Laser surfacing of copper-based alloys on steel

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Abstract. The paper presents metallographic studies of samples and the results of tribological tests of coatings. It is shown that the friction coefficients of powder coatings based on copper deposited by a laser beam are 2-3 times lower than those of samples made of bronze rods BrAZh 9-4 and brass L63. The influence of transverse beam oscillations on the quality and performance of the surfacing process is investigated. It is shown that at a beam scanning frequency of 217 Hz, the surfacing performance increases by 1.56-1.7 times

1. Introduction

Production of products from copper and its alloys leads to significant economic costs, and in some cases it is simply impossible because of the low tensile strength of copper and alloys. To reduce the consumption of copper alloys, they can be made by surfacing copper alloys on steel. The experiments were carried out using a diode laser with a power of up to 1600 watts. [1]. Bronze powder Cu15Sn0,4P with particle sizes 150 - 180 microns was selected for surfacing. Alloy steel AISI 4340 was used as a substrate. The laser beam was focused using a lens with a diameter of 50 mm and a focal length of 250 mm. A laser spot with a diameter of 3 mm was formed on the substrate surface. Single tracks were deposited at a laser power of 1000 W, a beam travel speed of 10 mm / s and a powder consumption of 24 g / min. The average radiation power density was 142 W / mm². The width of a single surfaced track was 3 mm at a height of 0.8 mm. Surfacing of the sample surface was performed with an overlap coefficient of 66%. The hardness of the bronze coating HV 172±12 and it is higher than that of phosphorous bronze 100 HB or 110 HV. The hardness of the heat affected zone, up to 0.5 mm thick, was 630±50 HV, which is significantly higher than the hardness of alloy steel (335±40 HV).

Laser surfacing of samples of SAE1045 steel with dimensions of 40×30×8 mm was performed on a CO₂ - laser at a radiation power of 2 kW, beam velocities of 5, 9 and 13 mm/s, and a beam diameter of 3 mm [2]. A slip coating up to 1 mm thick containing Cu5Al powder and a binder was applied to the surface of the sample. At a processing speed of 5 mm/s, spherical iron particles are observed uniformly distributed in the surfacing zone, except for the dendrite structure located at the substrate. When the scanning speed increases to 9 and 13 mm / s, the dendrite microstructures disappear, the distribution of spherical iron particles becomes heterogeneous, and the electrical resistance of the deposited layer
decreases with increasing beam velocity.

The powder containing copper, nickel and tin in the proportion of 77:15:8 was mixed and applied in a uniform layer with a thickness of 1.2 mm on a steel plate Q235 with dimensions of 100×100×10 mm [3]. Surfacing was carried out by continuous radiation of a CO₂ - laser with a power of 2 kW, at a beam travel speed of 400 mm / min and a beam diameter on the sample surface of 4.5 mm. then the sample was aged at a temperature of 370°C for 30-480 min. The microhardness of the coating is twice as high after aging at 370 ° C for 2 hours and its maximum value is 390 HV. At the same time, the electrical resistivity of the coating decreases from 2.87×10⁻⁵ to 1.52×10⁻⁵ Ohms • cm.

A CO₂ - laser "Kometa-2" with a radiation power of 1 kW was used for surfacing aluminum bronze [4]. The power density was ~1.27 • 105 W / cm². 45 steel was used as a substrate. Single tracks and multilayer bronze surfacing for testing samples for friction and wear were applied at a beam travel speed of 100-300 mm / min and a nozzle distance above the surface of 10-14 mm. under friction test conditions without lubricant at surfacing speeds below 140-160 mm / min, the friction coefficient is stable 0.17-0.2 and significantly lower compared to cast aluminum bronzes.

Railway buffers during operation are in almost constant contact with each other and have significant wear, to reduce the intensity of wear buffer heads are covered with graphitized grease, but this method has many disadvantages. It is proposed to cover the buffer head with bronze using laser surfacing [5]. Aluminum bronze CuAl9Fe3 was chosen as the filler material. Laser surfacing was carried out using a robotic stand equipped with ABB industrial robots and a high-power diode laser HPDL LDF 4000-30 manufactured by LaserLine with a maximum output power of 4.0 kW. Base material S355J2 mild steel circle having a nominal diameter of 38.0 mm, the hardness of the deposited coating ranged from 178-189 HV0.2.

Samples with aluminum bronze layers (10 mg on average) and steel samples with lubricated surfaces (7.5 mg on average) showed the least wear. The wear of the samples was the same throughout the four series. Thus, it can be assumed that the use of aluminum bronze CuAl9Fe3 after laser surfacing will eliminate the need for lubrication during the operation of the rolling stock.

The purpose of the work is to determine the friction coefficients depending on the sliding speed and the influence of transverse oscillations of the laser beam on the mixing of the deposited charge with the base material and the surfacing performance.

2. Materials and equipment

The laser complex IMASH RAS was used in experimental studies [6]. Samples were made of steel 40Cr, dimensions 15 × 20×70 mm. for surfacing selected powders based on copper PR-BrAMts 9-2, PR-BrOS 10-1,5, PR-BrAZh 9.5-1, PR-L63 with a particle size of 40-150 microns. Radiation power P=700-1000 W, processing speed V=and 5-10 mm / s and beam diameter d=1-3 mm were chosen as variable parameters. beam scanning with fixed frequency f=217 Hz was considered as an additional factor. A resonant type transformer with an elastic element on which a mirror is fixed was used. Metallographic studies of the deposited coatings were carried out on the microhardness measurements on PMT-3M at a load of 0.98 N, metallographic microscope Altami MET 1C and digital microscope AM413ML. The structure and chemical composition of the deposited layers were studied on the scanning electron microscope TESCAN VEGA 3 SBH with the system of energy dispersion analysis using the modes of reflected and secondary electrons.

To determine the tribological characteristics of the deposited samples, a universal friction machine MTU-01 was used. The tests were carried out according to the scheme plane (deposited sample or sample of bronze BrAZh 9-4, brass L63) - ring steel 50 CrFA (51-55 HRC).The sliding speed and pressure on the sample varied discretely in the range of 0.1-2.7 m / s and 1-3 MPa, respectively. Transmission oil Tszp-8 was used as a lubricant.

3. Results of experiments and calculations

Laser surfacing of samples was performed with a defocused beam and transverse oscillations of the
beam normal to the laser processing velocity vector. For figure 1 (a and b) are micro-plates of deposited tracks with dimensions of 0.75×2.1 mm, hardness (181-208HV), and 0.68×3.38 mm-(204-224HV), obtained by a defocused beam and a scanning beam with a frequency of 217 Hz, respectively. The penetration zone of the substrate during processing with a defocused beam and a scanning beam was 380 and 150 microns, respectively. The cross-sectional area of a single deposited layer is 1.5 times larger when scanning the beam than when surfacing with a defocused beam.

For figure 2 (a,b) shows the fusion zone of the coating with the base and the chemical composition in the surfacing zone, in the transition zone and the base material. From the presented results it follows that when processing with a defocused beam in the deposited layer there is a higher iron content, which is a consequence of deeper penetration of the base.

Figure 1. Surfacing of bronze powder BR-BrAMc 9-2 on steel 40Cr×75: a-surfacing defocused beam, b-surfacing scanning with a frequency of 217 Hz beam

Figure 2. Areas of fusion of the coating and the base: a, c - surfacing defocused beam, b, d - surfacing scanning beam
When determining the friction coefficients, samples from bronze BrAZh 9 – 4 (115-126 HV) and brass L63 (129-138 HV) were used as standards. For figure 3 the dependences of the change of friction coefficients on the sliding speed are presented. As a counter-used steel 50CrFA. The hardness of the deposited coatings PR-BrOS 10-1, 5, PR-L63 (1), PR-BrAZh 9,5-1, PR-L63 (2) was respectively 169-178; 174-196; 179-208; 192-218 HV. Coatings PR-L63 (1) and PR-L63 (2) differed modes surfacing.
Figure 3. Dependence of coefficients of friction on sliding speed: samples from rods – a - BrAZh 9-4, b - L63, samples with laser surfacing – c - PR-BrOS 10-1, 5, d - PR-L63 (1), e - PR-BrAZh 9,5-1, g - PR-L63 (2)

The analysis of dependences of coefficients of friction showed that at the samples made of a bar material, coefficients of friction at small sliding speeds of 0.23 m/s are 2-3 times higher, in comparison with the deposited coverings with use of powders of bronze and brass. At a sliding speed of 1 m/s, bronze samples have a coefficient of friction 2 times higher than laser-deposited coatings, and brass samples have close values of the coefficient of friction with coatings. A sharp increase in friction coefficients in bar bronze and brass was observed at a sliding speed of 1.32 m / s, and for deposited coatings PR-L63 (1), PR-BrAZh 9.5-1, PR-L63 (2), PR-BrOS 10-1, 5, respectively, at sliding speeds of 1, 62, 2.05, 2.79 m/s. As a result of the increase in the coefficient of friction, the friction pair was grasped and the tests stopped.

It was found that the cross-sectional area of the deposited track by the scanning beam is 1.56-1.7 times larger than by the defocused beam under the same treatment modes.

Laser surfacing of antifriction coatings on steel surfaces can be used in marine engineering, friction units of hydraulic units, in heavily loaded sliding bearings and high-speed mechanisms. The modern technological equipment equipped with fiber, diode and other lasers allows to weld working surfaces of flat details, bodies of rotation and details of the difficult spatial form. The adhesion strength of laser-applied copper-based coatings is higher than the shear strength of normalized and improved steel and is 350-480 MPa.

4. Conclusion
The technology of laser surfacing of antifriction coatings based on copper powder materials PR-BrAMts 9-2, PR-BrOS 10-1, 5, PR-BrAZh 9,5-1, PR-L63. The coefficient of sliding friction when used as a lubricant transmission oil Tszp-8 when surfacing scanning with a frequency of 217 Hz beam is 2-3 times lower than that of bar bronze and brass. The performance of laser surfacing with transverse oscillations of the beam to the surfacing velocity vector increases by 1.56 -1.7 times compared to surfacing with a defocused beam.
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