The restoration of the friction surfaces by laser cladding

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Abstract. The paper deals with laser cladding of wear-resistant coatings for restoring friction surfaces. It describes the modes of cladding technological process, and presents the results of wear tests. Wear-resistant coating based on the Ni-Cr-B-Si and alumina system, which exceeds 30HGSa steel by 11.5 times by wear resistance.

1. Introduction
Improving the reliability and durability of machine parts and structures remains a very important task due to the increase in efficiency of technology, saving material and technical resources. In repair practice, various methods of repairing worn parts are used. To restore the worn surfaces of hardened parts [1], it takes place especially when repairing parts in the aviation industry; traditional technologies for cladding surfaces are unacceptable because they cause the material to be dispensed under the weld layer. Laser cladding of wear-resistant coatings allows preserving the bulk hardness of the underlying layers. As a rule, after the restoration of the part in one of the ways, it is subjected to mechanical or metalworking, which is necessary to restore the fit of the mating parts, eliminate ovality or taper of their surfaces, ensure the required cleanliness of processing. Laser cladding is used in cases where the rubbing surfaces need to give greater durability. Two, three or more layers are often fused with wear-resistant alloys, which allows extending the service life of parts by several times. The cladding quality largely depends on the condition of the surface being repaired. Coating by laser melting of pre-sprayed powders, such as molybdenum is known [2-4].

Laser cladding of wear-resistant coatings represents a new technology, it refers to local methods of heat treatment. The high concentration of energy input and locality allow processing only the surface area without disturbing its structure and the properties of the part as a whole. The possibility of controlling the parameters of laser processing and the composition of the materials being processed in a wide range of values makes it possible to obtain qualitatively new wear-resistant materials [5]. The use of laser cladding to increase wear resistance of surfaces is particularly promising. Moreover, it is especially important for hardening parts operating under high temperatures [6].

During laser cladding of metal and alloy surfaces, intense hydrodynamic flows arising due to large temperature gradients accelerate mass transfer processes throughout the flashing zone. This circumstance allows carrying out the process of obtaining surface coatings, as well as laser doping. Due to the convective mixing of the melt with distance from the surface, there is no transition from phases with a higher concentration of the alloying element to phases with a lower concentration. All phases in the doped zone are mixed approximately uniformly in depth [7].
2. Equipment and materials
The aim of this work is to study the wear resistance of laser-deposited coatings for restoring friction surfaces.

Laser cladding of wear-resistant coatings was carried out on the equipment developed at the Blagonravov Institute of Mechanical Engineering, Russian Academy of Sciences (IMASH RAN), namely on the LTK-01 laser technological complex using tooling. The novelty of the proposed laser technology consists in using two coordinate scanning of the beam in the zone of interaction of the beam with the surface, which allows to form a given thermal cycle for a given powder material. The physical model of the process is described in [8]. The scheme of laser cladding is shown in figure 1.

![Figure 1. Diagram of gas-powder laser cladding: α - angle of the nozzle inclination to the axis of the laser beam, V - sample moving speed, L - nozzle distance to the sample surface, Δf - degree of defocusing, h - height of the weld bead, 1 - laser beam, 2 - sample, 3 - nozzle, 4 - powder feed.](image)

The feed of powder materials to the laser impact zone is carried out using a gas jet and the force of gravity of the powder through the nozzle 3. This method of feeding the powder material during laser impact is used when processing continuous lasers mainly. When cladding, penetration of the substrate is insignificant and the chemical composition of the coating is formed by the powder material.

At present, the industry produces a fairly wide range of powder materials suitable for producing wear-resistant coatings and restoring worn surfaces. Powder coatings are widely used: PN55T45, PN65T35, PT88N12, PN70Yu30, PN85Yu15, PT65Yu36 and others. Ni-Cr-B-Si alloys are a large range of powder materials - these are PR-H67H18S5Z4, PS-12NVK-01, PG-10N-01, PG-10K-01, etc. These powder materials do not fully provide the required wear resistance of coatings in heavily loaded friction units. A scientific approach to achieving high wear resistance of coatings based on dispersion hardening of a plastic matrix has been developed for many years around the world, since it allows to combine difficult compatible properties of high hardness and plasticity. The wear resistance of a material is closely related to its microhardness, plasticity, and microstructure. Thus, it is desirable that complex coatings be composed of solid particles that are distributed in a relatively soft metal matrix. The main feature of the microstructure of complex coatings lies in the fact that the solid ultra-fine particles of aluminium oxide [9], tungsten or titanium carbides [10] and distribute as homogeneously as possible in plastic metal, for example Ni-Cr [11]. The introduction of solid particles, as a rule, increases the hardness of complex coatings and may lead to an increase in the plasticity of complex coatings. It is also known that, the smaller the grain size, the higher the external voltage required for breaking the grain boundary and its separation in the form of a wear particle. For the development of new compositions of powder materials, the basis was determined on the basis of the Ni-Cr-B-Si system with the introduction of a reinforcing phase in the form of electro corundum (α-Al₂O₃ phase),
which has a hexagonal lattice. With the introduction of the hardening phase, the aim was to create a heterogeneous structure of solid grains distributed evenly in the elastic-plastic matrix. To test this assumption samples were deposited for testing. The samples had a rectangular shape of 90x20x10 mm. The following powder materials were used: PN70U30, PG-10N-01, PGSR-4 + 17% Al₂O₃, PG-10N-01 + 20% Al₂O₃. The coating thickness after finishing was 0.5 ... 0.6 mm. The laser power was 3.8 ... 4.0 kW.

3. Results and discussions

An important characteristic of the deposited wear-resistant layer is the strength of adhesion to the base. Thermal activation of the cladding surface and the formation of a diffusion zone leads to an increase in adhesive strength. The degree of dissolution of the base in the deposited layer in the partition zone has a great influence on the bond strength between them. The higher is the degree of dissolution, the higher is the bond strength. But the zone of the transition zone and its depth, should be optimal, since the intensive interaction of the deposited material with the base in the presence of a liquid phase leads to a change in its composition, which is not always desirable.

The main problem of the limiting possibilities of laser cladding technology is cracking, which depends on the difference in thermal expansion coefficients. Most of the system studies of the tribotechnical characteristics of the deposited coatings are associated with the process of optimizing the process according to various empirical relationships between the wear rate and the hardness characteristics of friction surfaces, elastic moduli, contact stresses and fracture toughness coefficient. Optimization of the laser cladding process was carried out according to the criterion of plasticity of the coating, which was monitored by the kinetic microhardness test method [12].

Tests on the wear resistance of the material deposited by a laser were carried out according to the method of accelerated tests on a Havor-type friction machine. Wear of the test sample of the material occurred when it was rubbing against a rubber disk, the contact pressure between which was 1 MPa. The abrasive previously dried in the furnace was fed to the friction zone [13]. The circumferential speed of the rubber disc in the zone of contact with the test sample was 2.5 m / s. The test time was 30 minutes. To assess the effectiveness of surface hardening of the sample, the wear resistance coefficient is taken - this is the ratio of the volume wear of the reference sample to the volume wear of the test sample [14]. The test results are shown in figure 2.

![Figure 2. Wear resistance coefficient of laser-deposited coatings: 1 - 30HGSA steel, 2 - PN70Yu30 steel, 3 - PG-10N-01 steel, 4 - PGSR-4 steel + 17% Al₂O₃, 5 - PG-10N-01 steel + 20% Al₂O₃.](image-url)
30KhGSA steel, which has a coefficient of wear resistance equal to 1 (K = 1), was chosen as a point of reference for the wear resistance coefficient. The PG-10N-01 + 20% Al2O3 coating has K = 11.5. The welded coating does not significantly reduce the fatigue strength of the part [15].

The calculated value of the weight content of Al2O3 lies in the range of 15 ... 25% (weight). Increased wear resistance can be achieved by creating gas-thermal powder compositions that interact with each other under the influence of laser radiation to form solid solutions and intermetallic compounds, and also form a hardening phase with oxygen and nitrogen. In this case, it is possible to synthesize the optimal amount of the hardening phase in the plastic matrix from the point of view of ensuring the specified service properties.

4. Conclusion
A wear-resistant coating was developed and investigated to restore worn friction surfaces on the basis of the Ni-Cr-B-Si system and aluminium oxide, which, by wear resistance indicators, exceeds 30HGSAl steel by 11.5 times.

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