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ON CREATING HIGH-STRENGTH ECONOMICALLY ALLOYED MANUFACTURABLE STEELS FOR THE ARCTIC

M. V. KOVALCHUK, Corresp. Member of the RAS, A. S. ORYSHCHENKO[2], Dr. Sc. (Eng), V. A. MALYSHEVSKY[2], Dr. Sc. (Eng), S. N. PETROV[2], Cand. Sc. (Chem), E. A. SHUMILOV[2]

NRC "Kurchatov Institute" – 1, Square Akad. Kurchatov, 123182, Moskow, Russian Federation

NRC "Kurchatov Institute" – CRISM "Prometey", 49, Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

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Abstract—The paper is devoted to the problems of creating technologies for manufacturing of steels with ultra-fine grains, characterized by a high combination of physical and mechanical properties with moderate alloying. Using the plastometer Gleeble 3800 and the Quarto 800 mill, the possibility of grain refinement up to 1–1.5 microns is shown. When the content of grains (less than 500 nm) equals to 30–50%, the strength of the steel exceeds 1000 MPa at high plasticity. In this case, alloying can be reduced to minimum in comparison with well known steels. The possibility of modeling industrial production processes on the Gleeble 3800 and the Quarto 800 mill is shown.

Keywords: structure fragmentation, plastic deformation, nanostructuring, misorientation angles, thermomechanical treatment, unification of chemical composition.

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TEMPERATURE AND DEFORMATION INFLUENCE ON FORMATION OF EXCESS PHASES IN AUSTENITIC HIGH-STRENGTH NITROGEN-CONTAINING STEEL AT HIGH-TEMPERATURE THERMOMECHANICAL PROCESSING

O. V. FOMINA, Cand. Sc. (Eng), M. V. KOSTINA, Dr Sc. (Eng),

[1]NRC "Kurchatov Institute" – CRISM "Prometey", 49 Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

[2]Baikov Institute of Metallurgy and Material Science RAS, 49 Leninsky pr., 119991, Moscow, Russian Federation

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Abstract—During the manufacturing process it is necessary to exclude the formation of large inclusions of excess phases (carbides and nitrides) in nitrogen-containing steel, in particular along the grain boundaries, and also in triple joints of grains, which significantly influence the initiation of cracks and the

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development of material destruction. The paper studies thermodynamic processes occurring in a high-strength non-magnetic corrosion-resistant steel grade 04Kh20N6G11M2AFB (04Х20Н6Г11М2АФБ) with a nitrogen content of 0.45%. A theoretical calculation of the equilibrium phase composition of steel has been performed using the Thermo Calc software. With the help of dilatometric and metallographic studies, the temperature intervals for the formation of dispersed carbonitride particles after cooling have been established, and also the absence of the propensity to intermittent decay and the formation of the δ-phase at temperatures below 900°C.

The temperature range for the formation of carbonitride phases varies from 1020 to 850°C. Deformation of 10–30% increases it to 1050–410°C. The degree of deformation in one pass has a significant effect on the intensity of the formation of carbonitrides directly under high-temperature thermomechanical treatment.

Keywords: austenitic nitrogen-containing steel, carbonitrides, phase composition, deformation, temperature interval of excess phases' formation

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CARBURIZATION OF HEAT EXCHANGE PIPES FROM STEEL GRADE Cr18Ni9 IN CONTACT WITH LIQUID SODIUM

A. S. KUDRIAVTSEV, Cand. Sci. (Eng), K. A. OKHAPKIN, Cand. Sci. (Eng)

NRC "Kurchatov Institute" – CRISM "Prometey", 49 Shpalernaya St, 191015 St Petersburg, Russian Federation. E-mail: mail@crism.ru

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Abstract—The research of carburizing process of heat-exchange pipes from steel grade Cr18Ni9 under conditions of long-term operation at 515°C in liquid sodium was carried out. On the experimental assessment of the carbon content in the surface metal layer, the value of the effective diffusion coefficient was determined and the depth of carburization was calculated in the temperature range 450–515°C.

Keywords: steam generator, heat exchange tubes, sodium coolant, carburization, effective diffusion coefficient.

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INFLUENCE OF CARBAMIDE-CONTAINING BRIQUETTED MODIFICATORS ON THE PROPERTIES AND STRUCTURE OF THE GRAY CAST IRON

G. A. BAGLIUK, Dr. Sc. (Eng), V. Ya. KUROVSKY, E. V. ZAKHARCHENKO, Cand. Sc. (Eng)

I. N. Frantsevich Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, 3 Krzhizhanovskogo St, 03142 Kiev, Ukraine

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Abstract—The paper presents studies of the effect of carbamide-containing briquetted modifying agents, component composition and modifiers consumption at ladle inoculation of the melt on the basic mechanical properties and structure of cast iron. The efficiency of melt cast iron processing with powder briquetted modifiers containing carbamide is shown. Increase of briquettes consumption, containing 8% carbamide, from 0.25 to 5–6% of the melt weight results in a substantial growth of the cast iron strength achieving the values of high-duty cast iron (about 490 MPa). With increasing of briquettes consumption from 1 to 6% the degree of nitrogen assimilation decreases from 29% to 14% and the chilling effect increases. Morphology of graphitic phase with increasing of nitrogen content in the alloy varies from mixture of lamellar and vermicular inclusions up to vermicular particles, and their amount and size are being reduced in the cast iron with a higher content of nitrogen. The matrix phase of the cast iron with any nitrogen content has a structure of fine laminar perlite.

Keywords: cast iron, inoculation, nitrogen, carbamide, chilling effect, strength, graphite.

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ASSESSMENT OF MATERIAL REGENERATION OF TURBINE ROTOR BLADE BY METHODS OF THE QUANTITATIVE ANALYSIS OF THE STRENGTHENING PHASES AND RESEARCH OF LOCAL MECHANICAL CHARACTERISTICS

Yu. P. TARASENKO, Cand Sci (Phys-Math), S. V. KIRIKOV, O. B. BERDNIK, Cand Sci (Phys-Math), L. A. KRIVINA

Mechanical Engineering Research Institute of RAS (MERI RAS), Nizhny Novgorod branch of the Federal Research Center “The Institute of Applied Physics of RAS”, 85, St Belinskogo, 603024 Nizhny Novgorod, Russian Federation. E-mail: npktribonika@yandex.ru

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http://www.crism-prometey.ru

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Abstract—The object of research is the first stage rotor blade of gas turbine GTE-45-3 engine from heat-resistant EP800VD nickel alloy after operation of 14 000 hours and after carrying out the reductive heat treatment.

The paper studies distribution parameters of strengthening intermetallic **γ'**-phase and local mechanical characteristics of material defined in the different thermal loaded zones in a post-operational state and after the reductive heat treatment.

The work defines possibilities of material structure regeneration after operation by methods of the quantitative assessment of alloy microstructure parameters and research of local mechanical characteristics in different thermally loaded zones of the blade.

The quantitative metallographic analysis, electronic microscopy, hardness and microhardness measurements, relaxation tests of local strength properties, creep tests have been selected as methods of investigation.

It is established that degradation of local mechanical characteristics of material proceeds with different intensity in thermally loaded zones of the blade and is associated to processes of the coagulation and dissolution of intermetallic γ'-phase. It is shown that the quantitative research techniques of a microstructure, namely, the strengthening phase in case of high-temperature nickel alloys, are rather informative and allow to give an assessment to a condition of material in general.

Keywords: turbine blades, heat-resistant nickel alloy, alloying elements, intermetallic phase, mechanical properties, relaxation.

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REFRACTORY MONOCARBIDES AND DIBORIDES OF TRANSITION METALS: PROMISING COMPONENTS OF HIGH-TEMPERATURE COMPOSITE MATERIALS

G. S. BURKHANOV, Corresp. Member of the RAS, V. A. DEMENTIEV

Baikov Institute of Metallurgy and Material Science RAS,
49 Leninsky Prospect,119991, Moscow, Russian Federation. E-mail: genburkh@imet.ac.ru

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Abstract—Creation of new generation composite materials, working in extreme conditions, requires a comprehensive design, technological and materials science approach. One of the components of such materials can be monocarbides and diborides of transition metals of groups IV–VI of the periodic system of elements – titanium, zirconium, hafnium, vanadium, niobium, tantalum. In addition to individual monocarbides and diborides, their binary systems also cause great interest. Most isomorphic pairs of monocarbides and diborides have unlimited mutual solubility. Of particular significance is the HfC–TaC system. The TaC–4HfC compound has a temperature exceeding 4000°C, which is a record of refractoriness among all known synthesized substances.

Keywords: structural materials, composite materials, carbon materials, refractory compounds, carbides, borides, solidification, physicochemical analysis.

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ON MICROSTRUCTURE AND PROPERTIES OF NIOBIUM-SILICON COMPOSITE OBTAINED BY DIRECTIONAL SOLIDIFICATION IN LIQUID METAL

Yu. A. BONDARENKO, Dr. Sc. (Eng), M. Yu. KOLODYAZHNY, A. B. ECHIN, Cand. Sc. (Eng), A. N. RAEVSKIKH

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http://www.crism-prometey.ru

Federal State Unitary Enterprise "All-Russian Scientific Research Institute of Aviation Materials" (FSUE VIAM), 17 Radio St, 105005 Moscow, Russian Federation. E-mail: admin@viam.ru

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Abstract—Directional solidification conditions, structure and properties of the niobium-silicon composite obtained by liquid metal cooling have been studied. Natural composition and microstructure of the ingot after directional solidification have been considered. The phase composition and microstructure of Nb–Si composite have been analyzed, and short-term strength levels have been determined at 20 and 1200°C and values of long-term strength at 1200°C.

Keywords: directional solidification; refractory eutectic alloy; eutectic composite structure; niobium silicide; solid solution of niobium; niobium solid solution; short-term strength; long-term strength.

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COMBINED METHOD OF CASTING MICROWIRES IN GLASS INSULATION

B. V. FARMAKOVSKY, Cand. Sc. (Eng)

NRC "Kurchatov Institute" – CRISM "Prometey", 49 Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

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Abstract—The results of research of casting microwires in glass insulation in terms of stabilizing the chemical composition and parameters of the casting process are presented. On the basis of these data, a combined method has been developed and actually mastered, realizing the technological replenishment of the required volume of molten metal by creating a second autonomous additional drop,

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where the same physical and chemical processes are realized as in the main drop. This method has significantly increased the productivity of the microwires casting process.

Key words: microwires, glass insulation, casting, process performance.

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ANALYSIS OF THE PROPERTIES OF THIN MEMBRANE STRUCTURES, MODIFIED BY LASER TREATMENT OF TITANIUM NITRIDE SURFACE

O. S. YULMETOVA[1], Cand. Sc. (Eng), M. A. TUMANOVA[1], A. G. SHCHERBAK[1], Dr. Sc. (Eng), R. F. YULMETOVA[2], Cand. Sc. (Chem)

[1] *JSC Concern CSRI "Electropribor", 30 St Malaya Posadskaya, 197046 St Petersburg, Russian Federation. E-mail: office@eprib.ru*

[2] *ITMO University (Saint Petersburg National Research University of Information Technologies, Mechanics and Optics), 49A Kronverksky Ave, 197101 St Petersburg, Russian Federation*

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Abstract—Research results of composition, structure, and optical properties of membranes formed on the surface of a titanium nitride coating after multipass laser processing are presented. The modes of forming raster pattern with a contrast of 0.14–0.6 at a wavelength of 860 nm are determined without changing the roughness of the base surface. Features of surface modification are shown, due to the fact that the number of laser passes increases the saturation of the titanium nitride membrane with oxygen forming titanium oxide of anatase and rutile phases, as well as of titanium oxynitride with formula TiO0.3N0.7. The process of phase transformations is accompanied by the growth of structural fragments and a change in the color of the membrane. The thickness of the modified layer after four-pass laser processing is about 0.5–0.7 μm.

Keywords: titanium nitride, laser surface treatment, optical contrast, stoichiometry, oxynitrides.

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PRODUCTION OF HYDROGEN BY USING SMALL-SCALE TRANSPORTABLE PLANTS BASED ON HIGH-TEMPERATURE SYNGAS GENERATORS

Yu. V. ZAGASHVILI[1], Dr Sc. (Eng), A. A. LEVIKHIN[2], Cand. Sc. (Eng), A. M. KUZMIN[3], Cand. Sc. (Eng), Yu. V. ANISKEVICH[2], Cand. Sc. (Eng), O. V. VASILIEVA[4], Cand. Sc. (Eng)

[1] *OOO "VTR", 40, 1 lit. A, 2-n, Maurice Thorez Ave., 194223 St. Petersburg, E-mail: zagashvili@yandex.ru*

[2] *HPE BSTU "VOENMEKh" named after D.F. Ustinov, 1, 1st Krasnoarmeyskaya St, 198005 St. Petersburg, Russian Federation*

[3] *OOO "GSG", 15, building 1, apt. 49, Olga Forsh St, 195297 St. Petersburg, Russian Federation*

[4] *NRC "Kurchatov Institute" – CRISM "Prometey", 49, Shpalernaya St, 191015 St Petersburg, Russian Federation. E-mail: mail@crism.ru*

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Abstract—The physical model and system of synthesis gas (syngas) generator designed by OOO VTR, as well as structural features of the mixing head – the most important element of the gas generator, are considered. The paper presents studies of partial oxidation at steady state modes in the combustion chamber of a gas generator for various combinations of raw material – oxidant. It is shown what influence have the main parameters (oxidizer's excess factor, degree of air enrichment, degree of moistening of raw material, pressure in the combustion chamber, temperature of components' heating) on the balance ratios of the incomplete combustion. The possibility of obtaining the syngas of the required composition and parameters for the synthesis of the final target products (hydrogen, methanol, etc.) is regarded.

Keywords: partial oxidation of hydrocarbons, low-tonnage syngas production, gas generator, combustion chamber.

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ON MODIFYING OF SLIDING SURFACE OF HIGH SPEED FRICTION PAIR BY PULSE FREQUENCY IMPLANTATION

L. A. KRIVINA, I. N. TSAREVA, Cand Sci (Phys-Math)

Mechanical Engineering Research Institute of RAS (MERI RAS), Nizhny Novgorod branch of the Federal Research Center "The Institute of Applied Physics of RAS", 85, St Belinskogo, 603024 Nizhny Novgorod, Russian Federation. E-mail: npktribonika@yandex.ru

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Abstract—The object of research is a detail of high speed friction pair "needle thrust bearing" of the gas centrifuge – a needle from steel U10, in the initial, post-operational status and after radiation by different doses of C^+ ions on the pulse-frequency "Rainbow" accelerator.

The paper presents optimum mode of implantation by C^+ ions of needle sliding zone to increase operability of frictional unit "needle thrust bearing" of the gas centrifuge.

The metallographic analysis, microhardness measurements, determination of friction coefficient and wear resistance have been selected as methods of investigation.

It is established that pulse frequency implantation of C^+ ions dose of 10^{18} cm^{-2} leads to the optimum combination of physicomechanical and tribological properties of needle working surface providing better wear resistance of friction pair "needle thrust bearing".

This method of surface treatment is recommended to use when operating friction pair "needle thrust bearing" for increasing working capacity and a resource of operation of high speed friction pair of the gas centrifuge.

Keywords: friction pair, needle, ionic implantation, microhardness, friction coefficient, wear resistance.

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OPTIMIZATION OF THE COATING PROCESS BY GAS DYNAMIC COLD SPRAY APPLIED TO ALUMINUM POWDER

A.M. MAKAROV, D.A. GERASHCHENKOV, Cand. Sc. (Eng), A.F. VASILIEV

NRC “Kurchatov Institute” – CRISM “Prometey”, 49, Shpalernaya St, 191015, St Petersburg, Russian Federation. *E-mail: mail@crism.ru*

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Abstract—The paper is devoted to the development of practical recommendations for using the method of gas dynamic cold spray to obtain functional coatings under production conditions. Using the example of aluminum powder ASD-1, the temperature and speed parameters of the process have been optimized, ensuring high adhesion and hardness of the coating at maximum productivity and a high coefficient of powder utilization.

Keywords: gas dynamic cold spray, functional coatings, temperature and speed parameters, production conditions, aluminum powder material.

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WEAR AND CORROSION RESISTANT FUNCTIONALLY GRADIENT COATINGS BASED ON COMPOSITE POWDERS OF METAL – NON METAL SYSTEM

T. I. BOBKOVA, B. V. FARMAKOVSKY, Cand. Sci. (Eng.)

NRC "Kurchatov Institute" – CRISM "Prometey", 49, Sphalernaya St, 191015, St Petersburg, Russian Federation. *E-mail: mail@crism.ru*

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Abstract—The technology of obtaining wear-resistant corrosion-resistant functional gradient coatings of composite nanostructured powders has been developed by microplasma spraying. Coatings'microhardness reaches 10.27 GPa, providing effective protection of precision engineering components in extreme operating conditions.

Keywords: matrix material, mechanosynthesis, composite powder, microplasma spraying.

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WEAR-RESISTANT FUNCTIONALLY GRADIENT QUASICRYSTAL COATINGS PRODUCED BY SUPERSONIC COLD GAS DYNAMIC SPRAYING

B. V. FARMAKOVSKY, Cand. Sc. (Eng), D. A. GERASHCHENKOV, Cand. Sc. (Eng), R. Yu. BYSTROV, A. F. VASILIEV, I. V. ULIN, Cand. Sc. (Eng), T. I. BOBKOVA

NRC “Kurchatov Institute” – CRISM “Prometey”, 49, Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

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Abstract—A new technology of supersonic cold gas-dynamic spray producing functionally gradient coatings based on Al65–Cu23–Fe12 quasicrystal compound has been developed. Possessing high hardness (above 220 HV) and wear resistance (less than $1{,}6\cdot10^{-9}$ μm/km) the coatings can be used in friction pairs, ship fittings, and important structural and functional elements of transport equipment and power systems.

Keywords: functional gradient coatings, supersonic cold gas dynamic spraying, quasicrystalline structure.

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STUDYING STRUCTURE AND PROPERTIES OF WELDED WEAR-RESISTANT LAYER ON THE BASIS OF THE POWDER OF THE Fe–Ni SYSTEM REINFORCED BY NANO-POWDER WC

N. A. SOKOLOVA[1], T. I. BOBKOVA[1], E. Yu. GERASHCHENKOVA[1],
B. V. FARMAKOVSKY, Cand. Sc. (Eng), M. A. YURKOV[2], Cand. Sc. (Eng)

[1]NRC "Kurchatov Institute" – CRISM "Prometey", 49 Shpalernaya St, 191015 St Petersburg, Russian Federation. E-mail: mail@crism.ru

[2]Federal State Unitary Enterprise "All-Russian Scientific Research Institute of Aviation Materials" (FSUE VIAM), 17 Radio St, 105005 Moscow, Russian Federation. E-mail: admin@viam.ru

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Abstract—A complex study of welded wear-resistant layer samples on the structural element of agricultural machinery was carried out. The technique of combining data obtained from scanning probe and electron microscopes is described.

Keywords: surfacing, scanning probe microscopy, scanning electron microscopy, microhardness, carbide phases.

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OPTIMIZATION OF THE TECHNOLOGICAL PARAMETERS AND DETERMINATION OF SELECTIVE LASER MELTING MODES OF 316L-BASED COMPOSITION POWDER

B. K. BARAKHTIN, Cand. Sc. (Phys-Math), V. V. BOBYR, A. V. VOZNIUK, A. A. DEEV, A. S. ZHUKOV, P.A. KUZNETSOV, Dr. Sc. (Eng)

NRC "Kurchatov Institute" – CRISM "Prometey", 49 Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

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Abstract—Standard specimens made of 316L austenitic steel powder were produced by the selective laser melting (SLM method). Studies of the mechanical properties showed a strong dependence on the parameters of powder melting and the direction of specimens building. Melting modes were found, which allow obtaining a set of mechanical properties, exceeding the characteristics of monolithic samples.

Keywords: powder mixtures, selective laser melting, mechanical properties, complex shape.

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ARAMID FIBER REINFORCED PLASTICS (AFRP) FOR AIRCRAFT ENGINE FAN CASE

G. F. ZHELEZINA, Cand. Sc. (Eng), S. I. VOINOV, T. D. KARIMBAEV, Cand. Sc. (Eng), A.A. CHERNYSHOV

Federal State Unitary Enterprise "All-Russian Scientific Research Institute of Aviation Materials" (FSUE VIAM), 17 Radio St, 105005 Moscow, Russian Federation. E-mail: admin@viam.ru

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Abstract—The article considers the problem of choosing materials for aircraft engine fan case, which provides impenetrability if the blade breaks. Physical and mechanical characteristics, operational properties, high-velocity impact resistance of layered woven organoplastics with special structures were investigated, including after exposure to environmental factors. Application **of** aramid fibers (AFRP) in construction of aircraft engine fan case allows improving its weight and protective characteristics according the continually increasing requirements to modern aircraft engines.

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Key words: aramid fibers **(**AFRP)**,** organoplastics, polymeric composites, aircraft engine**,** ballistic resistance, impact resistance.

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EFFECT OF LONG CLIMATIC AGING ON MICROSTRUCTURE AND NATURE OF FRACTURE OF EPOXY FIBREGLASS IN THE CONDITIONS OF BEND

I. S. DEEV, Dr. Sc. (Eng), E. V. KURSHEV, S. L. LONSKY

Federal State Unitary Enterprise "All-Russian Scientific Research Institute of Aviation Materials" (FSUE VIAM), 17 Radio St, 105005 Moscow, Russian Federation. E-mail: admin@viam.ru

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Abstract—Patterns and mechanisms of epoxy fiberglass fracture after long (till 5 years) aging in different climatic zones (in the conditions of industrial zone of temperate climate of Moscow – MTsKI; temperate warm climate Gelendzhik – GTsKI; warm humid climate of Sochi – GNIP Russian Academy of Sciences) and subsequent testing for static bend have been investigated by methods of the microstructural and fractographic analysis. The structure of obverse and reverse surfaces, and nature of destruction under bending of samples before aging and after natural exposure (specimens were mounted at an angle of 45 degrees from horizontal) have been studied. The general patterns and features of fracture under bending after weathering in different climate are determined.

Keywords: fiberglass, long climatic aging, macro- and microstructure, scanning electron microscopy, durability at bend.

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ANTIFRICTION CARBON PLASTICS FOR FRICTION UNITS WORKING UNDER ARCTIC AND FAR NORTH CONDITIONS

V. Ye. BAKHAREVA, Dr Sc (Eng), Yu. V. ZELENIN, Cand Sc. (Eng), G. I. NIKOLAEV, Dr Sc (Chem), I. V. NIKITINA, Cand. Sc. (Chem)

NRC "Kurchatov Institute" – CRISM "Prometey", 49, Shpalernaya St, 191015, St Petersburg, Russian Federation. E-mail: mail@crism.ru

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http://www.crism-prometey.ru

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Abstract—The reliability of equipment working under Arctic and Far North conditions is provided to great extent by application of cold resistant antifriction polymer composites in friction units. The article is devoted to antifriction carbon plastics developed by CRISM “Prometey” and based on thermosetting and thermoplastic matrices preserving mechanical and tribological features at low and ultralow temperatures, without lubrication or lubricated by any working liquid or liquefied gas at temperatures as low as minus 200°C.

Keywords: antifriction carbon plastics, friction unit, thermosetting plastics, thermoplastic, lubrication by working liquid, northern execution.

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MODERN MATERIALS AND TECHNOLOGIES USED FOR BODY ARMOR

M. I. VALUEVA, Cand. Sc. (Eng)

Federal State Unitary Enterprise "All-Russian Scientific Research Institute of Aviation Materials" (FSUE VIAM), 17, Radio St, 105005 Moscow, Russian Federation. E-mail: admin@viam.ru

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Abstract—The article presents the material science aspects of modern body armor using modern technologies. Particular attention is paid to polymeric composite materials based on textile reinforcing fillers. The equipment and practical means to test the effectiveness of body armor have been described.

Keywords: polymer composites, reinforcing fillers, body armour.

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CALCULATION OF THERMAL PROCESSES AROUND MOVING MOLTEN POOL USING BOUNDARY ELEMENT METHOD

V. A. KARKHIN, Dr Sc. (Eng), P. N. KHOMICH, Cand. Sc. (Eng), O. V. PANCHENKO, Cand. Sc. (Eng), S. Yu. IVANOV

[1]*Peter the Great St Petersburg Polytechnic University, 29 St Polytechnicheskaya, 195251, St Petersburg, Russian Federation. E-mail: victor.karkhin@mail.ru*

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Abstract—A technique for calculating the steady-state temperature field in a solid part of welded workpiece has been developed by using the moving molten pool dimensions as input data and the boundary element method for solving the heat conduction problem. The technique enables the heat source efficiency and thermal efficiency of base metal melting to be calculated. An example of full penetration GTAW of 1565 aluminium alloy demonstrates the distributions of temperature gradient and cooling rate. Good agreement between the computed and experimental thermal cycles is observed. The hardness distribution across a butt welded joint is shown.

Keywords: arc welding, aluminum alloy, heat conductivity, boundary element method, weld pool, temperature field, temperature gradient, cooling rate.

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