

**SCIENTIFIC AND TECHNICAL
JOURNAL "VOPROSY
MATERIALOVEDENIYA"**

N 2(86), 2016

CONTENTS

METALS SCIENCE. METALLURGY

- Riabov V. V., Kniaziuk T. V., Mikhailov M. S., Motovilina G. D., Khlusova E. I. The structure and properties of new wear-resistant steels for agricultural machine-building 7
- Alekseev A. A., Grinberg E. M., Sheverev S. G. Changes of fine structure at low-temperature martensite decomposition in the hardened medium-carbon steel 20
- Olenin M. I., Gorynin V. I., Mikhailov M. S. Carbide phase changes in the 09G2SA-A steel after additional tempering at medium temperature 26
- Dushyn Yu. V., Krasilnikov A. Z., Petrov S. N., Popova I. P., Ptashnik A. V. Approximate calculation of the carburizing in equipment material for high-temperature hydrocarbons pyrolysis 33
- Kudriavtsev A. S., Chudakov Ye. V., Kulik V. P., Tretiakova N. V., Berestov A. V., Fedorov S. A. Optimization of heat treatment hardening modes for semi-finished products of titanium pseudo- β -alloy 5553, for marine applications 51

FUNCTIONAL MATERIALS

- Klimov V. N., Kovaleva A. A., Bobkova T. I., Deev A. A., Chernysh A. A., Yurkov M. A. Structure and properties of the bronze-based functional coating obtained by gas-dynamic and microplasma spraying 57

POLYMERIC COMPOSITE MATERIALS

- Sedakova E. B., Kozyrev Yu. P. The influence of the polytetrafluoroethylene viscoelastic properties on a range of working loads of a friction pair polytetrafluoroethylene – steel 69
- Deev I. S. Microstructural features of erosive destruction of polymeric composite materials at the dust and rain erosion 76
- Mostovoy A. S., Panova L. G., Kurbatova E. A. Modification of epoxy polymers with silicon-containing filler to improve operation properties 87
- Gogoleva O. V., Petrova P. N. Development of self-lubricating materials based on polytetrafluoroethylene 96

WELDING AND RELATED PROCESSES. WELDING MATERIALS AND TECHNOLOGIES

- Vlasenko V. D., Verkhoturov A. D. Production of welding electrodes with local mineral raw materials containing wolfram and titan by aluminothermy 104
- Gorynin I. V., Farmakovskiy B. V., Vasiliev A. F., Vinogradova T. S., Samodelkin E. A. Activated diffusion bonding of dissimilar materials with amorphous fillers 111

CORROSION AND PROTECTION OF METALS

- Khromushkin K. D., Ivanov V. G., Medvedev G. V. Relative corrosion resistance of oxidized titanium alloy coatings in corrosive environment 120
- Stavitsky O. A., Kuzmin Yu. L., Podshivalov A. V. Efficiency and operating parameters in arctic conditions of cathodic protection against corrosion-erosion damage of steel-clad ice belt of the nuclear-powered 50 Let Pobedy vessel 127
- Stavitsky O. A., Kuzmin Yu. L., Troshchenko V. N. New ice-resistant platinum-niobium anodes for cathodic protection systems against corrosion-erosion damage of icebreakers and ice-resistant offshore structures 137
- Radzhabaliev S. S., Ganiev I. N., Amonov I. T. Effect of lead on the anode behavior of Al-2,18%Fe alloy 147

RADIATION MATERIALS SCIENCE

- Margolin B. Z., Yurchenko E. V., Morozov A. M. Threshold and limit impurity contents in WWER reactor pressure vessel materials 152

Margolin B. Z., Yurchenko E. V. Prediction of radiation embrittlement of WWER-1000 reactor vessel materials considering the influence of alloying elements and high content of copper	164
TESTS, DIAGNOSIS AND QUALITY CONTROL OF MATERIALS	
Kosulnikov V. Yu., Lebedev V. L., Troshkin S. N. A simple hardware design of techniques for mechanical loss factors measuring	175
NEWS AND EVENTS	
Conferences 2016	187
For information	189
Abstracts of published articles	191
Index of authors	201
Instructions for authors of the scientific and technical journal "Voprosy Materialovedeniya". Manuscript requirements	203

ABSTRACTS OF PUBLISHED ARTICLES

UDC 669.14.018.295:539.538:631.3

The structure and properties of new wear-resistant steels for agricultural machine-building. Riabov V. V., Kniazuk T. V., Mikhailov M. S., Motovilina G. D., Khlusova E. I. – Voprosy Materialovedeniya, 2016, N 2(86), p. 7–19.

New high-strength competitive steels with tensile strength of 1200, 1500 and 1700 MPa have been developed for agricultural machinery industry on the basis of research results under hot rolling, forging and heat treatment. Phase transformations, structure and mechanical properties changes of high-strength steel have been studied.

Keywords: high-strength wear-resistant steel, agricultural machine-building, phase transformations, structure and properties.

UDC 621.785.616:669.15–194.2

Changes of fine structure at low-temperature martensite decomposition in the hardened medium-carbon steel. Grinberg E. M., Alekseev A. A., Sheverev S. G. – Voprosy Materialovedeniya, 2016, N 2(86), p. 20–25.

The change in the characteristics of martensite fine structure in the hardened medium-carbon steel in the process of aging at room temperature has been studied. The heat treatment of the steel included hardening in different media (at room temperatures): mineral oil, water, 10% aqueous solution of NaCl and aging at room temperature.

It is shown that the behavior of the degree of tetragonal occur in the hardened steel 40Kh aging over time at room temperature (after the stage of the formation of the Cottrell atmosphere) is the same as the change in the microhardness steel for both studied cooling rates upon hardening. The decomposition of martensite during maturing is accompanied by a decrease in the internal stresses and the dislocation density. End of the first stage of decomposition correspond to the same values of these characteristics that do not depend on the cooling rate upon hardening.

Keywords: cooling rate, neutron diffraction, low-temperature martensite decomposition, aging.

UDC 669.15–194:52:621.785.72

Carbide phase changes in the 09G2SA-A steel after additional tempering at medium temperature. Olenin M. I., Gorynin V. I., Mikhailov M. S. – Voprosy Materialovedeniya, 2016, N 2(86), p. 26–32.

The fine structure of ferrite-pearlite steel 09G2SA-A after thermal improvement and additional tempering at a temperature of 450°C has been studied. It is shown that additional tempering increases steel resistance to brittle fracture due to coagulation and spheroidization of cementite type carbides.

Keywords: ferrite-pearlite steel, brittle fracture resistance, thermal improvement, additional tempering, spheroidization of carbides.

UDC 669.018.44:621.785.51:665.633

Approximate calculation of the carburizing in equipment material for high-temperature hydrocarbons pyrolysis. Dushyn Yu. V., Krasilnikov A. Z., Petrov S. N., Popova I. P., Ptashnik A. V. – Voprosy Materialovedeniya, 2016, N 2(86), p. 33–51.

Approximate calculation of the carburizing in centrifugally cast tubes of radiant coils has been made by numerical solution of equations of diffusion, kinetics, thermal conductivity and heat transfer taking into account temperature changing with the depth and time. The reliability of the results has been tested on the alloy HP-type after gasoline pyrolysis (8 cycles per 500 hours). The proposed solution helps determining pyrolysis technology effect on material mechanical properties and equipment life.

Keywords: pyrolysis, radiant coils, coke layer, kinetics, diffusion, cycle, carbides.

UDC 669.295:621.785.5:629.5

Optimization of heat treatment hardening modes for semi-finished products of titanium pseudo- β -alloy 5553, for marine applications. Kudriavtsev A. S., Chudakov Ye. V., Kulik V. P., Tretiakova N. V., Berestov A. V., Fedorov S. A. – Voprosy Materialovedeniya, 2016, N 2(86), p. 51–56.

The paper studies structure and mechanical properties of the titanium plates of pseudo- β -alloy 5553 after the heat treatment hardening in various modes. The possibility of obtaining the necessary set of

physical and mechanical properties of deformed semi-finished products of large thickness, used in ship-building, by selecting the optimal mode of hardening heat treatment.

Keywords: titanium pseudo- β -alloys, semi-finished products of large thickness, hardening heat treatment, physical and mechanical properties.

UDC 621.793.74:669.35'71

Structure and properties of the bronze-based functional coating obtained by gas-dynamic and microplasma spraying. Klimov V. N., Kovaleva A. A., Bobkova T. I., Deev A. A., Chernysh A. A., Yurkov M. A. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 57–68.

Taken as a basis, a bronze powder was used to investigate the possibilities of applying functional-gradient coatings by the gas-dynamic and microplasma spraying. It was experimentally stated, that the oxide film on bronze particles surface prevents the appearance of coating impeding the process of gas-dynamic spraying. Two methods of the film destruction have been suggested: first – alumina utilization in the spraying process; second – manufacturing of composite bronze-based powder in the vibrating mill. An influence of ceramic particles on the coating hardness has been investigated. The paper analyzes perspectives of bronze coatings using for protection of important parts of marine equipment.

Keywords: BrAZhNMts8-1.5-5-1.5 bronze, powder, microplasma spraying, oxide film destruction, coating hardness.

UDC 678.067:620.193.1

The influence of the polytetrafluoroethylene viscoelastic properties on a range of working loads of a friction pair polytetrafluoroethylene – steel. Sedakova E. B., Kozyrev Yu. P. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 69–75.

Experimental research on the wear and friction of the polytetrafluoroethylene against steel has been carried out at a variation of sliding speed. The paper shows essential influence of sliding speed on polymer volumetric frictional warming up which increases a range of working loads and simultaneously decreases polymer wear resistance. An expression that allows predicting a range of polytetrafluoroethylene working loads in view of its viscoelastic properties has been received.

Keywords: friction, wear, polytetrafluoroethylene, working load, temperature, wear resistance.

UDC 678.01:539.3:539.27

Microstructural features of erosive destruction of polymeric composite materials at the dust and rain erosion. Deev I. S. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 76–86.

Microstructural features of erosive destruction of polymeric composite materials samples (glass fibres reinforced plastics and polymer fibres reinforced plastics), tested for dust and rain erosion have been investigated. It is shown that destruction nature depends on composition and structure of materials, abrasive particles nature and erosion conditions: particle sizes, speed and impact corner. For polymeric composite materials in aviation structures it is necessary to consider possible erosion of plastics microstructure surface at dust and rain conditions which can change their strength characteristics and facilitate further destruction at the subsequent mechanical influences.

Keywords: polymeric composite materials, rain and dust erosion, wear, microstructure.

UDC 678.686:539.4

Modification of epoxy polymers with silicon-containing filler to improve operation properties. Mostovoy A. S., Panova L. G., Kurbatova E. A. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 87–95.

The paper evaluates the efficiency of epoxy resins modification made to improve its physical, chemical and mechanical properties, using brick dust as high performance filler, dust is a huge waste of ceramic bricks production. The presented data shows a possibility of using brick dust to increase flexural strength, compressive strength and hardness, as well as heat resistance and thermal stability of materials on the basis of epoxy oligomer.

Keywords: epoxy resin, modification, filler, brick dust, mechanical properties.

UDC 678.743.41:621.891

Development of self-lubricating materials based on polytetrafluoroethylene. Gogoleva O. V., Petrova P. N. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 96–103.

This paper presents the results of studies on the development of self-lubricating polymer composite materials based on polytetrafluoroethylene containing porogen and zeolite. It is found that friction coefficient and temperature reducing in the contact area, increase wear resistance, and thereby reliability, safety and efficiency of transport and technological equipment operation.

Keywords: polytetrafluoroethylene, porogen, zeolite, structure, friction coefficient.

UDC 669.719:621.791.042

Production of welding electrodes with local mineral raw materials containing wolfram and titan by aluminothermy. Vlasenko V. D., Verkhoturov A. D. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 104–110.

High technologic production of composite materials containing W and Ti with Far Eastern ore concentrates is of significant scientific and practical interest. The method of aluminothermy has been applied for the synthesis of a new class of electrode materials with scheelite and ilmenite concentrates. Calculation method of the reaction batch composition ensures the recovery of W and Ti, alloying and product separation on metal and slag phases, and optimization process to obtain the largest possible quantity of the electrode material.

Keywords: electrode materials, electrospark alloying, aluminothermy, wolfram and titanium oxides.

UDC 621.791.3:539.213

Activated diffusion bonding of dissimilar materials with amorphous fillers. Gorynin I. V., Farmakovskiy B. V., Vasiliev A. F., Vinogradova T. S., Samodelkin E. A. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 111–119.

The features of brazing process of dissimilar materials with amorphous fillers (for example, steel–titanium pair) have been investigated. Amorphous alloy compositions have been developed for reducing the brazing temperature below the phase transformation temperature and preserving the advantages of diffusion layer, alloys represent a powder mixture of amorphous solder based on titanium (VPr-16) and fusible solders based on gallium and indium. The cylindrical butted samples, tube board elements, and specific complex structures for heat-exchange systems have been tested to determine bonding effectiveness, i. e. the mechanical strength.

The paper presents results of the X-ray spectral analysis obtained by Camebax micro, and states that the diffusion zone is about 100 mcm. The filler is completely consumed while the diffusion layer is being formed, the independent phase does not preserve, which provide high strength properties of the brazed junction.

A base approach developed for creating firm-and-impervious joints of dissimilar materials has been successfully implemented for other compositions, including brazing of aluminum, steel and NiCr; copper and quasicrystalline alloy of Al–Cu–Fe system; titanium and ruthenium. The paper provides specific examples of implementation successful cases.

Keywords: activated bonding with amorphous fillers, diffusion layer.

UDC 669.295:620.193.4

Relative corrosion resistance of oxidized titanium alloy coatings in corrosive environment. Khromushkin K. D., Ivanov V. G., Medvedev G. V. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 120–126.

Corrosion resistance of titanium 3M alloy has been investigated after thermal and micro-arc oxidation under general and crevice corrosion in comparison with non-acidic alloy resistance.

Keywords: titanium alloy, corrosion resistance, thermal oxidation, microarc oxidation.

UDC 620.197.5:669.14.018.293:629.561.5

Efficiency and operating parameters in arctic conditions of cathodic protection against corrosion-erosion damage of steel-clad ice belt of the nuclear-powered 50 Let Pobedy vessel. Stavitskiy O. A., Kuzmin Yu. L., Podshivalov A.V. – *Voprosy Materialovedeniya*, 2016, N 2(86), p. 127–136.

Full-scale measurements of parameters and dock survey of the electrochemical protection against corrosion-erosion damage of steel-clad ice belt of the nuclear-powered 50 Let Pobedy vessel (outer layer is of stainless steel). The parameters of an effective system of protection against vessel steel corrosion in ice conditions have been determined.

Keywords: electrochemical protection system, corrosion-erosion damage, clad steel, ice belt, anode structure.

UDC 620.197.5:620.193.1:629.561.5

New ice-resistant platinum-niobium anodes for cathodic protection systems against corrosion-erosion damage of icebreakers and ice-resistant offshore structures. Stavitsky O. A., Kuzmin Yu. L., Troshchenko V. N. – Voprosy Materialovedeniya, 2016, N 2(86), p. 137–146.

The paper shows how new generation of platinum-niobium anodes has been elaborated based on 15-year experience of AKK-M-4 anodes operating as a part of cathodic protection system for nuclear-powered 50 Let Pobedy icebreaker, which can provide protection against corrosion-erosion damage to modern icebreakers and undocking ice-resistant offshore structures without repair and replacement for up to 25 years or more. Updated ice-resistant anodes such as AKL-2MU and AKL-3MU have been developed.

Keywords: electrochemical protection system, corrosion-erosion damage, new generation platinum-niobium anodes.

UDC 669.71'12+669.4:620.197.5

Effect of lead on the anode behavior of Al–2,18%Fe alloy. Radzhabaliev S. S., Ganiev I. N., Amonov I. T. – Voprosy Materialovedeniya, 2016, N 2(86), p. 147–151.

Anodic characteristics of Al–2,18 wt. % Fe alloy, doped with lead in an electrolyte medium (3%NaCl solution) have been defined by potentiostatic method. It is shown that the addition of lead up to 0.05 wt. % somewhat decrease corrosion rate of initial alloy, while potentials of free corrosion and pitting shift into the negative range of values.

Keywords: Al + 2.18% Fe alloy, lead, potentiostatic method, corrosion rate, corrosion current, potential corrosion, pitting potential.

UDC 621.039.536.2:669.15–194

Threshold and limit impurity contents in WWER reactor pressure vessel materials. Margolin B. Z., Yurchenko E. V., Morozov A. M. – Voprosy Materialovedeniya, 2016, N 2(86), p. 152–163.

The physical nature of threshold and limit values of phosphorus and copper contents in the material for WWER reactor pressure vessels has been investigated. The numerical values have been estimated and proposal for upgrade trend curves for prediction of transition temperature shift has been performed.

Keywords: WWER-1000, reactor pressure vessels materials, threshold and limit impurity contents.

UDC 669.15–194:621.039.536.2:539.422.22

Prediction of radiation embrittlement of WWER-1000 reactor vessel materials considering the influence of alloying elements and high content of copper. Margolin B. Z., Yurchenko E. V. – Voprosy Materialovedeniya, 2016, N 2(86), p. 164–174.

Basing on the analysis of the radiation embrittlement of RPV materials, the paper proposes a model and dependencies for description of WWER-1000 vessel material embrittlement with copper content more than 0.10%. Regulatory dose-time dependencies have been revised.

Keywords: WWER-1000 reactor vessel, vessel materials, irradiation embrittlement, alloying elements, method of prediction.

UDC 669.018.64:531.6

A simple hardware design of techniques for mechanical loss factors measuring. Kosulnikov V. Yu., Lebedev V. L., Troshkin S. N., Logunova A. A. – Voprosy Materialovedeniya, 2016, N 2(86), p. 175–186.

A simple hardware design of techniques for mechanical loss factors measuring is suggested for samples of damping materials. Method is applicable to polymeric and metallic structural materials.

Keywords: mechanical loss factor, damping materials.