ABSTRACT

of thesis for a PhD degree by speciality 6D071000 – “Materials science and technology of new materials” of

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on theme **“Production of protective ceramic coatings on the surface of metallic materials by plasma-electrolytic treatment”**

The aim of the thesis. Investigation of the phase composition, structure and properties of low-alloy steels and aluminum alloy, development of high- efficiency, energy-saving and environmentally friendly technology of thermocycling electrolytic-plasma treatment of parts of drilling equipment for oil and gas equipment, providing high surface strength and wear resistance, as well as manufacturability of drilling oil and gas equipment.

The main objectives of research:

-Design and manufacture a laboratory plant for electrolytic plasma treatment for samples of details from ferrous and non-ferrous alloys.

-Study of regularities in the formation of the phase composition andstructure of surface layers of low-alloy steels and non-ferrous alloys depending on the electrolytic-plasma treatment regimes;

-Investigation of the effect of the phase composition and structure of surface layers on the mechanical strength, hardness and wear resistance of parts of the oil and gas industry from steel 20X;

-Develop a technological process for manufacturing parts of oil and gas equipment with electrolytic-plasma hardening.

Methods of research.

Theoretical research methods based on the basic concepts ofsimilarity theory, the theory of chemical-thermal treatment and solid-state physics, modern experimental methods for computer analysis of microstructure images, raster electron microscopic and elemental analyzes, X-ray structural analysis, and methods for determining mechanical properties and wear resistance of materials from steel 20X oil and gas equipment. The metallographic analysis was carried out with the "Axioscop-2MAT" microscope with a digital camera "Sony". A qualitative and quantitative phase analysis of the structure of the steel samples was carried out on a Xanert X-ray diffractometer by PANanalytical, using Cu-K□ radiation. Microhardness measurements were carried out on a PMT-3 device, witha diamond pyramid, with a load on the 2H indenter in accordance with GOST 9450-76. The wear resistance of the samples was estimated from the loss of mass per unit time, as a result of abrasion of the test specimen on a disk with an abrasive, in sliding friction without a lubricant [4]. To measure the mass of the samples we used an electronic scale VL-120 with an accuracy of 0.1 mg.

The main scientific provisions submitted for defense:

-Patterns of phase transformations and structural changes in the surface layer during electrolytic-plasma machining of parts from low-alloy steels and non- ferrous metals;

-Establishment of mechanisms for increasing the surface hardness and wear resistance of the drill bit parts as a result of alloying and modifying the surface layer during electrolytic-plasma treatment; the basic principles of predicting the quality parameters of the modified layer in relation to the electrolytic-plasma treatment regimes;

-Method of mathematical modeling of structural-phase transformations occurring during electrolytic-plasma treatment of low-carbon alloyed steel 20X, calculation and experimental confirmation of the selection of optimal electrolytic- plasma treatment regimes for steel parts of oil and gas equipment, analytical dependence of heating temperature on heating and cooling time, and values voltage:

$$T = 4{,}5xt^2{}_{heat}. + 4{,}8xU - 18xt_{cool};$$

-Technology of thermocycling electrolytic-plasma hardening of low-carbonalloyed steel of a drill bit;

-The results of the introduction of electrolytic-plasma treatment of parts, as a more energy-saving and environmentally friendly method of chemical-thermal processing, in the process of manufacturing parts of oil and gas equipment, instead of cementation on a solid carburetor followed by quenching.

The main results of research aviation. The thesis is devoted to the development of technology of thermocycling electrolytic-plasma treatment of low-carbon alloyed steel and aluminum alloys of mining industry components. Using the theoretical and modern experimental methods of metallographic, scanning electron-microscopic and X-ray structural analysis, as well as methods for studying mechanical properties and wear resistance, the purposeful change in the structure and properties of thin surface layers of parts under external physical action of ions of high-temperature plasma and electric discharge under cyclic electrolyte- plasma treatment. The principal possibility of surface doping and modification during electrolytic-plasma treatment of details is shown. Optimum regimes of electrolytic-plasma treatment of details are determined. The energy-saving and environmentally friendly technological process of manufacturing details of the bearing assembly of the drill bit with electrolyte- plasma hardening is proposed for introduction.

The practical utility of the work is to create and approbate the technology of electrolytic-plasma hardening in the technological processes of production of parts. The proposed technology makes it possible to significantly increase, in comparison with the existing technology, the surface strength, hardness and wear resistance of parts of oil and gas equipment.

Its main advantages are:

-possibility of hardening of a complex profile, internal surfaces and cavities; no need for special preparation of surfaces before coating;

-Electrolyte-plasma treatment has high ecological safety: no waste disposal and use of special treatment facilities;

-Electrolyte-plasma treatment is an energy-saving technology with low laborinput;

-easily lends itself to automation, both at the stage of design and production, which leads to improved quality and a significant cost reduction;

-To test specimens for wear resistance, treated under different conditions, a laboratory plant for testing abrasion resistance was designed and manufactured;

-The main advantage of EPO is the absence of deformation of the metal; in contrast to the hardening by gas carburizing followed by quenching, electrolytic-plasma treatment is carried out locally, which excludes the formation of cracks, warpage of the metal, and decarburization of the surface.

Substantiation of novelty and importance of the obtained results.

-The regularities of changes in the phase composition, structure, and properties of surface layers of samples of low-alloy steels, depending on the electrolytic-plasma treatment (EPO) regimes, have been studied theoretically and experimentally.

-The microstructure of the steel samples after EPO is characterized by the presence of a dark surface layer with a thickness of up to 100 μm, a thin acicular structure of martensitic origin is observed under the dark layer, which goes over into the initial plate-like pearlitic-ferrite structure; the total thickness of the strengthened surface layer is 1000-1700 μm; the microhardness of a hardened zone with a martensitic structure is 6500-7200 MPa;

-For the purpose of determining the optimum conditions for electrolytic- plasma treatment of steel products, a full-scale multifactorial experiment was implemented; It is established that the main factors determining the quality of hardening of steel in EPO are: heating time, quenching time and voltage; The dependence of the heating temperature on the heating and cooling time, as well as the voltage values:

$T = 4,5xt^2_{heat.} + 4,8xU - 18xt_{cool}$;

-Raster elemental analysis of the surface layer showed that directional mass transfer of alloying elements both from the anode and from the electrolyte is activated in the plasma flow under EPO; as a result of the redistribution of the alloying elements in the surface layer of the samples during the electrolyte-plasma heating of the samples, a chemical modification of the surface layer of the metal occurs;

-It has been established that in the plasma layer of an electric gas discharge, when an electric current flows from an aqueous solution of calcined sodium carbonate, Na_2CO_3, charged carbon ions form, which carburize the surface of the samples and lead to the formation of carbide phases;

-X-ray diffraction analysis showed that X-ray diffraction patterns of 20X steel samples are in the delivery state, there are lines of the phase based on Fe, the Cr0.6 Fe1.4 phase line, and also the Fe2.7 Mo0.8 Ni0.1-phase lines; After electrolytic-plasma treatment on the diffractograms of the samples, in addition to the lines of the above listed phases, lines of residual cementite Fe3C appear, the formation of which leads to a sharp increase in the surface strength and wear resistance of steel;

-Dependences of surface hardness and depth of the quenched layer on the electrical parameters of electrolytic-plasma treatment are established;

-A pilot laboratory installation of electrolytic-plasma treatment for samples of detailsmade of steel 20X was designed and manufactured.

Compliance with the direction of development of science or government programs. Scientific research aimed at developing a highlyefficient technology for the production of new materials from domestic raw materials, as well as technologies for obtaining and processing finished products from them, are an urgent problem of the innovative and industrial development of the Republic of Kazakhstan.

Specification of theoretical aspects of doping, modification and heat treatment of surface layers of products, as well as the study of their structure and properties allow solving the actual problem of creating new, highly efficient technological processes for obtaining hardening and protective coatings, increasing the reliability and durability of machines and mechanisms.

Increasing the requirements for the quality of machine parts stimulates the creation of new methods for the purposeful change in the phase composition and the structure of their surface layers. In particular, methods of influencing the surface of parts by concentrated energy flows have become widespread. The most promising, energy-saving and environmentally friendly technology among them is the electrolytic-plasma treatment (EPO) method. This changes the structure and properties of the material in thin surface layers due to the physical action of high-temperature plasma ions and electric discharge.

Additional increase in surface hardness, hardness and wear resistance of parts in EPO can also be achieved due to a purposeful change in the chemical composition of the surface layer by alloying and modifying.In the thesis for research, details were selected: "Equipment of wedge columns" from the operating plant of JSC "Ust Kamenogorsk factory of industrial fittings". Contact durability, abrasive and shock-abrasive wear resistance of parts of wedge columns of steel 20X in the production of JSC "UZPA" are satisfied by cementation on a solid carburizer with subsequent hardening. Disadvantages of this technology of processing parts are the formation of buckling and cracking of parts from low- carbon steels, as well as the high labor intensity and energy intensity of production.

The analysis of existing technologies for heat treatment of similar products from low-carbon and alloyed steels shows that the task of developing electrolytic-plasma treatment for drilling tool parts ensuring high performance characteristicsis timely and timely.

Practical results approbation. The dissertation work is an integral part of the state budget issue No. 277 of KazNTU and "ALATAU-PLANT" LLP. The results of the research are targeted to the introduction into the production of JSC "UZPA", and are also used in the educational process of the department "Mechanical engineering and technology of structural materials" EKSTU them. D. Serikbayev.

Description of the contribution of the doctoral PhD student to the preparation of each publication. Statement of problems, the way to solve them, theoretical and experimental studies, main scientific results. Publications. 8 scientific works were published on the topic of the thesis, including 5 in the publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, and also received 2 conclusions: on issuing an innovative patent for an invention and on granting a patent for a utility model.