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EFFECTS OF ADDITIONAL HEAT TREATMENT ON STRUCTURE AND MICROHARDNESS OF HIGH-STRENGTH STEEL SHIPBUILDING

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Abstract—The paper studies kinetics of austenitic grain growth (when heating) and the peculiarities of phase transformations (when cooling) that depend on the manufacturing technology of high-strength steel. The method of vacuum etching has been applied to reveal former austenitic grain boundaries in steel. It is shown that the necessary homogeneous structure in morphology and dimensions of structural elements in martensitic steels is formed under the influence of additional quenching from furnace heating with tempering after quenching from rolling heating.

Keywords: low-carbon high-strength steel, quenching with tempering, quenching from rolling heating, vacuum etching, austenitic grain size, phase transformations, rolled sheets, structure, microhardness

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STRUCTURE AND MECHANICAL PROPERTIES OF SHIPBUILDING STEEL PRODUCED BY DIRECT LASER DEPOSITION AND HOT ROLLING

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Abstract—The structure and properties of specimens obtained by direct laser deposition from 09CrNi2MoCu steel have been investigated. The results of anisotropy of properties and structural heterogeneity induced by high rate of obtaining cold-resistant steel specimens are presented. It is shown that the content of residual austenite and cementite in the steel structure, after direct laser deposition at the boundaries of fusion rolls is significantly higher, which contributes to anisotropy. Rolling of the deposit specimens was carried out in order to reduce the anisotropy of properties and to increase the strength and plastic properties. In the work two rolling technologies are considered: hardening from furnace heating and from rolling heating, as well as the next high tempering.

Keywords: direct laser deposition, additive technologies, hot rolling, shipbuilding steel, microstructure, mechanical properties

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MICROSTRUCTURAL ASPECTS OF FATIGUE STRENGTH OF WELDED JOINTS OF MEDIUM CARBON STEELS PRODUCED BY ROTARY FRICTION WELDING

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Abstract—The paper studies the resistance to fatigue failure of welded joints of steels 32Mn2-40CrNi2Mo, intended for the production of drill pipes for geological exploration. The connection of pipe billets for the purpose of manufacturing experimental samples was carried out by means of rotational friction welding at various process parameters. The assessment of resistance to fatigue loads was carried out on solid cylindrical samples with a welded joint under conditions of bending with rotation, which made it possible to identify the weakest zone in which the initiation and development of a fatigue crack occurred. The microstructure was studied using optical and electron scanning microscopy using the electron backscatter diffraction (EBSD) method. In the course of research, it was found that the greatest resistance to fatigue loads is provided due to the intensive development of strain hardening processes in the thermomechanical affected zone of welded joints, which depend on the parameters of rotary friction welding.

Keywords: rotary friction welding, medium carbon steels, welded joint, thermomechanical affected zone, cyclic durability, strain hardening

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GRADIENTS OF STRUCTURE, PHASE COMPOSITION AND DISLOCATION SUBSTRUCTURE OF THE RAIL HEADS MADE OF HYPEREUTECTOID STEEL AFTER OPERATION

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Abstract—The analysis of gradients of structure-phase states and dislocation substructure at a depth of up to 10 mm along the central axis of the head of DT400IK rails after 234.7 million tons passed on the Transbaikal railroad has been carried out using transmission electron microscopy methods. The formation of bending contours of extinction, indicating the elastically stressed state of the material, is revealed. Sources of curvature-torsion of the crystal lattice are indicated: intra- and interphase boundaries. The mechanisms of destruction of lamellar pearlite (cutting by moving dislocations) and dissolution with displacement of carbon atoms to defects are considered.

Keywords: hypereutectoid steel, rail head, gradients, dislocation density, fragments

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AN IMPROVED METHOD FOR DETERMINING THE DIFFUSION TRANSFORMATIONS OF AUSTENITE UNDER ISOTHERMAL CONDITIONS. Part 1. Analysis of standard diagrams and the possibility of using an improved isothermal transformation diagram in the diffusion region

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Abstract—The improved method of determination of diffusion transformations of austenite under isothermal conditions is considered. The applicability of standard diagrams in determining the conditions of preheat treatment at the stage of cooling after forging (accumulation stage) of large-sized billets is evaluated.

Keywords: austenite transformation diagrams, isotherm diagrams, ferrite-perlite transformation, dilatometry, metal science, large-size billets

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AN IMPROVED METHOD FOR DETERMINING THE DIFFUSION TRANSFORMATIONS OF AUSTENITE UNDER ISOTHERMAL CONDITIONS. Part 2. Isothermal transformation diagrams and their role in prescribing heat treatment regimes

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Abstract—The improved method for determining diffusion transformations of austenite under isothermal conditions is considered. The applicability of standard diagrams in determining the conditions of preheat treatment at the stage of cooling after forging (accumulation stage) of large-sized billets is evaluated.

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Keywords: austenite transformation diagrams, isotherm diagrams, ferrite-perlite transformation, dilatometry, metallurgy, large-size billets

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SOLUTION OF THE HEAT CONDUCTION PROBLEM FOR COMPUTATIONAL MODELING OF THE HYDROGEN CONTENT REDUCTION IN LARGE-SIZE FORGINGS DURING ANTIFLOCKEN HEAT PROCESSING

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Abstract—The paper investigates problems of flock formation in large-sized billets during heat treatment increasing hydrogen degassing. The solution of thermal conductivity problem is given, the estimation of thermal cycles at preliminary heat treatment for the subsequent solution of hydrogen diffusion problem is carried out on the example of medium-alloyed steels of 5KhNM and 20Kh3NMFA grades.

Keywords: metallurgy, heat conduction problems, heat treatment, thermal cycles, finite difference method, heat transfer coefficient

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CHEMICAL-THERMAL TREATMENT TECHNOLOGY FOR MANUFACTURING PARTS OF ELECTRICAL EQUIPMENT FOR AUTOMOBILE TRANSPORT

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Abstract—The state of technology and equipment for thermal and chemical-thermal treatment used for manufacturing of the main parts of starters, ignition distributors, generators has been analyzed. It is noted that the technical level of these technologies and equipment does not meet modern requirements. Technologies of carburization in solid carburizer and cyanidation in liquid medium often lead to formation of unstable parameters of diffusion layer on the surface of parts and finally to “spot” hardness and intensive wear of parts during operation.

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In order to modernize the processes of cementation and cyanidation, environmentally friendly technologies of chemical-thermal treatment have been developed, which provide stable parameters of the diffusion layer, thereby contributing to the improvement of the operational characteristics of automotive transport electrical equipment products.

Keywords: chemical-thermal treatment, hardening, cementation, cyanidation, fluidized bed, hardness

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STUDY OF THE MECHANISM OF NUCLEATION OF SINGLE CRYSTALS FROM Re–Ru-CONTAINING NICKEL SUPERALLOYS WITH A GIVEN SPATIAL CRYSTALLOGRAPHIC ORIENTATION FROM THE SEEDS OF THE Ni–W–Re–C SYSTEM WITH A LIQUIDUS TEMPERATURE OF 1550–1600°C

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Abstract—The article presents the results of a study of the mechanism of nucleation of single crystals of a given crystallographic orientation from rhenium-ruthenium containing nickel superalloys from the seeds of the Ni–W–Re–C system with a liquidus temperature of 1550–1600°C

Keywords: single crystal structure, crystallographic orientation, nickel superalloy, liquidus temperature, directional crystallization

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EFFECT OF TUNGSTEN ON STRUCTURE OF CHROMIUM-BASED HEAT-RESISTANT ALLOYS

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Abstract—The effect of tungsten on the structure and properties of Cr–32Ni–W alloys was studied. Characteristic tungsten concentrations were separated: up to 3%, 3–10%, and more than 10%, which determine the structure of the alloys. The mechanical properties of the alloys are determined. The area of rational application of the alloy Cr–32Ni–W is shown.

Keywords: solid solutions of substitution of Ni in Cr (α-phase) and Cr in Ni (γ-phase), σ-phase; phase properties, scope of alloys of the Cr–32Ni–W system.

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THERMOMECHANICS OF Al–Cu–Li ALLOY PLASTIC FLOW

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Abstract—Flat compression tests of Al–Cu–Li alloys are made. Samples deformed in isothermal conditions at deformation value ε = 55%, in strain rate intervals 10^{-3}–10^{-1} s^{-1} and temperatures 400–480°C. The empirical equations connecting thermomechanical parameters of Al–Cu–Li alloys deformation are received. The high-temperature deformation mechanism diagrams (DMD) Al–Cu–Li alloys are plotted. Temperature and strain rate mechanisms action areas of hot deformation and warm deformation are specified. It is shown that the warm deformation area on DMD is equal to the dynamic poligonization area on structural conditions diagram, and the hot deformation area is equal to the partial recrystallization area.

Keywords: flat compression, thermomechanical behavior, Zener–Hollomon parameter, hot deformation, warm deformation, high-temperature deformation mechanisms diagrams

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DEVELOPMENT OF TECHNOLOGY FOR OBTAINING FUNCTIONAL COATINGS FROM Kh15Yu5 STEEL POWDERS

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The paper presents the results of research on the development of technology for the application of functional coatings with high values of adhesion strength, microhardness and wear resistance using the method of supersonic cold gas dynamic spraying. Oxidized powder from X15Yu5 steel was used as a starting material for obtaining such coatings.

Keywords: oxidation, powder, functional coating, adhesion strength, microhardness, wear resistance

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ANALYSIS OF BASALT-LIKE SLAG OF PLASMA WASTE PROCESSING. THE INFLUENCE OF MORPHOLOGICAL COMPOSITION OF WASTE

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Abstract—The analysis of basalt-like slag obtained by pyrolysis of waste in a high-temperature plasma converter using various physicochemical methods has been carried out, and the possibility of obtaining basalt fibers from slag has been shown. The effect of the morphological composition of waste on the yield of basalt-like slag has been studied. With the use of statistical methods, a mathematical model was obtained that relates the yield of basalt-like slag to the morphological composition of the waste. A promising direction for the use of basalt fibers is their use in the composition of basalt and basalt-carbon composites to create strength shells.

Keywords: plasma pyrolysis of waste, waste composition, basalt-like slag, basalt fiber, mathematical model, basalt and basalt-carbon composites, strength shells

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ACOUSTIC EMISSION IN HYDROSTATIC STRENGTH TESTS OF SPHEROPLASTICS

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Abstract—Registration of acoustic emission in the process of spheroplastics destruction in a high-pressure hydrostatic chamber is realized. Hardware design does not require specialized equipment and is based on available components. Time synchronization on pressure and acoustic emission graphs ensures pressure fixation of pressures at which the formation of cracks in the spheroplastic sample begins. It is shown that

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accumulation of destructions begins with pressure, smaller, than pressure fixed as short-term hydrostatic durability.

Keywords: spheroplastics, hydrostatic strength, acoustic emission

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IMPROVEMENT OF THE COOLING CONTROL DURING ELECTROFUSION WELDING OF POLYETHYLENE PIPES AT LOW TEMPERATURES

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Abstract—A method has been developed for determining the heater power at the cooling stage when welding polyethylene pipes for gas pipelines at low ambient temperatures (below those recommended by regulatory documents). Efficiency of the method is verified by studies of materials crystallization kinetics in the heat-affected zones of welded joints

Keywords: polyethylene, welding, low temperatures, thermal process, inverse problem, functional minimization, thermal analysis

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STUDY OF THE SURFACE ENERGY CHARACTERISTICS OF GLASS AND CARBON FIBER BY THE WASHBURN METHOD

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Abstract—The Washburne adsorption method (capillary rise method), as an alternative to the standard single fiber method, is proposed to investigate the surface energy characteristics of glass and carbon fibers using a K-100 processor tensiometer. The paper considers sample preparation of fibrous materials measured by the Washburn method: filling a Teflon tube with glass and carbon fibers, packing density of the resulting capillary, and determination of the capillarity constant. The results of measurements of the wettability of fibers in test liquids (water, hexane) and in the solution epoxy binder UP-2227N are presented. The influence of appretting on the surface energy characteristics of glass fiber and carbon fiber was studied, a comparative analysis of the obtained values (wetting angle, SEP, adhesion) was carried out before and after the removal of lubricants.

Keywords: K-100 tensiometer, glass fiber, carbon fiber, binder, Washburn method, contact angle, surface free energy, adhesion, impregnation, lubricant

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FUNCTIONAL-GRADIENT CARBON FIBER-REINFORCED PLASTIC BASED ON EPOXY MATRIX MODIFIED WITH THERMOPLASTIC ELASTOPLAST

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Abstract—Modification of epoxy binders with butadiene-styrene thermoplastic elastomers was used to obtain functional-gradient carbon plastics with increased impact resistance. Samples were made and comparative tests of carbon fiber-reinforced plastics for resistance to impact loads and compression after impact were carried out. It is shown that smooth change of modifier concentration at transition from the external surface of the part to the internal one allows to increase effectively the impact strength of carbon fiber-reinforced plastic while maintaining the rigidity of the composite material.

Keywords: epoxy polymer, butadiene-styrene thermoplastic elastomers, composite material, composition gradient, carbon fiber-reinforced plastic, impact strength, modification

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LIGHTWEIGHT THERMO- AND HEAT-RESISTANT COMPOSITE MATERIALS BASED ON POLYIMIDE FOAM

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Abstract—A prepolymer foaming composition based on 3,3',4,4'-benzophenonetetracarboxylic acid dianhydride methyl ester and diamines: 4,4'-diaminodiphenylmethane and m-phenylenediamine for the production of high-temperature polyimide foam (PIF) is proposed. The possibility of using PIF as a binder for composite materials (foam composites) reinforced with carbon or organic fibers with low density (0.4–1.1 g/cm^3) as a result of foaming of the binder during the formation of the foam composite is shown. The density and mechanical properties of the foam composite can vary within a relatively wide range depending on the volume content of the fiber and air pores. The high glass transition temperature of 260°C, combined with the high thermal stability of carbon or polyimide fibers, contributes to the retention of the mechanical properties of such composites at elevated temperatures. The temperature of the start of mass loss of the foam composite must be at least 550°C, and it depends on the type of fibrous material. The combination of the excellent thermal and mechanical properties of lightweight PIF composites, together with the exceptional fire resistance of polyimide materials, may provide new applications in advanced aircraft and shipbuilding technologies.

Keywords: polyimide foam, foam composite, thermal stability, mechanical properties

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COMPARISON OF THE AGGRESSIVENESS OF HYDROGEN SULFIDE MEDIA TO STEEL IN THE VAPOR AND WATER PHASES

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Abstract—Corrosion resistance in hydrogen sulfide-containing environments of the main structural steels used in infrastructure facilities of gas fields has been studied. Gas objects are distinguished by the fact that most of the internal space of equipment and pipelines is in contact with the vapor phase, the internal corrosion of which under hydrogen sulfide conditions has been little studied. The corrosion rates and the composition of the formed corrosion products, which differ depending on the type of medium (water or steam), are determined. The phase composition (crystalline or X-ray amorphous) of the resulting products affects their protective ability and differs in the vapor and aqueous phases. It has been established that under gaseous conditions of moisture condensation, local pitting lesions are formed under fragile corrosion products. The thickness of the iron sulfide film in the vapor phase turned out to be lower than in the aqueous medium. It was revealed that dangerous corrosion consequences (in the form of blisters and cracking) appear on the studied samples of carbon and low-alloy steels, which are characteristic of the process of hydrogenation under conditions of hydrogen sulfide corrosion.

Keywords: microstructure of steel, hydrogenation, iron sulfide, corrosiveness, corrosion products, hydrogen sulfide cracking

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STUDY OF STRESS CORROSION CRACKING SUSCEPTIBILITY OF IRRADIATED FERRITE-MARTENSITIC STAINLESS STEEL 07Kh12NMFB IN SUPERCRITICAL WATER. Part 1. Autoclave testing

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Abstract—The studies of corrosion cracking of stainless ferrite-martensitic steel with chromium content of 12%, irradiated to a damage neutron dose of ~12 dpa, selected as a candidate material for internals of supercritical water-cooled reactors (SWCR), have been carried out. Corrosion cracking tests were carried out in autoclaves in supercritical water (at a temperature of 450°C and a pressure of 250 atm) simulating the primary circuit coolant of SWCR. Tests were performed on specially designed miniature disk specimens under constant load. The load was maintained by means of the developed compact loading devices whose size allows them to be placed in the autoclave up to nine pieces at a time and to test several specimens under different loads in the same environment. In the first part of the present work, loads providing tensile stresses on the specimen working surface in the range of ~$0.3\sigma_Y$–$0.7\sigma_Y$ were calculated and autoclave tests in supercritical water were carried out.

Keywords: ferritic-martensitic stainless steel, supercritical water-cooled reactors (SWCR), neutron irradiation, stress corrosion cracking, autoclave tests

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