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IMPROVING THE WEAR RESISTANCE OF COATINGS AND SURFACE TREATMENT OF STEEL 50 AND U8A ON SHS

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Abstract

Methods of obtaining chromium-coated coatings are considered and a new technology for the formation of boron, silicon and titanium protected layers on steels under conditions of self-propagating high-temperature synthesis is presented. Using the methods of mathematical modeling, when obtaining wear-resistant coatings on machine parts in conditions of self-propagating high-temperature synthesis, optimal compositions of SHS mixtures have been developed. When tested in sliding friction conditions, the best abrasion resistance, among the coatings under consideration, are chromoaluminium-coated coatings. Their wear resistance is 4,8-5 times higher than in uncoated samples, chromoaluminosilicated and chromoalumotated in 2,1-3,5. The gas-transport method of coating with the help of SHS makes it possible to obtain steel 50 and U8A with increased physical and mechanical properties, without requiring high energy costs and time.

Formulation of the problem

From the correct choice of hardness of the surface of machine parts, the effectiveness of the final result depends to a large extent - long-term performance at minimal costs. Test algorithms should form the technology in such a way as to determine what and how to apply in the technology of obtaining protective coatings. The technology should provide for a range of different modes of chemical-thermal treatment, control and diagnostic devices - from manual to automated execution with rationally connected their applications in the production, testing and operation of parts of maschins. It should have a wide range of algorithms and programs that are applied to specific details, operations and tasks of increasing the wear resistance of steel parts operating under sliding friction conditions. The use of a new technology for the formation of wear-resistant coatings in conditions of self-propagating high-temperature synthesis requires thorough study and research.

Analysis of the latest sources of research and publications

Currently, the main methods of applying a protective coating are: galvanic precipitation during electrolysis, gas-thermal spraying or metallization, thermal diffusion saturation in powder, immersion in molten metal, cladding. The most advanced techniques in this area include surface hardening using laser technology, electron beams, ion implantation, etc., as well as classical methods of chemical-thermal surface treatment (nitriding, boriding). Methods of obtaining protective coatings on metal products differ in coating technology, and the main purpose of the creation is good adhesion to the substrate, as well as obtaining a continuous, non-porous and resistant to this environment protective layer. By the type of joining the protective layer with the substrate, adhesive and diffusion metallic coatings are distinguished.

Surface saturation of steel with aluminum, chromium, zinc and other elements is called diffusion saturation with metals [1-2]. The product, the surface of which is enriched with these elements, acquires valuable properties, including high heat resistance, corrosion resistance, increased wear resistance and hardness.

In this regard, the actual application of technologies that allow to receive coatings with limited or minimal time of their formation. One of these technologies is the self-propagating high-temperature synthesis method [3-7].

Many scientists are engaged in issues of increasing the wear resistance of machine parts. Recently, the use of chromoalinated coatings has become widespread. Chromoalimation - simultaneous or sequential saturation of metals and alloys with chromium and aluminum - is used primarily to increase wear, heat and corrosion resistance of parts [8-11].

The main methods of chromium-imaging include: solid, from the vapor phase, gas and liquid. In turn, the saturation from the vapor phase is divided into contact and non-contact, gas - simultaneous and sequential, solid - simultaneous and from the slip.

Doping of chromium-plated coatings with titanium silicon and boron allows to dramatically increase performance and, along with high corrosion and heat resistance, to obtain more universal layers with high surface hardness, scale and corrosion resistance due to the formation of additional silicon and titanium oxides [12-14].

Research materials

In the work to apply coatings, steel 50 and U8A were used. Chemical-thermal treatment was carried out in an open-type reactor ($P = 10^5$ Pa) in the temperature range 900-1050 ºC and the total duration of isothermal soaking up to 60 min.

In order to search for compositions of powder SHS mixtures providing high wear resistance, a full factor experiment

As independent variables, the following were chosen: the content in the SHS mixture of the chromium component, silicon, boron and aluminum. As the starting material, steel 50 was chosen. The process activator is J_2 and NH_4F for all systems.

The calculated levels of the variation intervals, the nature of their variations and the coding schemes are presented in Tables 1 and 2 Introduction of more than 5% of the gas transport agent into the mixture leads to a strong etching of the sample surface, less than 1% does not activate the course of all gas transport reactions.

To obtain a 100% composition of powdered SHS mixtures, Al_2O_3 was used as the final product.

As a result of regression analysis, a number of equations were obtained showing the dependence of the wear resistance of protective coatings on the regime of thermal autoignition and the content of alloying elements.

To assess the adequacy of the equations, a calculation was made of the regression equations obtained for the optimum regime of thermal autoignition. The results of the calculations were compared with experimental studies. As can be seen from Table 4, the error between the calculated and experimental values of the response function does not exceed 5.

For the purpose of determining the regime and SHS-compositions ensuring the optimal indices of wear resistance of the coatings, three-dimensional graphical dependences were constructed (Fig. 1-2).

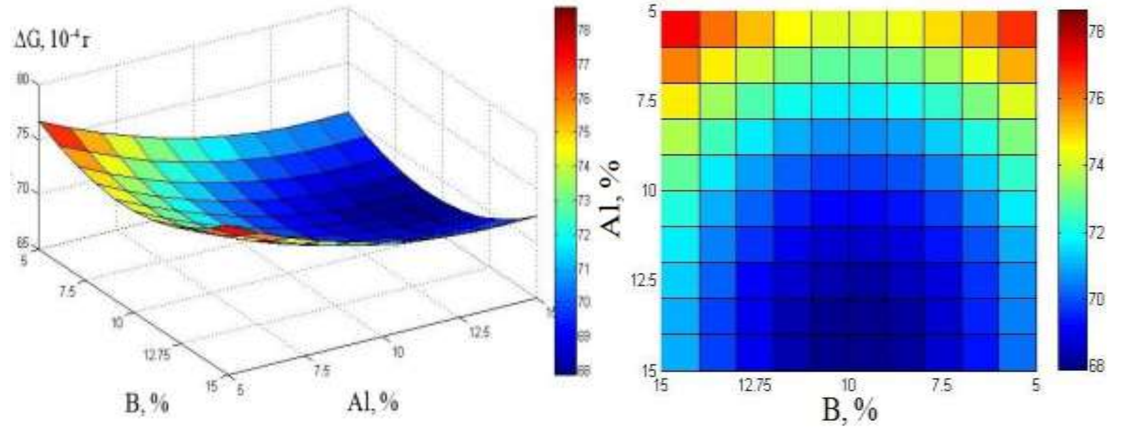


Fig. 1 Optimization of the abrasion resistance of the surface layer for the Cr-Al-B system: the effect of boron and aluminum on the wear resistance of steel

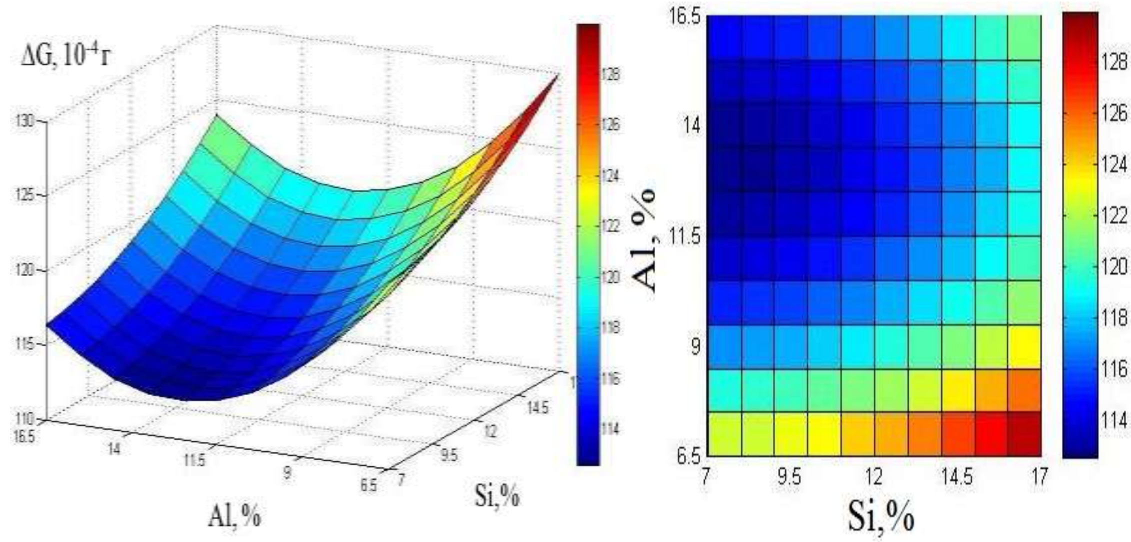


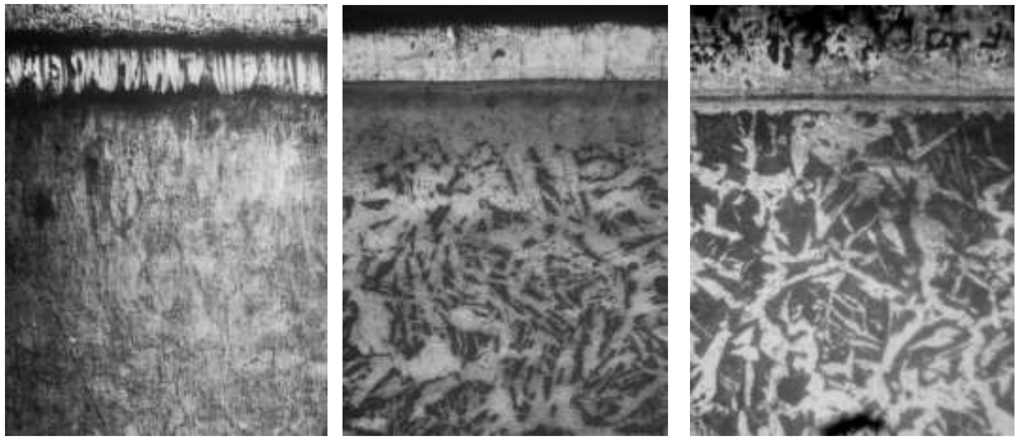
Fig. 2 Optimization of the wear resistance of the surface layer for the Cr-Al-Si system: the effect of boron and chromium content on the wear resistance of steel 50

Results and discussion. Analysis of the reactions taking place in the SHS process, as well as the results of experiments and metallographic studies, allowed to obtain a scheme for the formation of protective coatings. The process of formation of protective coatings in the regime of thermal autoignition can be conditionally divided into five stages-inert heating of the SHS mixture to the autoignition temperature, thermal autoignition, heating of the parts, isothermal aging and cooling.

Studies have shown that such a high rate of formation of coatings can be explained by the fact that austenite formed during high-temperature heating due to the autoignition stage is characterized by high structural defectiveness and fine-grained, which sharply increases its diffusion susceptibility by saturable elements. Thus, it is possible to control both the growth rate of the layers and their phase composition and structure. The main factors influencing the kinetics of the formation of protective layers are the composition of SHS-charge, the amount of chromium component, the time of isothermal aging, the composition of the processed steel, and the type of SHS process passing in combustion or in the regime of thermal autoignition.

When depositing chromium-plated silicon-doped layers on the surface, a $(FeCrAl)_3C$ layer is formed on materials with a high carbon content (steel 50, U8A), carbides $(FeCr)_{23}C_6$

are formed. Directly to the layer adjoins the carbon-rich transition zone formed by the counter diffusion of carbon, followed by a depleted carbon-ferrite zone.



a b c

a – alloying B; b – alloying Ti; c – alloying Si.

Fig. 3 - Microstructures of multicomponent chromium-plated coatings obtained in the regime of thermal self-ignition of SHS

The results of testing steel specimens for wear under conditions of sliding friction on the friction machine SMT-1 are shown in Fig. 4. Here, the wear resistance of the treated samples is 2-3 times higher than the wear resistance of the untreated samples.

The result obtained correlates with the hardness of the hardened zones. With increasing hardness, wear resistance increases. The hardness was measured on transverse sections on a PMT-3 device, using a standard procedure. As the carbon content in steels increases, the microhardness of the surface layer increases.

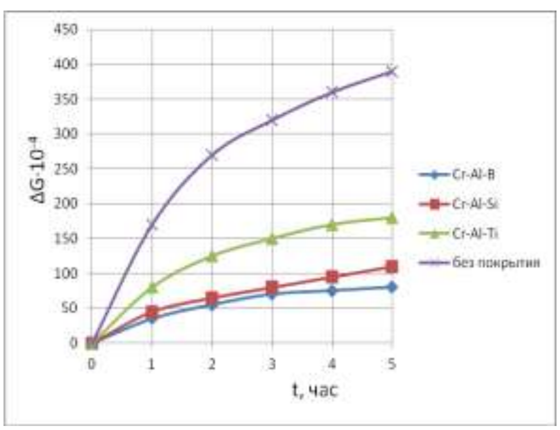


Fig. 4 Effect of the test time on the wear resistance of coatings on steel 50 when tested on a CMT-1 friction machine

Conclusions. Modeling has been carried out to find the optimum powder SHS-mixtures for the production of wear-resistant protective coatings on steel 50 and U8A using self-propagating high-temperature synthesis technology. The structures of the protective layers and their wear resistance under conditions of sliding friction are investigated. The best wear resistance, among the coatings under consideration, are Cr-Al-B coatings. Their wear resistance is 4,8-5 times higher than in uncoated samples, Cr-Al-Si and Cr-Al-Ti in 2,1-3,5 times.

References

[1] Trefilova N.V. An analysis of modern methods of application of protective coatings // *Modern science-intensive technologies. - 2014*. - No. 10. - P. 67

[2] Sereda B.P. Surface reinforcement of materials: Monograph / Sereda B.P., Kalinina N.E., Krugliak I.V. - *Zaporozhye: RVB ZDIA, 2004*. - 230 p.

[3] Lakhtin Yu.M. Metallurgy and thermal processing of metals. / Yu.M. Lakhtin // - *Moscow: Metallurgy, 1993*. - 448 p.

[4] Merzhanov A.G., Rogachev A.S. Phase and structure transformations during SHS.*Adv. Sci. Techn.* 2003, v.31, pp. 271-282

[5] Lakhtin Yu.M. Metallurgy and heat treatment of metals. / Yu.M. Lakhtin // *- M.: Metallurgy, 1993*. - 448 p.

[6] Sereda B. Production of highly effective SHS coatings operating in oxidizing and corrosive environments / Sereda B., Sereda D., Kryglyak I. // *Material science and technology - 2017. Pittsburgh. Pennsylvania USA. 2017.* - P.424-429

[7] Sereda B. Simulation and modeling of metallurgical phenomena produced on pressing in SHS-condition/ Sereda B., Sereda D., Kovalenko A., Kryglyak I. // *Material science and technology - 2017. Pittsburgh. Pennsylvania USA. 2017.* - P.727-732

[8] Establishment of the relationship between the microstructure characteristics and the heat resistance of silicate coatings obtained under SHS conditions/ Sereda B., Sereda D., Sereda I.// *Material science and technology - 2017. Pittsburgh. Pennsylvania USA. 2017.* - P.412-416

[9] Sereda B. Corrosion Resistance and Mechanical Properties Zinc Coating Sheet Steels, Received in Conditions of Self-propagating High Temperature Synthesis / Sereda D., Sereda B. // *Material science and technology- 2016. Salt Lake City, Utah USA 2016*. - P.825-829.

[10] Sereda B. Development of Protective Coatings Formulations Based on Boron for Units Operating at High Temperatures in Metallurgy / Sereda D., Sereda B. // *Material science and technology- 2016. Salt Lake City, Utah USA 2016*. - P.931-934.

[11] Sereda B. Modeling deformation in material processing and laws of phasic by SHS pressing intermetallics alloys / Sereda D., Sereda B. // *Material science and technology. Columbus. Ohio, USA 2015.* - P.611-617.

[12] Sereda B. Aluminized Multifunctional Coating on Steel in SHS Condition./ Sereda D., Sereda B. //*Material science and technology. Pittsburgh. Pennsylvania, USA 2014.* - P.482-486.

[13] Sereda B., Sereda D. Kinetiks formation of aluminized multifunctional coating on steel in SHS condition. *Material science and technology. Columbus, Ohio, USA. 2011*.- P.1667-1671.

[14] Sereda B. Advanced Chromoaluminizing Coatings for Wear and Heat-resistance on Composite Materials under SHS. / Sereda D., Sereda B. // *Material science and technology. Columbus, OH, USA, 2015.* - P.229-232.