OBTAINING MULTI-COMPONENT CHROME PLATED COATINGS FOR PRESS TOOLING EQUIPMENT

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INTRODUCTION

Composite materials like natural and synthetic rubbers are now integral to the metallurgical, textile, and chemical industries. These rubbers enable the creation of structural and tribotechnical products with superior damping properties, high elasticity, and corrosion resistance. Additionally, replacing metals with rubber decreases material consumption in structures and machinery, reduces the production time for parts, even those with complex shapes, and enhances corrosion resistance [1]. The manufacturing process utilized a 100-400 2E hydraulic vulcanization press, equipped with plates measuring 400 x 400. This method was employed to produce innovative elastomeric materials derived from a copolymer of vinylidene fluoride and hexafluoropropylene, along with ethylene-propylene rubber. The formulation of these materials incorporated carbonized fibers sourced from PAN (polyacrylonitrile), granite flour, and aluminosilicate microspheres, enhancing their properties. The inclusion of these additives aimed to improve the material's overall performance, providing superior strength, durability, and resistance to various environmental factors [2-3].

OBJECTIVE AND TASKS

The purpose of our study is to obtain multicomponent chrome coatings alloyed with titanium and aluminum to strengthen the working surfaces of parts operated under aggressive conditions on equipment for vulcanizing products from new elastomeric materials using modern methods of surface hardening of materials, including the SHS technology, with the main goal of developing new approaches to improve the mechanical properties and extend the service life of materials [4]. As part of this study, we plan to conduct a broad review of existing methods, thoroughly study the features of the SHS processes, conduct a series of experimental studies to determine the optimal process parameters, and analyze the data obtained to determine the effectiveness of the SHS method for improving the mechanical properties of materials and extending the service life of machine parts and equipment for vulcanizing products from new elastomeric materials[5].

MATERIALS AND METHODS

We used samples from mass-production steels such as steel 20, steel 45, U8, 40H, 40H16M for coating. As reaction agents, we used mixtures of powders with a dispersion of 60-250 microns of the following materials. In determining the required dispersion of the reagents, we were guided by studies that found that the maximum completeness of the transformation is observed when using a reaction mixture with a fraction of 100-120 microns. The protective coatings on samples under the conditions of the SHS were obtained using the developed pilot plant DSTU12, consisting of the following main functional systems: reaction equipment; system for monitoring and controlling technological parameters; gas utilization system. Microstructure of structural materials with protective coating was studied from cross-sections on metallographic microscopes "Neophot-21" and "Neophot-32". The range of image magnification varies from ×100 to ×500 times.

RESULTS

Coatings obtained under conditions of self-propagating high-temperature synthesis have special characteristics. They are formed from a film of the applied product, similar to the gas-phase deposition process, and a wide transient diffusion zone, similar to diffusion saturation. These features allow SHS coatings to have superior properties compared to other analogs: they can have improved characteristics of the applied material (e.g., improved wear or thermal resistance compared to the base material) and high adhesion strength between layers of powders where particles of one material are covered by a layer of the other [6]. This provides a large contact area for the reagents, especially when small particles are used. Micron particle sizes also remain acceptable under these conditions. If the particles do not melt, reactions between reactants proceed through the solid phase by reaction diffusion. The low values of mass transfer coefficients in the solid phase can be compensated by increasing the contact surface. An important factor is also high temperature, which intensifies the processes. Under certain conditions, it is possible to achieve a pure solid flame regime in which all substances, including intermediates, remain in the solid state

[7]. By analyzing the reaction products, we can create a model of the process of formation of protective coatings under SHS conditions. Based on calculations of adiabatic combustion temperatures of SHS systems, we can solve the heat balance equation for the systems under consideration.

When chrome coatings are alloyed with titanium on the steels under consideration (fig 1.), phases are formed $(Fe,Cr)_{23}C_6$, $(Fe,Cr)_7C_3$, Cr_3C_2, and phases: Fe_2Ti, Cr_2Ti. It was found that the alloying elements diffuse deep into the steel to a depth of 210 microns.

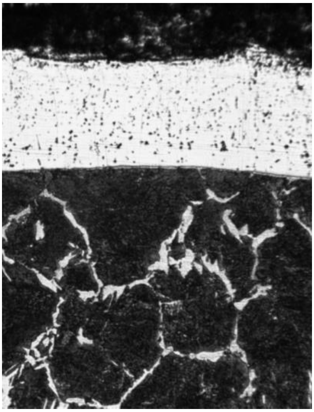

Figure 1 – Microstructures (x100) of titanium and chromium alloyed coatings on steel 45, ($t_п$ – 1000 °C, $\tau_в$=30 min.)

Al and Ti are evenly distributed over the thickness of the protective chromium coating. Unsteady-state temperature conditions lead to an increase in the concentration of alloying elements in chromium coatings, unlike isothermal conditions. Such a phase composition is explained by the fact that aluminum and chromium can be in a liquid state at the temperature of SHS treatment and diffuse into the substrate more actively than titanium. In addition, it should be noted that during the treatment process, aluminum can partially be in a liquid state, so titanium diffusion in this case will pass through the liquid phase, thus intensifying the coating formation process.

The thermodynamic modeling of thermochemical processes, which consists in the thermodynamic analysis of the equilibrium state of systems as a whole (full thermodynamic analysis), was carried out to study the mechanism of protective coating formation. Thermodynamic systems are conditionally distinguished material areas whose interaction with the environment is reduced to the exchange of heat and work. The use of thermodynamic modeling makes it possible to quantitatively simulate and predict the composition and properties of complex heterogeneous, multi-element, multiphase systems over a wide range of temperatures and pressures, taking into account chemical and phase transformations. This makes it possible to effectively study thermochemical processes in existing high-temperature installations and optimize their conditions, predict the results of high-temperature interactions, dramatically reduce the time and cost of research, and successfully systematize theoretical and experimental information.

With increasing temperature, the amount of products in the gaseous phase increases and condensed products are released, it is characteristic that in the temperature range of 400-1600° K the share of condensed phase decreases, which is associated with the evaporation of the used carriers. simultaneously, starting from the temperature of 800° K, the decomposition of reaction products occurs, essentially chemical transport of elements takes place. The existence of limiting temperatures, up to which the propagation of the combustion front is possible, introduces certain restrictions on the use of the combustion mode as a technological one. On the contrary, the thermal autoignition mode is free from these restrictions, by diluting the initial powder mixture with an inert substance up to 85-90% wt. %, it is possible to reduce the maximum temperature of the process to the technologically necessary temperatures. The main compounds in the gas phase in the temperature range of 400 - 1600 K are as follows: SiCl, $SiCl_2$, $SiCl_3$, $SiCl_4$, SiI_2, SiI_3, AlI, AlI_2, AlCl, $AlCl_2$, $CrCl_2$, CrF, CrF_2, CrF_4, $TiCl_2$, $TiCl_3$, $TiCl_4$, as well as iodine in atomic and molecular form.

CONCLUSIONS

We obtained a titanium-doped chromium coating to strengthen the working surfaces of parts used in aggressive conditions on equipment for vulcanizing products made of new elastomeric materials based on a copolymer of vinyl dell fluoride and hexopropylene, ethylene-propylene rubber. When chrome coatings are alloyed with titanium on the steels under consideration, the following phases are formed $(Fe,Cr)_{23}C_6$, $(Fe,Cr)_7C_3$, Cr_3C_2, and phases: Fe_2Ti, Cr_2Ti. It was found that the alloying elements diffuse deep into the steel to a depth of 210 microns. Al and Ti are evenly distributed over the thickness of the protective chromium coating. Unsteady-state temperature conditions lead to an increase in the concentration of alloying elements in chromium coatings, in contrast to isothermal conditions. the surface microhardness of aluminum-alloyed titanium coatings is: on steel 20 – H_{100}= 8000 MPa (phases: on the surface of Fe_2Al_5, doped with Ti and TiAl, under it is a zone of solid solutions of FeAl and Fe_3Al, alloyed with titanium inclusions Ti_3Al, Fe_2Al_5). According to the results of X-ray diffraction and metallographic analyses, it was found that the obtained coatings have a multiphase structure and are characterized by uniformity in thickness.

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