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CONTENTS

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STRUCTURE FORMATION OF NITROGEN-CONTAINING AUSTENITIC 04Kh20N6G11M2AFB STEEL. Part I. Influence of deformation temperature and strain rate on the dynamic recrystallization

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Abstract—The paper determines values of the deformation threshold necessary for the initiation and development of dynamic recrystallization in the investigated deformation temperature and strain rate. Analysis of diagrams shows that the deformation resistance increases with decreasing of temperature, while a weak peak is observed at temperature 1000–1200°C, when dynamic recrystallization starts. The structure of high-strength corrosion-resistant nitrogen-containing austenitic steel 04Kh20N6G11M2AFB after hot deformation with strain rate 0.1, 1.0 and 10 s^{-1} in the temperature range 900–1200°C has been studied by EBSD analysis and transmission electron microscopy.

Keywords: nitrogen-containing austenitic steel, EBSD analysis, structure, dynamic recrystallization, hot deformation, strain rate, deformation resistance.

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FORMATION OF STRUCTURE OF NITROGEN-CONTAINING AUSTENITIC 04Kh20N6G11M2AFB STEEL AT HOT DEFORMATION. Part 2. Influence of the phase composition and hot deformation conditions on the process of dynamic recrystallization

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Abstract—The effect of δ-ferrite in high-strength corrosion-resistant nitrogen-containing steel of 04Kh20N6G11M2AFB grade on deformation resistance during hot deformation in the temperature range of 900–1200°C and strain rates of 0.1–10 s^{-1} has been investigated. Analysis of diagrams shows that dynamic recrystallization of δ-ferrite steel starts at a lower threshold deformation rate comparing with pure

austenitic steel. The values of the deformation threshold necessary for the initiation and development of dynamic recrystallization depending on the phase composition of the nitrogen-containing steel have been determined. After structure complex analysis, it was established that δ-ferrite promotes the nucleation and development of dynamic recrystallization at temperature 1200–1000°C (starting at the lowest deformation threshold), and recrystallized structure forms in the larger volume range than in purely austenitic steel.

Keywords: nitrogen-containing austenitic steel, δ-ferrite, structure, dynamic recrystallization, hot deformation, strain rate, deformation resistance

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STRUCTURE AND PROPERTIES OF THE HEAT-AFFECTED ZONE OF LOW-ALLOYED COLD-RESISTANT STEEL FOR ARCTIC APPLICATION

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Abstract—The paper presents the results of a comprehensive study of structural and properties changes in the most dangerous regions of the heat-affected zone of low-alloyed cold-resistant steel with a guaranteed yield strength of 355–390 MPa before and after the post-welding tempering, including when the heating temperature is subjected to tempering and deformation, comparing with the base metal. The simulation was performed on the dilatometer DIL 805 and the Gleeble 3800 complex. The results of the investigation of the structure and properties of real welded joints after welding with different linear energy (3.5 and 6 kJ/mm) are presented.

Keywords: base metal, coarse-grain region of the HAZ, partial recrystallization region of the HAZ, post-welding release, bainite, ferrite-carbide mixture, recrystallization, deformation rate, deformation capacity, failure mode, welded joint.

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ON STRUCTURE AND PHASE COMPOSITION OF NiAl-Ni_3Al-BASED INTERMETALLIC ALLOYS OBTAINED BY HIGH-GRADIENT DIRECTIONAL CRYSTALLIZATION

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Abstract—The paper studies structure and phase composition of NiAl-Ni_3Al-based intermetallic alloys. It has been established that at high-gradient directional crystallization axis-oriented dendritic structure with high heat resistance, strength and ductility is being formed in NiAl and Ni_3Al intermetallic samples.

Keywords: high-gradient directional crystallization, intermetallic heat-resistant alloy, structure, phase composition, short-term strength, plasticity, heat resistance.

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INVESTIGATING OXIDATION OF NIOBIUM BY LASER TREATMENT

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Abstract—Composition, structure, and optical properties of films formed on the surface of niobium during laser processing are presented. Two modes of laser oxidation of niobium are empirically determined. The

first mode, using single-pass laser processing, create the blue shade oxide film, the second mode, using multipass laser processing, forms the green shade oxide film. The optical contrast, determined as a difference of reflection coefficients, in the infrared spectrum of the blue oxide film is equal to 0.2 and the green oxide film forms the contrast equal to 0.5. It was found that the niobium blue shade oxide films, obtained after laser processing, has stoichiometry NbO and the green oxide film has stoichiometry NbO_2.

Keywords: laser treatment, niobium, niobium oxides, laser polishing, optical contrast.

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MODERN APPROACHES FOR THE DEVELOPMENT OF MARINE ANTIFOULING COATINGS

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Abstract—At present, 75–80% of the current operating costs of conventional transport are expended for fuel. According to the International Maritime Organization the world fleet burns 300 million tons of fuel annually, releasing into the atmosphere 960 million tons of CO_2 and 9 million tons of SO_2. By 2020, without new technologies that reduce fuel consumption, air emissions can grow 40%, taking into account constantly increasing volumes of traffic. Therefore, defense methods against marine overgrowth are an urgent topic, and many leading firms are developing antifouling solutions. The paper considers the main means of protection against fouling with the help of polymer coatings, namely: contact active coatings; non-leaching coatings; self-polishing coatings; non-biocidal coatings. The mechanism of using polymer coatings, as well as their advantages and disadvantages, is described.

Keywords: fouling, self-polishing coatings.

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METHODS OF COMBINED PRODUCTION OF COMPOSITE POWDER MATERIALS AND FUNCTIONAL COATINGS ON THEIR BASIS

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Abstract— A technology for producing powder composite materials consisting of ductile Fe-Cr-Al matrix, a cladding component based on chromium and aluminum nitrides and solid nanosized tungsten carbide composites has been developed. Functional gradient coatings were obtained on basis of the developed powders by microplasma spraying, combining high adhesion and cohesive strength with high hardness of peripheral layers. So coatings based on the developed composite powders are very promising for the protection of parts and components of precision and power engineering from wear under high mechanical stress.

Keywords: composite powders, microplasma spraying, functional gradient coatings, cladding, tungsten carbide, precision power engineering.

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INFLUENCE OF COPPER CONTENT ON WEAR BEHAVIOR OF COMPOSITES “STEEL ShKh15/COPPER” AT SLIDING AGAINST COPPER UNDER ELECTRIC CURRENT OF CONTACT DENSITY HIGHER THAN 100 A/cm^2

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Abstract—Powder composites “steel ShKh15/copper” in alumina ceramics and graphite powders surrounding were sintered in the air. Powder steel was restored from grinding slime of bearings production. It is shown that the steel framework has low level of mechanical properties, but high pore space percolation. Copper concentration increases isolated pores concentration impeding oil impregnation. This effect did not allow making the long and steady sliding electric contact with contact current density higher than 150 A/cm^2. The sintered composites based on recycled bearing steel and containing near 15%Cu show high wear resistance at sliding with a contact current density 150–200 A/cm^2 under boundary lubrication.

Keywords: sliding electric contact, surface layer, specific surface contact, electric conductivity, sintered composite, pores space.

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CATALYTICALLY ACTIVE COATINGS FOR STEAM REFORMING SYSTEMS: SYNTHESIS AND CATALYTIC PROPERTIES

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Abstract—The paper considers science and engineering aspects of catalytically active compositions creation as regards immobilized catalysts for reforming hydrocarbon raw materials into hydrogen fuel. The authors investigate synthesis of catalytic powder mixtures and manufacturing of functional coatings by supersonic cold gas dynamic spraying. Research results in the field of creation of catalysts for steam conversion of methane to hydrogenous fuel on the metal support (Cr15Al15 tape support) are given. Composite powder mixtures (Ni–Al–$Al(OH)_3$ – $Ca(OH)_2$–$Mg(OH)_2$) were used as starting materials.

Keywords: steam methane reforming, immobilized catalysts, catalytically active powder mixtures, functional coating, surface morphology, tape support, promoting agent.

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CAST MICROWIRE WITH HIGH VALUE OF THERMOELECTROMOTIVE FORCE

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The paper studies precision alloy based on the intermetallic composition Ni_3Sn + SiB_3 and developed for casting thermoresistant microwires in glass insulation. Cast microwires have a temperature coefficient of resistance (7.8–8.2) 10^{-3} K^{-1} and a specific resistance of 0.68–0.83 Ohm·mm^2 / m, the wires could be recommended for miniature temperature sensors manufacturing.

Keywords: cast microwire in glass insulation, temperature coefficient of resistance, resistivity.

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CORRELATION OF THE DIAMOND/MATRIX INTERPHASE ZONE STRUCTURE WITH TOOL EFFICIENCY OBTAINED BY TECHNOLOGY COMBINING DIAMONDS METALLIZATION WITH MATRIX SINTERING

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Abstract—The paper studies structure and phase characteristics of the interphase zone diamond/matrix in dressers made by thermal diffusion metallization of a diamond combined with matrix sintering based on WC–Co and Cu impregnation. The compact arrangement of chromium powder particles around diamond grains and the shielding effect of copper foil create favorable conditions for thermal diffusion metallization of diamond at matrix sintering. A metallized coating chemically bonded with diamond and consisting of chromium carbide and solid solution of cobalt in chromium phases provides a strong diamond retention in the carbide matrix. It was shown that it is formed on the surface of the diamond under the conditions specified in the experiment and the temperature – time sintering mode. The specific productivity of experimental dresser made by hybrid technology at straightening green silicon carbide grinding wheel equaled 51.50 cm^3/mg exceeding that of the control dresser made without metallization of diamonds by sintering with copper impregnation by 44.66%.

Keywords: diamond retention, metallization, interphase zone, cemented carbide matrix, specific tool productivity, matrix sintering.

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MAIN DIRECTIONS FOR RESEARCH ON THE DEVELOPMENT OF TRIBOTECHNICAL COMPOSITES USED IN THE ARCTIC REGIONS (On the Experience of North-Eastern Federal University in Yakutsk)

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Abstract—Material science studies the relationship between materials structure and properties and its changes under external influence, and belongs to the priority domains of science and technology. The creation of new materials and also its performance improvement, efficient technologies for their processing is the main goal of material science. Today a substantial number of new metal alloys with special properties, different composites, ceramics, polymers, nanostructured functional powder and synthetic superhard materials, multifunctional coatings, etc. have been designed for various economic activities. But the creation of materials and technologies remains an urgent need, because of the progressive development of manufacturing which requires adaptive materials properties and technologies for their processing.

This review analyzes Ammosov North-Eastern Federal University research directions in the field of tribotechnical materials for use in the Arctic regions. Main areas of research are identified, such as developing of polymer composite materials (PCM) production and improving their performance properties. The prospects of physical processing and chemical modification of the polymer matrix surface are shown. Physicomechanical and tribotechnical properties of antifrictional PCM are discussed. The results of the main theoretical generalizations in the field of analysis of PCM supramolecular structures are presented: 1) effects of critical filler concentrations on the structure and properties of PCM; 2) hypothesis of the nature of intermolecular interaction between the filler and the polymer. The modern tendencies of scientific investigation are shown, namely tribo-oxidative processes in PCM. The specific development of scientific knowledge and the use of polymers for the northern regions are revealed.

Keywords: composite materials, polytetrafluoroethylene, ultrahigh molecular polyethylene, nanoparticles, dispersed fillers, layered silicates, mechanoactivation, wear resistance, coefficient of friction, tribotechnical properties, deformation-strength properties.

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INVESTIGATING HOLLOW CORUNDUM MICROSPHERES EXFOLIATION OF THE ELASTOMERIC MATRIX

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Abstract—The results of study of the influence of hollow corundum microspheres HCM-S (5–100 μm) and HCM-L (70–180 μm) on the properties of nitrile butadiene rubber BNKS-18 are presented. The dependence of elastomer resistance to abrasion impact and physic and mechanical properties on the dispersion and concentration of hollow corundum microspheres is shown. The process of hollow corundum microspheres exfoliation of the elastomeric matrix, which largely determines the change of physic and mechanical properties, has been studied by specially developed stretching device compatible with an atomic force microscope. The paper describes microspheres exfoliation which is conventionally divided into 3 stages.

Keywords: hollow corundum microspheres, nitrile butadiene rubber, wear resistance, physical and mechanical properties, atomic force microscopy, exfoliation, adhesion.

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ON THE MICROSTRUCTURE AND STRUCTURE OF THE POLYIMIDE FILM SURFACE AND CONDENSED SUBSTANCES AFTER LONG-TERM EXPOSURE ON THE MIR SPACE STATION

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Abstract—Complex research of polyimide film microstructure and chemical composition has been conducted by scanning electron microscopy, electronic probe microanalysis and infrared spectroscopy. Changes in layers' surface and in substances condensed on films were studied after long-term exposure (1218 days) on Mir space station. It is shown that during space exposure microstructure and chemical composition of the first layer suffer changes, but other layers of the package located below don't reveal similar transformations. New phase formations of different shape and size with film and needle structure varying by its chemical composition have been found on an open surface of the first polyimide film layer. It has been established that the condensed substances consist of silicon, iron, copper, zinc, chlorine, potassium and calcium compounds, which are probably deposited from the outer atmosphere of the orbital station.

Keywords: polyimide film, condensed substances, microstructure, chemical composition, Mir Space Station, long exposure.

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ARAMID FIBER REINFORCED PLASTIC FOR COMPOSITE MARINE CONSTRUCTIONS EXPLOITED IN SEA WATER

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Abstract— The article considers the results of investigation fiber reinforced plastic for middle layer of ship’s constructions exploited in sea water. Mechanical properties of material were investigated to justificate the right choice of basic materials, construction structure and manufacturing process.

Key words: Aramid fiber reinforced plastic, fiberglass, three-layer construction, epoxy resin

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MODERNIZATION OF DIGITAL BEAM WELDING SCANNING

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Abstract—Instead of outdated GUR-1, scanning electron beam control generator, a modernized system is proposed using digital beam control along special semi-elliptical welding trajectory. The new system has successfully passed approbation when welding aluminum on an ELU-20.

Keywords: electron beam welding, electron beam, beam scanning, digital beam control, weld seam quality.

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MANAGING JOINT WELD FORMATION PROCESS AT ELECTRON BEAM WELDING OF ALUMINUM ALLOYS OF INCREASED THICKNESSES

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Abstract—The technology of electron beam welding of homogeneous and dissimilar welds of aluminum alloys 1561, 1560M and 1980T1 has been developed. Beam scanning along semielliptical trajectory has secured the quality of the welded parts with fine mechanical properties. Welding scheme and optimal modes have been determined. Results of mechanical and corrosion tests, and of testing to destruction delayed in time have been defined. The technology is implemented for hydrofoil devices and for the manufacture of shipbuilding machinery components.

Keywords: electron beam welding, aluminum alloys, electron beam scanning, welds, mechanical properties, corrosion tests, testing to destruction delayed in time.

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ON THE RADIATION EMBRITTLEMENT OF MATERIALS OF SUPPORT STRUCTURES FOR WWER RPV . Part 1. Experimental studies

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Abstract—The features of the radiation embrittlement of materials of support structures for WWER RPV are considered. These features are connected with low irradiation temperature no exceeding 90°C and also with a use of the steels which are usually applied for building of the metal structures and have not a high resistance to the radiation embrittlement. It has been shown that support structure (SS) of WWER-440 of V-179, V-230 types may cause the operation life limit. The experimental data on the standard mechanical properties and fracture toughness are presented for different steels and weld metals in the initial and irradiation conditions. SEM investigation of fracture surface of broken specimens and atomic tomography have been performed.

Keywords: support structure, RPV, radiation embrittlement, resistance to radiation embrittlement, standard mechanical properties, fracture toughness, SEM investigation, microstructural investigation, atom probe tomography.

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ON THE RADIATION EMBRITTLEMENT OF MATERIALS OF SUPPORT STRUCTURES FOR WWER RPV. Part 2. Analysis of the completed studies

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Abstract—The features of the radiation embrittlement of materials of support structures for WWER RPV are considered. These features are connected with low irradiation temperature no exceeding 90°C and also with a use of the steels which are usually applied for building of the metal structures and have not a high resistance to the radiation embrittlement. The model for prediction of material radiation embrittlement as function of the neutron fluence and impurity of Cu and P is proposed. An irradiation temperature effect on the different mechanisms resulting in the material radiation embrittlement is considered: materials hardening due to nucleation of point defects and formation of dislocation loops, copper precipitation and materials non-hardening due to phosphorus segregation.

Keywords: support structure, RPV, radiation embrittlement, dose dependences, operation temperature, impurity elements.

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ZIRCONIUM ALLOYS WITH LOW MELTING POINTS

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Abstract—A novel class of low-melting Zr-based alloys has been developed. They are deep triple and quadruple eutectics with very low melting points from 690 to 860°C. Low-melting Zr-based alloys proposed as a matrix material for fuel elements with dispersed high-U fuel. Proposed fuel compositions have been developed with high thermal conductivity and U content (25–50% higher than in case of VVER and PWR fuel rods). As applied to PWR and BWR reactors, they have some advantages compared to conventional uranium dioxide fuel pellets. The use of new dispersion fuel can improve neutron-physical characteristics of the reactors, increase burn-out, reduce fuel temperature and improve fuel efficiency.

Keywords: Zr-based alloys, low-melting alloys, eutectics, atomic energy, fuel element.

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