SCIENTIFIC AND TECHNICAL JOURNAL
"Voprosy Materialovedeniya", 2023, № 2(114)

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UDC 669.15–194:621.785.3:621.73

EVALUATION OF THE INFLUENCE OF HOMOGENIZATION ANNEALING ON THE CRITICAL BRITTLE TEMPERATURE OF FORGED BLANKS FROM STEEL 15Kh2MFA-A

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Received January 16, 2023
Revised March 10, 2023
Accepted March 10, 2023

Abstract—The effect of the homogenization annealing duration on the critical brittle temperature of 15Kh2MFA-A vessel reactor steel has been studied. The criterion for calculating the duration of the annealing is determined – this is the total duration of heating of the ingot and forging before the first and second removals. It is shown that in order to achieve $T_{к0}$ not less than minus 50°C, a total specific exposure at a temperature of 1220±20°C of not less than 2.5 min/mm of section is required.

Keywords: reactor vessel steel, forged blanks, homogenization annealing, critical brittle temperature

ACKNOWLEDGMENTS

Experimental studies were carried out on the equipment of the Center for the Collective Use of Scientific Equipment "Composition, Structure and Properties of Structural and Functional Materials" of the National Research Center "Kurchatov Institute" – Central Research Institute of Structural Materials "Prometey" with the financial support of the Ministry of Science and Higher Education – Agreement No 13.TsKP.21.0014 (075-11-2021-068). Unique identification number – RF-2296.61321X0014.

DOI: 10.22349/1994-6716-2022-112-4-05-14

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UDC 669.15′26′24′28–194: 669.785.017.3

EFFECT OF VANADIUM AND NIOBIUM ON PHASE TRANSFORMATIONS IN CHROMIUM-NICKEL-MOLYBDENUM SHIPBUILDING STEEL

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Received March 1, 2023
Revised March 15, 2023
Accepted March 21, 2023

Abstract—The effect of microalloying with niobium and vanadium on phase transformations and the structure of chromium-nickel-molybdenum steel during hardening, including after previous hot plastic deformation, has been studied. A low-carbon chromium-nickel-molybdenum steel with a different content of alloying and microalloying elements was chosen as the object of study. The performed studies made it possible to establish the regularities of the influence of microalloying additives, hot plastic deformation and grain size on phase transformations and structural features of chromium-nickel-molybdenum steel. The results of the study could be used to improve known technologies or create some new types of production.

Keywords: low-carbon microalloyed chromium-nickel-molybdenum steel, niobium, vanadium, phase transformations, hot plastic deformation, structure, thermokinetic diagram

DOI: 10.22349/1994-6716-2023-114-2-15-26

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UDC 669.046.554:669.049.7

INFLUENCE OF CALCIUM CONSUMPTION AND CONTENT ON THE QUALITY OF 10KhSND STEEL MADE FROM CONTINUOUSLY CAST SLABS

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Received March 20, 2023
Revised March 29, 2023
Accepted April 3, 2023

Abstract—The effect of calcium consumption during out-of-furnace processing and its content in the finished metal on the quality of sheet steel grade 10KhSND, obtained from continuously cast slabs, has been studied. The research is based on the results of evaluating the macrostructure of slabs obtained from a continuously cast billet, as well as after testing the finished metal to determine impact strength, contamination with non-metallic inclusions, and ductile-brittle transition temperature. The paper analyzes the effect of consumption and calcium content in the metal.

Keywords: quality of sheet metal, out-of-furnace processing, processing with calcium-containing materials, continuously cast billet, macrostructure, impact strength, non-metallic inclusions, ductile-brittle transition temperature

DOI: 10.22349/1994-6716-2023-114-2-27-35

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UDC 669.14.018.295:621.771.016:669.017.3

INFLUENCE OF THE CONTENT OF CHROMIUM IN LOW-CARBON BAINITIC-MARTENSITIC STEELS ON THE EFFICIENCY

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Received March 27, 2023
Revised May 11, 2023
Accepted May 15, 2023

Abstract—The effect of chromium content on phase transformations in low-carbon high-strength steel for shipbuilding has been studied. Under industrial conditions, two rolled sheets 50 mm thick were manufactured from steel with a chromium content of 1.08% and 0.42% using hot rolling technology, followed by furnace hardening and high-temperature tempering, standard mechanical properties and performance characteristics were determined. With the help of optical and transmission electron microscopy, the structural features of steel were revealed.

Keywords: economically alloyed high-strength steel, furnace hardening, phase transformations, sheet metal, structure, lath martensite, granular bainite, lath bainite, properties

ACKNOWLEDGMENTS

Experimental studies were performed on the equipment of the Center for Collective Use "Composition, Structure and Properties of Structural and Functional Materials" of the NRC "Kurchatov Institute" – CRISM "Prometey" with financial support from the Ministry of Science and Higher Education of the RF, Agreement 13.TsKP.21.0014 (075-11-2021-068), unique identifier RF–2296.61321X0014.

DOI: 10.22349/1994-6716-2023-114-2-36-47

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UDC 669.245.018.44:621.785

THE EFFECT OF HEAT TREATMENT ON THE STRUCTURE AND PROPERTIES OF A HEAT-RESISTANT NICKEL ALLOY BASED ON Ni–Fe–Co–Nb–Ti–Ta

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Received January 31, 2023
Revised February 10, 2023
Accepted February 21, 2023

Abstract—The effect of heat treatment on the structure and properties of a new weldable heat-resistant alloy based on Ni–Fe–Co–Nb–Ti–Ta with a low coefficient of thermal expansion for parts of gas turbine engines was studied. The stability of the intermetallic globular phase, the features of precipitation of lamellar particles during annealing after quenching were studied. It is shown that the structure formed during heat treatment with nanosized cuboid and rounded particles of the γ′-phase, as well as with a small

amount of lamellar η-phase precipitates along the grain boundaries, provides a high set of properties and excellence heat-resistance in comparison with iron-nickel commercial alloys of a similar purpose. With uniform precipitation of the γ′-phase higher tensile strength are achieved.

Keywords: superalloy, heat treatment, coefficient of thermal expansion, intermetallic phase, lamellar phase, heat-resistance, strength, age-hardening treatment

DOI: 10.22349/1994-6716-2022-112-4-48-59

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UDC 669.017.165:669.017.3:621.78.013

INVESTIGATION OF STRUCTURAL-PHASE TRANSFORMATIONS IN A FOUNDRY STRUCTURAL ALLOY BASED ON Ni_3Al INTERMETALLIC COMPOUND AFTER HIGH-TEMPERATURE EXPOSURES AND DURING THE OPERATION OF THE ALLOY AS A NOZZLE BLADE

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Received February 9, 2023
Revised February 13, 2023
Accepted February 21, 2023

Abstract—The paper presents studies of structural and phase transformations in intermetallic compositions based on the Ni_3Al compound depending on alloying and high-temperature treatments, carried out in the process of creating a cast structural alloy for operation in the temperature range of 900–1200°C. Experimentally, when testing the developed intermetallic alloy as nozzle blades of the 1st stage of a high-pressure turbine, it was confirmed that the alloy is thermally stable at temperatures up to 1200°C.

Keywords: cast structural alloy, intermetallic alloys, nozzle blades, high-temperature holding, structural-phase transformations

DOI: 10.22349/1994-6716-2023-114-2-60-70

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UDC 621.791.3:669.295

STRUCTURE AND PROPERTIES OF THE T-JOINTS MADE OF TITANIUM ALLOY VT6S DURING DIFFUSION BRAZING

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Received February 27, 2023
Revised March 1, 2023
Accepted March 3, 2023

Abstract—The paper studies structural transformations of the brazing seam and fillet of the T-joints formed during the diffusion brazing of the titanium alloy VT6S with filler alloy of the Ti–Cu–Ni–Zr system. The soaking time during brazing under the designed temperature is regarded as one of the most important processing terms. It is shown that the satisfactory level of the mechanical properties of the joints could be achieved at the proper technological parameters that provide removal of any alloying additions from the brazing seam as well as the minimum fillet size. The lamellar structure of the base titanium alloy could be recommended as the most desirable for the diffusion of brazed joints.

Keywords: titanium alloy, diffusion brazing, T-joints, structure, mechanical properties

ACKNOWLEDGMENTS

Experimental studies were performed on the equipment of the Center for Collective Use "Composition, Structure and Properties of Structural and Functional Materials" of the NRC "Kurchatov Institute" – CRISM "Prometey" with financial support from the Ministry of Science and Higher Education of the RF, Agreement 13.TsKP.21.0014 (075-11-2021-068), unique identifier RF–2296.61321X0014.

DOI: 10.22349/1994-6716-2023-114-2-71-79

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UDC 621.793.7:621.762:669.295

STUDYING THE DEPENDENCE OF THE PROPERTIES OF TITANIUM COATINGS ON THE TECHNOLOGICAL MODES OF MICROPLASMA SPUTTERER UGNP-7/2250

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Received February 17, 2023
Revised April 6, 2023
Accepted April 10, 2023

Abstract—The results of optimizing the technological modes of deposition of titanium coatings by the microplasma method are presented in order to identify the most productive one. Variable values of the current strength of the electric arc, the flow rates of the plasma-forming and transporting gases were used as variable parameters. The sputtering material was PTOM-1 grade titanium powder of various fractional compositions: 20–32, 32–40, and 40–71 μm. A series of experiments was carried out on a combination of a number of factors. The following factors were considered: a coating thickness of at least 200 μm, the exclusion of sintering of the sprayed powder in the channels of the plasma torch, low porosity of the coating (no more than 5%), a tight fit of the coating to the substrate, and the exclusion of delamination of the coating during mechanical processing. As a result, the most optimal modes of coating deposition were identified. For coatings with the lowest porosity (from 1.0 to 1.9%), when all the above indicators were achieved, the morphology and microhardness were studied. According to the SEM microimages of transverse sections, it was determined that the coatings adhere tightly to the substrate material, there are no areas with delamination of the coating, and the microhardness of the coatings is in the range of 685–744 HV.

Keywords: microplasma sputtering, spraying modes, titanium powder PTOM-1, titanium coating, research of morphology, porosity and hardness

ACKNOWLEDGMENTS

The study was supported by a grant from the Russian Science Foundation, project No 21-73-30019.

Experimental studies were performed on the equipment of the Center for Collective Use "Composition, Structure and Properties of Structural and Functional Materials" of the NRC "Kurchatov Institute" – CRISM "Prometey" with financial support from the Ministry of Science and Higher Education of the RF, Agreement 13.TsKP.21.0014 (075-11-2021-068), unique identifier RF–2296.61321X0014.

DOI: 10.22349/1994-6716-2023-114-2-80-86

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UDC 621.762.224:669.713

ON A MATHEMATICAL MODEL OF THE COOLING AND CRYSTALLIZATION OF METAL DROPS DURING CENTRIFUGAL GRANULATION

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Received February 27, 2023
Revised April 5, 2023
Accepted April 12, 2023

Abstract— A mathematical model has been developed for the crystallization of aluminum alloy granules under cooling conditions in an aqueous and water-steam media. The practical significance of the mathematical model lies in predicting the average value of the dendritic parameter of the obtained granules depending on the granulation method, the characteristics of the granulation process and the size of the obtained granules. The average value of the dendritic parameter makes it possible to predict the fineness of the granule structure and, consequently, the mechanical properties of the granular material. The mathematical model makes it possible to determine the speed of a melt drop in an aqueous media and takes into account the presence of a steam jacket effect, i.e., a vapor layer that appears between a crystallizing drop and an aqueous media, which significantly reduces the intensity of heat removal and the rate of crystallization. The application of the mathematical model was tested on the obtaining of granules of high-alloyed aluminum alloys (alloys D1 and D16 of the Al–Cu–Mg system, alloys V95 and V96Ts of the Al–Zn–Mg–Cu system), made by centrifugal spraying of the melt from a perforated rotating crucible and drip method during cooling in an aqueous media. The cooling rate and the crystallization rate of the granules obtained in real experiments were determined by measuring the dendritic parameter of the material structure. The mathematical model showed a high convergence of the simulation results and of real experiments of aluminum alloy granulation.

Keywords: granulation, melt drop, drop velocity, cooling rate, crystallization rate, granule size, granule sphericity, mathematical model, input and output model parameters, crystallization features, heat removal rate, liquid phase, dendritic parameter, differential continuity equations, momentum conservation equations

DOI: 10.22349/1994-6716-2023-114-2-98-112

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UDC 549.324.62:622.345

INVESTIGATION OF THE PHASE COMPOSITION OF THE MIDDLINGS WITH SUBSEQUENT SIMULATION OF THE COMPOSITIONS OF POTASSIUM AND SODIUM SALTS FOR THE DECOMPOSITION OF ARSENOPYRITE

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Received February 1, 2023
Revised April 7, 2023
Accepted April 12, 2023

Abstract—The results of the study of tin-bearing middlings are presented. The mineralogical composition obtained by micro-X-ray diffraction analysis was determined and thermodynamic modeling, using the software package Thermo-Calc, was carried out. The aim of this work was a comprehensive study of the interaction of arsenopyrite and cassiterite with salts of alkali earth metals and the search for the optimum composition and ratio of salts for the decomposition of arsenopyrite into separate easily removable components. With the help of these results further work on the development of a complex technique for the selective separation of arsenopyrite and cassiterite and the extraction of tin and associated metals from these middlings is relevant.

Keywords: arsenopyrite, cassiterite, ore, arsenic, sulfur, tin, computer modeling, mineralogical composition, X-ray microanalysis, X-ray phase analysis, pyrite

DOI: 10.22349/1994-6716-2023-114-2-113-124

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UDC 678.067:621.785

OBTAINING HIGH-STRENGTH CARBON FIBER BASED ON POLYPHENYLENE SULFIDE BY ATL METHOD WITH LASER HEATING

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Received January 27, 2023
Revised March 9, 2023
Accepted March 10, 2023

Abstract—The method of manufacturing high-strength structural carbon fiber from toupreg based on PPS-214 grade polyphenylene sulfide (Fortron, Germany) and AS4 high-strength carbon fiber (Hexcel, USA) using a promising ATL-technology (Automated Tape Laying) with laser heating is considered. The technology was adapted for the material under study, laboratory models in the form of plates were made, physical and mechanical tests of laboratory samples were carried out. The quality of the binder distribution and the presence of defects were assessed by raster electron microscopy. The influence of the reinforcement, pressing and vacuum heat treatment schemes on improving the mechanical properties of the studied carbon fiber was investigated. It has been found that the samples subjected to vacuum heat treatment have higher mechanical properties due to an increase in the adhesion of the toupreg tapes to each other and the removal of discontinuities formed during the calculation. The value of the ultimate strength at interlayer shear of samples made using a parallel-diagonal scheme increases by 108%, at bending by 370% and by 65% at compression.

By processing the toupregs by the ATL with laser heating and subsequent thermal treatment of the products, it is possible to obtain high-strength structural materials with improved physical and mechanical properties, as well as high repeatability and equality of properties throughout the area of the products, even using complex reinforcement schemes.

Keywords: polymer composite material, structural carbon plastic, method ATL, polyphenylene sulfide, thermoplastic matrix, multiaxial reinforcement scheme, triaxial reinforcement scheme, laser heating

ACKNOWLEDGMENTS

The work was nominated for the first prize at the 19th Conference of Young Scientists and Specialists.

DOI: 10.22349/1994-6716-2023-114-2-125-135

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UDC 539.422.24

CALCULATION OF FATIGUE DAMAGE UNDER CYCLIC COMPLEX LOADING CONSIDERING THE EFFECT OF THE STRAIN RATE

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Received February 9, 2023
Revised March 27, 2023
Accepted April 3, 2023

Abstract—A method has been proposed for calculating fatigue damage under cyclic loading, in which the loading in half-cycles is not simple, i.e., the stress components in a half-cycle do not change proportionally to one parameter. In addition, the proposed method takes into account the situation when the strain rate in a half-cycle affects the degree of damage to the material (for example, in the case of material deformation under conditions of creep or exposure to a corrosive environment) and this rate can change in different loading half-cycles.

ACKNOWLEDGMENTS

The work was performed using the equipment of the Center for Collective Use "Complex for Modeling and Processing Data of Mega-Class Research Installations" of the National Research Center "Kurchatov Institute", http://ckp.nrcki.ru/.

DOI: 10.22349/1994-6716-2023-114-2-136-146

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UDC 669.58′71:620.193

ANODE BEHAVIOR AND OXIDATION OF Zn22Al ALLOY DOPED WITH SCANDIUM

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Received December 8, 2022
Revised March 14, 2023
Accepted March 15, 2023

Abstract—The article contains the results of potentiodynamic and thermogravimetric research of anode behavior and oxidation of Zn22Al alloy, doped with scandium, in various media. The anode, kinetic and energy characteristics of alloys in isothermal conditions have been established. Doping of the Zn22Al alloy with scandium in an amount of 0.1 to 1.0 wt. % contributes to the increase of its anodic resistance to oxidation. The rate of oxidation and corrosion of alloys doped (0.01–0.1%) with scandium is 1.5–3 times

lower than that of the Zn22Al alloy. Alloy oxidation products consist of a mixture of protective films ZnO, Sc_2O_3, $ZnAl_2O_4$ and $Al_2O_3 \cdot Sc_2O_3$.

Keywords: Zn22Al alloy, scandium, oxidation kinetics, activation energy, corrosion rate, anodic behavior

DOI: 10.22349/1994-6716-2023-114-2-147-154

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UDC 621.039.534:669.15–194.55

STRUCTURAL MATERIALS SELECTION FOR THE SODIUM-COOLED REACTOR PLANT STEAM GENERATOR

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Received February 8, 2023
Revised March 31, 2023
Accepted April 3, 2023

Abstract—Steels and alloys of various structural classes are considered from the point of view of the required level of service characteristics necessary for the safe operation and manufacture of a sodium-cooled reactor plant steam generator. After the analysis, it was found that the optimal structural material for the steam generator of a high-power reactor plant with a sodium coolant is martensitic stainless steel with a chromium content of 12 wt.%.

Keywords: sodium cooled reactor plant, steam generator, structural material, service characteristics, martensitic stainless steel

DOI: 10.22349/1994-6716-2023-114-2-155-165

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UDC 621.039.531:539.422

DOSE DEPENDENCES FOR MATERIALS OF VVER PRESSURE VESSELS AND THEIR SUPPORT STRUCTURES

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Received March 1, 2023
Revised March 17, 2023
Accepted March 21, 2023

Abstract—The basic equations for structural integrity assessment on brittle fracture criterion are presented. The main mechanisms of radiation and thermal embrittlement of materials used for WWER RPV (15Kh2MFA, 15Kh2NMFA grade steels and its weld metal) and their support structures (St.3, 09G2S grade steels and its weld metal). The main considerations for construction of the trend curves are given and various types of trend curves are presented. The trend curves taken into account metallurgical and operational factors, such as content of alloying and impurity elements, neutron fluence, operating time and irradiation temperature. The analysis of the neutron flux effect under different dominant mechanisms of embrittlement of RPV materials is presented. The effect of irradiation temperature on contribution of different mechanisms of radiation embrittlement typical for materials of WWER RPV and SS is considered.

Keywords: dose dependence, radiation embrittlement, VVER-1000, VVER-440, VVER-TOI, reactor pressure vessel, support structure, thermal aging, neutron irradiation, impurity elements, alloying elements

DOI: 10.22349/1994-6716-2023-114-2-166-194

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UDC 621.3.084.89:548.736.332

EFFECTS OF γ-RADIATION ON FLUORITE CRYSTALS WITH A TRIVALENT RARE-EARTH IONS

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Received March 21, 2023
Revised April 6, 2023
Accepted April 12, 2023

Abstract—The paper considers phenomena of formation of color centers due to intrinsic and impurity defects in fluorite crystals activated by rare-earth ions Pr^{3+}, Nd^{3+}, Yb^{3+} under γ- and UV-radiation. Using CaF_2 activated with Yb^{3+} and Pr^{3+} ions as an example, the work shows the effect of the photodynamic process on the photochemical resistance to formation of color centers of a Yb-containing crystal. It also demonstrates the effect of heating on the restoration of the original color of a Pr-containing crystal after γ-radiation as a result of change in the electronic state of praseodymium ions. The features of the formation of ions in the R^{2+} state in CaF_2:R^{3+} (R^{3+} = Pr, Nd, Yb) crystals after γ-irradiation are investigated and explained, and quantitative estimates of the $R^{3+}\rightarrow R^{2+}$ conversion processes are given.

Keywords: ionizing radiation, fluoride single crystals, high-temperature crystallization from a melt, radiation resistance

ACKNOWLEDGMENTS

The work was supported financially by the National Research Center "Kurchatov Institute" (according the order No 89 dated January 20, 2023 "On conducting applied research and development work on the complex topic 'Applied research and development in the field of creating new materials, including an electronic component base, and development of additive technologies").

DOI: 10.22349/1994-6716-2023-114-2-195-202

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