surface of the aluminum alloy, and then they were fused with the aid of laser radiation.

In consequence of the high cooling rate in crystallization, the α-solid solution and the eutectic become refined in the fused layer, a finely disperse structure forms (Fig. 1b). Moreover, the addition of alloying elements to the surface layer leads to the formation of metastable solid solution supersaturated with the added elements [4]. As a result the

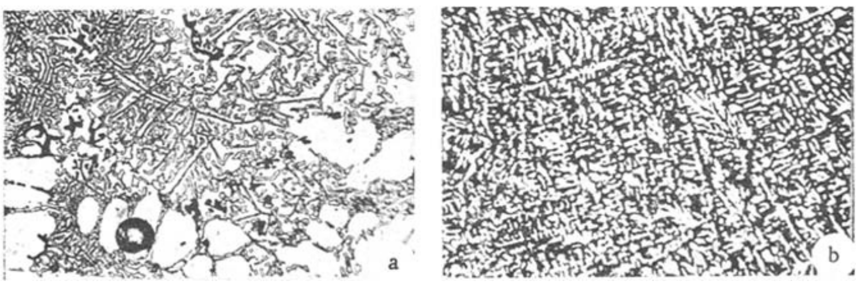

Fig. 1. Microstructure of the alloy AL25 in the initial state (a) and after laser alloying with nickel and chromium (b). ×200.

Scientific and Production Association "NIITavoprom." Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 5, pp. 24-25, May, 1988.

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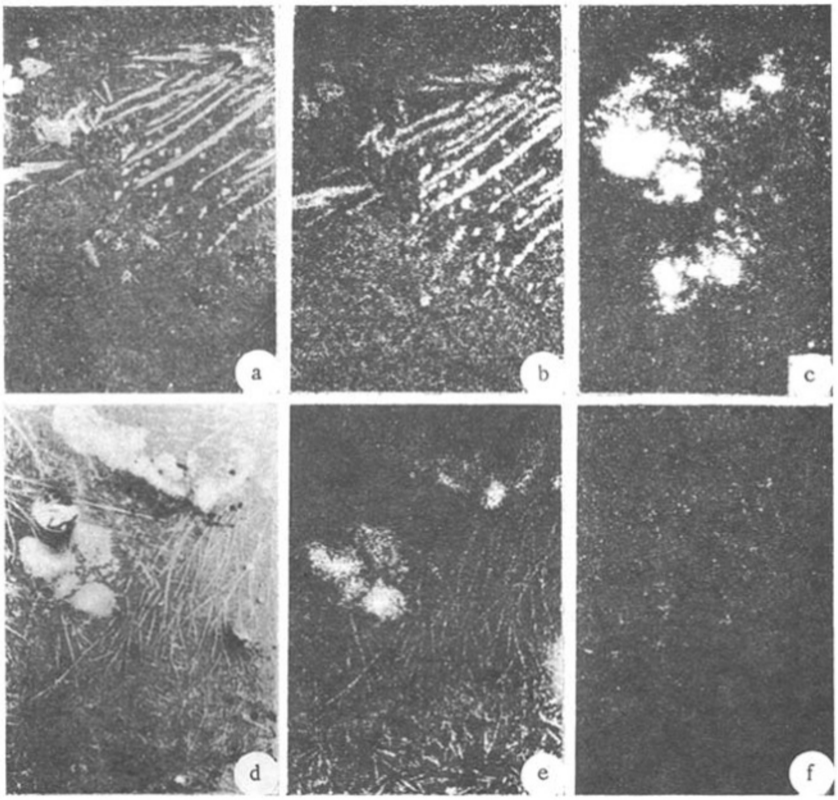

Fig. 2. Scintigram of the near-boundary layer of the alloy AL25 alloyed with nickel, chromium (a-c) and with iron, copper, boron (d-f) (×130): a, d) in absorbed electrons; b, c, e, f) in nickel, chromium, iron, and copper K_α radiation, respectively.

microhardness of the treated zone increases. For instance, in alloying with NiCr it amounts to H 130-140, in alloying with FeCuB to H 105-120, in alloying with NiCrMo to H 140-150 (the initial microhardness of α-solid solution was H 60-65, of the eutectic H 70-80). The distribution of microhardness across the fused layer is uniform.

The results of the investigation of the distribution of Ni and Cr (Table 1), and also of Fe in the modified layer showed that the distribution of the alloying elements is uniform. The layer alloyed with NiCr contains 1.0-1.3% Cr, when Mo is added to the layer the content of Cr increases all in all to 2%. Thus the addition of the expensive Mo is not always justified because the increase in content of the strengthening addition in the layer is negligible.

On the boundary of the laser-treated layer with the matrix there is some nonuniform increase in concentration of the alloying elements on account of the presence of segregations with different configuration.

Electron microprobe analysis of the segregations (Fig. 2a-c) in alloying with NiCr showed that the acicular segregations contain chiefly Ni, and the round ones Cr; we also encountered segregations with variable composition (20-30% Ni and 50-60% Cr). It is obvious that in consequence of the very high speeds of mass transfer and of mixing of the melt, the particles of the alloying powder are thrust to the boundary with the matrix in consequence of the convective fluxes, and also as a result of the higher specific weight, they are partly fused and crystallize either in the form of needles with predominant content of Ni or in the form of round particles with predominant content of Cr. Microanalysis of the segregations accompanying the alloying with FeCuB showed that iron is distributed in the layer in the form of needles and segregations with round shape, copper is uniformly distributed (Fig. 2d-f).

The addition of large amounts of alloying substances leads to the cumulation of conglomerates of segregations with variable composition and different configuration on the boundary with the matrix, and this is associated with the limited solubility of the alloying

TABLE 1

Distance from surface, mm	Content of elements in zone of treatment, %	
	Ni	Cr
0,3	6	1,3
0,6	4	1,1
0,9	4	1,1
1,2	4	1,0
1,5	4	1,0
1,8	4	1,0
2,1	4	1,0
2,5	5	1,2
3,0	5	1,2
Base	1	—

TABLE 2

Material	Hardness HB at	
	20 °C	270 °C*
Alloy AL25 without laser treatment	70—80	34—46
Alloy AL25 after laser treatment	105—108	54—60
Alloy AL25 alloyed with NiCr	130—140	92—94
Alloy AL25 alloyed with FeCuB	105—120	72—80
Alloy AL25 alloyed with NiCrMo	140—150	94—96

*The operating temperature of the piston in the zone of the upper compression groove.

elements in the material of the matrix. The presence of colonies of coarse segregations on the boundary with the matrix may lead to the formation of cracks and spalling of the layer. A uniform layer with improved mechanical properties can be obtained by introducing alloying additions into the zone of treatment in amounts determined by the limit of their solubility in the base metal.

Table 2 presents the results of measurement of the hot hardness of alloy AL25 before and after laser alloying.

Together with the investigations carried out on specimens we also applied laser alloying to pistons of the engine UMZ-414M in the region of the upper groove. The results of bench tests of pistons alloyed with NiCr showed that their resistance was 3-3.5 times greater than the resistance of ordinary pistons. Therefore, to improve the wear resistance of carburetor engine pistons made of aluminum alloys, it is recommended to alloy their grooves with the aid of laser radiation.

Conclusions. 1. Alloying the alloy AL25 with the aid of laser radiation helps refine its structure and increase its hardness.

2. The distribution of alloying elements in the fused layer is uniform and does not depend on the amount of added elements.

3. A uniform layer with good physical and mechanical properties can be obtained by enriching the surface layer with alloying additions in amounts determined by the limit of their solubility in the matrix of the base metal.

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