

**SCIENTIFIC AND TECHNICAL JOURNAL
"VOPROSY MATERIALOVEDENIYA"**

N 4(64), 2010

CONTENTS

METALS SCIENCE. METALLURGY

- Malyshevsky V. A., Khlusova E. I., Barakhtin B. K. Structural-mechanical properties of promising FCC alloys subjected to hot plastic deformation 7
- Afanasyev N. I., Avramchik A. N., Lepakova O. K., Galchenko N. K. Structure and properties of high-nitrogen steels produced by SHS-method and injection casting with crystallization under pressure 21
- Golosienko S. A., Motovilina G. D., Khlusova E. I. Possibilities of increasing strength characteristics of economically alloyed high-strength steels due to the formation of nanosized carbides 27
- Barakhtin B. K., Vargasov N. R., Savenkov G. G. Structural changes in steel 10 by the action of shock wave action..... 33
- Artemyeva D. A., Kudryavtsev A. S., Markov V. G. Promising materials for steam turbine blades with oversupercritical steam parameters 41
- Zhilkashinova A. M., Skakov M. K., Popova N. A. Second phases formed in Fe–Mn–C alloys 48
- Veselovsky A. A. Determination of diffusion coefficients for carbide-stabilizing elements at the graphite inclusion boundaries in grey cast iron using the Fisher's model for grain boundary diffusion 55
- Barakhtin B. K., Savenkov G. G. Changes in the structure of a copper deformed shell in forming a cumulative jet 60
- Glushenkov V. A., Igolkin A. Yu., Chernikov D. G., Tikhomirov M. D. CAE system "Poligon" for simulating the additional heating of molten metal with magnetic-impulse treatment 66
- Minakov V. F., Arustamyan A. I. Technology of controlling the ladle position when pouring metal into molds 72

NANOSTRUCTURED FUNCTIONAL MATERIALS

- Ziganshin I. R., Porozova S. E., Trapeznikov Yu. F. Formation of a porous material based on nanodispersed ZrO_2 –15 mol.% CeO_2 powder 79
- Boyko V. F., Gostishchev V. V., Zaitsev A. V., Komkov V. G. Estimation of surface energy of tungsten and chrome carbides on the results of their simultaneous milling with iron powder 85

WELDING AND CLADDING, WELDING MATERIALS

- Skutin V. S., Galyatkin S. N., Shcherbinina N. B., Vorobyeva N. Yu. Welding consumables and method of welding silicon-manganese steel structures used in containers for transportation and long-term storage of spent fuel 90
- Vaynerman A. E., Veretennikov M. M., Petrov S. N., Drozdova N. F. Structure and composition of joints made by argon-arc cladding aluminium-nickel bronze with copper-nickel alloys 104
- Vinogradov S. E., Vasilyeva O. B., Kusnetsov V. E., Kuzmin K.A., Safronov A. A., Ovchinnikov R. V., Shekalov V. I., Shiryaev V. N. Examination of the effect of submicron chrome particles on the properties of copper-based alloy electrodes used in low-temperature plasmatrons..... 111

STRUCTURAL-WORKING STRENGTH AND SERVICEABILITY OF MATERIALS

- Margolin B. Z., Gulenko A. G., Buchatsky A. A., Nesterova E. V., Kashtanov A. D. The effect of long-term thermal aging on the creep-rupture properties of 18Cr–9Ni austenitic steels 118
- Gorynin V. I., Golub S. A. Brittle and ductile fracture resistance of cold-resistant low-carbon pipe and shipbuilding steels with a banded structure 128

NEWS AND EVENTS

Information on the Conference Held in Kiev	136
Conferences 2011 Year	137
Index of authors	140
Abstracts of published articles	141
Copyright transfer agreement	151
Instructions for authors of the scientific and technical journal “Voprosy Materialovedeniya”.	
Manuscript requirements	153

ABSTRACTS OF PUBLISHED ARTICLES

UDC [669.715+669.15]:621.77.016.2

Structural-mechanical properties of promising FCC alloys subjected to hot plastic deformation. Malyshevsky V. A., Khlusova E. I., Barakhtin B. K. – Voprosy materialovedeniya, 2010, N 4 (64), p. 7–20.

They obtained data on the change in mechanical properties of an Al–Mg–Sc alloy (type 1575) and a Fe–Cr alloy with high nitrogen concentration in compression at temperatures of $(0.3–0.9) T_{pl}$ with rates of $10^{-3}–10 \text{ s}^{-1}$ in the form of dependences $\sigma(\epsilon)$ and $\sigma(t)$. Relying on the data of thermomechanical treatment simulation in the form of mechanical energy dissipation factor distribution maps and the results of structural examination by methods of light and electronic microscopy, they revealed regions for the TMT parameters (ϵ, T) allowing the realization of the best conditions of hot plastic deformation and activation of the relevant mechanism of structural formation.

Key words: Al–Mg–Sc (type 1575), alloy with high nitrogen concentration, hot plastic deformation, structure, mechanical properties.

UDC 669.15'786–194:669.18

Structure and properties of high-nitrogen steels produced by SHS-method and injection casting with crystallization under pressure. Afanasyev N. I., Avramchik A. N., Lepakova O. K., Galchenko N. K. – Voprosy materialovedeniya, 2010, N 4 (64), p. 21–26.

An austenitic stainless steel with a 0.78 mas. % nitrogen content was produced by metallothermic reduction of oxides in the self-propagating high-temperature synthesis (SHS) mode. The stress-strain properties and structure of SHS-steels are similar to those of steels produced by injection casting with crystallization under pressure. The decomposition of supersaturated solid solutions proceeds by a discontinuous mechanism. The steels studied show superplasticity after their thermomechanical treatment.

Key words: high-nitrogen steels, decomposition of supersaturated solid solution, structure, stress-strain properties, superplasticity.

UDC 669.14.018.295:539.434

Possibilities of increasing strength characteristics of economically alloyed high-strength steels due to the formation of nanosized carbides. Golosienko S. A., Motovilina G. D., Khlusova E. I. – Voprosy materialovedeniya, 2010, N 4 (64), p. 27–32.

They examined the formation of a structure of an economically alloyed high-strength steel made using different methods of its improvement by heat treatment – water quenching following furnace heating and followed by tempering as well as quenching from rolling heat and the following tempering. They revealed the possibility to compensate the carbon contribution to the steel strengthening with decreasing its concentration for weldability to be improved.

Key words: economically alloyed high-strength steel, strengthening, carbides.

UDC 620.178.7

Structural changes in steel 10 by the action of shock wave action. Barakhtin B. K., Vargasov N. R., Savenkov G. G. – Voprosy materialovedeniya, 2010, N 4 (64), p. 33–40.

A steel 10 target subjected to a 13 GPa shock wave with the following effects: 1) fragmentation of high-strength structural constituents and void formation in the zone of frontal loading; 2) initiation of a periodic variable amplitude wave on the steel target – charge case due to a high-rate plastic flow ($\sim 3 \text{ km/s}$) of the case material from the place of impact to the periphery. Off the zone of frontal loading, structural relaxation was localized in plastic instability channels with the transfer of the material mass by organized flows of crystalline structure defects.

Key words: steel 10, shock wave action, crystalline structure defects.

UDC 669.018.44:621.165

Promising materials for steam turbine blades with oversupercritical steam parameters. Artemyeva D. A., Kudryavtsev A. S., Markov V. G. – Voprosy materialovedeniya, 2010, N 4 (64), p. 41–47.

The paper gives an overview of foreign and domestic materials designed for long-term operation under the action of supercritical steam at temperatures of 650–700°C. It has been found that the best candidates for steam turbine blades working at temperatures of 650–700°C are austenitic nickel-base steels and alloys. Among the domestic alloys the most promising is that of XH35BT type, among the foreign ones is austenitic steel NF709.

Key words: promising materials, steam turbine blades, oversupercritical steam parameters.

UDC 669.15

Second phases formed in Fe–Mn–C alloys. Zhilkashinova A. M., Skakov M. K., Popova N. A. – Voprosy materialovedeniya, 2010, N 4 (64), p. 48–54.

Reported in the work are the results of electron microscope and X-ray analysis of carbide phases in Fe–Mn–C alloys (6.2–18.2%Mn; 0.36–1.16%C; 0.3%Si; 0.12%S, remaining Fe). Experimentation has shown that in quenched alloys of the above composition most carbide particles have a $M_{23}C_6$ structure. M_3C carbides are 1.5–2 times less common, ϵ - Fe_3C carbides occur even more rarely (5–7 times). The amount of Fe_3Si silicides is nearly the same as that of ϵ - Fe_3C . With increasing the Mn content of 1–1.2%C alloys, $M_{23}C_6$ and M_3C carbides are more common while Fe_3Si occur more rarely, the amount of $M_{23}C_6$ and M_3C carbides as well as ϵ -carbides is nearly the same.

Key words: Fe–Mn–C alloys, carbide phases, fraction, mechanical properties, electron microscopic analysis, X-ray diffraction analysis.

UDC 539.219.3:669.111.2

Determination of diffusion coefficients for carbide-stabilizing elements at the graphite inclusion boundaries in grey cast. Veselovsky A. A. – Voprosy materialovedeniya, 2010, N 4 (64), p. 55–59.

The paper considers the possibility of applying the Fisher's model for grain boundary diffusion to calculations of diffusion processes proceeding along graphite inclusions in grey cast iron. A manganese diffusion coefficient was numerically determined.

Key words: diffusion along graphite inclusions, Fisher's model, manganese diffusion.

UDC 620.178.7

Changes in the structure of a copper deformed shell in forming a cumulative jet. Barakhtin B. K., Savenkov G. G. – Voprosy materialovedeniya, 2010, N 4 (64), p. 60–65.

The results of metallographic examination of structural changes in a copper shell due to nonuniform compression in forming a cumulative jet have shown that anomalously high copper plasticity is caused by successive actions of several mechanisms contributing to the effect of superplasticity. They found conditions and constructed a diagram of consecutive transitions from structural superplasticity to phase transformation superplasticity which are separated by stages of structural imperfection and fragmentation accumulation.

Key words: copper deformed shell, cumulative jet, nonuniform compression, superplasticity effect, metallographic examination

UDC 669.715–404:537.633

CAE system "Poligon" for simulating the additional heating of molten metal with magnetic-impulse treatment. Glushenkov V. A., Igolkin A. Yu., Chernikov D. G., Tikhomirov M. D. – Voprosy materialovedeniya, 2010, N 4 (64), p. 66–71.

The CAE system "Poligon" allowed the action of an impulse magnetic field on liquid aluminum-silicon alloy to be investigated. Magnetic-impulse treatment together with a force acting on the melt was shown to result in an increase in the liquid metal temperature. It should be taken into consideration when using such a modification method.

Key words: aluminum-silicon alloy, magnetic-impulse treatment, liquid metal temperature, CAE system.

UDC 621.746.32

Technology of controlling the ladle position when pouring metal into molds. Minakov V. F., Arustamyan A. I. – Voprosy materialovedeniya, 2010, N 4(64), p. 72–78.

A method of controlling the ladle position when pouring metal into molds and the relevant system providing higher-quality machinery have been advanced.

Key words: control, ladle position, molten metal, molds, casting quality, machinery, metal temperature, pouring time, mass flow rate, emission spectrum.

UDC 666.762.52–127

Formation of a porous material based on nanodispersed ZrO_2 –15 mol.% CeO_2 powder. Ziganshin I. R., Porozova S. E., Trapeznikov Yu. F. – Voprosy materialovedeniya, 2010, N 4 (64), p. 79–84.

Nanodispersed zirconia powder doped with 15 mol. % cerium dioxide has been synthesized in laboratory conditions, more than 98% particles being less than 61 nm. Permeable material based on the powder shows an open porosity of 50%. The powder and the material sintered were investigated by Raman spectroscopy and X-ray analysis methods. It has been found that both the original powder and the material sintered consist of a well-crystallized tetragonal zirconia phase. The permeable ceramic material pore-size distribution has a bimodal nature.

Key words: zirconia, cerium dioxide, tetragonal phase, Raman spectroscopy, X-ray analysis.

UDC 621.762.222

Estimation of surface energy of tungsten and chrome carbides on the results of their simultaneous milling with iron powder. Boyko V. F., Gostishchev V. V., Zaitsev A. V., Komkov V. G. – Voprosy materialovedeniya, 2010, N 4 (64), p. 85–89.

They substantiated a method of determining a surface tension factor of solids which is alternative to the well-known methods. The method consists in the comparison of results of diffraction analysis of simultaneously milled powders of a prototype (iron) and originals (tungsten and chrome carbides) in a planetary mill PM400. As a mathematical support they use an analogue of the widely known Rittinger's formula applied to milling ground materials. The paper gives an estimation of confidence intervals for surface energy values.

Key words: surface tension factor, Rittinger's formula, diffraction granulometric analysis, tungsten carbide, chrome carbide.

UDC 621.791:621.039.746:621.642

Welding consumables and method of welding silicon-manganese steel structures used in containers for transportation and long-term storage of spent fuel. Skutin V. S., Galyatkin S. N., Shcherbinina N. B., Vorobyeva N. Yu. – Voprosy materialovedeniya, 2010, N 4 (64), p. 90–103.

They developed and brought to a commercial level a process of welding load-bearing elements of metal-concrete containers for transportation and long-term storage of spent fuel. Welding with advanced welding consumables provides high cold resistance of the weld metal and heat-affected zone of welded joints made of 09Г2СА-A steel as-welded and as-heat-treated.

Key words: containers for transportation and long-term storage of spent fuel, silicon-manganese steel, welding process and welding consumables.

UDC 621.791.92:669.35'71'24

Structure and composition of joints made by argon-arc cladding aluminium-nickel bronze with copper-nickel alloys. Vaynerman A. E., Veretennikov M. M., Petrov S. N., Drosdova N. F. – Voprosy materialovedeniya, 2010, N 4 (64), p. 104–110.

The paper deals with metal composition and structure features of joints made when cladding aluminium-nickel bronze with copper-nickel alloy high in nickel, which are due to much aluminium transfer into the clad metal. The study revealed that a first layer of low-nickel (~5%) copper-nickel alloy applied to bronze before its cladding with high-nickel copper-nickel alloys prevents from the formation of cracks in the fusion zone.

Key words: aluminium-nickel bronze, cladding with copper-nickel alloys, fusion zone, composition and structure.

UDC 621.382.032.27:621.387.143:[669.35+669.26]

Examination of the effect of submicron chrome particles on the properties of copper-based alloy electrodes used in low-temperature plasmatrons. Vinogradov S. E., Vasilyeva O. B., Kusnetsov V. E., Kusmin K. A., Safronov A. A., Ovchinnikov R. V., Shekalov V. I., Shiryaev V. N. – *Voprosy materialovedeniya*, 2010, № 4(64), p. 111–117.

The paper reports experimental data and reviews the literature on the effect of superdispersed chrome particles on the set of physicomechanical properties and wear resistance of the copper-based material of low-temperature plasmatron electrodes. It has been found that adding submicron chrome particles to the copper substrate results in a considerable increase of its strength, plasticity, and thermal conductivity as well as a reduction in residual porosity and electrical resistance. The positive effect of submicron particles is due to a higher activation energy in sintering through the growth of surface energy and internal energy of submicron particles they acquired during high-energy ultrasonic fragmentation.

Key words: low-temperature plasmatron electrodes, copper-based alloys, superdispersed chrome particles, physicomechanical characteristics, wear resistance, service life.

UDC 669.15–194:621.039.534.25:539.4.016:621.785–978

The effect of long-term thermal aging on the creep-rupture properties of 18Cr–9Ni austenitic steels. Margolin B. Z., Gulenko A.G., Buchatsky A. [A., Nesterova E. V., Kashtanov A. D. – *Voprosy materialovedeniya*, 2010, N 4(64), p. 118–127.

For thermal aging analysis on mechanical properties and microstructure, 18Cr–9Ni steel are investigated after operation (operation time is $170 \cdot 10^3$ hours and operation temperature is 518–550°C) and the same steel after homogenized annealing ($T = 1050^\circ\text{C}$, $t = 0.5$ hour). The tests for determination of standard mechanical properties and creep-rupture properties have been performed for steels after homogenized annealing and after thermal aging. On the basis of the physical-mechanical model of fracture under creep which was developed earlier the thermal aging effect on the creep-rupture properties is simulated. Comparison of calculative and experimental results on creep rupture properties is carried out. On the basis of microstructure and SEM investigations, and also the obtained results on mechanical tests the thermal aging effect on standard mechanical properties and creep-rupture properties is explained. Method of calculation of damage under creep and interaction of creep and fatigue with regard for thermal aging is proposed.

Key words: thermal aging, creep rupture properties, simulation, damage.

UDC 669.14.018.41:539.422.22

Brittle and ductile fracture resistance of cold-resistant low-carbon pipe and shipbuilding steels with a banded structure. Gorynin V. I., Golub S. A. – *Voprosy materialovedeniya*, 2010, N 4 (64), p. 128–135.

The paper considers a system of failure criteria that allows the estimation of the anisotropy of resistance to brittle and ductile fracture of high-loaded materials with structural-integrity quasidefects oriented differently to the deformation direction over a wide temperature range. Within the criteria system the wall thickness and mechanical properties of the structural steels applied are taken into consideration for shipbuilding structures and main pipelines. It allows the selection of optimal thermomechanical treatment temperature-time parameters for controlling the anisotropy level not only in view of the structural directionality composition and mechanical characteristics but resistance to brittle-ductile fracture for higher- and high-strength structural materials.

Key words: cold-resistant low-carbon steel, banded structure, resistance to brittle-ductile fracture, anisotropy of properties, thermomechanical treatment, system of failure criteria.