Determination of the Seizure load of copper-based coatings on steel obtained by laser surfacing

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Abstract. The paper considers the process of surfacing a copper-based powder PR-BrAlFe 9.5-1, PR-L63, PR-BrSnPb 10-1.5 on 40Cr steel samples using continuous CO2 -laser radiation and cross-beam scanning with a frequency of 227 Hz. It is shown that the jamming load depends on the powder material and processing modes. The influence of transverse beam vibrations on the quality and productivity of the surfacing process is studied.

1. Introduction
The laser surfacing process is one of the potential methods for developing coating technologies on stainless steel substrates. One of the areas of application is the surfacing of copper-based alloys on hull elements for modern thermonuclear reactors [1]. Copper-based coatings applied to steel parts of friction units are widely used in automotive and mechanical engineering due to their high tribological properties [2-4]. They are used to protect against corrosion, reduce and increase the coefficient of friction, as antifriction and friction coatings, depending on the composition of the powder charge. Comparative characteristics of aluminum bronze coatings applied to steel by plasma deposition and laser deposition are given in [5]. It was noted that the microstructure of the laser-applied coating is more uniform and consists of finer microstructural components compared to plasma deposition. The mass loss during the wear test and the coefficient of friction depending on the load in plasma coatings is significantly higher than those deposited with a laser.

Laser surfacing of CuAl10 aluminum bronze powder with a particle size of 20-120 microns was performed using a TruDiode 4006 diode laser, manufactured by TRUMPF, on a substrate of stainless steel17-4PH with a diameter of 100 mm and a length of 150 mm [6]. The overlap coefficient of the surfaced tracks was 50%. The treatment was performed at a laser power of 1500 W, a beam diameter of 3.5 mm, a travel speed of 300 mm / min, a powder consumption of 16 g / min, in an argon medium. The introduction of chromium into the composition of the surfaced charge leads to a decrease in the iron content in the coating and an increase in its corrosion resistance.

Laser surfacing of copper powder with a size of less than 63 microns was performed on SS316L steel samples with dimensions of 60×60×10 mm [7]. The coatings were applied using a 4 kW CO2 laser system (TRUMPF, TruPrint Serie 1000, Germany). After optimizing the modes, layers with a thickness of 1 mm for a single pass, and 3 mm for multi-pass surfacing were obtained. It is planned to use copper coatings for processing the internal surfaces of components of modern thermonuclear reactors, as well as for the production of cast-iron containers with an internal coating of copper for storing radioactive waste.

For laser surfacing of 5140 steel, we chose aluminum bronze powder with a particle size of 40-100 microns, used a 4 kW fiber laser with a radiation wavelength of 1065-1075 nm (LS-4), and a KUKA R-120 robot [8]. As an additive to the charge, iron powder was used 12-50% by weight. the Power of laser radiation varied within the range of 600-2200 W, with a diameter of 2 mm, the speed of
its movement of 12 mm/s, the consumption of powder 15 g/min, argon 22 l/min. Tribological tests were
carried out according to the pad – roller scheme on the friction machine II-5018. The
microhardness of the coating varies within the range of 173-382 HV with an iron content of 12%.
With further increase of iron in the coating, the minimum microhardness increases to 232 HV, and the
maximum decreases to 328 HV when 50% iron is added to the charge. The coefficient of friction
without lubricant for the studied samples was in the range of 0.389-0.574. It was found that the
coefficient of friction increases with an increase in the iron content. The resulting coating can be
attributed to friction materials.

The purpose of this work is to determine the composition of a copper-based powder material on
the load of jamming depending on the sliding speed and changes in the coefficient of friction from
pressure, as well as the effect of transverse vibrations of the laser beam on the performance of the
surfacing process.

2. Materials and methods
In experimental studies, the IMASH RAS laser complex was used. Samples were made of 40Cr steel
with dimensions of 15×20×70 mm. Copper – based powders PR – BrAFe 9.5 –1, PR – L63, PR–
BrSnPb 10-1.5 with a particle size of 40-150 microns were selected for surfacing. The radiation power
P=700-1000 W, the processing speed V=5-10 mm/s, and the beam diameter d=1-2 mm are accepted as
variable parameters. Laser surfacing of samples was performed with a defocused beam and with
transverse beam fluctuations normal to the laser processing speed vector, with a step between the
tracks of 3 mm. A resonant type scanner with an elastic element on which the mirror is fixed was used.

Metallographic studies of surfaced coatings were carried out on a PMT-3 microhardometer at a
load of 0.98 N, a metallographic microscope Altami MET 1C and a digital microscope AM413ML.
A universal MTU-01 friction machine was used to determine the load of the deposited samples.
Tests were carried out according to the scheme " plane (deposited sample) - ring (steel 50CrVA, 51-
55HRC)". The sliding speed and pressure on the sample varied discretely in the range of 0.1-4.0 m/s
and 1-4.5 MPa, respectively. Hydraulic oil MGE-10A was used as a lubricant.

3. Research results and discussion
Laser surfacing of the samples was performed with a defocused beam and with transverse fluctuations
of the beam normal to the laser processing speed vector, with a step between the tracks of 3 mm. For
Figure 1a and 1b are represented by microslice of surfaced tracks with PR-BrAFe 9.5-1 powder with
dimensions of 0.879×1.866 mm, hardness (181-194HV), and 0.617×3.336 mm – (198-218HV),
obtained by a defocused beam and a scanning beam with a frequency of 227 Hz, respectively. For
uniform surfacing of the sample surface with a defocused beam, the step between the tracks was
reduced to 1.5 mm, which reduced the processing performance by 2 times. The deposited surface of
the samples was sanded, as a rule, to the thickness of the coating layer of 0.4 mm.

(a)  
(b)

Figure 1. Microslice of zones of laser surfacing with PR - BrAFe 9.5-1 powder:
a-unfocused beam; b-with transverse vibrations of the beam 227 Hz.
For Figure 2 the dependence of the jamming load on the sliding speed for bar materials of brass L63 (128-139 HV) and bronze BrFe9-4 (114-127 HV) and coatings deposited by a laser beam (PNLL) BrFe 9,5-1, L63 (174-196 and 192-228 HV surfacing mode 1 and 2), BrSnPb 10-1,5 (169-178 HV) is presented. Analysis of the jamming load – sliding speed curves shows that samples made of brass and bronze bar materials are significantly inferior to coatings made of powder materials deposited by a laser beam in terms of jamming pressures. At a sliding speed of 2 m/s, the Seizure load for bar brass and bronze is 0.5 and 0.8 MPa, respectively, and for surfaced coatings 1.0 – 1.5 MPa, depending on the composition of the powder material and the processing mode for L63.

Figure 2. Dependence of the Seizure load on the sliding speed:
1 - bar brass L63; 2 - bar bronze BrFe9-4; 3 - PNLL BrFe 9,5-1
4 - PNLL L63 (2); 5 - PNLL L63 (1); 6 - PNLL BrSnPb 10-1, 5

Figure 3 shows the dependence of the friction coefficients on the pressure at a constant sliding speed of 1.6 m/s. With increasing pressure, the coefficient of friction of almost all coatings and bar materials decreases. From the results obtained, it follows that the lowest friction coefficients of 0.02-0.04 were obtained when laser surfacing of powder materials BrSnPb 10-1, 5 and L63 (1) curves 5 and 6. Z – distance to the focal plane, mm.
Figure 3. Dependence of the coefficient of friction on pressure: 1-bar brass L63; 2-bar bronze BrAFe 9-4; 3-PNLL BrAFe 9,5-1; 4-PNLL L63 (2); 5-PNLL L63(1); 6 - PNLL BrSnPb 10-1, 5

When developing the design of friction pairs of turbines, compressors and other friction units, it is very important to know the change in the coefficient of friction from pressure to calculate the power of drive systems.

4. Summary

The developed technology of laser surfacing of copper-based powder materials with transverse beam vibrations with a frequency of 227 Hz increases productivity by 2 times compared to surfacing with a defocused beam under the same processing modes.

The lowest values of the friction coefficients of 0.02-0.04 were obtained for laser surfacing of BrSnPb 10-1,5 and L63 powder materials, surfacing mode 1.

The jamming pressure of the surfaced coatings and the sliding speed are 1.5 – 2.0 times higher compared to the samples made of L63 bar brass and BrAFe 9-4 bronze.

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