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## ABSTRACTS OF PUBLISHED ARTICLES

UDC 669.15–194.55:621.785.3

**Increasing resistance of high-chromium martensitic and ferritic-martensitic steels to brittle fracture by homogenizing.** Berezhko B. I., Olenin M. I., Gorynin V. I., Stolny V. I. – Voprosy Materialovedeniya, 2016, N 3(87), p. 7–13.

Structural transformations caused by homogenizing and subsequent thermal improvement of 15Kh11MFB steel have been researched. The paper shows that homogenizing before the final heat treatment enhances steel resistance to brittle fracture without reducing its strength properties.

*Keywords:* martensitic and martensitic-ferritic steels, homogenizing, structural transformation, resistance to brittle fracture.

UDC 621.14.018.293:669.046.516

**Increasing purity of vessel steel treated by complex modifiers.** Miliuts V. G., Tsukanov V. V., Petrov S. N., Efimov S. V. – Voprosy Materialovedeniya, 2016, N 3(87), p. 14–22.

The paper describes effects of complex modifiers with rare-earth metals (REM) at high-strength steel quenching on contamination by non-metallic inclusions. It is possible to produce pure steel without inclusions with high impact strength values and plasticity in the Z-direction using the optimal amount of REM along with the basic technology of steel modified by ferro calcium. X-ray microanalysis of morphology and elemental composition of the inclusions demonstrate that the large non-metallic inclusions are multiphase oxide conglomerates of different compositions with a small amount of sulfide phase.

*Keywords:* vessel steel, rare-earth metals, X-ray microanalysis, ferro calcium, modification, non-metallic inclusions.

UDC 669.295

**Development of near- $\beta$ -titanium alloy and technologies for semi-finished products manufacturing thereof.** Kablov E. N., Nochovnaya N. A., Gribkov Yu. A., Shiriaev A. A. – Voprosy Materialovedeniya, 2016, N 3(87), p. 23–31.

A high-strength titanium near- $\beta$ -alloy (VT 47) containing rare earth metals has been developed, the alloy having been designed especially for irregularly shaped sheet constructions of flying objects. A combination of mechanical and technological properties has been shown for the VT47 alloy after various heat treatments thereof. The further possible development of new materials with regulated  $\beta$ -structure has been shown.

*Keywords:* titanium near- $\beta$ -alloys, alloying, rare earth metals, heat treatment, regulated  $\beta$ -structure.

UDC 669.295:621.039.531:620.187

**Studies of nanostructured Ti–5Al–4V–2Zr alloy.** Leonov V. P., Schastlivaya I. A., Rogozhkin O. A., Nikitin A. A., Orlov N. N., Kozodaev M. A., Vasiliev A. A., Orekhov A. S. – Voprosy Materialovedeniya, 2016, N 3(87), p. 32–49.

The paper studies microstructure and chemical composition of phases and impurities in Ti–5Al–4V–2Zr titanium alloy in the initial state, irradiated by titanium ions till radiation dose, which was 1 dpa at 260°C and after aging at 450°C during 1000 hours. Microstructures have been scanned by transmission electron microscope and atom probe tomograph. Phases have been analyzed with energy-dispersive X-ray spectroscopy. Results of elemental analysis of  $\alpha$ -phase matrix grains and  $\beta$ -phase interlayer have been presented. Space distribution of chemical elements in  $\alpha$ - and  $\beta$ -phases has been analyzed by atom probe tomograph. Nanosized vanadium segregations formation has been detected in  $\alpha$ -phase of irradiated titanium alloy.

*Keywords:* titanium alloy, chemical and phase composition, radiation dose, radiation damage, nanosized segregations.

UDC 669.245:621.746.6

**Directional solidification of superalloy with variable controlled gradient.** Bondarenko Yu. A., Echin A. B. – Voprosy Materialovedeniya, 2016, N 3(87), p. 50–58.

The paper presents the results of studies of directional solidification conditions with variable controlled gradient in the structural features of nickel superalloy samples with monocrystalline structure with CLC <001>. Results of the study of the microstructure of the samples show that with increasing temperature gradient from 20 to 200°C/cm interdendritic distance decreases to about 2 times the particle size of the strengthening  $\gamma'$ -phase axes and between axes space dendrites – 2.5–3 times, particle size  $\gamma/\gamma'$ -eutectic – 2.5 times the volume fraction of microporosity – ~10 times. Increasing the temperature gradient also reduces dendritic segregation. With the rise of the temperature gradient in the single crystal alloy samples investigated in the cast state the rise of mechanical properties.

*Keywords:* directional solidification, heat resistant alloy, temperature gradient,  $\gamma'$ -reinforcing phase,  $\gamma/\gamma'$ -eutectic, dendrite segregation, microporosity, short-term strength, long-term strength.

UDC 669.2471

**Single crystal intermetallic Ni<sub>3</sub>Al alloy's mathematical calculations.** Arginbaeva E. G., Ospennikova O. G., Bazyleva O. A., Turenko E. Yu., Shestakov A. V. – Voprosy Materialovedeniya, 2016, N 3(87), p. 59–65.

Searching optimum composition for new intermetallic alloys it is necessary to make mathematical calculations with the view of reducing the number of experiments. The paper presents the calculating method for single crystal intermetallic Ni<sub>3</sub>Al alloy based on regression analysis of available statistic data subject to balance between chemical and phase compositions by electron density and atomic mass.

*Keywords:* nickel intermetallic compound, single crystal, long-term strength, structure, crystallographic orientation, lattice parameter, misfit, experiment.

UDC 621.793.6:669.14.018.258: 537.622

**Diffusive boride coatings influence on electromagnetic properties of die steel.** Pugacheva N. B., Zadvorkin S. M., Bykova T. M. – Voprosy Materialovedeniya, 2016, N 3(87), p. 66–73.

Phase and chemical structures of diffusive boride coatings on die steel X40CrMoV5-1 have been investigated. Values of electromagnetic properties of samples without coating and with diffusive boride coating of different thickness have been defined. It is shown that boriding of steel changes parameters of magnetic hysteresis loop, increasing values of coercive force, the residual magnetic induction and reducing magnetic permeability. While boride coatings thickness increases magnetic characteristics change slightly, and values of specific resistance increase too. Measurement of values of the maximum differential magnetic permeability can be used at control of boride coatings with not less than 100 microns thick existence dies after operation at the solution of resource extension, and resistance values – for control of boride coatings thickness.

*Keywords:* steel, die, coating, boride, diffusion, hysteresis loop, coercive force, magnetic induction, maximum differential magnetic permeability, specific resistance.

UDC 621.793.7:669.26:539.23

**On the formation of thin-film functional Cr-coatings on spherical precise units of gyro devices.** Scherbak A. G., Belyaev S. N., Loginov B. A. – Voprosy Materialovedeniya, 2016, N 3(87), p. 74–81.

The paper shows research results of the chromium sputtering on the spherical surface of precision products (film thickness varying from ten nanometers to a few micrometers). Technical solutions for tools equipment development and methods of thickness control directly during spraying have been proposed. The details of electrical conductivity dependence on thickness of the coating and sputtering conditions, as well as data on the effect of coating on operating parameters of the products have been presented considering electrostatic gyroscope rotor made of beryllium. There are prospects for this technology in the field of performance improving for units of gyro devices.

*Keywords:* spherical rotor, Cr-coatings, magnetron sputtering, resistance, granulometric composition, raster drawing, contrast.

UDC 621.793:615.4

**Biotechnological studies of the nanocentre at FSUE CRISM Prometey.** Gorynin I. V., Oryshchenko A. S., Farmakovskiy B. V., Vasilieva O. V., Vasiliev A. F., Vinogradova T. S., Eshmemetieva E. N., Mukhamedzhanova L. V., Samodelkin E. A., Kuznetsov P. A. – Voprosy Materialovedeniya, 2016, N 3(87), p. 82–96.

The paper presents results of experimental biotechnological research, effectuated by nanotechnological centre of FSUE CRISM Prometey. They develop gradient functional coatings (bactericide, anticorrosive, catalytically active); defensive systems for biological objects against negative influence of magnetic and electromagnetic radiation; high-speed treatment of medical and phytomaterials, alimentary, fodder and medicinal application, laser technologies of hybrid biomimetic application.

*Keywords:* biotechnology, functionally gradient bactericidal, anti-corrosion and catalytically active coatings, shock-wave treatment, medicines, phytomaterials, hybrid biomimetic composition.

UDC 666.3/.7:620.178.16

**Tribological express-studies of wear resistant  $Al_2O_3$ -based ceramics with SiC fibers against steel friction pair.** Markov M. A., Snimshchikov D. V., Krasikov A. V. – Voprosy Materialovedeniya, 2016, N 3(87), p. 97–103.

The paper shows results of tribological express studies of wear resistant aluminum oxide ceramics reinforced by SiC fibers in a frictional pair with steel rod.

*Keywords:* aluminum oxide ceramics, SiC fiber reinforcement, pair of friction, tribological express study.

UDC 678.067:620.174:620.193.21

**Effect of long climatic ageing on surface microstructure of the epoxy organoplastics and nature of its destruction under bend conditions.** Deev I. S., Kurshev E. V., Lonsky S. L., Zhelezina G. F. – Voprosy Materialovedeniya, 2016, N 3(87), p. 104–114.

The paper investigates different climate zones influence of long aging (5 years) on surface microstructure of epoxy organoplastics and nature of its destruction under bend conditions. The analysis and classification of the obtained microstructural and fractographic data considering influence of climatic factors and its duration have been carried out; main surface degradations of organoplastics have been established when aging and static bend testing. It is shown that the most considerable changes of macro- and microstructures of the studied materials have been observed at testing influence of atmospheric factors in the conditions of warm humid climate of Sochi (State Research and Proving Ground of Russian Academy of Sciences).

*Keywords:* epoxy organoplastics, long climatic aging, macro- and microstructure, scanning electron microscopy, durability under bend conditions.

UDC 621.791.762.5

**Physical and mathematical model of contact butt fusion welding.** Yerofeyev V. A., Piankov I. B. – Voprosy Materialovedeniya, 2016, N 3(87), p. 115–125.

The main source of heat at the flash-butt welding is explosion-spark process of the rise and release of liquid bridges, appearing when a gradual convergence of the welded parts takes place. This phenomenon is not described mathematically; therefore it is difficult to make computerized engineering analysis of this type of welding. The paper proposes to determine the energy parameters of the heat source based on the energy balance of the melting conditions, assuming that the temperature drops ejected from the junction, is constant. It is shown that the model, based on a thermal conductivity equation and the energy ratios describing the interaction interface with the welding machine, produces heat processes, taking into account the release of the metal in the form of a spray, as well as the effect of the speed of melting on the welding current and voltage at the junction at drops temperature equal to 1700–1800°C.

*Keywords:* contact butt welding, melting speed, welding current, heat in the joint, physical and mathematical model.

UDC 620.193.21

**Experimental justification for the schedule of natural climatic tests for metal materials in atmosphere of Black Sea Coast. Analytical review.** Lutsenko A. N., Kurs M. G., Laptev A. B. – Voprosy Materialovedeniya, 2016, N 3(87), p. 126–137.

Metal constructions for aviation receive most damage in conditions of high temperatures, humidity and chlorides medium corresponding to conditions of warm humid subtropical climate. The paper presents analysis of long climatic tests for metal materials in conditions of warm humid subtropical climate, including natural accelerated and cyclic tests which allow evaluating degradation level and justifying the life of the materials in the product. Research results of corrosion damage for metal materials (aluminum, magnum, titanium alloys and steels) with/without coatings in warm humid and warm climatic conditions at climatic stations of Batumi and Guelendzhik.

*Keywords:* natural climatic tests, corrosion, aluminum alloys, steels

UDC 669–419:620.193

**Corrosion-resistance evaluation of multi-layered metal materials.** Los I. S. – Voprosy Materialovedeniya, 2016, N 3(87), p. 138–144.

The object of the research is multi-layered corrosion-resistant material produced by explosive welding. The research subject is the process of corrosion attack in tested environment. An original method of corrosion testing for multilayer materials has been proposed. It is shown that the inner protector inhibits the nucleation and growth of pitting. Corrosion-resistance indicator for multilayer material has been calculated. It has been found that the corrosion resistance of the multi-layered material is 2.2 times higher than that of monometallic.

*Keywords:* multilayer material, pitting corrosion, explosive welding, corrosion test, protector.

UDC 621.039.534.25:539.375

**Estimating consequences of a fall of a container with a steam generator onto a platform of the rotating reactor roof in the BN-1200.** Vilensky O. Yu., Lapshin D. A., Malyguin M. G. – Voprosy Materialovedeniya, 2016, N 3(87), p. 145–158.

The main results of the computational analysis of the consequences of a fall of a container with a steam generator onto a platform of the rotating reactor roof have been presented. The results of experimental studies of deformation of steel St3 (Cт3) under static and dynamic loadings have been given. Parameters of Johnson–Cook model of LS-DYNA library used to perform computational analysis have been determined. The main results are presented that have been calculated in the elastoplastic formulation for stress-strain state of the rotating reactor roof, and the evaluations are provided of the reactor roof strength and operability.

*Keywords:* reactor, rotating reactor roof, container, elastoplastic deformation, strain rate, deformation model, fracture limit strain.

UDC 669.15–194.56:621.039.531:539.376

**Ductility and fracture toughness of irradiated austenitic steels with regard for deformation features and radiation swelling. Part 1.** Margolin B. Z., Sorokin A. A., Shvetsova V. A., Minkin A. I., Potapova V. A., Smirnov V. I. – Voprosy Materialovedeniya, 2016, N 3(87), p. 159–191

Fracture mechanisms of irradiated steels and effect of radiation swelling on ductility and fracture toughness have been investigated. Moreover, effects of test temperature and previous cyclic deformation on fracture properties have been considered.

*Keywords:* irradiated austenitic steel, neutron radiation, radiation swelling, ductility, fracture toughness, fatigue crack.

UDC 669.15–194.56:621.039.531:539.376

**Fatigue crack growth rate of irradiated austenitic steels with regard for deformation features and radiation swelling. Part 2.** Margolin B. Z., Minkin A. I., Smirnov V. I., Sorokin A. A., Shvetsova V. A., Potapova V. A. – Voprosy Materialovedeniya, 2016, N 3(87), p. 192–210..

Fracture mechanisms of irradiated austenitic steels under cyclic loading have been considered. Effects of radiation swelling on fatigue crack growth rate have been investigated.

*Keywords:* irradiated austenitic steel, neutron radiation, radiation swelling, fatigue crack growth rate.

UDC 669.15–194:621.039.531:539.422.22

**On modeling of thermal aging by neutron irradiation and annealing.** Margolin B. Z., Yurchenko E. V., Potapova V. A. – *Voprosy Materialovedeniya*, 2016, N 3(87), p. 211–219.

New method for prediction of long-term thermal embrittlement of RPV steels caused by phosphorus segregation has been verified. The method is based on impact strength and (or) fracture toughness test results after short-term neutron irradiation and post-irradiation aging of the specimens. The features of brittle fracture of material in different states have been considered. The great acceleration of phosphorus diffusion under neutron irradiation has been proved.

*Keywords:* steel, long-term thermal embrittlement, phosphorus segregation, neutron irradiation, brittle fracture, prediction method.