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## ON THE INFLUENCE OF HOT-BENDING DEFORMATION ON THE STRUCTURE AND PROPERTIES OF 10KhN4MFA STEEL BULB PROFILE FOR SHIPBUILDING

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In the process of bending of 10KhN4MFA steel flat-bulb profile, grain boundaries break down, brittle fracture of specimens takes place, and steel toughness decreases at a degree of deformation of more than 3% and heating by high-frequency currents of the deformation zone to the hardening temperature (960°C). There is no brittle fracture of the profile in the entire range of the degree of deformation when the heating temperature of the deformation zone raises to 1050°C.

*Keywords*: steel bulb profile; hot bending; hardening; deformation degree; brittle and ductile fracture; impact strength

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## INCREASING DURABILITY OF HAMMER DIES' STEEL BY CARBONIZATION IN PASTE CARBURIZING MATERIAL

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The paper considers carbonization features of die steels such as 5Kh2MNF (5Х2МНФ) and 5KhNSV (5ХНСВ) in azotic-carbonic paste in order to use it as a material for die makers. The results of examination of cemented carbide tools made of mentioned steel grades are given and the microstructure of carburized layers is shown. The changes of carbon concentration according to the depth of diffusion layers of examined samples are analyzed.

*Keywords*: 5Kh2MNF (5Х2МНФ) and 5KhNSV (5ХНСВ) steels, steel carbonization, azotic-carbonic paste, die makers, changes of structure and properties.

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## SCIENTIFIC AND TECHNOLOGICAL BASES FOR CREATION OF COLD-RESISTANT STEEL WITH A GUARANTEED YIELD STRENGTH OF 315–750 MPa FOR THE ARCTIC. Part 1: Principles of alloying and requirements for sheet metal structure

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The results of the choice of rational alloying and microalloying of cold-resistant steels with a guaranteed yield strength of 315–750 MPa are presented on the basis of the established interrelationship of phase transformations, structure, mechanical properties and performance characteristics when varying the content of basic alloying elements. Quantitative requirements for various structural parameters and their maximum permissible difference in sheet metal thickness up to 100 mm have been developed, depending on the strength category, manufacturing technology (thermomechanical treatment with accelerated cooling, hardening from separate furnace or rolling heating with high temperature tempering), which provide guaranteed characteristics of strength, cold resistance (impact work KV at test temperature –60 ... –80°C, critical temperatures of viscous-brittle transition $T_к$ and zero ductility NDT) and crack resistance under the criterion of the critical opening in the top CTOD fracture.

*Keywords*: low-alloyed steel, economically alloyed steel, Arc index, thermomechanical processing, hardening, quenching from rolling heating, tempering, mechanical properties, cold resistance, serviceability, crack resistance, structure parameters, ferrite, bainite, martensite.

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# THE INFLUENCE OF AGEING TEMPERATURE ON CARBIDE PHASES PRECIPITATION AT GRAIN BOUNDARIES OF P/M Ni-BASE SUPERALLOYS

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**Abstract—**The way to set ageing regimes of P/M Ni-base superalloy for disk application was demonstrated. The optimal ageing temperatures were identified by microstructure investigations. Mechanical tests of the material with different volume ratio of carbide phases were carried out. The obtained results confirm the correctness of the detected patterns.

*Keywords*: disk billet, jet-engine, powder, Ni-base superalloy, microstructure, carbide.

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## MECHANICAL PROPERTIES OF WELDED JOINTS OF THE PRESSED ALUMINUM-MAGNESIUM 1565Ch ALLOY AT LOW AND HIGH TEMPERATURES

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The paper studies structure and mechanical properties of welded joints of hot-pressed panels and profiles manufactured by JSC Arkonik SMZ from aluminum-magnesium 1565ch alloy at the temperature range of –165 to 150°C. It is established that the nature of changes in the properties of welded joints of pressed panels and profiles of 1565ch alloy made by manual argon-arc welding with non-consumable electrodes of ArDS with filler material SwAMg-61 at various test temperatures is similar to changes of welded joints of rolled sheets. When the test temperature is lowered, low-temperature hardening of the welded joints takes place – at a cryogenic temperature (–165°C), 20–30% of strength is gained comparing to 20°C. The prolonged aging of welded joints at an elevated temperature (150°C) leads to strength decrease by 25–30% compared to that of 20°C. The coefficient of strength of welded joints with reinforced joint is not less than 0.9 of the actual strength of the base metal at all test temperatures.

*Keywords*: pressed alloy of 1565ch grade, argon arc welding, welded joints, mechanical properties at low and high temperatures.

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## FACTORS OF STRENGTH INCREASING OF METALS PRODUCED BY SELECTIVE LASER MELTING OF POWDERS

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**Abstract**—Standard samples of metal powders of various chemical composition were made for mechanical tests by selective laser melting. The paper describes an increase in strength characteristics of all samples made by melting comparing with similar parameters of monolithic samples of identical chemical composition. It is established that ultrafine-grained structure and condensation of nanoparticles could be cosidered factors of strength increase.

*Keywords:* additive technologies, selective laser melting, metal powders, hardening mechanisms.

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## SPECIFIC FEATURES OF GLASS APPLIED FOR HIGH-SPEED MICROMETALLURGICAL CASTING OF MICROWIRES

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The present paper provides a justification for the selection of the basic composition of the system $SiO_2$–$B_2O_3$–MgO–BaO–$Na_2O$–$K_2O$; its additional alloying with such elements as oxides PbO, $Na_2O$ + $K_2O$, $ZrO_2$ and $TiO_2$ alters the main characteristics of glass tubes for casting microwires. The proposed glass compositions vary significantly the range of metals and alloys used to produce cast microwires in glass insulation.

*Keywords*: cast microwires in glass insulation, glass viscosity, crystallization ability of glasses, glass defects

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## MICROWIRES OF NICKEL, COBALT AND COPPER-BASED ALLOYS CHARACTERIZED BY HIGH LEVEL OF TEMPERATURE AND TIME STABILITY

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The results of investigations of temperature and time stability of cast microwires in glass insulation from resistive alloys of nickel–chrome, cobalt–chromium and copper–nickel systems are presented. It is established that microwires from the investigated alloys retain their temperature stability at temperatures not lower than 350°C. An investigation of the time stability showed that changes in the electrical resistance during long-term storage of microwires (up to 1 year) do not occur in warehouse conditions, and despite the high degree of nonequilibrium of alloys during high-temperature hardening of the melt, relaxation phenomena are not observed. Consequently, the investigated microwires from alloys based on nickel, cobalt and copper are a very promising material for manufacturing thermostable resistive elements for precision instrumentation.

*Keywords*: cast microwire in glass insulation, temperature stability, time stability, melt supercooling, temperature coefficient of resistance.

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## SYNTHESIS AND ELECTRON BEAM FACING OF TiB – TiC– TITANIUM MATRIX HYBRID COMPOSITE POWDERS

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**Abstract**—TiB – TiC – titanium matrix composite powders have been synthesized by self-propagating high temperature synthesis (SHS) in titanium, boron and carbon reactive powder mixtures. A target volume content of the titanium matrix (binder) in the powders was 50%. The SHS powders were cladded on VT1-0 titanium sheet by electron beam facing. A thickness of the cladded coatings varied from 1 to 3 mm depending on the pass number. A phase composition and a structure of the SHS powders and of the cladded coatings were invetigated be X-ray diffraction, optical and scanning electron microscopy. According to structure investigation and hardness profiles in the "coating – titanium base plate" transition zone an adhesion of the coating to the base is high. The hardness and abrasive wear resistance tests of the cladded coatings were carried out depending on the powder used for cladding. The maximum hardness increase of the coatings strengthened by titanium monoboride and titanium carbide inclusions is 2.2 times and abrasive wear resistance – 4.3 times as compared with VT1-0 base. According to authors' earlier results enhance hardness and abrasive wear resistant effects of titanium matrix by titanium carbide particles and titanium monoboride is near to the wear resistance of coatings deposited with SHS TiB + Ti powder, but ~5 times less than the wear resistance of coatings surfaced with SHS powder TiC + Ti.

*Keywords:* self-propagating high-temperature synthesis, metal-matrix composites, titanium monoboride, titanium carbide, titanium, surfacing, microstructure, hardness, abrasive wear resistance.

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## OBTAINING THE FUNCTIONAL INTERMETALLIC Ni–Ti COATINGS BY HETEROPHASE TRANSFER COMBINED WITH LASER TREATMENT

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The results of the investigation of the intermetallic Ni–Ti system coating obtained by complex method of cold gasodynamic spraying and laser treatment are presented. The dependence of the coating charge composition on the initial powder composition is shown. Its structure, porosity, and microhardness are studied, and also the results of X-ray phase analysis confirming the presence of intermetallic phase are presented. The microhardness increased more than 5 times to 632 HV, and porosity decreased 25 times up to 0.2%. Investigation of the substrate-coating boundary showed the presence of mutual diffusion.

*Keywords*: spraying, laser treatment, titanium nickelide, nitinol, intermetallide

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## EXPERIMENTAL PRODUCING OF Cu–Cr–N COMPOSITE ALLOYS AND THERMODYNAMIC MODELING OF THEIR PHASE COMPOSITION

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**Abstract—**Composite Cu–Cr–N alloys were obtained *in situ* under vibration of "copper melt – chromium powder" compositions before their crystallization. Two types of alloys were prepared, where chromium powder was freely dispersed or compacted into a tablet. Atmospheric nitrogen was used as a source of chromium nitrides in the alloys. The microstructure of the alloys is represented by a copper matrix hardened with chromium particles and numerous inclusions of non-stoichiometric chromium nitrides $Cr_2N_{1-x}$. Thermodynamic modeling showed that the composition and quantities of chromium nitrides in the Cu–Cr–N alloy depend on the partial pressure of nitrogen above the melt.

*Keywords:* composite alloy, copper, chromium, chromium nitrides, in situ synthesis, vibration, thermodynamic modeling.

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## THE INFLUENCE OF OXIDIZED TECHNICAL CARBON N121 ON THE PROPERTIES OF BUTYL-BASED RUBBERS

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**Abstract—**The subject of the study were samples of channel technical carbon K354, furnace technical carbon N121 and experimental – based on TU N121, oxidized with active forms of oxygen. Samples of carbon black were studied in the composition of a rubber mixture based on BK 1675N butyl rubber. The purpose of this study was to determine the possibility of using oxidized technical carbon N121 in fillers of rubber based on butyl rubber, instead of carbon black K354. The physicochemical properties of the samples of technical carbon under study, the results of physical and mechanical tests, and the gas permeability tests of rubber mixtures filled with the samples under study are presented. A conclusion is made about the possibility of replacing channel technical carbon K354 with furnace black carbon N121 oxidized with 30% hydrogen peroxide.

*Keywords*: technical carbon, functional groups, butyl rubber, rubber compound, rubber.

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## APPLICATION OF HYDROGENATED BUTADIENE-NITRILE RUBBERS FOR PRODUCTS OPERATED AT HIGH TEMPERATURES AND IN AGGRESSIVE ENVIRONMENTS

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**Abstract—**The subject of the study were rubber mixtures based on hydrogenated butadiene-nitrile rubbers (HNBR) Therban, Zetpol, NBR-B with an acrylonitrile (AN) content of 34% to 49% and unsaturation of 0.9% to 22% with sulfuric, peroxide and sulfuric-peroxide cure systems. The purpose of the study was to determine the effect of the AN content and the degree of unsaturation of HNBR on the properties of rubbers in products designed for operation under the influence of fuels and oils at increased temperatures.

The results of the determination of the mass swelling of rubbers in hydrocarbon media and the relative elongation in the process of thermal aging in air and in oil at increased temperatures are presented. The conclusion was made on the use of HNBR mixture with maximum content of AN (49%), with low (6%) and extremely low (0.9%) ODS content and sulfuric peroxide cure system to extend the product service temperature limit to 150°C.

*Keywords*: hydrogenated butadiene-nitrile rubber, acrylonitrile, degree of unsaturation, aggressive environment, thermal aging

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## DYNAMIC PROPERTIES OF ELASTOMER COMPOSITES FILLED WITH MULTIWALLED CARBON NANOTUBES

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**Abstract—**The paper studies the influence of multiwalled carbon nanotubes (MWCN) on vulcanizing and dynamic properties under shear and oscillating load. It was found that, despite the lack of preliminary preparation of MWCN, when their concentration increase the dynamic properties also increase under an oscillating load in highly elastic state. Thus, it is possible to use MWCN producing elastomer materials with improved properties.

*Keywords*: elastomer composites, multiwalled carbon nanotubes, vulcanizing and dynamic properties.

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## ZINC-STEARATE MODIFICATION OF EPOXY RESINS AND CARBON PLASTICS BASED ON THEM AND ITS INFLUENCE ON THE BASIC TECHNOLOGICAL PROPERTIES OF THE COMPOSITION

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**Abstract**—The influence of the special modification of epoxy resins and polymer composites based on them on the basic technological properties of the composition is investigated. Modification is performed in order to reduce the opening damage. The most important technological properties of the initial epoxy composition and modified technological additives are studied and compared by standard methods (viscosimetry, thermoanalytical methods). A kinetic model of the curing process was created, the experimental production of samples from plastics filled with carbon long filler (impregnation under pressure, autoclave molding) and its non-destructive testing were carried out.

*Keywords*: technological properties, epoxy resins, carbon plastic, modifier zinc stearate, pressure impregnation, autoclave molding

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## EFFECT OF LONG CLIMATIC AGEING ON THE MICROSTRUCTURE OF THE SURFACE OF CARBON-FIBER-REINFORCED PLASTICS ON BASE EPOXY MATRIX

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**Abstract**—Studies and experimental data on the microstructure of the surface of samples of epoxy carbon-fiber-reinforced plastics that have undergone long-term (up to 5 years) climatic aging in different climatic zones of Russia have been conducted: under conditions of the industrial zone of temperate climate (Moscow, MTsKI); temperate warm climate (Gelendzhik, GTsKI); a warm humid climate (Sochi, GNIP RAS). It is established that the determining factor for aging of carbon plastics is the duration of the complex effect of climatic factors: the longer the period of climatic aging, the more significant changes occur in the microstructure of the surface of the materials. The intensity of the aging process and the degree of microstructural changes in the surface of carbon plastics are affected by the features of the climatic zone. general regularities and features of the destruction of the surface of carbon plastics after a long-term exposure to climatic factors have been established on the basis of the analysis and systematization of the results of microstructural studies.

*Keywords*: carbon-fiber-reinforced plastics, surface, long-term aging, climatic zones, macro- and microstructure, scanning electron microscopy.

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## THEORETICAL AND EXPERIMENTAL STUDIES OF COMPOSITE MATERIALS REINFORCED BY CARBON FABRICS.
## Part 3: Modeling and experimental studies of the carbon fabric structure

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**Abstract**— As a result of modeling and experimental studies of composite materials reinforced with carbon fabrics, the main parameters of the structure of carbon fiber have been determined. The experimental data were processed according to the standard methods of the state system for ensuring the uniformity of measurements. Comparison of the predicted and experimental values of the parameters showed a sufficiently high accuracy of the developed mechanical-analytical model of the structure of carbon fabric.

*Keywords*: carbon fiber, woven structure, reinforcing component, composite material, mechanical-analytical model.

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## HEAT-RESISTANT ANTIFRICTION CARBON PLASTICS FOR PUMPS SLIDING BEARINGS OF SHIP ENERGY STATIONS, THERMAL AND NUCLEAR POWER PLANTS

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**Abstract—**The paper summarizes experience of development and application of high speed sliding bearings for centrifugal pumps of ship energy units, thermal electric stations, nuclear power plants. Sliding bearings work with overheated water at temperatures 200°C and sliding velocities 20–40 m/s. Unlike metals, these sliding bearings don't need additional oil lubrication. Two antifriction carbon plastics, namely phenolic type FUT-B and new one polyphenylene sulfide type UPFS are discussed.

*Keywords:* centrifugal pumps, external and build in sliding bearings, antifriction carbon plastics, phenolic formaldehyde resin, polyphenylene sulfide.

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## DEGRADATION OF FUEL RODS MATERIALS BASED ON ZIRCONIUM AFTER OPERATION IN WWER-TYPE REACTORS

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**Abstract**—The paper presents microstructural studies of specimens cut from fuel elements made of E110 spongy zirconium-based alloy after operation in WWER-1000 before reaching the burnout of ~35 MW per day/kg U. As a result of exposure to high temperatures and neutron irradiation significant changes in the phase composition of the material of fuel rods claddings appear in particles β-Nb' size, density, and composition; composition of the Laves phase, formation of dislocation loops of α-type, as well as δ and γ hydrides. The main structural elements determining the degradation of the mechanical properties of the E110 alloy under irradiation are dislocation loops and fine-phase precipitates due to their relatively large density. The data obtained can be used to construct dose dependences of microstructural changes with the aim of predicting the residual life of claddings and fuel assemblies as a whole.

*Keywords*: WWER reactors, fuel rods shells, alloy based on spongy zirconium, neutron irradiation, degradation of properties, forecasting of residual resource.

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## POST-IRRADIATION EXAMINATIONS OF DISPERSION FUEL RODS WITH MODIFIED ZIRCONIUM ALLOYS CLADDINGS

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**Abstract**—Modified zirconium alloys E635M and E635opt based on E635 alloy (E635 was selected as master alloy) have been developed at Bochvar Institute. Fuel rods with such claddings were manufactured at Bochvar Institute and were irradiated at MIR reactor (SC RIAR, Dimitrovgrad). The results from the PIE performed at RIAR are presented. Such features of claddings as microstructures, corrosion resistance (width and structure of oxide), hydrogen contents, distribution of hydrides, mechanical properties were examined and discussed. Modifications of the alloy E635opt and E635M showed higher resistance to corrosion and hydrogen pick-up compared to the E635 alloy, while maintaining high strength and ductility. They have confirmed their prospects for use as cladding for fuel rods with enhanced characteristics.

*Key words*: Zr-base alloys, atomic energy, fuel rod, post-irradiation examinations, corrosion resistance, hydrides

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## X-RAY NON-DESTRUCTIVE TESTING – AN ESSENTIAL TOOL DURING MODERN AERONAUTICS MATERIAL TECHNOLOGY DESIGN AND DEVELOPMENT

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**Abstract**—The X-ray non-destructive testing process is carried out by the system, which includes: the object of control (OC); source of radiation; detector; operator. The X-ray radiation and the object of control interaction formed the radiation image as X-ray doze distribution in accordance with the properties of the OC. At this stage, useful information about the OK is formed, which one is partially lost, partially distorted, and veiled with noise when the radiation image is converted into an optical one. The optical image is analyzed by operator, and the result of the control depends from his physical and emotional state. This article presents a phased analysis of the entire radiation monitoring system. The first stage is the radiation image formation. Theoretical estimate of X-ray inspection system minimum detected defect size was made using space frequency spectrum analysis. The second stage is the transformation of the radiation image into an optical one. We represented the simulation of this process and obtained a modulation of how the operator sees the X-ray optical image and makes a decision about the OC state. Analyzed the X-ray digital image formation and determined the energy choice criteria when applied digital radiography.

*Keywords:* X-ray non-destructive testing, space frequency spectrum, modulation transfer function, probability of detection, digital radiography, signal-to-noise ratio.

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