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ABSTRACTS OF PUBLISHED ARTICLES

UDC 669.14.018.293:669.046.516.4

Effect of complex inoculation of a high-strength shipbuilding steel on the composition and morphology of nonmetallic inclusions. Miliuts V. G., Tsukanov V. V., Titova T. I., Nasonovskaya L. B., Vladimirov A. G., Golubtsov V. A., Levagin E. Yu. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 5–14.

The paper examines the effect of inoculating a high-strength shipbuilding steel with flux-cored wire containing ferrocalcium and complex materials containing rare-earth metals (REMs) on the distribution, composition and morphology of nonmetallic inclusions.

It is shown that inoculation both with FeCa and FeCa combined with REMs with the calcium and cerium content of the metal within 0.002–0.003% for each of them allows obtaining a high-strength shipbuilding steel with low level of impurity inclusions.

Key words: shipbuilding steel, inoculation, ferrocalcium, rare-earth metals (REMs), composition and morphology of nonmetallic inclusions.

UDC 669.14.018.294.2:539.538

Fine structure formation of rails with high wear resistance. Gromov V. E., Volkov K. V., Ivanov Yu. F., Yuriev A. B., Konovalov S. V., Morozov K. V. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 15–23.

The layer by layer analysis of rails with high wear resistance and contact durability is carried out by transmission electron microscopy methods. Quantitative parameters of structure phase states and defect substructure formed according to diffusion and shear γ - α transformation are established. The evaluation of steel strengthening mechanisms being qualitatively agreed with hardness measurements is made.

Key words: rails, structure, phase composition, dislocation density, strengthening.

UDC 669.715:621.785.7:539.4

Evolution of mechanical and corrosion properties of 1913 aluminium alloy during artificial aging. Ryabov D. K., Kolobnev N. I., Samokhvalov S. V., Vakhromov O. V. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 24–29.

Aluminium alloys, which are used for aerospace applications, mostly are heat-treatable. Heat treatment of these alloys including solid solution treatment, quenching and natural or artificial aging can lead to different properties of semi products. Al–Zn–Mg–Cu (7xxx series) alloys after heat treatment demonstrate high tensile strength up to 700 MPa (especially in T6 temper) but this leads to moderate characteristics of corrosion resistance. Al–Zn–Mg alloys after long term aging for T6 temper demonstrate improved corrosion resistance.

The paper describes effect of one artificial aging stage (temperature range 80–185°C with maximum time of aging up to 36 hours) on mechanical (TYS, UTS) and corrosion (IGC, EXFO) properties of Russian medium strength corrosion resistant weldable alloy 1913 (Al–Zn–Mg with small addition of Cu). Described areas of maximum strength and overaging, it is shown that one stage aging at temperature less than 120°C for maximum strength after water quenching leads to low corrosion resistance of cold rolled sheets and aging at temperatures above 120°C allows to achieve high corrosion resistance depending on the duration of aging.

Key words: 1913 alloy, heat treatment, artificial aging, mechanical properties, corrosion resistance.

UDC 669.245'71:669.046

Production of alloys based on nickel aluminides by metallothermic reduction of oxides. Gostishchev V. V., Khimukhin S. N., Teslina M. A., Astapov I. A. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 30–34.

Conditions of alloys Ni–Al, Ni–Al–Cr, Ni–Al–Mo, Ni–Al–W production have been studied by aluminothermy. The initial charge makeup providing the maximum runout of metals in an alloy has been fixed. Products of metallothermic recovery were identified by elemental analysis and X-ray diffraction as intermetallics NiAl, NiAl₃ and Ni₂Al₃ containing 2.9–3.7% chromium, molybdenum or tungsten.

Key words: intermetallics, Ni–Al, aluminothermy, microhardness.

UDC 669.3'26'296:621.789:539.374

Impact of the deformation-heat treatment on the mechanical and functional properties of Cu–Cr–Zr alloy. Sennikova L. F., Davidenko A. A., Spuskaniuk V. Z., Dmitrenko V. Yu., Zakoretskaya T. A. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 35–42.

The impact of combined plastic deformation on physical and mechanical properties of the alloy Cu–Cr–Zr has been researched by angular hydrostatic extrusion, hydrostatic extrusion and drawing together with heat treatment in various combinations and sequences. A scheme of deformation and heat treatment has been elaborated. The maximum hardness of the alloy significantly exceeding the known results has been received following the rational working conditions of the scheme. The correlation dependence of the hardness and density of the alloy on the degree of accumulated strain has been found according the hydrostatic extrusion scheme. The level of specific electric resistance of the alloy has been determined as a result of deformation-heat treatment.

Key words: angular hydrostatic extrusion, accumulated deformation, alloy Cu–Cr–Zr, heat treatment.

UDC 669.35

Forming a structure of composite bronze reinforced with steel dendrites. Potekhin B. A., Khristoliubov A. S., Zhiliakov A. Yu., Iliushin V. V. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 43–49.

The paper studies experimental type of BrZhNKA 9-4-1-1 (БрЖНКА 9-4-1-1) bronze, with BrNA 4-1 (БрНА4-1) matrix, reinforced with steel dendrites, based on maraging steel structure N12K8Yu (H12K8Ю). The number of dendrites can be adjusted. The morphology of dendrites (ingot, forging, welding), interphase mass transfer during heat treatment, and components dispersed hardening have been considered and its mechanical properties have been evaluated. Bronze tribological properties are equal to the well known antifriction BrO10 bronze, and its processability (formability, weldability), is substantially higher.

Key words: bronze, dendrite, solid solution, heat treatment, tribological properties.

UDC 669.295:621.438

Finite-element analysis of the stress-strain state of long turbine blades made of high-strength titanium alloys. Leonov V. P., Schastlivaya I. A., Igolkina T. N., Kikinov K. I., Kropotov V. A., Troshin A. N. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 50–60.

The methodology for manufacturing blades with longitudinal size 1600 mm has been developed and mastered using the Deform 3D computer simulation program. The paper analyzes three punching stages including heating, intermediate cooling (while transporting), cooling of the billet due to heat exchange with the die. The distribution of temperature and strain fields at different stages of stamping have been simulated. The calculation reveals that the billet temperature doesn't exceed polymorphic transformation temperature. The analysis confirmed that this model could be stamped according to the technology directions and requirements.

Key words: titanium alloys, turbine blades, stress-strain state, 3D computer simulation.

UDC 678.067:620.181.4

Dynamic mechanical analysis of KMU-4I carbon fiber reinforced plastic after 12 years of exposure to space environment. 1. Initial state. Startsev O. V., Makhonkov A. J., Deev I. S., Nikishin E. F. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 61–68.

Viscoelastic properties of KMU-4I carbon fiber reinforced plastic based on epoxy binder ENFB-2 with and without thermal control coating TR-SO-2 were investigated by sensitive inverted torsional pendulum. Data were acquired by three subsequent heat/cold scans in 20–200°C temperature interval. Effect of subsequent scans on glass transition temperature and shear modulus has been shown. The influence of surface coatings (VK-9 glue and TR-SO-2 coating) on viscoelastic properties of KMU-4I in a wide temperature range has been illustrated. Changes in mechanical properties and relaxation temperatures of carbon fiber reinforced plastic caused by moisture sorption/desorption process have been discussed.

Key words: viscoelastic properties, glass transition temperature, DMA, epoxy binder, torsional pendulum, carbon fiber reinforced plastic.

UDC 678.067:620.181.4

Dynamic mechanical analysis of KMU-4I carbon fiber reinforced plastic after 12 years of exposure to space environment. 2. Factor of specimens position in multilayer exposed stack. Startsev O. V., Makhonkov A. J., Deev I. S., Nikishin E. F. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 69–76.

Dynamic shear modulus and dynamic loss modulus of KMU-4I carbon fiber reinforced plastic based on ENFB-2 epoxy binder were measured. The samples (5–8 layers) were tested with and without thermal control coating TR-CO-2 in initial state and after 12 years of exposure to space within Komplast panels on exterior surface of functional cargo block of International Space Station. Changes of viscoelastic properties of the material in glass transition area are shown. Effect of samples positions exposed in multilayer structures on glass transition temperature was discovered. Cyclic heating caused by direct sun radiation was proposed as a reason for the effect observed.

Key words: dynamic shear modulus, dynamic loss modulus, glass transition temperature, dynamic mechanical analysis, epoxy binder, torsion pendulum, carbon fiber reinforced plastic.

UDC 678.067:620.181.4

Thermal expansion of carbon fiber reinforced plastic KMU-4I after 12 years of exposure to space environment. Startsev O. V., Kurs I. S., Deev I. S., Nikishin E. F. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 77–85.

The paper investigates thermal mechanical properties of KMU-4I carbon fiber reinforced plastic. The material samples (5–8 layers) were tested with and without thermal control coating TR-CO-2 in initial state and after 12 years of exposure to space within Komplast panels on the exterior surface of the module of International Space Station. Protective properties of TR-SO-2 coating and VK-9 glue in terms of thermal expansion properties were evaluated. It was established that a long-term exposure in outer space did not change mechanical characteristics of the material. For the “top” plates increasing of compressive stiffness and lowering in thermal expansion coefficient was observed.

Key words: carbon fiber reinforced plastic, Komplast panels, International Space Station, coefficient of linear thermal expansion, thermomechanical analysis.

UDC 678.7

Capillary number value in the process of preforms infiltration with liquid binders. Dushin M. I., Khrukov A. V., Gusev Yu. A., Karavaev R. Yu. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 86–91.

The paper deals with the theoretical and experimental studies of the mechanism of micro and macro pores formation in polymer composite materials depending on the feed rate of the binder related to the dimensionless quantity, which bears the name of the capillary number.

Key words: RTM (Resin Transfer Molding), voids, porosity, permeability, capillary number, capillary pressure.

UDC 678.743.41: 665.521.5:539.62

Used engine oils for production of wear resistant composites based on polytetrafluorethylene. Okhlopko A. A., Petrova P. N., Fedorov A. L. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 92–97.

The paper presents results of tribotechnical polymeric composite materials developing. Waste engine oils are used as modifiers for composites based on polytetrafluorethylene (PTFE). Results of IR spectroscopy for waste oils, friction surfaces and composites wear particles are shown. Used engine oils for production of wear resistant composites based on PTFE are proved to be very promising.

Key words: polytetrafluorethylene, engine oil, friction surface, wear.

UDC 669.14:621.833

Research of fine-dispersed metal powder of the heat resisting alloy on nickel basis for laser metal deposition (LMD). Nerush S. V., Evgenov A. G., Ermolaev A. S., Rogalev A. M. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 98–107.

Fine-dispersed metal powders of the heat resisting alloy brand EP648-VI for laser metal deposition (LMD), obtained by atomization at a facility HERMIGA10/100 VI have been investigated. The paper shows, that the obtained fine-dispersed powders when spraying by cold and hot gas have low oxygen

content, spherical form, and expressed dendritic structure in all range of the granulometric distribution. Adaptive laser metal deposition with application metal powder of the heat resisting alloy EP648-VI of the granulometric distribution 40–80 microns on working off technology of repair of monowheel sector guarantees high quality of welding material (microcracks, lack of penetration, porosity have not been revealed).

Key words: atomization, spraying, synthesis, welding, powders, granules, porosity, granulometric distribution, additive technologies.

UDC 621.791.76: 669.35:669.14.018.8

Some features of argon-arc welding of copper alloys with nitrous austenitic steel grade 04Kh20N6G11M2AFB (04X20H6Г11M2АФБ). Vainerman A. A., Vainerman A. E., Veretennikov M. M. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 108–122.

The paper shows welding possibilities of copper alloys and nitrous steel. Welding is carried out successfully with the help of sublayers. Steel EP-263SH St-08Kh32N8SH (ЭП-263Ш Св-08Х32Н8Ш) wire could be used for overlaying on nitrous steel.

Key words: nitrous steel, copper alloy, argon arc welding, overlaying welding.

UDC 621.791.048

Comparative testing of welding fluxes for bridge and building structures at production field. Pimenov A. V., Tarantaev A. V. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 123–130.

The paper shows the results of testing at production field of flux PFK-56C (ПФК-56С) in comparison with other fluxes applied in the bridge and building structures made of 10KhSND (10ХСНД), 15KhSND (15ХСНД) and 09G2S (09Г2С) steels. The competitiveness of domestic flux PFK-56S has been proved. Flux PFK-56S combined with wire Sv-08GA (Св-08ГА) has been certified and approved for steel bridges structures by National Agency of Welding Control.

Key words: welding, agglomerated flux, low-alloy steel, bridge engineering.

UDC 669.15–194:621.039.536.2:539.422.22

Brittle fracture origins when testing WWER-1000 vessels' steels in various states for fracture toughness. Kuleshova E. A., Artamonov M. A., Erak A. D. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 131–142.

Nuclear reactor vessel steels were tested for crack growth resistance by fractographic methods, and two major sources of brittle fracture were revealed: non-metallic inclusions, intergranular or subgrain boundaries. Micro X-ray analysis showed that the non-metallic inclusions were composed of manganese sulfide and silicon oxide. The probable size of non-metallic inclusions initiating the brittle fracture was revealed, it equals to approximately 1 micron. The connection between the value of the critical stress intensity factor (K_{Jc}) and cleavage initiation distance (CID) was confirmed for the investigated steels. The paper shows the effect of irradiation conditions on the values of steels crack growth resistance.

Key words: crack growth resistance, WWER-1000 vessel, irradiation embrittlement, brittle fracture, non-metallic inclusion.

UDC 658.562

On the results reproducibility of structures and fractures measurements using computerized procedures. Sokolovskaya E. A. – *Voprosy Materialovedeniya*, 2013, N 4(76), p. 143–153.

The factors that determine the reproducibility and comparability of geometry measurement results have been compared for a wide range of brittle and ductile fractures (dendritic pattern, metallographic sections of non-metallic inclusions, steel sheets microstructure). Thus, in particular, the paper considers binarization level of distribution matrix of brightness intensity and accumulated volume of statistics measurements (viewing field of metallographic sections, crack length as measured on the fracture). The results can be used in the development of documented procedures for measuring geometry images of structures and fractures and their application in practice.

Key words: structures and fractures images, computerized procedures, image binarization, statistics measurements.