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X-RAY AND NEUTRON DIFFRACTION STUDY OF HIGH-STRENGTH STEEL. METHODOLOGICAL ASPECTS

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Abstract—X-ray and neutron diffraction are indispensable in the analysis of the integral characteristics of the dispersed precipitates in high-strength medium-carbon steels. Advantages and limitations of methods application have been compared by studying dispersed phases changes in the qualitative and quantitative composition of steel. Wear-resistant B1700 steel was tested after quenching and tempering in the temperature range 150–600°C. Quantity of retained austenite decreased to zero when the tempering temperature rises more than 300°C. Cementite becomes noticeable in the diffraction patterns at the same temperature range. The results of the study show that neutron instruments can more reliably detect small amounts of retained austenite, while X-ray instruments provide better resolution, especially at large scattering angles.

Keywords: X-Ray and neutron diffraction, carbides, retained austenite, high-strength steel

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CALCULATION AND INVESTIGATION OF THE STRESS-STRAIN STATE OF A NITRIDED GEAR WHEEL

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Abstract—The article presents an analysis of the stress-strain state of the nitrided gear design using the SolidWorks Simulation and APM WinMachine (FEM) programs. Models, methods and examples of calculations are given. As a result of nitriding, the surface hardness of the product increases, the safety factor increases. The experiment proved that the optimal temperature for the formation of a nitrided layer with a hardness of 11,740–12,003 MPa for corrosion-resistant heat-resistant steel grade 12Kh18N9T was 570–590°C with a nitriding time of 48 hours. It is shown that after nitriding, the steel under study has a homogeneous structure with clearly defined transition layers, the average thickness of the nitrided layer is 60–90 microns. The stress-strain state of the product before and after nitriding, which determines the internal stresses and deformation of the wheel tooth, shows that the static characteristics are approximately equal. However, a wheel hardened by nitriding has a higher hardness, a greater safety margin and it is less prone to deformation under high loads.

Keywords: strength, corrosion-resistant heat-resistant steel, technology, gear wheel, static, nitriding, fatigue, reliability, hardness.

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HEAT TREATMENT OF WELDED JOINTS OF EXPERIMENTAL HIGHLY-DOPED TITANIUM ALLOY

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Abstract—In this article, the effect of heat treatment on the phase composition and structural state of welded joints of an experimental highly-doped titanium alloy, made by argon-arc and electron-beam welding, was investigated. As a result of the heat treatment of welded joints at a temperature of 690 ° C, the structure of the near-seam zone is stabilized. However, in order to fully restore the plasticity of the welded joint with the formation of alpha-phase globules of a simple structure in the structure of the near-seam zone, a higher heat treatment temperature is required.

Keywords: titanium alloys, welded joint, heat treatment, structure, microhardness

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INVESTIGATION OF THE PROPERTIES, STRUCTURE AND QUALITY OF THE ALLOY Ti-4.25Al-2V BLANKS PRODUCED BY DIRECT LASER DEPOSITION

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Abstract—The article presents the results of studies of the mechanical properties of the titanium alloy Ti-4.25Al-2V, fabricated by direct metal deposition on equipment developed by State Marine Technical University. A comparative analysis of the mechanical properties of the deposited metal in comparison with cast and forged metal is carried out. It is shown that the high level of its properties as regards cast metal is associated with differences in its structure, in particular, with high dispersion.

Keywords: additive technologies, direct laser deposition, near-α titanium alloys, structure, mechanical properties

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STUDY OF SURFACE LAYERS OF VT41 TITANIUM ALLOY AFTER MECHANICAL TREATMENT

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Abstract—The work studies residual stresses in the surface layer, roughness of flat surfaces of titanium alloy VT41 sample, obtained by milling with end mills, as well as conditions for relieving these stresses by means of incomplete annealing. The milling was carried out on a universal vertical milling machine, varying the conditions of the machining allowance in one pass and the cutters.

Keywords: titanium alloy, milling, roughness, residual stresses

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APPLICATION OF CARBON NANOTUBES PRODUCED BY CVD-METHOD FOR SUPERCAPACITOR WITH $LiPF_6$-BASED ELECTROLYTE

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Abstract—The paper studies carbon nanotubes (CNTs) synthesized by chemical vapor deposition (CVD) method on $Fe\text{-}_{0.7}Co/_{2.1}Al_2O_3$, $Fe\text{-}Co/_{2.1}Al_2O_3$, and $Co\text{-}Mo/Al_2O_3\text{-}MgO$ catalysts for supercapacitor electrodes with $LiPF_6$-based electrolyte. It was found that the specific capacitance of 150–200 F/g for electrodes made of a mixture of carbon materials and graphite depends significantly on the conditions of creating intergranular contacts between graphite particles and CNTs that form a system of vacancies for ion introduction, in which reversible intercalation of PF_6^--anions occurs with minimal difficulties.

Keywords: supercapacitor, carbon nanotubes, cyclic voltammetry, electrolyte, functionalization

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RESEARCH OF THE PROCESS OF ACTIVATED SOLDERING FOR GLASS/METAL

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Abstract—The article presents the results of research on the development of technology for joining glass-to-metal using activated soldering with amorphous solders.

Keywords: amorphous solders, activated soldering, liquid and solid phase energy relaxation, metal-glass pair, interfacial tension

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DEVELOPMENT OF A TECHNOLOGY OF PROTECTIVE FUNCTIONAL GRADIENT COATINGS OF TITANIUM DIBORIDE BY MAGNETRON SPUTTERING

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Abstract—This work presents the results of studying a composition based on titanium diboride TiB_2. Functional gradient coatings with high values of microhardness (28–32 GPa) and corrosion resistance in synthetic seawater, alkali (NaOH) and acid (HCl) were obtained using the method of magnetron sputter-

ing. The obtained functional gradient coatings are recommended for the protection of products of precision mechanical engineering and instrument making.

Keywords: titanium diboride, magnetron sputtering, functional gradient coatings, precision engineering

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DEVELOPMENT OF A TECHNOLOGY FOR MAGNETRON SPUTTERING OF COMPOSITE NANOSTRUCTURED COATINGS FROM AN ALLOY OF THE V–Ti–Cr–TiC SYSTEM

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Abstract—The results of the study of alloys of the V–Ti–Cr–TiC system for obtaining composite nanostructured coatings using the magnetron sputtering are presented. The studied coating has a high level of microhardness and wear resistance.

Keywords: nanocomposite materials, composite coatings, magnetron sputtering, microhardness, modulus of elasticity, coefficient of friction, wear rate

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FUNCTIONAL-GRADIENT COATINGS OF THE HfB_2–Si_3N_4 SYSTEM WITH HIGH WEAR RESISTANCE OBTAINED BY SUPERSONIC COLD GAS-DYNAMIC SPRAYING

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Abstract—The results of comprehensive studies of obtaining functionally graded coatings based on HfB_2–Si_3N_4–Zr compositions using the technology of supersonic cold gas-dynamic spraying are presented. Data are given on the measurement of adhesive strength (up to 62 MPa), microhardness (up to 42 GPa) and wear resistance (up to $1.2 \cdot 10^{-9}$ mm/km) of the obtained coatings.

Keywords: hafnium diboride, adhesion strength, microhardness, wear resistance, supersonic cold gas dynamic spraying, functionally graded coating

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THE INFLUENCE OF THE ZhS6K POWDER INITIAL CHARACTERISTICS ON THE ALLOY MICRORELIEF FEATURES AFTER SELECTIVE LASER MELTING

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Abstract—The analysis of the ZhS6K alloy granules appearance, their surface and internal structure, as well as the chemical composition by volume and structural elements is carried out. The formation control possibility is shown for desired state of interfaces (tracks, crystallization cells, hatch block boundaries, grains, phases, discontinuities - pores and cracks) through the fractional composition, packing density during filling, scanning speed that provide a more solid and qualitative material state of the sample. The initial state of the samples structure was studied. A connection between the structure of crystallization cells boundaries, dispersed particles and the fragments structure has been established. It is shown that all investigated samples have a different structure at the same power and scanning strategy. The analysis was carried out by optical metallography and scanning (raster) electron microscopy (SEM) methods.

Keywords: ZhS6K alloy, selective laser melting, SEM, interfaces, concentration inhomogeneities, image analysis, phase surface, γ'-phase, structural transformations

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COMPOSITE NANOSTRUCTURED POWDERS OF THE NITINOL–ZrC SYSTEM FOR OBTAINING COATINGS WITH HIGH PHYSICAL AND MECHANICAL PROPERTIES

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Abstract—The results of a study on the preparation of composite nanostructured powders of the Nitinol–ZrC system and functional coatings based on them with high performance properties are presented.

Keywords: composite, nanostructure, powder material, Nitinol, functional coating, adhesion, microhardness, porosity, wear resistance

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MOLECULAR-DYNAMIC MODELING APPLIED FOR ANALYSIS OF COMPOSITE WEAR RESISTANCE INCREASING AS COMPARED WITH THE ORIGINAL POLYMER MATRIX

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Abstract—The influence of filling on the mechanical properties of polytetrafluoroethylene (PTFE) was investigated by molecular dynamic modeling. Molecular models of PTFE and its composite F4K20 were built. Energy values of intermolecular interaction were determined, stiffness and flexibility matrices of PTFE and F4K20 were obtained. It was shown that energy of intermolecular interaction of F4K20 is approximately 15 times higher in comparison with energy of intermolecular interaction of PTFE. Calculation based on modeling showed that the introduction of the filler leads to a significant increase in the composite shear modulus in comparison with the initial matrix, which may be the reason of wear resistance increasing of polymer composites.

Keywords: polymer, polytetrafluoroethylene, composite, molecular dynamic modeling, friction, wear, intermolecular interaction energy, shear modulus

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INFLUENCE OF ION-PLASMA TREATMENT OF REINFORCING FILLERS ON THE COMPLEX OF PCM PROPERTIES

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Abstract—This paper presents the results of studying samples of glass-carbon plastics based on reinforcing fillers subjected to ion-plasma treatment. The influence of the speed of surface treatment on the complex of physical and mechanical characteristics of glass-fiber-reinforced plastics is shown. According to the results of microstructural studies, it was found that ion-plasma treatment promotes an increase in interfacial interaction at the fiber-matrix interface. The effect of ion-plasma treatment of reinforcing fillers on the properties of PCM samples in a moisture-saturated state is shown.

Keywords: ion-plasma treatment, ion-plasma treatment in vacuum, atmospheric ion-plasma treatment, fiberglass, strength characteristics, moisture absorption.

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PROPERTIES OF THE FIBERGLASS BASED ON THE FIRE-RESISTANT POLYESTER RESINS OF RUSSIAN BRANDS ARKPOL 40 M AND POLYMER 3088 TA

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Abstract—The article presents the results of technological, physico-mechanical and fire tests of the fire-resistant polyester resins, binders and fiberglasses based on them and manufactured by contact molding. The new brands are compared with those used in shipbuilding nowadays.

Keywords: fiberglass, polyester resin, contact molding, combustibility, shipbuilding

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INVESTIGATION OF STRUCTURAL-PHASE TRANSFORMATIONS IN METAL OF WELDED JOINTS OF REACTOR PLANTS FOR NUCLEAR ICEBREAKERS

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Abstract—The method of mathematical modeling was used to determine the rate of cooling of the heat-affected zone at performing assembling welded joints of reactor plants for nuclear icebreakers via preliminary surfacing. With the hardening-deformation dilatometer, an imitation effect of thermal cycles was carried out in various sections of the preliminary surfacing metal, made with three types of welding consumables: carbon steel, silicon-manganese steel and nickel-alloyed steel. Investigations of the structure and hardness of the samples after the imitation effect of thermal welding cycles have been carried out. It has been established that the Sv-06AA carbon steel wire in the entire range of cooling rates provides a ferrite-pearlite structure of the deposited metal. Manganese silicon steel welding wire Sv-08MnSi in a wide range of cooling rates provides the structure of the deposited metal in the form of acicular ferrite, while wire alloyed with nickel steel Sv-10MnNi forms acicular and quasi-polygonal ferrite.

Keywords: modeling of thermal welding cycles, preliminary surfacing, acicular ferrite, pearlite, thermo-kinetic diagram

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POST-RADIATION ANNEALING INFLUENCE ON THE EVOLUTION OF THE MATERIALS PROPERTIES OF THE SUPPORTING STRUCTURES OF WWER-440 REACTOR VESSELS.
Part 1: Problem statement and test results

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Abstract—Experimental studies have been carried out regarding the effect of annealing temperature on the degree of properties recovery of supporting structures materials for WWER-440 reactor vessels (low-strength ferritic-pearlitic steel and its weld metal) irradiated at low temperatures (50–90°C). Properties connected with material embrittlement have been determined on the basis of test results of tensile specimens, impact bending specimens and fracture toughness specimens. Dependence of properties recovery coefficient on annealing temperature have been determined. It is shown that for material with high content of copper dependence of properties recovery coefficient on annealing temperature may be nonmonotonic.

Keywords: WWER-440 reactor vessels, supporting structures, annealing temperature, ferritic-pearlitic steel, low-temperature irradiation, radiation embrittlement, mechanic properties

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POST-RADIATION ANNEALING INFLUENCE ON THE EVOLUTION OF THE MATERIALS PROPERTIES OF THE SUPPORTING STRUCTURES OF WWER-440 REACTOR VESSELS. Part 2: Analysis of the influence of material annealing after low temperature irradiation

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Abstract—The results of studying the influence of annealing temperature on the restoration degree of the materials properties of WWER-440 reactor vessels supporting structures (low-strength ferritic-pearlitic steel and its weld metal) irradiated at low temperatures (50–90°C) are analyzed. The main processes that occur during the annealing of the supporting structures materials after low-temperature irradiation and lead to an ambiguous effect of the annealing temperature on the recovery degree of the properties of supporting structures materials are revealed. The influence of impurities (phosphorus and copper) on the embrittlement of the material during irradiation and on the recovery of its properties after annealing is considered.

Keywords: WWER-440 reactor vessels, supporting structures, annealing temperature, ferritic-pearlitic steel, low-temperature irradiation, radiation embrittlement, mechanic properties

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INFLUENCE OF THERMOMECHANICAL EXPOSURE ON THE STRUCTURE OF HYDRIDES IN IRRADIATED E110 ALLOY CLADDING PIPES UNDER THE CONDITIONS OF LONG-TERM DRY STORAGE OF SPENT NUCLEAR FUEL

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Abstract—The penetration of atomic hydrogen into the cladding material of fuel elements of WWER-1000 reactors due to interaction with the coolant during operation can subsequently significantly reduce their plasticity characteristics with a decrease in temperature during long-term dry storage of spent nuclear fuel (SNF) due to the formation of brittle hydrides. The morphology of hydrides influenced by the hydrogen content, storage temperature and circumferential stresses plays a decisive role in the embrittlement of the fuel cladding material. Associated radial hydrides are of particular danger; they constitute the most favorable path for crack propagation.

In the present work, thermomechanical tests of irradiated fuel claddings samples made of the E110 alloy were carried out, simulating normal and emergency conditions of long-term dry storage. It was shown that under the conditions considered, the formation of a significant amount of radially oriented hydrides was observed, leading to degradation of mechanical properties (embrittlement) fuel cladding.

Keywords: WWER-1000, fuel element claddings, zirconium alloys, zirconium hydrides, mechanical properties, dry storage

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