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ON THE DISPERSE ACICULAR FERRITE FORMATION IN THE STRUCTURE OF COLD-RESISTANT JOINTS UNDER TEMPERATRES UP TO –70°C IN MMA WELDING OF 10KhSND STEEL. Part 1

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Abstract—The article presents an analysis of the metallurgical techniques that provide high quality electrodes for manual arc welding of low-carbon low-alloyed cold-resistant steels. It is shown that it is possible to improve technological and operational properties of welded joints at very low climatic temperatures up to –70°C implementing micro-alloying of the weld metal with nitrogen, titanium, cerium oxide and diamond nanopowder produced by detonation synthesis. The composition introduced into the electrode coating modifier mixture is identified. The cumulative effect of its components on the weld impact strength under temperature testing within the range from –20 up to –70°C was established. The matrix of the weld metal is composed mainly of disperse acicular ferrite, hardened by nanoparticles allegedly nitrides and carbonitrides of titanium and aluminum. It is shown that the centers for the crystallization of acicular ferrite are micro-sized non-metallic inclusions formed on ultrafine titanium nitrides. It was revealed that the toughness of the weld metal at low climatic temperatures is higher than toughness of joints welded by massively imported Japanese KOBELCO electrodes LB-52U. The results of the study make it possible to increase the cold resistance of welded structures for petrochemical plants and other facilities located in the Extreme North of the Russian Federation.

Part 2 of the article will be devoted to the study of the welding and technological properties of coated electrodes.

Key words: coated electrode, modifying mixture, welds, microalloying, acicular ferrite, toughness, cold resistance.

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STRUCTURE AND PROPERTIES OF RAILS AFTER EXTREMELY LONG-TERM OPERATION

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Abstract—The paper reveals regularities and mechanisms of structure-phase states and properties formation of of differentially hardened 100-m rails of DT 350 category after the passed tonnage of 1411 mln. tons brutto. The formation of highly defective surface layer with nanosize (40–50 nm) grain-subgrain structure of pearlite colonies and submicrocrystal (150–250 nm) structure grains with structure free ferrite is detected. The change of hardness, microhardness, crystal lattice parameter, microdistorsion level, scalar and excess dislocation density on the rails head section are analyzed. The possible mechanisms of cementite plates' transformation at extremely long-term operation are discussed.

Keywords: properties, phase composition, rails, submicro/nanocrystal structure, long-term operation.

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INFLUENCE OF POST-WELDING TEMPERING ON MECHANICAL BEHAVIOR OF FRICTION WELDED JOINTS FROM MEDIUM-CARBON STEELS DURING TENSILE TEST

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Abstract—The paper presents an analysis of the mechanical behavior of friction samples of welded joints from steels 30G2 (36 Mn 5) and 40 KhN (40Ni Cr 6), made by rotary friction welding (RFW). The influence of various temperature conditions of postweld tempering on the mechanical properties and deformation behavior during uniaxial tensile testing is analyzed. Vulnerabilities where crack nucleation and propagation occurred in specimens with a welded joint were identified. It was found that with this combination of steels, postweld tempering of the welded joint contributes to a decrease in the integral strength characteristics under conditions of static tension along with a significant decrease in the relative longitudinal deformation of the tested samples.

Keywords: rotary friction welding (RFW), thermomechanical affected zone (TMAZ), medium carbon steels, uniaxial tension, tensile strength, deformation

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THERMOCYCLIC STRENGTH OF GREY CAST IRON SCh20 AT HIGH TEMPERATURE SHIFTS

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Abstract—To predict the durability of casting molds made of SCh20 cast iron under thermal fatigue during its filling by liquid metal the thermocyclic strength of the casting molds metal (grade SCh20 gray cast iron, analog of A48-30B AISI cast iron) was investigated. The specimens were tested by cyclic heating in the furnace to maximum temperatures from 700°C to 1000°C with following cooling in air and water. The Coffin equation and the dependence of crack growth rate in specimens are obtained on the basis of metallographic measurements of crack length in specimens and strain ranges FEM calculations. The investigations results allow one to predict the durability of casting molds made of SCh20 cast iron under thermal fatigue during its filling by liquid metal.

Keywords: casting mold, grade SCh20 cast iron, thermocyclic strength, durability, phase transformations.

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STUDY OF THE HEAT RESISTANCE CHARACTERISTICS OF METAL OF CENTRIFUGALLY CAST PIPES MADE FROM 45Kh32N43SB ALLOY AND THEIR WELDED CONNECTIONS AT TEMPERATURES UP TO 1150°C

Part 1: Heat resistance characteristics of pipes at temperatures up to 1100°C

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Abstract—The paper studies heat resistance properties of 45Cr32Ni43SiNb alloy developed at the CRISM “Prometey” for reformer systems of high-temperature ethylene production plants. The macrocrystalline structure is analyzed and quantitative phase data for metal of centrifugally cast tubes is collected. It is shown that the alloy under investigation is characterized by structural stability, long-term durability, and high-temperature creep resistance up to 1000–1100°C.

Keywords: heat-resistant alloy, long-term durability, macrocrystalline structure, centrifugally cast pipes, carbides.

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EFFECTS OF THE ALLOYING ELEMENTS RATIO IN THE Ni–Al–Cr–W–Mo–Ta SYSTEM ON THE THERMAL FATIGUE RESISTANCE OF THE DEPOSITED METAL

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Abstract—The article presents an analysis of the influence of the alloying elements ratio in the Ni-Al-Cr-W-Mo-Ta system on the resistance of the deposited metal against thermal fatigue. The combined effect of alloying elements on the crack resistance of weld metal under cyclic temperature changes in the range of 20–1150°C is established. It is shown that in the alloying system, the sensitivity of a metal to the formation of thermal fatigue cracks mainly depends on the number of refractory elements that cause the formation of topologically close-packed (TCP) phases. The content in the deposited metal of 3.5 wt.% tungsten, 3.0 wt.% molybdenum, 2.5 wt.% tantalum does not cause the appearance of fatigue cracks. The developed deposited metal provides high level of thermal and oxidation wear resistance compared to highly doped nickel and cobalt industrial alloys.

Keywords: deposited metal, thermal cycling, refractory alloying elements, topologically close-packed (TCP) phases, thermal fatigue cracks, thermal stability, oxidative wear.

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TRIBOTECHNICAL CHARACTERISTICS OF HARD ALLOYS IN SLIDING FRICTION UNITS

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Abstract—The paper presents experimental data on the study of the friction parameters of hard alloys in sliding friction units, including the heating temperature, surface roughness, wear and friction coefficient, depending on the duration of the test and the friction path.

Keywords: friction, wear, hard alloys, surface roughness, friction coefficient, heating.

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HYDROGEN DIFFUSION KINETICS UNDER DIFFERENT CONDITIONS APPLIED TO VT6 ALLOY

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Abstract—Research of hydrogen diffusion in VT6 alloy is carried out considering different types of heat treating and hydrogen charging. The influence of microalloying on the susceptibility to hydride formation and embrittlement of titanium alloys is analyzed, and also effects of an oxide film on hydrogen charging during heat treatment without protective atmosphere, are studied.

Keywords: titanium alloys, hydrogen charging, alloying, oxide film

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OPTIMIZATION OF THE COATING PROCESS BY COLD GAS DYNAMIC SPRAYING APPLIED TO PRODUCTION CONDITIONS OF Ni–Ti AND Ni–Al SYSTEMS

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Abstract—This study developed practical recommendations for using the method of cold gas dynamic spraying to obtain functional coatings in a production environment using powders of nickel, titanium and aluminum of the grades: PNE-1 (Ni), PTOM-1 (Ti) and PA-VCh (Al). The temperature and speed parameters of the process were optimized using mechanical mixtures (Ni + Ti) and (Ni + Al) as an example. High adhesion of the coating and coefficient of powder use were ensured with maximum productivity at the DIMET-403 installation.

Keyword: powders, protective coatings, laser treatment, "precursor", gas thermal spraying, supersonic cold gas dynamic spraying.

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TECHNOLOGY FOR THE PRODUCTION OF NANOSTRUCTURED COATINGS FROM NANOPARTICLES OF TUNGSTEN CARBIDE AND METAL CHROMIUM

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Abstract—This paper presents results of a study of complex processes for producing composite powder materials from tungsten carbide and metallic chromium. Technological methods for the formation of functionally gradient coatings with high microhardness up to 426 HV through microplasma spraying technology are disclosed.

Keywords: plasma chemical synthesis, spray drying method, granulation method using a binder material, microplasma spraying method, microhardness.

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STRUCTURE AND MAGNETIC PROPERTIES OF THE MATERIAL OF THE Fe–Cr–Co SYSTEM PRODUCED BY THE SELECTIVE LASER MELTING

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Abstract—In this work, we studied the structure of the magnetically hard material of the Fe–Cr–Co system manufactured at the Russian SLMFACTORY system by selective laser melting from spherical powder, particles' size less than 80 μm. The powder was obtained by melt atomization. To study the structure, magnetic and mechanical parameters, samples were made at various scanning speeds and laser power. By constructing a hysteresis loop, data are obtained that indicate a higher level of magnetic characteristics (B_r, B_d, H_d, H_{cb}, H_{cm}, and BH_{max}) of the metal of the samples obtained by selective laser melting than similar samples obtained by foundry technology.

Keywords: selective laser melting, metal powders, structure, magnetic properties.

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HIGH-CYCLE FATIGUE OF A METAL MATRIX COMPOSITE BASED ON AN ALUMINUM ALLOY 7075-T1 REINFORCED WITH SILICON CARBIDE PARTICLES

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Abstract—The article presents results of the fatigue strength study of a metal matrix composites based on an aluminum alloy of the 7075-T1 grade, containing 20 vol.% silicon carbide obtained by powder technology using mechanical alloying followed by hot pressing. The high-cycle fatigue (HCF) study was carried out at five levels of stress amplitude at room temperature and at four levels of stress amplitude at high temperature (100°C). Smooth samples of corset type with a circular cross section were manufactured in accordance with the requirements of GOST 25.502–79. Synthesized samples went through the heat treatment stage characteristic of the matrix aluminum alloy 7075. Spherical particles within the range from 5 to 70 μm served as the raw material for the initial matrix of the composite material, and the raw material for the reinforcing component were silicon carbide powder particles, which after a long mechanical alloying with matrix particles take the form of granules from 400 to 600 microns.

The study of fatigue characteristics led to the conclusion that the introduction of a 20% reinforcing phase into the 7075-T1 matrix alloy based on silicon carbide particles made it possible to achieve a 1.3 times increase in endurance limits based on $2 \cdot 10^7$ cycles. An increase in the test temperature (100°C) leads to a decrease of 8% in the endurance limit. The change in the values of progressive deformation and resonance frequency during testing at room and high temperatures (100°C) is considered. At room temperature, it was found that with increasing durability, progressive deformation accumulates. At high temperature (100°C), it was found that with a decrease in durability, resonance frequency decreases more pronouncedly at each stress level.

Keywords: metal matrix composite, dispersion-reinforced composites, aluminum alloy, mechanical characteristics, endurance limit.

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PROPERTIES OF BASALT-FIBER-REINFORCED POLYAMIDE-6 FILLED BY POLYMERIZATION AT THE SYNTHESIS STAGE

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Abstract—The composition, physical-mechanical and structural features of polyamide-6 modified at the stage of synthesis by basalt fillers are investigated. The influence of the introduced fillers on the structural features, deformation-strength, technological and physic-chemical properties of the synthesized polymer is established. The positive effect of heat treatment of fillers on their adhesion interaction with the polymer matrix in the synthesis of the composite is revealed. It is shown that with the introduction of a fibrous filler of more than 7.5 wt%, there is a tendency to increase the physical and mechanical characteristics of the synthesized polymer. The behavior of the synthesized composite under high temperature conditions was evaluated by thermo-gravimetric analysis, which showed that the thermal treatment of basalt fiber can significantly increase the activation energy of destruction, which confirms the effectiveness of the thermal modification of the basalt thread. With the help of infrared spectroscopy, it is shown that the synthesized polymer is fully identified with the spectral pattern characteristic of polyamide-6.

Keywords: Polyamide-6, basalt fillers, polymerization combination of components, structural features, technological properties, physical and mechanical characteristics.

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PREDICTION OF CHANGES IN PROPERTIES OF ELASTOMERS BASED ON HYDROGENATED BUTADIENE-NITRILE RUBBERS DURING THERMAL AGING IN AGGRESSIVE ENVIRONMENT

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Abstract—The subject of the study was rubber based on partially and fully hydrogenated butadiene-nitrile rubbers (HNBR) Therban AT 5065 VP and Therban AT 5005 VP, taken in the ratios 100:0, 80:20, 70:30, 60:40, 50:50 accordingly. The purpose of the study was to evaluate the technical resource of RKO operation by predicting changes in properties of rubbers during thermal aging in air and in M-14B_2 engine oil at elevated temperatures in accordance with State Standards and methods developed at FRPC "Pro-

gress". Aggressive environment and high temperatures thermal aging of elastomers based on HBNR are described. The performance of rubbers was evaluated by predicting changes of relative elongation near to end of service life product to State Standards and "Progress" recommendations. It is found that elastomer with 50:50 HNBR Therban AT 5065 VP and Therban AT 5005 VP content proved itself as most thermally stable and has the longest service life possible.

Keywords: hydrogenated butadiene-nitrile rubbers, aggressive environment, thermal aging, prediction, service life.

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ON CORROSION RESISTANCE OF NITROGEN-CONTAINING STEEL IN ABRASION CONDITIONS

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Abstract—This work presents tests' results on the corrosion and erosion resistance of nitrogen-containing steel 04Kh20N6G11M2AFB in comparison with steel 08Kh18N10T, AB2-2 and VT1-0 titanium alloy. It is difficult to determine steel wear resistance against ice with abrasive (20%) due to the rapid melting of ice. It has been shown that the most effective methodology for assessing the corrosion-erosion resistance to simultaneous impact of abrasive and a 3.5% solution of NaCl to the metallic surface consists in the determination of the repassivation rate of the oxide film. It was found that the electrochemical potential of 04Kh20N6G11M2AFB stainless steel recovers 1.5 times faster than that of 08Kh18N10T steel, so it is very promising to use nitrogen-containing steel for the manufacture of the ice belt of icebreakers as a cladding layer of bimetallic alloy.

Keywords: stainless steel, nitrogen-containing steel, corrosion and erosion resistance, bimetal, clad steel

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STRENGTH ASSESSMENT OF AUSTENITIC STEEL GRAIN BOUNDARIES BY IMPACT BENDING TESTS FOR MINIATURE SPECIMENS

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Abstract—The paper proposes methods for assessing the strength of grain boundaries according to the results of testing miniature samples by impact bending. Results of bending at low temperature are given to assess the strength of grain boundaries in austenitic chromium-nickel steels. The test temperature was determined when the proportion of brittle intergranular fracture of embrittled chromium-nickel steel 10Kh18N9 is at least 90%. Three types of miniature specimens of different geometric shapes have been developed, providing approximately the same absorbed energy when tested for impact bending. It is shown when it is necessary to use such miniature samples.

Keywords: austenitic steel, grain boundary strength, impact bending tests, miniature specimens, brittle intergranular fracture, research methodology.

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MECHANISMS OF STRESS CORROSION CRACKING OF IRRADIATED AUSTENITIC CHROMIUM-NICKEL STEELS USED FOR WWER AND PWR VESSEL INTERNALS

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Abstract—This paper presents results of a corrosion cracking test of specimens of irradiated austenitic chromium-nickel steels of grades 321 (Kh18N10T), 316 (06Kh16N11M3) and 304 (02Kh18N9). Specimens were irradiated to different damage dose from 4.5 to 150 dpa. The tests were carried out in autoclaves in the water environment simulating a coolant of the first circuit of WWER reactors at temperatures of 290–315°C. The influence of the damaging dose and the neutron energy spectrum on the tendency of steels to stress corrosion cracking (SCC) is analyzed. The dominant SCC mechanisms for various austenitic steels are determined. Loading modes effects on the SCC resistance of specimens irradiated to the same damage dose are compared.

Keywords: austenitic steel, corrosion cracking, damage dose, coolant, stress corrosion cracking, neutron energy spectrum.

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EVALUATION OF RESISTANCE TO CORROSION CRACKING OF IRRADIATED AUSTENITIC CHROMIUM-NICKEL STEELS BY IMPACT BENDING TESTS ON MINIATURE SPECIMENS

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Abstract—In this work, we present results of a bending test of miniature samples made of chromium-nickel stainless austenitic steels of grades 321 (08Kh18N10T), 316 (06Kh16N11M3) and 304 (02Kh18N9) irradiated to various damaging doses from 4 to 125 dpa in different energy neutron spectra. Effects of the damage dose and the neutron energy spectrum on the intergranular fracture energy, which determines the strength of grain boundaries, are studied. Two neutron spectra are considered: one characteristic of the active zone of PWR and WWER reactors, and the other is typical for the active zone of fast core reactors. The relationship between the resistance to corrosion cracking of irradiated chromium-nickel steels 321, 316 and 304 and the strength of grain boundaries is considered.

Keywords: austenitic chromium-nickel steels, stress corrosion cracking, miniature specimens, impact bending tests.

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