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Quantitative Determination of Yttrium in Ceramic Coatings by Laser Method of Spectrum Microanalysis

18420162k Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 27 Feb 86) pp 55-59

[Article by G. M. Grigorenko, V. I. Krivko, V. V. Grabin and A. S. Demyanchuk, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] The laser method of spectrum microanalysis was tested experimentally on heat-resistant ceramic coatings, ZrO_2 coatings with Y_2O_3 stabilizer, for determination of the yttrium content which largely contributes to the corrosion resistance as well as the heat resistance of these coatings. The chemical method of analysis is not expedient here, separation of a coating from the substrate metal or alloy being very difficult and time consuming. The laser method is the preferable spectral method, because it facilitates local microanalysis, all other spectral methods being adequate for macroanalysis only. An apparatus consisting of a ruby laser with a research microscope and a spectrograph can detect 10^{-10} - 10^{-8} g or even smaller amounts of an element, being suitable for analysis of emission spectra covering the 200-1000 nm range of wavelengths. A determination of yttrium in 100-150 μm thick coatings was made in a "Karl Zeiss Jena" LMA-10 laser spectrum microanalyzer with an optical adapter, this instrument being suitable for determination of 63 elements from Li_3 to U_{92} in 10-250 μm wide segments of a coating. The depth and diameter of the crater produced in a coating by the laser beam depend on the duration of the laser pulse and on its form (number of "micropulses" constituting its ripple) as well as on the power density. Measurements were made using a 900 V flash lamp and laser pulses of 300 μs duration with 25 "micropulses" within each and with a power density of 10 MW/cm^2. Four reference specimens of ZrO_2-Y_2O_3 ceramic were prepared with 1.83% Y, 3.18% Y, 4.28% Y, 5.45* Y respectively, according to chemical analysis, for a calibration curve. Laser spectrum microanalysis of 10 coating samples yielded results fitting this curve with an absolute error not larger than 0.04% and a relative error not larger than 1.0%. References 4: 2 Russian, 2 Western (both in Russian translation).

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Determination of Link Limiting Niobium Denitration Reaction During Electron-Beam Remelting

18420162j Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 27 May 86) pp 52-54

[Article by S. V. Akhonin, A. L. Tikhonovskiy, A. A. Tur and A. I. Kravets, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] Electron-beam remelting of niobium, which facilitates removal of H2, O2, N_2 and C impurities during the final stage of producing compact niobium, is analyzed mathematically for the effectiveness of this refining process. Since removal of nitrogen is most difficult, heat and mass transfer in the melt is calculated for a determination of the weakest link in the niobium denitration process. It is assumed that thorough stirring of the melt takes place throughout the crystallizer volume, except within a thin diffusion layer at the interphase boundary, and that only a chemical reaction $2[\Gamma] \rightleftarrows \{\Gamma_2\}$ takes place. The corresponding equations of impurity balance and impurity migration kinetics involving both zones indicate that the steady-state N2 content in the final ingot depends on the value of parameter

$\varepsilon = \frac{\beta}{C_0}\left(\frac{1}{K}+\frac{L}{\beta_v}\right)$, where β, β_v (m/s) are coefficients of impurity mass transfer

in liquid and in vapor respectively, C_0 (mol./m^3) is the impurity concentration in the initial ingot before melting, K (m^4/(mol.·s) is the rate constant of chemical reaction at the interphase boundary, L (mol./m^3) is the equilibrium coefficient of impurity distribution between phases. A low value of this parameter ensures a low N_2 content in the final ingot and thus a high refining efficiency. This conclusion was verified by remelting 32 epxerimental production ingots in a YeMO-250 furnace. Since the rate constant K is in the case of nitrogen almost independent of the excess temperature above the melting point of the metal, parameter ε can be regarded as a constant one which in the case of niobium has the value $6.2 \cdot 10^{-4}$ and thus is much smaller than K and β_V. On this basis, the N_2 content in the final ingot and also the loss of metal by evaporation during melting can then be calculated with the aid of experimental data by curve fitting in successive approximations. References 6: all Russian.

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Electron-Beam Apparatus for Coating Metal Tape

18420162h Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 22 Jul 86) pp 44-47

[Article by G. F. Badilenko, A. V. Demchishin, A. Ye. Kushnirenko, V. V. Stetsenko and V. M. Shinkaruk, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] A special-purpose electron-beam apparatus has been developed, designed, and built at the Electric Welding Institute for continuous coating of 0.25-0.40 mm thick steel tape with at least 6 μm thick nickel layer. This apparatus includes three vacuum chambers, four electron guns inside the central chamber under a residual pressure of 6-10 mPa with auxilliaries, a vacuum system consisting of a forevacuum pump and a booster suction pump as well as two high-vacuum sets, a power supply, and a control system. The central chamber is rectangular in shape, its walls as well as those of the two smaller outer chambers being made of low-carbon steel. The electron guns, which vaporize the coating material and adequately heat the tape, are mounted on a plate made of stainless steel. Each gun is individually powered and regulated, the full set having a 180 kW capacity. An electromagnetic deflection system ensures necessary deflection of the four electron beams in two mutually orthogonal directions. A pyrometer for measurement of and monitoring the surface temperature is provided which consists of a primary total-radiation transducer and a secondary instrument transducer. The drive consisting of a chain mechanism and two pulleys inside each outer chamber for moving the tape across the central chamber has tension and speed control facilitated by a reference-speed setter and a speed-change indicator which feed signals through thyristor electronic circuits. The apparatus, with the tape velocity adjustable over the 0.2-15 m/min range, is capable of depositing a Ni coating up to 50 μm thick on one side of the steel tape. References 3: all Russian.

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Model Study of Thermal Stresses in Gas-Turbine Blades With Protective Coating

18420161d Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 16 Jan 86) pp 67-70

[Article by G. N. Tretyachenko, K. P. Buyskikh, L. V. Kravchuk and G. R. Semenov, Strength Problems Institute, UkSSR Academy of Sciences, Kiev]

[Abstract] A model study of thermal stresses in gas-turbine blades with protective coating was made, such blades being simulated by nine different wedges of the ZhS6U heat-resistant alloy. All wedges were 80 mm high with a 15° opening angle and had their edges rounded to a 0.7 mm radius. Their chords were 27 mm, 43 mm, 57 mm long and the three wedges of each size had been coated by the electron-beam method with Ni-Co-Cr-Al-Y alloy, Ni-Cr-Al-Y alloy and Co-Cr-Al-Y alloy respectively. For comparison, one wedge of each size was not coated. In the experiment these wedges were tested under a heat load simulating the most typical severe transient conditions in service, namely starting and stopping of the engine. Accordingly, they were heated to 1100°C within 60 s and cooled to 350°C within 70 s. The test results based on measurement of surface temperatures by 5-7 chromel-alumel thermocouples and calculation for the center section based on a radially nonuniform two-dimensional discretization grid, assuming negligible heat dissipation inside the wedge, indicate that a proper coating (Co-Cr-Al-Y on 27 mm wide wedge, Ni-Co-Cr-Al-Y on 43 mm wide wedge) can increase the asymmetry of the thermal load cycle with a shift of stresses more into the compressive range while lowering their amplitude so that such a coating will not only protect blades against corrosion and erosion but also raise their mechanical load capacity. References 9: 8 Russian, 1 Western (in Russian translation).

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Dependence of Structure of Stabilized-ZrO_2 Coatings on Condensation Rate

18420162i Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 21 Nov 86) pp 47-51

[Article by A. M. Martirosyan, V. V. Grabin, N. I. Grechanyuk, I. Ya. Dzykovich, A. A. Trofimenko and A. L. Samsonov, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] An experimental study of ZrO2 coatings stabilized with Y_2O_3 for gas turbine blades was made, its purpose being to find the causes of their high thermal shielding capability as well as their proneness to peeling off the heat-resistant steel. The coating material was produced by mixing

powders of pure ZrO_2 and high-purity Y_2O_3 in a 23:2 ratio and then pressing the mixture into cylindrical rods 65 mm in diameter and 40-50 mm long. From these rods, by means of an electron beam under a vacuum of 1.33-2.66 mPa, 60-80 μm thick coatings with an 8% Y_2O_3 stabilizer content were deposited upon evaporation on 1 mm thick and 60x90 mm^2 large plates of CrNi60WTi heat-resistant steel at a temperature of 950 ± 15°C. The frame holding these plates was rotated about its horizontal axis at a speed adjustable over the 0.5-0.6 rpm range so that the rate of ZrO_2 vapor condensation was either 0.56 μm/min or 1.52 μm/min. The condensate was annealed at a temperature of 1050°C for 2 h under a vacuum of $1.33 \cdot 10^{-2}$ Pa. The bond strength was subsequently measured by counting the number of thermal cycles withstood: holding at 1110°C in a furnace for 5 min + cooling in air to 40-30°C within 15-20 min. Microstructural examination with quantitative x-radiographic analysis and microhardness measurements revealed formation of two layers in such a coating. The thin lower layer adjacent to the steel substrate was denser and continuous without growth channels, its thickness depending almost linearly on the condensation rate. The upper layer was porous with growth channels, its porosity depending inversely on the condensation rate. This can be explained by dissociation of ZrO_2 during evaporation with attendant departure from chemical stoichiometry, this process intensifying as the evaporation rate increases, while metallic Zr initiates sintering so that a denser coating is produced by condensation at a higher rate. In the meantime Ni diffuses from the steel into the condensate, remaining pure at the boundary and forming NiO with atmospheric oxygen upon reaching the surface, while the volume fractions of Cr and W in the steel increase with an attendant stress redistribution owing to different coefficients of linear thermal expansion. These processes also intensify as the coating condensation rate increases. Density was measured with an ADB-200 analytical balance and microhardness was measured with a PMT-3 tester under a 50 g load. The distribution of alloying elements at the substrate-condensate boundary was determined in an "MS-46" microanalyzer and phase analysis was done in a DRON-3.0 x-ray diffractometer. Coatings produced by condensation at a rate of 0.56 μm/min withstood more than 20 thermal cycles, those produced by condensation at a rate of 1.52 μm/min broke down after one or two. References 7: 3 Russian, 4 Western (all in Russian translation).

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Cyclic Creep of Steel With Vitreous Enamel Coating

18420161b Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 3 Dec 85) pp 29-32

[Article by V. M. Plastinin, V. M. Mizonov, P. S. Shkolyar and V. L. Sukhotinskiy, Scientific Research Institute of Enameled Chemical Apparatus, Poltava]

[Abstract] A study of low-carbon steel and a low-alloy steel with vitreous enamel coating for chemical apparatus was made, its purpose being to determine their creep during temperature cycling over the 20-300°C range, on the premise that the strength of such a composite material is limited largely by the behavior of the coating. Flat 3 mm thick and 12 mm wide specimens of 08 carbon steel and 08MnTi alloys steel were coated on both sides with UES-300 general-purpose enamel on a prime coat of 3132 industrial varnish, two layers of prime coat and two layers of enamel together 0.7-0.8 mm thick on each side. Fracture of a coating was recorded by a 2-5 μm thick and 4 mm wide Ag film on top of the enamel breaking with the latter and thus opening an electric circuit. The method of acoustic emission was used for tracking the fracture kinetics. Residual stresses were calculated according to A. Ditzel (GDR, 1962), using $135 \cdot 10^{-7}$/°C and $100 \cdot 10^{-7}$/°C as coefficients of linear thermal expansion for steel and enamel respectively. Each thermal cycle consisted of a fast heating at a constant rate, a long flat holding period, and an equally long period of exponential cooling. An evaluation of the thermomechanical characteristics on this basis reveals that cyclic creep retards fracture while reducing the strength margin after each cycle, the principal fracture mechanism being microplastic deformation of the steel substrate as a result of movement of dislocations into retarded clusters in the steel-enamel transition layer with attendant buildup of local overstress zones and subsequent macroelastic instability, but also that the critical breaking stress is 40-50 MN/m^2 lower than under a constant load of short duration. A semiempirical design relation is derived for the critical stress as the sum of a temperature-dependent component and successive stress differentials. References 12: 10 Russian, 1 East German, 1 Western.

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Durability of Compound Cylinder Under Static Internal-Pressure Repeat Load of Long Duration

18420161c Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 26 Mar 85) pp 42-47

[Article by G. P. Zaytsev, G. V. Arkhipov and N. M. Kopyl, Moscow Aviation Technical Institute]

[Abstract] The durability of compound cylinders consisting of a metal shell and a reinforced-polymer one under static internal pressure is evaluated, taking into account the creep of the composite polymer material with attendant buildup of stresses and strains of the metal shell. Elastic and elastoplastic states of stress and strain of the metal shell are calculated by the conventional method with correction for viscoelasticity of the composite polymer material, considering a long period under load followed by load removal for recovery and subsequent repeat loading. The results reveal eventual loss of gas-tightness, especially in the case of an initially imperfect or cracked welding seam. Theoretical calculations only slightly overestimate the life of a balloon having one shell made of acrylic glass with fiber reinforcement and tested according to two loading programs: 30 MPa for 260 h + no load for 48 h + 34 MPa repeat or j = 13 cycles of 29 MPa for 1500 h + no load for 1500 h, such a balloon lasting for 2.05 h under the 34 MPa repeat load and for 660 h under the 14th 29 MPa repeat load respectively. Intermediate recovery is thus found to either extend the life under a subsequent repeat load or raise the subsequent load capacity. References 4: 3 Russian, 1 Western (in Russian translation).

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Induction of Superplastic State in Metal Bicrystal

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 16 Oct 87 p 1

[Article by V. Lagovskiy, special to SOTSIALISTICHESKAYA INDUSTRIYA: "A Mysterious 'Boundary': A Discovery Made"; the first paragraph is a boldface introduction]

[Text] Yesterday, a new discovery was entered into the State Registry of the USSR in the field of physical material science. The authors of the discovery are O. Kaybyshev, doctor of technical sciences, and R. Valiyev, doctor of physical-mathematical sciences, scientists from the Ufa Aviation Institute.

... First, a tiny bump appeared on a smooth metal sheet. Then it began to swell. The bubble continued to grow like a rubber balloon, gradually taking the shape of a ... tea kettle--complete with a spout.

Until quite recently, such an experiment would sound like science fiction. But now it is possible in a laboratory to blow out a component from a metal sheet by compressed air. Certainly, the experiment with the tea kettle was, in a way, an advertisement. It was a witty and graphic way for the Ufa scientists to show how a metal converted to a superplastic state can be molded to any desired shape.

In order to have the power metal, to work miracles with it and make metals with the desired properties, one must understand the secrets of metals. There are many such secrets, but the Ufa scientists have probably discovered one of the most important. They have understood the laws that govern the properties of polycrystalline materials. Metals are polycrystals. Looking through the microscope at a cut section of a metal, one clearly sees densely packed tiny crystal grains. Between the grains one sees boundaries. It is these vanishing thin lines that aroused the explorers' interest. What are the processes that take place here and how do they affect the properties of the material as a whole?

"Metals are never free of defects," said R. Valiyev. "The crystalline lattice may lack atoms, or the atoms can be stringed into chains of dislocations. These defects largely determine the characteristics of a solid. We constructed a simple model--a bicrystal. It is two large grains with a single boundary between them. We decided to see what would happen if the dislocation began to interact with the boundary."

Previously, it was assumed that nothing in particular would happen: that the boundary would simply absorb a chain of atoms. Careful experiments, though, showed the opposite. It was discovered that defects, brought directly onto the boundary, excite it, disrupting the equilibrium and, importantly, changing the mechanical and physical characteristics of the material. This is the gist of the discovery and clue to controlled change of properties.

"If we help the defects to advance to the boundary, we can endow a material with high plasticity," explained R. Valiyev. "Conversely, if we hinder its advance, the metal becomes heat resistant."

The key that they have found can open many more "doors." It will give us the power over corrosion resistance, strength, reliability and magnetic properties --in a word, over the structure of materials.

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Kuznetsk Oxygen Converter Project Delay

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 16 Oct 87, p 5

[Article by V. Bedarev, shop manager, oxygen converter shop, Kuznetsk Integrated Metal Works imeni V.I. Lenin, and V. Barsukov, deputy editor of the factory newsletter METALLURG: "Schedule Without Responsibility: An Urgent Matter"]

[Text] Sibgipromez [Siberian State Institute on Design of Metallurgical Plants] has completed an oxygen converter shop project for Kuznetsk Integrated Metal Works. This laid the foundation for a drastic reconstruction of this plant, the first Soviet metal plant in Siberia.

The current reconstruction is the most important in the history of the enterprise. It will involve the building of an oxygen converter plant with continuous casters and change drastically the rolling operations with an orientation toward higher quality products. A number of social issues will also be resolved.

Our metalworkers have been dreaming of these changes for a long time.

Yet, the first snags and disappointments were soon to follow. The "open passage" promised to the factory by the first deputy minister of ferrous metallurgy, L. Radyukevich, with this reconstruction suddenly became a narrow trail. The participants of the project keep running into more and more red lights. The facts speak for themselves. Initially, the commissioning of the first converter shop was planned for 1990. A sum of 250 million rubles was earmarked for this purpose. However, the plan was changed. For the 12th Five-Year-Plan period Minchermet SSSR [The Ministry of Ferrous Metallurgy of the USSR] assigned to the plant just 160 million rubles. This cut in financing was followed by a reduction of the commissioning sequence. It was divided into two stages, with the second stage moved back to 1992. Is this fragmentation justified?

All that, however, would still be, as they say, a small loss. Of the 160 million budgeted for the current five-year-plan period just 2.5 million was planned for the first year; for the current year just 10 million! Who wouldn't agree that with this financing even the "pared down" tasks become unrealistic?

The groundwork is now under way at full speed on the construction site. The Novosibirsk management of Soyuztyazhekskavatsiya [All-Union Industrial Association for Heavy Excavation Work] is efficiently digging the foundation pits for the basements of the future shop. The construction of the building and the installation of industrial equipment are not far ahead. Since much of that equipment will be unique, care should be given even today to its manufacture and supplies. That is how it is spelled out in the plan-schedule approved by the deputy minister of heavy power and transport machine building of the USSR, A. Lazarev. In practice, however, compliance is poor. Machine builders, ignoring the decision of industry headquarters, are violating the schedule. For example, the production association Zhdanovtyazhmash [Zhdanov Heavy Machine Building Assocation]--the manufacturer of the converters--is half a year behind schedule in submitting the detailed design of equipment. This threatens the installation of the converters planned for 1989.

The schedule (incidentally, approved a year ago) calls for preparing technical documents and submitting initial data on mechanized equipment for maintenance of the converter steel outlet and slag cutter and the unit for mechanized replacement of the lining of the converter bottom. The manufacturer is again Zhdanovtyazhmash. Its general director, I. Nagayevskiy, cannot complain that metallurgists have paid little attention to monitoring what was happening to their orders. It is upon our insistent requests that the deputy minister of heavy power and transport machine building, V. Aleksandrov, has written the director several times reminding him of the schedule. Moreover, he obligated the director to have the equipment come in on time. And what happened? Instead of executing the order of the industrial manager, Nagayevskiy suddenly "dug out" a joint order of the Mintyazhmash [Ministry of Heavy and Transport Machine Building] and Minchermet dated ... 1974, according to which equipment for mechanization of repair work in steel smelters should be designed and manufactured by enterprises of ferrous metallurgy. Nagayevskiy then went on to say that his plant was too busy because it was making similar units for the newly constructed projects in Magnitogorsk and Cherepovets Integrated Works and for the electric metallurgical integrated works. One can ask, where is the logic in this response?

The situation is similar with the delivery of crane equipment. The shop will have as many as 60 units of this equipment. While with smaller cranes and overhead track hoists everything is on schedule, this is not true of the main industrial cranes that will be needed for construction--for installing the equipment. These are casting, repair and specialized cranes (for transportation and turning of scoops). Their installation is scheduled for the third quarter of 1988. Sibtyazhmash [Siberian Heavy Machine Building Factory], however, after accepting the order, promised to deliver the equipment a year later than scheduled. How can one hope for a favorable outcome?

Some things are ironic. For example, the metallurgists have ordered Lenpodyemtransmash [Leningrad Factory of Hoisting and Transportation Machines] to make hoists with tongs for the loading of hot cast billets. Half a year later, after the initial specifications were fully agreed to, the chief engineer of that enterprise, V. Alekseyev, suddenly sent a letter to the integrated works, informing us that "because of the nonexistence of reliable designs of tong grips, it does not seem possible to design and manufacture the hoists." Is this so? After all, similar hoists are working successfully at Nizhniy Tagil, Kommunarsk and Zhdanovsk Integral Metal Works and at other enterprises. And what did the manufacturers think when they accepted the order?

Finally, another obstacle. According to the schedule, the production association Nevskiy Zavod imeni V.I. Lenin is to deliver to our works in the first quarter of 1989 two compressor units as part of the oxygen converter shop equipment. The enterprise started to prepare the technical assignment, developed it ... and reported that the complete set of documents would not be ready before the first quarter of 1989. The manufacture of the equipment will accordingly be moved back to the next year. But it is for 1990 that the launch of the first stage of the shop is scheduled. How can this be accomplished if we need compressor units for smoke removal, without which one cannot even speak about launching the converter.

This is the kind of "open passage" that has been created for the reconstruction of our plant. The management of Minchermet, Mintyazhmash and other ministries and departments concerned ought to take expedited measures to remove these difficulties. Otherwise, the renovation of the enterprise will run into a dead end.

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Changing in Heat-Resistance Characteristics of 07Cr15Ni35Mo3 Alloy Upon Irradiation and Preliminary Plastic Deformation

18420161a Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 9 Sep 85) pp 18-20

[Article by V. N. Kiselevskiy and V. V. Kovalev, Strength Problems Institute, UkSSR Academy of Sciences, Kiev]

[Abstract] An experimental study of austenitized heat-resistant 07Cr15Ni35Mo3 alloy was made for a determination of changes in its creep resistance and long-term strength upon 20% cold predeformation inside and outside a reactor with subsequent annealing at a temperature of 1073 K for 1 h in each case. Flat specimens of this alloy in a linear state of stress at a temperature of 923 K were bombarded by either fast neutrons with an intensity of $4.5 \cdot 10^{17}$ n/($m^2 \cdot s$) or thermal neutrons with an intensity of $0.2 \cdot 10^{17}$ n/($m^2 \cdot s$). Cold predeformation was effected by holding the specimens under a load of 100-120 MPa for 1000 h inside the reactor or under a load of 50-60 MPa for 1000 h outside it. An evaluation of the data, based on the approximate equation of fracture kinetics $t = B\sigma^{-n}$ and equation of creep $\dot{p} = A\sigma^{m}$ (t- time till fracture, σ- stress, $\dot{p}$- creep rate) with appropriately fitted values of constants, B,n and A,m respectively, reveals that neutron bombardment changes the anisotropy pattern in the predeformed alloy and consequently causes a greater change in its strength characteristics than does predeformation under normal conditions. References 4: 3 Russian, 1 Western (in Russian translation).

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Quality of Billets of 1Cr16Ni4Nb Steel Produced by Centrifugal Electroslag Casting

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[Article by A. V. Chernets, N. V. Zhuk, B. I. Medovar, G. S. Marinskiy, V. V. Rovnyagin, V. L. Shevtsov, V. P. Lukyanets and V. V. Savakova, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] Centrifugal electroslag casting, a process which had been developed at the Electric Welding Institute, was evaluated on blank parts of 1Cr16Ni4Nb stainless steel. Blanks cast in the form of cylinders with flanges in a USh-139 machine (with a consumable electrode and rotating about its vertical axis) were analyzed for chemical composition, tested for mechanical strength and ductility characteristics, and examined for microstructure as well as nonmetallic inclusions. The Cr,Ni,Nb contents as well as the C,Si,Mn,S,P contents were found to be within specifications. Yield strength and ultimate strength, percentage elongation and reduction, and impact strength after standard heat treatment were found to be satisfactory. Metallographic qualitative analysis under a "Neophot" microscope in polarized, bright, and dim lights with x800 or x 2000 magnification as well as quantitative analysis in a "Quantimet-360" apparatus identified the globular nonmetallic inclusions 0.5-3 μm in diameter as four complex oxides ($FeO.SiO_2$, $FeO.Al_2O_3.SiO_2$, $FeO.MnO.Al_2O_3$, $FeO.MnO.Al_2O_3.SiO_2$) and sulfides. Structural examination by x-ray diffractometery revealed 13% residual austenite in castings, 2% less than in castings produced by the conventional electroslag process. References 2: both Russian.

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Production of Shaft-With-Pinion Machine Parts by Electroslag Chill Casting at Moscow Experimental Machine Manufacturing Plant

18420162c Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 28 May 86) pp 22-24

[Article by Yu. V. Orlovskiy, V. V. Lupan, L. N. Babich, V. L. Leykin, M. S. Fradkin, L. B. Arabey and S. S. Ivashkov, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev; Moscow Experimental Machine Building Plant, Ministry of Construction of Petroleum and Gas Industry Enterprises]

[Abstract] An electroslag chill casting technology for producing the shaft-with-pinion for ETR-254 excavators from $20CrNi3N_2$ steel has been developed,

this part being the one of the most critical ones and weighing 9.7 kg. The raw casting weighs 16 kg and is to replace a forging, the latter weighing 39.8 kg and requiring much more machining to final dimensions. The equipment is very simple, consisting of a UFEL-100 electroslag machine energized through a TDFZh-2002 welding transformer. Molten steel is poured into cast-iron molds without forced cooling. The castings have a smooth surface requiring no rough machining, only fine machining. The castings are heat treated by quenching from 820°C in oil + tempering at 500°C + slow cooling in water. The results of mechanical tests for yield and ultimate tensile strength, percentage elongation and reduction, and impact strength indicate that such castings exceed specifications. With a 2.5 times better material utilization and a 5-6 times lower machining cost, production of this part from castings instead from forgings should save 235 rubles/ton. Electroslag chill casting of this part should save even more, 503 rubles/ton, when it replaces rolling of open-hearth ingots. References 1: Russian.

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Use of Hollow Electroslag Castings for Manufacture of Heavy Machinery

18420162d Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 22 Apr 86) pp 24-27

[Article by B. B. Fedorovskiy, G. A. Timashov, Yu. G. Yemelyanenko, A. I. Borovko, V. I. Gaponov, S. Yu. Andriyenko, V. I. Zayats, A. S. Volkov, V. Z. Kamalov and I. A. Lantsman, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] Hollow forgings for heavy machinery components are being extensively replaced with hollow electroslag castings, which appreciably reduces the material and labor cost of producing finished parts. For a comparative evaluation, an experimental lot of 1600 mm long tubular castings of $38Cr2Ni2MoN_2$ steel, with a 348 mm inside diameter and a 50 mm wall thickness, was heat treated by standard quenching + tempering. Subsequent structural and chemical analysis, mechanical tests, and metallographic examination revealed a high degree of homogeneity and a uniform density over the entire length. The Cr,Ni,Mo contents and the C,Si,Mn,P,S contents were found to be within specifications for forgings. The structure after heat treatment was found to be predominantly pearlitic with fine-disperse nonmetallic inclusions. The mechanical characteristics (yield and ultimate tensile strength, percentage elongation and reduction, Brinell hardness, impact strength) were found to exceed specifications for forgings. The process has been adopted for production of collars to be hot-shrunk on rollers in cold-rolling mills. The casting technology had been developed using a 6EShP-20SV electroslag furnace at the Novo-Kramatorsk Machine Building Plant (NKMZ) with a short but wide crystallizer and a bifilar set of six electrodes. References 6: all Russian.

2415/9835

UDC 669.187.56:62-412.004.12.001.5

Quality of Sleeve Billets of EI961 Heat-Resistant Steel Produced by Centrifugal Electroslag Casting

18420162e Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 29 May 86) pp 28-32

[Article by B. I. Medovar, A. P. Ignatov, V. L. Shevtsov, V. V. Rovnyagin and V. A. Drapey, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] The centrifugal electroslag casting technology was evaluated on sleeves of EI961 (W-Mo-V) heat-resistant steel,220 mm long with a 300 mm inside diameter and either a 12 mm thin or 34 mm thick wall. The castings were heat treated by quenching from 1020°C in oil + tempering at 570°C + slow cooling in air, without or with prior diffusional homogenizing at 1200°C for 10 h. The castings were then analyzed for chemical composition, tested in flexure for mechanical characteristics at 20° and at 550°C, and after rolling cut into specimens for metallographic microstructural examination. The results indicate a chemical composition exceeding specifications, with higher W,Mo,V contents and lower S,P contents. The mechanical characteristics (yield and ultimate tensile strength, percentage elongation and reduction, impact strength) at both temperature were found to be satisfactory, plasticity within specification and strength exceeding specifications for rolled product. Diffusional homogenizing was found to produce a fine acicular martensite with uniformly distributed carbides. Such castings are, accordingly, suitable for replacement of much less economical forgings, especially since their surface finish is much better. References 5: all Russian.

2415/9835

UDC 669.187.58:669.14.018.001.4

Feasibility of Using Drills Made of High-Speed-Tool Economy-Alloy Steel Produced by Plasma-Arc Remelting

184201621 Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 28 Apr 86) pp 67-72

[Article by G. M. Grigorenko, V. I. Zhilis, G. P. Negoda, P. K. Banatov, Yu. M. Pomarin, A. I. Trush, T. V. Postizhenko, O. V. Zuyev, R. I. Shcheglova and T.II. Grishchenko, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] An alloy steel with low tungsten content was sought, experimentally, for high-speed drills. Such a steel, in which carbide grains must be fine (5-10 μm) and uniformly distributed, was found to be producible by

plasma-arc remelting of open-hearth R-2Mo5 steel with subsequent heat treatment by first heating to 830°C in salt bath, then to 1050°C, and finally to 1140-1170°C before quenching. The results of microstructural examination after heat treatment as well as hardness and wear measurements during drill operation at a speed of 500 rpm indicate that drills made of this steel will have a life comparable with that of drills made of standard open-hearth R-6AMo5 steel and longer than that of drills made of standard open-hearth R-2Mo5 or plasma-arc remelted R-2AMo5 steel. References 6: all Russian.

2415/9835

UDC 621.745.4:669.14

Use of Directly Reduced Iron for Smelting of 110Mn13VTi Cast Steel

18420171a Moscow LITEYNOYE PROIZVODSTVO in Russian No 5, May 87 p 4

[Article by S. G. Bratnikov, doctor of technical sciences, S. V. Zhitnov, engineer, V. V. Zheltyakov, engineer, and Ye. S. Studenok, engineer]

[Abstract] A study was made concerning the use of directly reduced iron in the form of metallized nodules for smelting 110Mn13VTi cast steel and in this way reducing the phosphorus content to two-thirds that in conventionally produced steel. The dependence of the mechanical properties of this steel, including its impact strength at temperatures from 20°C to -60°C, and of its impurity content, consisting of other metals (Cr, Ni, Cu, Pb) as well as nonmetallic inclusions (SiO_2, Al_2O_3, FeO, MgO + CaO, TiO_2), on the fraction of metallized iron nodules in the charge was measured after smelting in an electric-arc furnace with basic lining and subsequent heat treatment by quenching from 1100°C in water. The results indicate that, as the fraction of metallized iron nodules in the charge is increased, this high-Mn steel will have a higher impact strength especially at low temperatures and a much lower impurity content. Increasing that fraction from 50% to 75% was found to result in a tremendous improvement. Such a steel is now used in the production of armor for KKD 1500/180 crushers at the Starooskolskiy Mining Equipment Repair Plant. References 2: both Russian.

2415/9835

UDC 621.74:669.14

Dependence of Oxidation Level and Quality of Carbon Steel on Technological Parameters

18420171b Moscow LITEYNOYE PROIZVODSTVO in Russian No 5, May 87 pp 6-7

[Article by V. G. Gorelov, candidate of technical sciences, N. V. Karagodin, engineer, and Yu. I. Rubenchik, doctor of technical sciences]

[Abstract] Smelting of acid low-carbon (up to 0.2% C) and medium-carbon (0.2-0.5% C) steels in an electric-arc furnace was studied by the e.m.f. method with a concentration cell and a solid electrode, this electrode having a constant oxidation potential and the molten steel constituting the other electrode. The solid electrolyte in this cell was ZrO_2 stabilized by Y_2O_3 and the reference electrode was made of a Mo-MoO_2 powder mixture. The e.m.f. readings of an EPP-15AM high-resistance potentiometer and the temperature readings of a W/Re thermocouple in parallel with an EPP-09 potentiometer were used to calculate the oxygen activity $\log \alpha_0 = 2.68 - (10.08E + 5661)/(T + 273)$. Metal was sampled for chemical analysis and viscosity measurement: 1) after melting of the charge, 2) after addition of iron ore, 3) after addition of ferroalloys FeMn75 and FeSi45 as oxidizers, 4) 5-7 min before pouring into ladles. Its oxidation level was found to be determined principally by the carbon content and to rise with a decrease of the latter, but at a carbon content below 0.2% to also depend on the amounts of added iron ore, slag forming elements, and ferroalloys.

2415/9835

UDC 621.74.002.6:669.018.58

Producing Single-Crystal Castings of Grade-AA Al-Ni-35Co-5Ti Alloy

18420171c Moscow LITEYNOYE PROIZVODSTVO in Russian No 5, May 87 pp 7-8

[Article by M. V. Pikunov, doctor of technical sciences, Ye. V. Sidorov, engineer, and I. V. Belyayev, candidate of technical sciences]

[Abstract] Casting of Al-Ni-Cu-Co-Ti magnetic alloys into single crystals was studied, taking into consideration possibility that Ti oxides, Ti nitrides, Ti carbides, and Ti carbonitrides can become seeds of a polycrystalline structure and the unfavorable role of carbon present in concentrations much higher than those of oxygen and nitrogen. Addition of sulfur, which narrows the crystallization temperature range, has been found to improve the quality of single crystals, but only when initially completely dissolved in the molten alloy. In the Al-Ni-Cu-35Co-5Ti alloy this sulfur forms Ti sulfide and with carbon also Ti carbosulfide after the beginning of crystallization and thus below the 1345 ± 5°C liquidus temperature. However, their complete dissolution requires a higher temperature.

2415/9835

UDC 669.187.56:621.35'71.054.11

Induction Melting With Flux and Electroslag Remelting of Hypereutectoid Aluminum Bronzes

18420162g Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 27 Jun 86) pp 41-43, 59

[Article by V. K. Larin, Kiev Polytechnic Institute, and N. N. Kalinyuk, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] Induction melting with flux and electroslag remelting as means of refining hypereutectoid aluminum bronzes containing Mn or Ni and having special properties, particularly shape memory and a high damping coefficient, was evaluated for effectiveness in minimizing gaseous (O_2, H_2) and nonmetallic inclusions so as to ensure excellent characteristics of the material. A bronze containing 83.75% Cu + 11.85% Al + 5.6% Mn was tested for strain attainable under constant stress during cooling through the temperature of forward martensite transformation, maximum strain removable during shape recovery, and for stress regenerated during reverse martensite transformation under a constraint which almost completely prevents shape recovery. The best results were obtained with an 85% Na_3AlF_6 + 15% CaF2 flux (melting point near 1270 K) and by electroslag remelting with a consumable electrode made of the induction-melted bronze, the total loss of Al and Mn then not exceeding 0.15%. Ingots produced by this method have smooth surfaces and no blowholes. References 7: all Russian.

2415/9835

New Method of Grafting Crystals

18420150b Moscow TEKHNIKA I NAUKA in Russian No 5, May 87 pp 16-17

[Article by N. Krivenko, candidate of technical sciences, under the rubric "In Scientific Laboratories": "Composites from Crystals"; first paragraph is "Tekhnika i nauka" introduction]

[Text] Quantum electronics, piezotechnology, microelectronics, the chemical and even the jewelry industry — this is only a partial list of branches in which a new method of growing crystals and a progressive technology unparalleled in world practice may be used.

What do a tape recorder and solar battery, sonar and a polarizing microscope have in common? Despite their different purposes, these devices have a common feature -- crystals are used in each.

Semiconductors, integrated circuits, photoresistors, piezoelectric devices, optical instruments... The applications of crystals in modern technology are unlimited.

Once we tried to use and used only natural mineral crystals -- diamond, quartz, ruby, but now crystals grown artificially are the most common. The overwhelming percentage of these are semiconductors -- of germanium, silicon, gallium arsenide, gallium phosphide, and others. These are the ones used in modern devices and instruments.

The needs of instrument building and electronics have posed several problems related to synthesizing new materials and giving them the required structure and geometric configuration. In most cases as yet we can grow small crystals, preserving preplanned properties. Specific products often require monocrystals which are not only large, but of an assigned shape, e.g. "sleeve," or "tee" (pipe element) or even more complicated. How can such a monocrystal be grown?

The answer came from scientists at the Laboratory of Crystal Mechanical Properties of the Crystallography Institute (IKAN). Their research was based on the well known works of N. F. Kazaknov. For many years he was our country's leading developer and active promoter of the introduction of diffusion welding into the national economy (remember, its essence is in joining materials at an elevated temperature on the atomic level). It turned out to be irreplaceable when one had to reliably "fuse" iron and steel, ceramic and copper, titanium and aluminum and obtain many other combinations of materials regardless of differences in materials (cf. "TN," No. 3, 1982, No. 6, 1983).

An approach similar in nature -- joining homogeneous crystals -- was studied by a IKAN member V. G. Govorkov and later laboratory head V. R. Regel and Ye. A. Stepanstov. The task turned out to be more complex than joining different metals and alloys. In this case one had to obtain not only a strong and reliable bond, but also to preserve the electrophysical, optical, and other properties in the structure of the transition layer.

As a result of their studies, the scientists found the crystal heating conditions and compressive forces at which the boundaries between them disappeared entirely. They managed to produce composites from two, and then even several, crystals — bi- and heterocrystals which uniform mechanical, optical, dielectric and semiconductor properties throughout their entire volume, including grafting zones.

A method of solid-phase grafting has already been worked out for a wide range of crystals: semiconductors (silicon, germanium, boron, gallium arsenide), for quantum electronics (ruby, sapphire, garnets, magnesium oxide), piezoelectric (quartz, zinc oxide), super-ion (zirconium oxide, hafnium oxide).

The electrical conductivity of semiconductor crystal depends on its structure and impurity composition. For example, in a germanium crystal, even one atom of foreign matter per 10 billion atoms of the base crystal considerably affects electrical conductivity. The concentration and type of impurities may alter not only the magnitude, but even the sign of electrical conductivity. This means that, for the same crystal, introducing impurities according to a preset program can create areas of different conductivities -- electron and hole. Correspondingly, electron transition zones develop between them.

Electronic circuits on crystal film are usually grown in crystallizers. However, they are so thin and flimsy that they do not withstand mechanical loads. Here is where TFS [solid-phase grafting] comes to the rescue. It made it possible to produce, for example, a silicon bicrystal with electron-hole conductivity by grafting a crystal with hole conductivity with a crystal with electron conductivity. The transition takes place in the mass of the bicrystal, which can withstand both high pressures and impacts.

Modern microelectronics requires increasing sensitivity and accuracy in crystal-based electronic circuits. This, as we have already said, greatly depends on the purity of the crystal -- the substrate -- and on the extent to which the crystal can be protected from penetration by foreign atoms when it is manufactured. Here producers ran into difficulties. When a complex circuit is grown on a silicon crystal, the production process calls for heat treating the substrate. Until now it was placed in a container made of a special quartz glass and heated to do this. However, absolute purity was unattainable even in such a reliable container. When heated, quartz glass inevitably gave off a certain number of oxygen atoms which contaminated the silicon crystal, often degrading its electrical properties.

To completely eliminate contamination by "foreign" atoms, silicon instruments have to be heat treated in silicon containers. It was possible to create this container by solid-phase grafting of artificially grown short silicon tubes with a silicon bottom disk.

Solid-phase grafting methods are also of interest for chemical machine building. For production processes which take place in aggressive media and at high temperatures, structural members of equipment have to be made of thermally and chemically resistant materials. Simplest of all to use is glass, but it does not always withstand given conditions -- it fails. Using precious metals such as platinum is too costly. It has turned out that synthetic sapphire may be the answer. Reliable and rather inexpensive piping, tees, and other equipment components can be produced from it by solid-phase grafting.

The possibilities of solid-phase grafting are undoubtedly of interest to artists in stone. If, for example, one joins a magnesium oxide crystal tinted green (thanks to addition of cobalt) with a zirconium oxide crystal tinted raspberry by the addition of erbium and then cuts it, one gets a unique play of colors. A multitude of similar combinations is possible.

In a word, the new technology for producing crystal composite has tremendous practical value and will help solve many problems in the national economy.

12809

UDC 537.226.3

Effect of Uniaxial Compression on Physical and Mechanical Properties of Ferroelectric Ceramic Material

18420161e Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 10 Apr 85) pp 74-77

[Article by S. P. Kovalev, G. G. Pisarenko and V. K. Khaustov, Strength Problems Institute, UkSSR Academy of Sciences]

[Abstract] An experimental study of thoroughly aged TsTBS-3 ferroelectric piezoceramic material was made for the purpose of determining the effect of an electrostatic field and then uniaxial compression on its complex dielectric permittivity and the relaxation of the latter. Bar specimens 100 mm long and 3 x 10 mm^2 in cross-section had electrodes covering two opposite faces. A strong constant electric field was applied for 1 h, whereupon before its removal and over a period of 10^5 min after its removal the complex dielectric permittivity $\varepsilon_{33} = \varepsilon'(1 - j \tan\delta)$ was measured in a weak 1 kHz alternating electric field of not more than 1 V/mm intensity. This test was performed five times with a constant electric field of successively 1, 2, 3, 4, 5 kV/cm intensity. Statis uniaxial compression was then applied hydraulically for 1 h and slowly removed within 30 s, for measurement of ε_{33} under full load and over a period of 10^5 min after its removal. This test was performed four times with compression in the direction of residual electric polarization and the pressure successively 3, 12, 19, 25 MN/m^2 as well as four times with compression perpendicular to the direction of residual electric polarization and the pressure successively 10, 20, 40, 60 MN/m^2. The results indicate a nonlinear relaxation process with the real part of ε_{33} (capacitance) relaxing faster than the imaginary part of ε_{33} (loss tangent). The evidently appreciable effect of uniaxial compression when parallel to the direction of residual electric polarization but not when perpendicular to itsis explained by a reorientation of domains with attendant stress relief. References 13: 11 Russian, 2 Western (1 in Russian translation).

2415/9835

UDC 666.76.01+620.174+621.48

Strength and Cracking Resistance of Ceramics, Report 3: SiC Ceramics

18420161f Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 22 Oct 85) pp 77-80

[Article by G. A. Gogotsi, G. G. Gnesin, Ya. L. Grushevskiy and V. P. Zavada, Strength Problems Institute, UkSSR Academy of Sciences, Kiev]

[Abstract] An experimental study of a SiC ceramic material was made for a determination of its strength depending on the temperature, on the size of specimen, and on the mode of loading. The material consisted of three grain size fractions (28, 40, 100 μm) with an admixture of 10% free Si. The average flexural strength in 3-point tests and in 4-point tests was found to remain the same over the 20-1200°C temperature range and to drop to approximately one fourth at 1400°C. The critical magnitude of the stress concentration coefficient, determined by the method of two-way torsion, was found to increase from 4.5 $MN/m^{3/2}$ at 20°C to 6.1 $MN/m^{3/2}$ at 1200°C. The strength was also found to decrease with increasing volume of specimen. An analysis of the stress-strain curves with best fitting of experimental data, including the volume factor based on three sizes of specimen (1.75 x 2.5 x 30 mm^3, 3.5 x 5 x 50 mm^3, 7 x 10 x 90 mm^3), indicates satisfactory characteristics of this material for industrial applications. References 9: 6 Russian, 3 Western.

2415/9835

UDC 620.172.251.224

Strength and Failure Rate of Composite Materials With Carbon in Ceramic Matrix

18420161g Kiev PROBLEMY PROCHNOSTI in Russian No 5, May 87 (manuscript received 5 Aug 85) pp 80-84

[Article by E. A. Eskin, G. P. Khristov, A. S. Petrov, V. K. Fedchuk and A. V. Izotov, Strength Problems Institute, UkSSR Academy of Sciences, Kiev]

[Abstract] A study of two composite materials with carbon filler in a ceramic matrix was made for the purpose of determining the effect of a hot oxidizing ambient medium on their load capacity, ultimate strength, and failure rate. Both materials were produced by the same technology, but the reinforcing carbon fabric in one of them had a heat resistant coating and the other did not. They were heated convectively in a plasmatron using atmospheric air as active gas, ionization of the latter in an electric arc producing the necessary amount of atomic oxygen and heating to 1773 K being sufficient for intense oxidation of the ceramic matrix (its oxidation beginning at 1300 K). On account of carbon being very brittle, testing for tensile strength was done indirectly by testing for flexural strength (assumed to be approximately

the same). Specimens 10 mm thick and with uniform width were thus tested in the 4-point configuration. The thickness of defective layers was measured as a function of the heating time. An analysis of the experimental data indicates that the material with uncoated carbon fabric is more resistant to cracking at higher temperature and that defects in it become cured upon cooling to room temperature when oriented along fibers only, but not when randomly oriented, with formation of a frictional bond between fibers and matrix. A theoretical analysis based on equations of fracture mechanics for composite materials, with appropriately fitted coefficients, confirms the results. References 11: all Russian.

2415/9835

UDC 621.315.592

Implantation of Molecular Ions in Diamonds

18420173a Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87 (manuscript received 29 Apr 86) pp 3-5

[Article by B. S. Zhakupbekov and Sh. Sh. Sarsembinov, Kazakh State University, V. S. Vavilov and A. A. Gippius, Physico Institute, USSR Academy of Sciences]

[Abstract] Ionic insertion of ammonium molecules in diamond single crystals was performed to clarify some of the specific features of the formation of complex centers resulting from the strong disordering of the crystalline lattice by ion implantation. The specimens used were plates of natural diamond with a nitrogen content of about 10^{23} m^{-3}. Ions were implanted with 10-300 keV energy at doses of 10^{27}-10^{29} m^{-2} on two accelerators. Cathode luminescence spectra of the specimens implanted with molecular $NH^{+}{}_3$ ions showed intensive lines of nitrogen-containing defects at 503 and 575 nm, plus weak specific lines at 409, 467, 538 and 584 nm. Ions of deuterated ammonia $ND^{+}{}_3$ were implanted to distinguish the influence of naturally contained hydrogen. The spatial separation of the implanted atoms may result from the different path lengths of heavier and lighter impurities or the greater standard deviation of the projected path length for deuterium in comparison with nitrogen due to the great scattering of the lighter atoms. A slight increase in temperature over 900°C results in a decrease in the intensity of the band at 545 nm, which agrees with electron spectroscopic data indicating that at 900°C the properties of the surface of the diamond change and hydrogen is desorbed. At 1150°C, only the lines of the nitrogen centers and the band at 538 nm are present. The nitrogen-containing defect at 503 nm apparently stabilizes impurity hydrogen in the lattice, capturing it, while the deuterium center at 545 nm is less thermally stable. Separation of impurity hydrogen from microscopic inclusion is quite probable. References 11: 7 Russian, 4 Western.

6508/9835

UDC 549.211+542.943+541.183.59

Influence of Treatment of Diamond Surface With Hydrogen and Methane on Its Wettability and Oxidation Resistance

18420173b Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87 (manuscript received 4 Apr 86) pp 5-9

[Article by A. N. Pushkin, F. M. Taprayeva, I. I. Kulakova, and A. P. Rudenko, Moscow State University]

[Abstract] A study was made of the influence of the temperature of preliminary treatment of diamond with methane and hydrogen on its wettability with water and a potassium hydroxide melt and on its resistance to the effects of gaseous oxidizing media. The hydrophilic-hydrophobic properties of the surface were estimated based on the contact wetting angle with water at room temperature. The nature of the interaction of hydrogen or methane with diamond was judged from the flow time of a drop of KOH melt at 673 K. Interaction of hydrogen and methane with the surface of the diamond was studied in the 293-1173 K temperature interval. Whereas adsorbed methane only slightly inhibits oxidation by air, water vapor does not oxidize the surface at all. Treatment in hydrogen at 723 K results in the formation of various oxygen-containing groups on the surface. At high temperatures, hydrogen and methane can chemically interact with the oxygen-containing diamond groups. The surface becomes less hydrophilic and wettability changes, indicating two forms of hydrogen or methane bonded with the surface. Up to 573 K primarily an adsorbed layer is formed. At above 873 K, both gases change the initial functional cover of the diamond surface, chemically interacting with it. In the case of physical adsorption, the diamond surface retains the oxygen-containing functional cover. The resistance of diamond to oxidation clearly depends both on the nature of the functional cover on its surface and on the adsorption of other substances, competitive with oxidation. References 12: 10 Russian, 2 Western.

6508/9835

UDC 541.124.16:546.26-162:543.87

Thermal Strength and Oxidation Resistance of Diamond Compacts Obtained Using Hydrocarbons

18420173c Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87 (manuscript received 25 Feb 86) pp 10-13

[Article by O. A. Voronov, Ye. S. Chebotareva and Ye. N. Yakovlev, High Pressure Physics Institute, USSR Academy of Sciences]

[Abstract] A study was made of the thermal stability and oxidation resistance of compacts produced from diamond powder synthesized from hydrocarbons. The

compacts were manufactured at high pressures and temperatures in a toroid apparatus with a hole diameter of 15 mm. The studies were intended to determine the possibility of their use in tools. The compacts were first fracture tested at room temperature under uniaxial compression. The mean ultimate strength was determined as a function of temperature by finding the characteristic specimen failure temperature under a fixed load. It was found that polycrystals produced without metals or alloys present may be more suitable than polycrystals containing metal inclusions for use in tools, the manufacture or utilization of which is accompanied by heating to 1000-1200°C without access to oxygen. Polycrystals can be used in such cases to replace natural single crystals measuring over 500 μm. Single crystals should be used when tools operate in air at temperatures over 600°C. References 6: all Russian.

6508/9835

UDC 541.183:666.233:539.89

Influence of Capillary Properties and Carbide-Forming Capacity of Metal Melts on Degree of Recrystallization of Graphite to Diamond

18420173d Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87 (manuscript received 22 May 86) pp 16-19

[Article by V. M. Perevertaylo, O. B. Loginova, A. A. Shulzhenko, V. A. Shishkin and Yu. V. Naydich, Institute of Materials Science Problems, Ukrainian Academy of Sciences; Superhard Materials Institute, Ukrainian Academy of Sciences]

[Abstract] A study was made to establish the quantitative relationship between the degree of conversion of graphite to diamond and the intensity of carbide formation in a metal melt-carbon system. The wettability of the solid body by the metal melt, resulting from the nature and intensity of the interaction of the contacting phases depends primarily on the chemical affinity of the components of the melt and the substance of the solid phase. The experiments were performed on melts of germanium containing nickel, manganese, chromium, vanadium and titanium. Germanium, inactive with respect to carbon, acted as a solvent for the refractory transition metals. The wettability of graphite and diamond by the metal melts was determined in a vacuum of $1 \cdot 10^{-3}$ Pa at 1200°C. With increasing intensity of carbide formation in the system, the degree of transformation of graphite to diamond decreased sharply. In the presence of alloys of germanium with titanium and vanadium, the degree of conversion was practically zero, apparently due to the intensive carbide formation in the system and resulting in a sharp decrease in the content of unbonded carbon. References 7: 6 Russian, 1 Western (in Russian translation).

6508/9835

UDC 621.315.592

Study of High Temperature Space Charge of Diamond Ceramic

18420173e Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87
(manuscript received 15 Apr 86) pp 19-25

[Article by A. V. Bogdanov, Kherson Industrial Institute, I. M. Vikulin, Odessa State University and A. S. Vishnevskiy, Superhard Materials Institute, Ukrainian Academy of Sciences]

[Abstract] When electric current passes through a diamond ceramic at high temperatures, a space charge of nonequilibrium carriers is formed which is capable of lasting a long time. This article describes studies of this space charge. The measurement installation allowed the temperature of the specimen to be varied from 300 to 900 K at 3 K/s. Three types of measurement were conducted. Specimens were heated to 800 K and charge voltages of 100-800 V were applied; the specimens were then cooled to room temperature at 3 K/s to fill trap levels with nonequilibrium charge carriers. Specimens were heated to 400-800 K, a voltage of 1000 V was then applied for three minutes and the specimens were then cooled to room temperature and uniformly heated and voltage measured as a function of temperature. Specimens were heated to 600 K, voltages of 100-800 V were then applied and the specimens were then cooled and voltage-temperature curves measured. The variation in residual polarity as a function of charge polarity indicated heterogeneous distribution of the space charge between the electrodes. High temperature and electric field strength was required for the charge carriers to overcome the potential barrier between grains. Charging of a specimen produces a concentration gradient of holes trapped at the acceptor level. Heating liberates non-equilibrium holes and causes a free hole concentration gradient. The maximum discharge voltage is observed at 700-750 K. The calculations performed permitted a qualitative explanation of the experimental results and determination of a number of parameters of the diamond. References 6: all Russian.

6508/9835

UDC 620.22:669.018.25

Mass Transfer of Metal Melts in Cylindrical Composite Products

18420173f Kiev SVERKHTVERDYYE MATERIALY in Russian No 3, May-Jun 87
(manuscript received 20 Jun 86) pp 25-29

[Article by A. F. Lisovskiy and N. V. Tkachenko, Kiev, V. I. Pavlov, Moscow, and T. E. Gracheva and Ye. S. Cherepenina, Kiev]

[Abstract] A study is made of certain peculiarities in the mass transfer of metal melts in cylindrical bodies 20 mm in diameter and 60 mm in length

manufactured from sintered hard alloys VK6 (Co-6, WC-94 mass %) and VK30 (Co-30, WC-70 mass %). The mass transfer of metal melts through a flat plate measuring 60 x 50 x 20 mm manufactured from VK6 alloy was studied for comparison. The specific surface of the tungsten carbide particles used in the experiments was $2.6 \cdot 10^6$ m^2/m^3. The interaction of the specimens with liquid copper and with a cobalt melt containing 65% Co, 32.86% W and 2.14 mass % C was studied, as well as a melt of nickel containing 60% Ni, 37.55% W and 2.45 mass % C. The interaction of the cylinders and plates with the metal melts was studied for both equilibrium and nonequilibrium chemical interactions. More intensive accumulation of the liquid phase was found in the cylindrical specimens in comparison with the process of migration of the fluid through the flat surface. Absorption of chemically nonequilibrium metal melts permits the creation in cylindrical products of coaxial zones with varying binder composition and content. References 4: all Russian.

6508/9835

UDC 666.3/.7:666.368

Effect of Added Refractory Oxides on Stability of Al_2TiO_5

18420164b Moscow OGNEUPORY in Russian No 4, Apr 87 pp 29-31

[Article by V. D. Tkachenko, Ye. S. Lugovskaya, Ye. P. Garmash and B. K. Lupin, Institute of Materials Science Problems, UkSSR Academy of Sciences]

[Abstract] An experimental study of the low-expansion compound Al_2TiO_5, the only one congruently melting at 1860°C, was made for the purpose of determining the effect of admixture of refractory oxides such as MgO, SiO_2, Cr_2O_3, NiO, SnO_2 and La_2O_3 or excess Al_2O_3 and TiO_2 on the stability of this ceramic material at temperatures below 1200°C. Specimens were synthesized from compacts of extra-pure TiO_2 and analytically pure Al_2O_3, annealed at 1450°C, by fusion in a reverberatory furnace. Turning such a radiative heat source on and off ensured high heating and cooling rates, respectively, as well as a high degree of homogeneity and minimum loss of volatile ingredients. Addition of excess Al_2O_3 was found to result in formation of the high-temperature α-Al_2TiO_5 modification along with β-Al_2TiO_5 modification and, according to phase analysis by x-ray diffractometry, also of TiO_2 and Ti_2O_7. Admixture of excess Al_2O_3 or of NiO, SnO_2 was found to facilitate formation of crystalline secondary phases along grain boundaries, while admixture of MgO, excess TiO_2, SiO_2, Cr_2O_3 and La_2O_3 listed in order of decreasing activity was found to inhibit decomposition of Al_2TiO_5 at temperatures below 1200°C and to stabilize its high-temperature α-modification. Addition of these latter oxides, alone or in combination with the others, is therefore preferable. References 4: 1 Russian, 3 Western.

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Segregation of Secondary Refractories Into Constituents by Radio Resonance and X-Radiometry Methods

18420164c Moscow OGNEUPORY in Russian No 4, Apr 87 pp 42-44

[Article by N. I. Baranovskiy, V. G. Rogozina, and N. V. Bortnikova, Ural Scientific Research and Planning Institute for the Concentration and Mechanical Processing of Useful Minerals, A. V. Koronchevskiy, A. M. Trufanov, and Yu. O. Fedorov, Siberian Scientific Research and Planning Institute for the Automation of Nonferrous Metals Processing (Sibtsetmetavtomalika)]

[Abstract] Two methods of ore concentration by segregation into constituents were tried for their effectiveness on secondary refractories such as mixtures of magnesium oxides and aluminum silicates. These were x-radiometry, based on any physical property as the separation criterion, and radio resonance, based on different changes in the Q-factor of the electric load circuit owing to differences in electric properties. Samples of these secondary refractories from the Orsk-Khalilovo Metallurgical Combine were segregated into periclase-periclasochromite and alumosilicate scrap fractions by the inductive variant of the radio resonance method at a frequency of 13.56 MHz in a mock-up SR-50 separator and by x-radiometry using radiation frcm a BS-1 tube with Cu anode either directly or through a Nb-foil filter for excitation and recording. Not only the principal constituents but also admixtures such as Al_2O_3, SiO_2, CaO, Cr_2O_3, Fe_2O_3 and metallic Fe, and with alumosilicate MgO as well were determined quantitatively in each case. An analysis of the data indicates that radio resonance is reliable, while x-radiometry is practical only for determination of periclasochromite. References 4: all Russian.

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Thermal Stability of Fused and Cast Baddelyite-Corundum Refractories

18420164d Moscow OGNEUPORY in Russian No 4, Apr 87 pp 49-53

[Article by Ye. F. Kolomeytseva and O. N. Popov, State Scientific Research Institute for Glass, and V. V. Kolomeytsev, General and Inorganic Chemistry Institute, USSR Academy of Sciences]

[Abstract] An experimental study of ZrO_2(baddelyite)-Al_2O_3(corundum)-SiO_2 cast refractory material for lining of glassmaking furnaces was made concerning the thermal stability of the BKCh-33 commercial product. Thermal stability was calculated on the basis of two criteria: $R = \sigma/\alpha E$(°C) (σ- tensile strength, α_m- mean coefficient of linear thermal expansion over 20-1200°C temperature range, E- dynamic modulus of elasticity) and $R' = R\lambda$(W/m) (λ- thermal conductivity at 300°C). Tensile and compressive

strengths were measured on 30 mm long solid cylinders 25 mm in diameter under diametral and axial compression respectively and the dynamic modulus of elasticity was measured on 180 mm long prisms with 20 x 15 mm^2 cross-section, all in a UKB-1M testing machine. Thermal stability was also measured by indirect radial heating of hollow rings with a SiC-bar heater inside, using TPP-0555 and TPR 30/6 thermocouples as well as a "Promin" optical pyrometer for temperature readings. Chemical and phase composition of BKCh-33 commercial refractory lining containing a glass phase were determined quantitatively in the eutectic zone with subzones A and B, in the macrocrystallization and glass concentration zone, and chemical composition only in the pipe zone. The zones were found to differ appreciably in composition and thermal stability according to both criteria, the latter depending on the heat load on the fusion and casting parameters, and on the mode of elastic-to-plastic transition. The highest thermal stability was found in a lining material with minimally defective microstructure and uniformly distributed glass phase, produced by simultaneous microcrystallization of baddelyite and corundum. The optimum heating rates in glassmaking furnaces with this lining have been established on the basis of the data, namely 5°C/h over the 20-120°C temperature range and up to 10°C/h over the higher temperature ranges up to 1400°C. References 9: 6 Russian, 3 Western (1 in Russian translation).

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Thermal Stability of SiO_2-Fiber Thermal Insulation

18420164e Moscow OGNEUPORY in Russian No 4, Apr 87 pp 53-55

[Article by A. V. Altunin, V. V. Yegorov and A. P. Shiray]

[Abstract] An experimental study concerning the thermal stability of sintered fibrous high-SiO_2 thermal insulation materials for high-pressure high-temperature gas-cooled reactors was made, the density of such materials with a crystalline cristobalite matrix and amorphous SiO_2 fibers typically 3.4 μm in diameter ranging from 150 kg/m^3 to 250 kg/m^3 depending on the weight fraction of the cristobalite. The latter was varied from 0 to 90% and monitored by structural examination in a DRON-2 x-ray diffractometer. The coefficient of linear thermal expansion α was measured in a DKV-4A dilatometer and the mechanical strength σ was measured in a latest-model tensile testing machine. The criterion of thermal stability selected was the temperature difference $\Delta T + C\sigma\lambda^n/\alpha E$ causing rupture (E- modulus of elasticity, λ- thermal conductivity, C- constant, n = 0.5-1.0). The temperature dependence of the rupturing temperature difference calculated for insulation material with 80 wt.% cristobalite and referred to that for fibers alone without crystalline matrix reveals a very sharp decrease of this temperature difference within the 200-250°C range of ambient temperature. The results of mechanical tests performed on these materials after thermal cycling by heating to 800°C at a rate of 15°C/min and cooling to 20°C at a rate of 4°C/min up to 100 times

indicate that the thermal stability decreases with an increasing weight fraction of cristobalite, evidently owing to crystallization of amorphous fiber. References 7: 6 Russian, 1 Western.

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High-Strength Ceramic Based on Tetragonal ZrO_2 With Al_2O_3 Admixture

18420164a Moscow OGNEUPORY in Russian No 4, Apr 87 pp 27-29

[Article by S. Yu. Pliner, Yu. I. Komolikov, V. G. Peychev, M. V. Safronov and A. A. Dabizha]

[Abstract] An experimental feasibility study of producing high-strength $ZrO_2(Y_2O_3)Al_2O_3$ ceramic was made, considering that the $Y_3Al_5O_{12}$ garnet crystals which form along with the solid solution of these three oxides inhibit compaction during sintering. Mixing powder of tetragonal ZrO_2 and α-Al_2O_3 powder in aqueous suspensions was tried as a way to facilitate sintering under high pressure. Accordingly, ZrO_2 + 5% Y_2O_3 powder and α-Al_2O_3 powder in stable suspensions were mixed in a rotating polyethylene drum, with the α-Al_2O_3 content varied up to 60 wt.%. Ingots produced by casting into gypsum molds were annealed in air inside an electric furnace at temperatures of 1400-1550°C. Subsequent mechanical tests for flexural strength by the 3-point method at room temperature have revealed that high-strength ceramic can be produced only with an α-Al_2O_3 content not higher than 25 wt.%. Phase analysis in a DRON1-UM x-ray diffractometer indicates that a higher α-Al_2O_3 evidently transforms the structure from a ZrO_2 matrix with isolated α-Al_2O_3 grains into two continuous phases: α-Al_2O_3 with isolated ZrO_2 grains and ZrO_2 with isolated α-Al_2O_3 grains. References 8: all Western.

2415/9835

Method To Improve Metal Ductility Examined

18420150a Moscow ZNANIYE-SILA in Russian No 2, Feb 87 pp 9-15

[Article by I. Usvitskiy: "The `Wind' That Softens Metal"; first paragraph is "Znaniye-sila" introduction]

[Text] The electron-plastic effect, which was discovered by Soviet scientists, makes it possible to sharply increase the ductility of metals and save huge amounts of energy expended during such types of working as, for example, rolling or drawing. The result is a metal of improved quality. Certain especially hard and brittle metals are now being worked, something which could not have even been dreamed of before.

A Few Words About Metal "Bread" and Dough

"Metal is the bread of industry." How many times we have heard this striking metaphor and how glad we were because there is more and more of this "bread" and because new blast furnaces, open hearths, and converters are being built. But, in reality, the comparison implied in this phrase limps on both legs -- both "metal" and "bread."

Do you and I really eat just bread? Hardly. You, for example, love white, I — dark; he — rolls. In the same way industry does not use just metal, but prefers something specific. "Metal is the dough for the bread of industry" -- that, if you will, is more correct. And then whatever you like. If we continue the bakery comparison, then one branch might be satisfied with coarse black "bread" in the form of steel ingots, while another demands products of a better sort -- rolls, puff pastry, bagels -- which means, if we switch to the "metal" part of the metaphor rolled product in all possible and increasingly complicated shapes, pipe, thin metal strip, etc., etc. The demand for precisely these types of rolled products is growing and growing. It is much more economical to work a shape close to the shape of the future product than to cut, saw, and grind tens and hundreds of kilograms of metal from a shapeless ingot.

Metallurgists are not limited to the first two proces stages -- from iron ore to pig and from pig to steel; they also use a third process stage -- rolling, forging -- and a fourth -- shaping and drawing. What happens to the metal in the third and fourth process stages is described by just two words -- plastic deformation. There are no chemical conversions, the metal's composition remains the same, but its shape changes. It is precisely in these process stages that the metal "dough" becomes bread.

However, metal is strong stuff, and it is not so easily deformed. The gigantic foundations of powerful rolling mills, the huge rollers and multi-kilowatt electric motors which turn them all provide some idea of the forces required to bake metal "bread." And this is still not enough. Metal is heated to make it more ductile. In special furnaces, tongues of flame many meters long lick the ingots, making them glow to temperatures of hundreds of degrees, and sometimes even more. Only after this does the white-hot ingot, blazing with heat and giving off sparks, go to the rolling mill.

There are metals which are entirely unsuited for deformation at low temperatures. They are hard, heat-resistant, and brittle. It happens that thin strip or very small-section wire must be made from them. An error in conditions -- and the thin wire stretched through the die (this is how the working tool of a drawing mill, through the hole in which the wire is drawn, is called) breaks.

All these processes -- heating, subsequent deformation -- require huge energy expenditures. Reducing heating several percent from the temperatures now used or increasing the metal's ductility by the same few percents would produce tremendous savings considering the scale of metallurgical production in our country.

But what if we are talking about tens of percents, or even not percents, but times? Fantasy? No, its is quite practicable. A new effect — electron-plastic — will help do this. Discovered more than 20 years ago at the USSR Academy of Sciences Institute of Physical Chemistry by Oleg Aleksandrovich Troitskiy, now doctor of technical sciences, and being developed by his group at the USSR Academy of Sciences Institute of Mechanical Engineering, it indeed sharply increases metal ductility and improves its properties. To understand how this happens, we have to look more closely at what the metal to be deformed actually is.

From a Life of Dislocations

A crystal is the symbol of symmetry, pattern, and regularity. The repeating planes of its lattice always seem perfect. With cold geometric delineation, the lattice cells of a crystal, theoretically identified by scientists, follow one after another. What irregularities can creep into this picture?

Quite a few. Apparently nature does not tolerate stultifying order; she complicates the problem, introducing some chaos, which, however, has critical consequence. Disruptions called defects develop in the periodicity of the crystal's lattice structure. Of the multitude of crystal defects, we will be interested primarily in dislocations.

There it is -- a regular and perfect crystal lattice. But look more carefully at figure 1 (on page 9): the top portion of the lattice has one more atomic plane than the bottom. This is a dislocation, called an edge dislocation.

The "extra" atomic plane is, of course, a distortion in the lattice, and it is primarily the part of the crystal which is directly adjacent to the extra plane that is distorted. The farther from this spot, the less noticeable the disruption, and at a distance of a few inter-atomic spacings it is almost invisible. There is another type of dislocation called spiral (fig. 2, page 9). Here too everything nearly evens out after a few inter-atomic spacings. These slight disruptions would be unnoticeable if there were not several of them throughout the entire volume of the crystal. But the number of dislocations in a crystal is measured not in ones or in hundreds. Even good natural crystals have several tens of millions of dislocations per cubic centimeter of volume.

The presence of dislocations leads to a decrease in strength. And plastic deformation itself is the process by which dislocations originate, move, and interact. (Footnote 1) (Details for those who are interested. In plastic deformation, some crystal layers glide relative to others. Explaining this to me, Candidate of Physico-Mathematical Sciences Vladimir Ivanovich Stashenko sets a neat stack of coins on the table and then slightly shifts the top coins sideward. The top coins in the resulting leaning tower were shifted relative to the lower ones. This simple model rather precisely reflects the processes actually taking place in a crystal during deformation (fig. 3, page 12). This is how it happens on the atomic level as well. The force applied breaks the bonds between atoms in the atomic plane closest to the dislocation. The resulting unoccupied bond grabs the atom of the "extra" plane, and it becomes a full member of the atomic lattice. And the "extra" plane becomes the top of the former "good" plane. So our dislocation has shifted one step. This process takes place more quickly than described. The lower boundary for the speed at which dislocations move is about one one-thousandth of a centimeter per second, the upper -- it's hard to believe -- reaches the speed of sound in a crystal. But it's true -- dislocations move only because the functions of the "extra" atomic plane are transferred to its neighbor, that is, because the atomic bonds are switched, and this process is rapid.)

The basic force which acts on a dislocation and forces it to shift is mechanical. Only a few grams per square millimeter of specimen cross section are sufficient to shift a dislocation from its spot. Tenths and even hundredths of units of this force are sufficient for a further shift. Since there are several dislocations, we must multiply their number times these fractions and grams, and we obtain the force required to deform a sample, that is, these are the same laws of deformation which are studied in all physics courses both in schools and institutes.

However, we have looked at an unlikely, but far from perfect, crystal. In it, dislocations actually driven by mechanical force move freely, converting their "race" into plastic deformation. In reality, this movement is much more difficult. The crystal also contains inclusions, whose atoms build up in the dislocation region where the lattice is distorted and which find a spot for themselves. These atoms act as stoppers to which a dislocation sticks. Therefore, inclusions also improve metal strength. Consequently, steel, i.e. iron with carbon inclusions, is stronger than pure iron.

Of course, it's good when a metal gets stronger; good even at the stage when it is becoming a finished product. But when it still needs to undergo plastic deformation, it's bad. (Footnote 2) (Details for those interested. When dislocations move and are blocked, surprising things happen. One of them is the so-called Frank-Reed source. Its formation is shown in figure 4. As external stresses increase, the dislocation, stuck on two stoppers, bends more and more and finally creates a circular dislocation around itself moving like a wave from its point of origin, followed then by another and another. A wave source of deformation develops.) As deformation increases, the number of moving, nascent, and decelerating dislocations becomes approximately equal. The material enters the stable region. To "revive" the dislocations, to force them to move more quickly, load must be added to the specimen.

So the dislocation is stuck on a stopper. A second, and then a third, approach and slow down... An aggregation develops. But remember that a dislocation is the absence of a full atomic plane, a unique macrovoid in a regular crystal lattice. When these macrovoids merge, pores, microcracks develop in the metal and, in turn, they become even stronger stoppers. But external load increases, and newer and newer dislocations approach the microcrack -- it is no longer micro, but an entirely perceivable quantity, and it finally opens outward -- and the metal fails. It turns out that to mobilize dislocations is to make the metal not only more pliable during working, but stronger as a consequence, without pores and internal cracks.

So that dislocations can "jump over" the potential barrier formed by the stopper one can increase the deforming load. We have seen what this comes to. One might increase temperature so that the increased oscillation intensity of atoms in the crystal lattice nodes makes the dislocations "breath" more freely. This is also not easy to do, and one cannot heat every metal on account of processing conditions.

But one can... And here we have come to the electron-plastic effect.

The Electron-Plastic Effect in Theory...

Metals are excellent heat and electricity conductors. We have long known why this is so: because metals have many free electrons. So many that one may even speak of an electron gas, and Academician L. D. Landau used the expression "electron fluid," apparently because the electron community possesses the quite real properties of a viscous medium.

If no additional steps are taken, this viscous medium obstructs the motion of dislocations and, consequently, deformation. Dislocations literally have to bore through the electrons, losing energy. The retarding effect of electrons was historically studied first. Scientists of the Kharkov school of physics under V. I. Startsev and I. A. Gindin brought specimens of certain metals to a superconductive state and observed the effect of softening. At low temperatures, the electron gas lost its viscosity, and dislocations started to move more energetically.

All this applies to electrons free of any sort of external action and, therefore, behaving as "God ordained." But is it impossible to create any organized collective out of the anarchy of the electron community or, let's say, force them to move in the same direction? No, of course not.

The method has been known for many years. It is the most ordinary electrical current, i.e. the directed movement of electrons.

And now the last force, and we have reached our goal. The directed flow of electrons may exert mechanical pressure on the dislocations. Bombarded by this flow, they take on additional energy and are enabled to overcome the potential barriers of stoppers. That's all there is to it...

But, in fact, it was more complicated. (Footnote 3) (Details for those who are interested. What exactly was observed at first? Irradiating metal crystals with electrons reduces deformation forces if the electron flow moves in the same direction as the crystals' gliding plane, along which, as we remember, the dislocations move. This was in 1962. Then in 1969 Troitskiy, along with A. G. Roznio, observed this same effect in an electrical current. A set of problems arose which had to be solved before one could even mention that a new phenomenon had been discovered.

First, everyone knows that a current passing through metal heats it. Is it possible that ductility increases simply because the metal heats? Does it matter whether it is heated by current or a special furnace? A whole series of experiments was required before direct evidence was obtained: heating is irrelevant here. Increased ductility was observed even at temperatures of liquid nitrogen, whose cold completely cancelled out the heating.

The main problem confronting researchers was even more complicated: can electrons actually "nudge" dislocations? It turns out that they can.

First, there are a lot of electrons -- about 10^{22}-10^{23} per cubic centimeter of volume.

Second, the electron gas in metals is in a special, high-energy state. Calculations show that the electrons' energy is very high -- thousands of kilowatt-hours per cubic meter of metal. Only it was impossible to take advantage of it. For the first time the electron-plastic effect made this energy suitable for practical tasks. To bring about a substantial increase in ductility required a powerful flow of electrons, i.e. high current. But this involves an increase in the density of the current through the deforming metal, and excessively high density may overheat and even destroy it -- remember how a light bulb filament overheats. The solution is to deliver a pulsed current. For a short time, 10^{-4} to 10^{-5} sec, a current of tremendous density -- up to 100,000 amperes per square centimeter -- is created in the metal. This is enough to move almost any dislocation from its spot, and then for the next pulse to nudge it, to force it to speed up and interact. This is advantageous in terms of energy, since the average energy of powerful, but short and infrequent, pulses is quite low.)

...And in Practice

So we've constructued a good theory, and we can move on to practice. It looks tempting: strong pulses of current have to be supplied to the deforming metal. But simply passing a current through a piece of metal does nothing -- the metal has to be under high mechanical stress -- specifically under a stress near the yield limit. Only then is the electron-plastic effect fully manifest. This condition is met in rolling and drawing mills. And we gain another advantage: only the section of metal directly between the rolling mill rolls or in the draw holes deforms. This means that current has to be supplied to only this section, without wasting it to heat the rest of the blank.

Figure 5 shows a simplified diagram of the process. One contact before the drawing die, one after it, a pulse current source -- that's basically all.

"It seems to me that the practical importance of the electron-plastic effect is rather great," says Oleg Aleksandrovich Troitskiy. "We have now entered a period when we need not just good, but intense technologies. And the use of our effect in production is just such an example of the most present-day intensive technology. Think for yourself: changing the shape of metal is an ancient process; mankind has used it to produce metal goods for thousands of years. And that whole time the material in no way has participated in the process; it simply has reacted passively to everything done to it. We are forcing it to be an active participant in the working process, using its internal structure. In one article I once used the expression 'the electron wind fills the sails of dislocations.' That's how it is: the mechanisms existing in the metal -- the fact that it always has free, high-energy electrons -- blow the stagnant dislocations off the stoppers, and the metal's ductility increases drastically."

The electron-plastic effect is already yielding practicable industrial results. For example, copper's ductility is increased dozens of times. Exactly -- dozens of times. The forces required for rolling and drawing are sharply decreased. It is possible to draw incredibly thin copper wire without breaking it in the process. Moreover, it has lower electrical resistance. If we consider how much copper is used in electrical cable, then the reduction in resistance alone and, therefore, the decrease in losses in cables easily pays back all expenditures to introduce the process.

Tungsten shows great prospects for applying the effect. It is extremely difficult to deform, and a great deal of thin tungsten wire is needed: tungsten wire illuminates our incandescent bulbs. For tungsten, ductility under the action of current increases 5-10 percent. Because of this, the temperature at which drawing is done can be decreased to 200-250 degrees, i.e. by one-third as compared to current practice. Drawing forces drop one-fourth.

All this is done by a pulsed electric current, whose power -- if we take the average actually displayed meter readings -- is 250-300 W. One bulb unscrewed in the shop where drawing is done compensates for all additional energy expenditures from introducing the new process. Admittedly, drawing a 2-millimeter wire requires additional power of about one kilowatt, but anyone familiar with rolling can only laugh at that figure.

These outstanding results have also been obtained during the rolling of molybdenum, also a "hard nut" for metallurgists. Tungsten and molybdenum alloys become more ductile as do the high-strength heat-resistant and alloyed steels which are increasingly used in modern technology. They can be rolled to micron strip thicknesses without significant heating.

"Is it a matter only of reducing working forces and temperatures?" says Troitskiy. "Downstream we obtain some sort of the same metal, but in fact, it is entirely different. It even looks different: smooth, without galling, shiny as if polished. Even more important are the changes which occur in its internal structure. The electron wind that nudges the dislocations destroys their aggregations, which means every type of pore and microcrack. Each current pulse brings tens and hundreds of thousands of dislocations to the metal's surface. Mechanical stresses inside the metal decline. Structure improves, the material easily assumes the required shape during subsequent working, and it has a good texture. For example, tungsten and molybdenum exhibit residuals increased ductility — superthin threads are easily wound into spirals of any configuration with record-breaking small bending radii."

It is possible to roll to previously unattainable sizes and shapes. Extremely thin stainless steel tubes and thin bimetal sheets have already been produced. There is still a great deal to be calculated and drafted, but industrial outlines will be developed in the near future."

There is another aspect which we cannot ignore -- the increase in rolling equipment service life. Temperature and mechanical loads on the processing tool — be it rolling mill rolls or dies through which wire is drawn -- are sharply decreased. The savings here are also quite real and large.

There are still many unexplored areas ahead. Stimulating plastic deformation in crystals with current pulses offers new opportunities for studying their ordinary and irregular deformations and makes it possible to solve the most varied problems of deformation hardening. A significant increase in crystal ductility before brittle failure due to current may be the basis for a method of reducing brittleness in metal-based materials.

There are examples when the electron-plastic effect occurs spontaneously and is then harmful. Apparently, it is in part to blame for sagging in electric line wiring and for the permeation of copper into the most stressed locations of electric machinery commutators. In both cases powerful "electron winds are blowing," and, as a result, our effect may arise. Knowing the reason for the harmful phenomenon and its mechanisms means half knowing how to overcome it.

"Everything looks elegant, beautiful, industrially proven, cost-effective now. Could it have been so from the very beginning?"

"No," Troitskiy laughs, apparently remembering something, "Not quite. When we detected this phenomenon, it was so inexplicable that publication of the results was delayed about a year. Then different specialists expressed their doubts. Some stated that this was nothing new and that everything was explained by local heating due to the current. Actually, we don't deny this, some of the energy of the electron wind that blows the dislocations away is consumed in heating the metal. If this is so, our opponents said, then this is simply a masked Joule effect and nothing electron-plastic exists in nature. However, if they were right, the polarity of the effect of the current on plastic deformation, which we established quite precisely in a whole series of experiments, would not have arisen. Nor would there have been the relationship between dislocation travel speed and the direction of the current through the crystals which scientists at the Siberian Metallurgical Institute observed. Nor would there be the relationship to the current direction of the copper and tungsten wire drawing forces which both we and specialists at the Magnitogorsk Mining and Metallurgical Institute detected. And finally, in a series of extremely carefully structured experiments followed by us, an American, H. Conrad, famous for his basic research on titanium deformation, identified the thermal portion of the current's action and showed that our effect exists for titanium as a completely independent phenomenon and is related precisely to the nonthermal interaction of electrons and dislocations. And while debates have continued, articles have been written, experiments posed -- both to prove and to refute, we have introduced our results into industry. Not as quickly or easily as we would have liked, but we have introduced them. Academician Viktor Ivanovich Spitsyn, director of the Institute of Physical Chemistry, where our group was then working, has actively participated in this important matter. He organized our work, supported it in difficult times when criticism became aggressive, urged us toward introduction, and used his authority to facilitate this introduction. Nor did he limit himself to these directorial functions: he himself proposed experiments and took part in discussing their results. What hasn't happened in 24 years... Don't be surprised, you haven't heard wrong — that's how long it's been since our first work, done in 1962."

In truth, the electron-plastic effect is an example of the fact that it is easier to discover something than to prove that you have done it. But, it seems, everything is coming to a head. At the end of 1984 an expert commission of the State Committee for Inventions and Discoveries recognized the electron-plastic effect as a discovery. When you read this article, it will possibly have its number and all the appropriate attributes.

Born in a scientific laboratory, the electron-plastic effect is becoming one of the new and promising techniques for electroprocessing of metals and alloys. It intensifies metallurgical production, makes it possible to obtain high-quality products, and is easily automated, which is a necessary condition for any technology of the future. Multiplied by the huge scales of our industry, it promises great savings. One may be sure that we will hear more about it.

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Assaying Technology of Electroslag Chill Casting in Production of Billets for Excavator Ball Supports

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[Article by Yu. V. Orlovskiy, N. P. Ilyenko, Yu. A. Lyashenko, V. V. Zabiyaka and L. N. Babich, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev; All-Union Planning-Design and Technological Institute of Construction and Road Building Machinery]

[Abstract] A new technology of producing billets for excavator EO-4321A ball supports made of 40Cr steel has been developed and evaluated, namely electroslag chill casting with a consumable electrode made of wrought 40Cr steel. The chill mold consists of two half-copes and a drag, all made of VCh-50-2 heat-resistant high-strength cast iron. Mold parts were produced by casting under vacuum and film cooling. Ten billets were analyzed for chemical composition of the steel, examined for surface finish and internal macrostructure, and tested for mechanical characteristics (yield and ultimate tensile strength, percentage elongation and reduction, impact strength). The finished product, ball supports produced by machining of these billets, was tested for performance: 500 engine-hours on an experimental excavator proving ground. The results indicate that this technology yields flawless castings which meet all specifications.

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Electron-Optical Study of Sintering Kinetics of Tungsten Powders With Spherical Grains: Experimental Study of Sintering of Tungsten Powders

18420166a Kiev POROSHKOVAYA METALLURGIYA in Russian No 5, May 87 (manuscript received 28 Feb 86) pp 11-14

[Article by V. V. Skorokhod, L. A. Vermenko, O. I. Getman, I. I. Karpikov and S. P. Rakitin, Institute of Materials Science Problems, UkSSR Academy of Sciences]

[Abstract] An experimental study of sintering of two tungsten powders comminuted to spherical grains, finer ones with a 4 μm average diameter and coarser ones with a 10 μm average diameter respectively, was made for an analysis of the process kinetics. Both powders with a 40±1% initial porosity were sintered in a hydrogen atomsphere at temperatures of 1800-2000°C, a different specimen at each temperature. Isoporous disks 9 mm in diameter had been produced by pressing with paraffin, the pressure being 0.2 GPa nd 0.1 GPa for the finer powder and the coarser powder respectively, whereupon the paraffin was removed by slow heating to 800°C. They were then annealed at 1400°C for 0.5 h, without shrinkage, which improved their mechanical characteristics for measurement by the Barus-Bechgold method. The grain size distributions in both nondisperse sintered and annealed specimens, fractograms, and the curves of compaction kinetics agree closely with theoretical calculations. Accordingly, intense volume shrinkage and enlargement of the contact surface under given conditions occurred in both materials within the initial 15-20 min long period. References 2: both Western.

2415/9835

UDC 669.018.9

Sintering Metal-Oxide Cermets With Ni Content

18420166b Kiev POROSHKOVAYA METALLURGIYA in Russian No 5, May 87 (manuscript received 16 Jul 85) pp 14-18

[Article by A. V. Fedotov, S. T. Zhukov and V. S. Shkirov, Moscow]

[Abstract] An experimental study of sintering and annealing compact corundum ceramic with Ni content was made, annealing in a moist hydrogen atmosphere having been found to ensure retention of Ni and thus a high product quality. Powders of α-Al_2O_3 (1-2 μm grains), NiO (1-3 μm grains), fine-grain Ni (2-4 μm grains), coarse-grain Ni (12-17 μm grains), and TiO_2 (1 μm grains) were mixed into composite compacts containing 42.09-47.68 wt.% α-Al_2O_3 and 1.35-3.59 wt.% TiO_2 with 54.74-54.81 wt.% NiO, or 48.73-48.80 wt.% fine Ni, or 48.80 wt.% coarse Ni. Their porosity was measured by hydrostatic

weighing. Their phase composition was determined in a DRON-3 x-ray diffractometer with CuKα-radiation source and Ni filter. The results confirm the correctness of this technology with some water vapor in the gaseous atmosphere and with sufficient excess TiO_2 in the mixture. During annealing TiO_2 reduces to Ti_2O_3, forming a solid solution with α-Al_2O_3 along with other phases such as $AlTi_2O_3$ which contributes to compactness of the product and retention of Ni in it. References 6: 5 Russian, 1 Western.

2415/9835

UDC 621.762:669.018.25

Heat Treatment of WC-Co Hard Alloys and Their Products

18420166c Kiev POROSHKOVAYA METALLURGIYA in Russian No 5, May 87
(manuscript received 18 Mar 86) pp 56-61

[Article by V. I. Kudryavtseva, I. N. Chaporova and A. V. Varaksina, All-Union Scientific Research and Design Institute of Refractory Metals and Hard Alloys]

[Abstract] An experimental study of WC-Co hard alloys was made for the purpose of determining the effect of quenching on their structure and properties as well as on the residual stresses and their role. Products made of four of these alloys, containing either 6 wt.% Co (WC-Co6, WC-Co6+Co_2C) or 20 wt.% Co (WC-Co20, WC-Co20+Co_2C) were heated to 1200°C, some in brine and some with high-frequency electric current, and then cooled to 40°C, some in oil and some in air at a rate of 10-15°C/s in each case. Quantitative microstructural analysis, x-ray structural analysis, and examination under an electron microscope were done before and after heat treatment. Microphotographs were obtained under a "Neophot-21" optical microscope with x1000 magnification by the method of random secants. The results identify magnitude and sign change of macrostresses, increase of microstresses in the carbide phase, and additional dissolution of W and C in Co as the favorable effect of such a heat treatment. Although separation of these simultaneous effects is not possible, change of sign of macrostresses in the surface layers appears to be most significant one. References 8: 5 Russian, 3 Western.

2415/9835

UDC 621.357.74:621.785.54

Electron-Beam Heat Treatment of Titanium Alloys With Chromium Coating

18420158 Minsk DOKLADY AKADEMII NAUK BSSR in Russian Vol 31, No 6, Jun 87 (manuscript received 14 Jul 86) pp 526-529

[Article by M. N. Bodyako, corresponding member, BSSR Academy of Sciences, A. A. Shipko and I. G. Urban, Physical Technical Institute, BSSR Academy of Sciences]

[Abstract] An experimental study of Cr coatings galvanically deposited on Ti alloys was made for a comparative evaluation of their fast electron-beam heat treatment and slow conventional heat treatment by heating and cooling at a rate of 0.2°C/s each, the advantages of the fast process being avoidance of detrimental excessive grain growth with attendant proneness to oxidation and hydrogenation. Two Ti alloys, VTZ-1 and VT-20 with galvanic Cr coatings, were treated in an A 306 07 electron-beam welding machine by heating at rates of 10-500°C/s to temperatures of 700-1400°C without intermediate isothermal holding periods. After this treatment coatings were examined for surface and subsurface structure as well as phase composition in a DRON-2.0 x-ray diffractometer and under a "Neophot 2" optical microscope with x250-1000 magnification. The study of surface topology was done with an MYe 10 profilograph and under a "Nanolab 7" scanning electron microscope with x100-10,000 magnification. The results indicate that during electron-beam heat treatment diffusion of Cr into Ti is completed before the 900°C recrystallization temperature of Cr has been reached. Formation of the intermetallic compound $TiCr_2$ can be prevented by first striking Ti with a Cu or Ni interlayer. Electron-beam heat treatment was found to produce Cr coatings with strong adhesion and high wear resistance. Friction tests in an SMTs-2 machine at a rubbing velocity of 0.1 m/s under loads of 981-22,275 N have revealed that the electron-beam heat treatment can be optimized in terms of temperature and heating rate so as to produce Cr coatings with a lower friction coefficient under a heavier load. References 4: 3 Russian, 1 Western.

2415/9835

UDC 669.187.56:669.14.001.5

Properties of Quasi-Laminate 17Mn1Si Steel After Regulated Cooling

18420162f Kiev PROBLEMY SPETSIALNOY ELEKTROMETALLURGII in Russian No 2, Apr-Jun 87 (manuscript received 10 Apr 86) pp 37-40, 59

[Article by B. I. Medovar, V. I. Us, A. I. Krendeleva, N. B. Pivovarskiy, N. A. Astafyev and N. M. Shelestyuk, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences, Kiev]

[Abstract] Two new classes of structural materials for high-pressure gas pipe-lines have been developed at the Electric Welding Institute, quasi-laminate

ones and reinforced quasi-monolithic ones, to provide a more economical alternative to steel alloys containing scarce Ni or Nb and specially vacuum treated with synthetic slag containing rare-earth elements. 17Mn1Si steel (0.17% C, 1.30% Mn, 0.56% Si, 0.06% Cu, 0.05% Cr, 0.04% Ni, 0.019% S, 0.017% P) with a 0.38 carbon equivalent belongs in the first class. In order to ensure excellent mechanical characteristics, it is necessary to regulate the cooling after hot rolling. Multilayer 400x400 mm^2 large plates consisting of four 8 mm thick sheets stacked together by manual electric-arc welding around the periphery were heated to 1150°C, held at that temperature for 30-35 min, and then rolled down to 16 mm thickness in 4-6 passes in a 2-roller mill. The billets were cooled to 800-700°C in air and then to room temperature in water, for subsequent self-tempering at the optimum temperature empirically determined by varying the length of cooling time in water. After cooling from 750°C in water within 5 s and subsequent self-tempering, notched-bar Charpy and Mesnager test specimens cut from such plates were found to have impact strength values KCV^{-15} = 62-90 J/cm^2 and KCU^{-60} = 97 - 102 J/cm^2 (the specification for standard 17Mn1Si steel is KCU^{-40} = 50 - 55 J/cm^2). Other mechanical characteristics were found to be within specifications for standard 17Mn1Si steel: yield strength 380 MPa, ultimate tensile strength 560 MPa, percentage elongation 26%. Microstructural examination has revealed that fast cooling facilitates transformation of austenite into not hardenable intermediate structures, ferrite-bainite and ferrite-pearlite-bainite, which ensure high strength and excellent formability. References 6: all Russian.

2415/9835

Dependence of Material Removal Rate on Flow Rate of Working Fluid Between Electrodes During Engraving by Electroerosion Process

18420165a Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 2, Mar-Apr 87 (manuscript received 3 Feb 86) pp 16-20

[Article by M. L. Levit and M. V. Paradisova, Moscow]

[Abstract] The electroerosion method of engraving is analyzed to find ways to speed up the process by increasing the material removal rate. This essentially requires heavier loading of the tool-electrode above its conventional current carrying capacity. One possibility is forced cooling of this wire electrode with a coaxial jet of working fluid. The problem then reduces to one of optimization of thermal and hydrodynamic conditions in the interelectrode space. Experiments were performed in a 4735F3 machine using a ShGI-63-440 power supply with pure water (electrical resistivity o = 1 Mohm' cm) as working fluid and a brass wire 0.3 mm in diameter as the tool-electrode. Water was pumped under a pressure of 4 atm and the flow rate varied over the 0-16 l/min range. The wire electrode was rewound with the speed varied over the 0-6 m/min range and the tension varied over the 3-15 N range. Voltage and current pulses were monitored on an S1-55 double-beam oscillograph and their spectra on an N-117 loop oscillograph. Three different configurations of water feed were tested, namely through a single conoidal nozzle around the

wire, through two conoidal nozzles, an inner one and an outer one coaxial around the wire, and through two such nozzles with the outer one having a different shape. In each case the water flow rate as a function of the electrode surface wettability and of the electrode rewinding speed was measured first, then the material removal rate as well as the pulse utilization factor and the effective change of the interelectrode gap width owing to wire vibrations as functions of the water flow rate. An analysis of the data and of the water flow pattern, the formation and location of the stagnation zone being especially important, indicates that at any given level of electric power input there is an optimum water flow rate which maximizes the material removal rate. Attenuating the wire vibrations by increasing the rewind tension will increase the efficiency of the process. Formation of a boundary layer on the wire surface, with the latter having the necessary finish, will increase the water jet utilization without causing additional wire vibrations. The stagnation zone should be located where it will allow the material removal rate to increase maximally without loss of stability. References 6: 5 Russian, 1 Western.

2415/9835

Dependence of Structure and Properties of Laser-Treated Alloy Steel on Thermal Load

18420165b Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 2, Mar-Apr 87 (manuscript received 15 Apr 85, after revision 1 Jun 86) pp 21-23

[Article by V. N. Dubnyakov, O. L. Kashchuk and O. P. Osipov, Novyy Byt (Moscow Oblast)]

[Abstract] An experimental study of Cr-W-Mn tool steel was made for the purpose of determining the effects of laser treatment and subsequent heating on its structure and properties. Specimens of this steel were treated with a 1 kW continuous-wave CO_2-laser, its beam 3 mm in diameter scanning the surface at a velocity of 20 mm/s. They were then heated to temperatures of 100-400°C at a rate of 10°C/min to each, whereupon they were held at each temperature for 30 min and then cooled in the furnace. Changes in their surface microhardness and scratch hardness under a 100 g load were measured with a "Durimet-2" tester. Quantitative metallographic structure analysis was done in a "Leitz T.A.S." automatic image analyzer which determined the volume fractions of carbides and residual austenite as well as the austenite grain size. Laser treatment was found to have transformed the original pearlite-cementite structure of this steel at the surface into a layer of martensite without carbides, the latter having been completely dissolved at a temperature above A_{c3}, but with 20-22 μm large grains of residual austenite. A highly nonhomogeneous second layer underneath contained austenite clusters as well as carbides. Subsequent heating to increasingly higher temperatures was found to decrease the case depth along with the microhardness, owing to precipitation of very fine carbide grains and breakup of the austenite at 200-300°C followed by breakup of the martensite into a much softer disperse

ferrite-carbide mixture at higher temperatures. However, low-temperature tempering at up to 350°C does not significantly cancel the effects of laser treatment and reduce the wear resistance of this steel. References 4: all Russian.

2415/9835

Feasibility of Case Hardening Metals with 'Razryad' Electric-Spark Alloying Equipment

18420165c Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 2, Mar-Apr 87 (manuscript received 31 Oct 85) pp 24-27

[Article by A. Ye. Gitlevich, P. A. Topala, I. I. Kuku, V. I. Ivanov and V. A. Snegirev, Kishinev]

[Abstract] The feasibility of using a Razryad ("Discharge") electric-spark machine for case hardening of steels and alloys is analyzed, this machine having been developed for alloying a metal with powder of another element by injection of the latter into the interelectrode space for interaction with pulse discharge and transport of the interaction product onto the target metal mass as the cathode. This process was tried experimentally on carbon steels (3, 45) and Ti alloys (VT1, VT6). Both continuous and monopulse treatments were tested, with either the cathode-target moving under the tip of a stationary spinning graphite-rod anode or a spinning copper-disk moving on-edge over the stationary cathode-target. The clearance between them was varied over the 0.03-2.5 mm range and the discharge voltage from a 600 μF capacitor bank was varied over the 160-400 V range. The repetition rate of firing pulses was varied over the 1-40 Hz range. Surface roughness and microhardness of the target case being determined by discharge parameters. the optimum discharge voltage and interelectrode gap can be established. The accordingly modified machine can then be adapted for applications other than coating. References 8: all Russian.

2415/9835

UDC 621.791:621.371.3

Use of Millimetric-Wave Electromagnetic Radiation for Heating Materials During Welding and Other Treatment

18420168a Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87 (manuscript received 18 Sep 86, in final version 11 Feb 87) pp 1-3

[Article by Academician B. Ye. Paton, V. Ye. Sklyarevich, candidate of technical sciences, and M. V. Shevelev, engineer, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences]

[Abstract] A gyrotron, a maser operating at cyclotron resonance, developed by the A. V. Gaponov group of scientists has been found to be a much more effective heat source than conventional electric arcs or electron beams for welding and heat treatment of nonmetallic materials. A variant of this device, a 30 kW gyromonotron operating in the continuous mode at a frequency about 80 GHz with a normal output intensity distribution, is included in a facility which has been built at the Electric Welding Institute. The results of experimental feasibility studies confirm that concentrated millimetric-wave electromagnetic radiation can be used for chemothermal or heat treatment, facing, coating, and welding of not only most dielectric and semiconductor materials no matter what their melting point is but also of metals and alloys with a dielectric material such as a flux serving as energy absorber. Welding of ceramics, which must be done without melting them, and especially of ceramics with a low absorption coefficient is done by first facing the edges to be joined with a fusible material and then heating under compression. In the gyromonotron this is achieved with a high efficiency and a small temperature gradient across the thickness of material. References 4: all Russian.

2415/9835

UDC (621.791.754'291.052:669.296'293):620.193.2

Stress-Corrosion Cracking of Welded Joints of Zr + 2.5% Nb Alloy

18420168b Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87
(manuscript received 27 Mar 86, in final version 19 Jun 86) pp 10-13

[Article by A. B. Goncharov, candidate of technical sciences, V. A. Gorban, engineer, M. M. Nerodenko, doctor of technical sciences, and L. M. Onopriyenko, engineer, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences]

[Abstract] An experimental study of welded joints of the Zr + 2.5% Nb alloy was made for a determination of their proneness to stress-corrosion cracking and its dependence on the welding process parameters and subsequent heat treatment. Welding was done with high-purity tungsten electrodes in a controlled helium atmosphere, 2 mm thick specimens being joined at a rate of either 0.28 cm/s (welding current 65 A, voltage 16 V) or 1.68 cm/s (welding current 180 A, voltage 18 V). The joints were annealed under a vacuum of $0.26 \cdot 10^{-2}$ Pa or higher successively at temperatures of 850 K (α range), 1020 K ($\alpha + \beta$ range), and 1270 K (β range) for a total of 2 h with 10-15 min at 1270 K. They were then quenched from that temperature in water. Stress-corrosion tests were performed in methanol containing 0.4 g/dm^3 HCl at room temperature, with periodic inspection after every 24 h. Similarly produced joints of iodine-treated pure Zr were also tested, before and after annealing at 850 K, for a determination of the effect of Nb on stress-corrosion cracking. The results of subsequent microstructural and fractographic examination indicate that the alloy as delivered and joints annealed at 1270 K (cracking after 240 h) are most resistant, quenched joints with a martensitic structure (cracking after 168 h) are less resistant, and joints with fine-disperse β-phase inclusions (cracking after 24 h) are least resistant. References 9: 6 Russian, 3 Western (2 in Russian translation).

2415/9835

UDC 621.791.72:621.373.826:535.51

Dependence of Welding Seam Formation on Polarization of Radiation Emitted by Continuous-Wave CO_2-Laser

18420168c Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87 (manuscript received 27 Jan 86, in final version 16 Jan 87) pp 18-20

[Article by V. I. Kirsey, engineer, and V. P. Garashchuk, candidate of technical sciences, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences]

[Abstract] An experimental study of welding with polarized radiation from a continuous-wave CO_2-laser was made to supplement theoretical data on the dependence of welding seam formation on the orientation of the $\vec{E}$-polarization plane relative to the $\vec{v}$-direction of welding. Tests were performed with a 3 kW industrial CO_2-laser with an electric-discharge system consisting of 110 bar cathodes in a row and a common plane anode, the interelectrode gap being 40 mm wide. The active medium, a CO_2-N_2-He mixture under a pressure of 4.67-5.33 kPa, was located inside an unstable cavity with $M = 2.4$ magnification between a concave mirror and a convex mirror behind a rotatable plane exit mirror at a 45° angle to the cavity axis. A polarizer, a 10 mm thick KCl disk 60 mm in diameter in a cylindrical metal frame, was inserted into the cavity not at the Brewster angle but at a 45° angle to the cavity axis. The polarizer frame was rotated so as to make the laser beam impinge on it in the same plane as on the exit mirror. Both polarizer plate and exit mirror were then rotated so as to make the plane of laser beam polarization either coincide with or perpendicular to the plane of laser beam incidence on both. A beam splitting KCl plate passed most laser radiation for welding, after 90° reflection by a 45° mirror and focusing by a lens, and diverted some to a ZnSe analyzer plate at the Brewster angle to the laser beam axis in a frame carrying two water-cooled calorimeters for measurement of radiation power reflected and tramsitted by that analyzer. Welding was done with the angle $\angle(\vec{E},\vec{v}) = 0, 45°, 90°$. The results of measurements under an MMI-2 optical instrument microscope indicate minimum fluctuation (up to 10%) of the radiation penetration depth and thus optimum quality of welding seams when $\vec{E}\perp\vec{v}$, and maximum fluctuation (up to 50%) of the radiation penetration depth with attendant irregular melting ripples when $\vec{E}||\vec{v}$. References 8: 7 Russian, 1 Western.

2415/9835

UDC 621.791.14:(669.15-194.3+669.15-194.2):621.824

Mechanical Strength of Shafts in Hydraulic Machines Made of Different Steels and Joined by Friction Welding

18420168d Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87 (manuscript received 27 May 86) pp 37-38

[Article by A. F. Dashchenko, candidate of technical sciences, Odessa Polytechnic Institute, and Yu. A. Mirgorod, engineer, Electric Welding Institute imeni Ye. O. Paton, UkSSR Academy of Sciences]

[Abstract] The problem of joing piston shafts in axial-flow hydraulic machines by friction welding is analyzed on the basis of theoretical fracture mechanics and experimental data, such shafts being generally multisegmental stepped ones with widely different diameters. For economy reasons, mechanically understressed segments are made of lower-grade steel (40Cr) and fully or overstressed segments are made of higher-grade steel (38Cr2MoAlN2). Friction welding is the accepted method of joining these segments, but no test equipment is available for evaluating such joints. A special test stand has therefore been developed at the Electric Welding Institute for determinig the toughness of such joints. It includes a pulley for axial loading with weights and a pinion as well as a flywheel on the horizontal drive shaft. The results of calculations and measurements indicate that the strongest joints are produced with coaxial holes $h = 0.6D$ deep and $d = 0.3D$ in diameter (D- diameter of segments to be joined), smaller holes causing fracture in the 40Cr segment and larger holes causing fracture within the welding zone. Without holes fracture will occur in both. References 5: 4 Russian, 1 Western (in Russian translation).

2415/9835

UDC 621.791.72.052:621.772-419:620.18

Dependence of Characteristics of Electron-Beam Welded Joints in Vessels Made of Coiled Strip on Shape of Welding Seam

18420168f Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87 (manuscript received 7 Apr 86, in final version 4 Jun 86) pp 79-80

[Article by A. Ye. Stronskiy, candidate of technical sciences, Irkutsk Scientific Research and Design Institute for Chemical Machine Building]

[Abstract] Electron-beam welding of coiled strip to form high-pressure vessels was studied experimentally for attainment of a welding seam with uniform mechanical characteristics, such vessels being usually made of pearlitic manganese steels (10Mn2Sil, 08Mn2SiVNb) or heat-resistant bainitic chromium-manganese-nickel steels (12CrMnNiMo, 15CrMnNiVTi). Available theoretical and practical data indicate that a daggerlike vertical melting

zone produces a seam with a very nonuniform vertical temperature profile, its nonuniformity being magnified by the anisotropy of thermophysical properties in a multilayer structure. As a consequence, impact strength and hardness of the seam both decrease in the direction from top to bottom. In a special experiment the possiblity of equalizing the seam characteristics by modifying the seam shape was tried on vessels made of 12CrMnNiMo steel, 4 mm thick strips coiled into 53 mm high and 100 mm high stacks, with vertical movement of a horizontal electron beam. A uniform distribution of heat and cooling rates of 0.4-2.0°C/s in the thermal influence zone were achieved by recessing the electron beam focus at 3/4 height of the stack. This resulted in an impact strength of 0.6-0.7 MJ/m^2 and a Brinell hardness of 190-200 over the entire height of the seam. References 3: all Russian.

2415/9835

Some Features of Rutile Comminution by Electrohydraulic Sputtering

18420165d Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 2, Mar-Apr 87 (manuscript received 12 Jul 84) pp 42-44

[Article by I. N. Godovannaya, V. B. Vishnevskiy and V. D. Tkachenko, Kiev]

[Abstract] Experimental electrohydraulic treatment of polycrstalline rutile lumps by sputtering with discharge pulses in distilled water between two colinear electrodes inside a cylindrical chamber with steel walls has yielded some comminution. Rutile ingots produced by the floating-zone method of induction melting had been crushed into lumps of 0.065-3.0 mm size fractions. Electrohydraulic treatment was done with an either 1:10 or 1:2 ratio of liquid phase (H_2O) to solid phase (TiO_2). The number of discharge pulses was increased stepwise from 200 to 600. After each run not only was the size distribution of rutile powder measured but also the pH factor of the water, which had increased as a result of TiO_2 dissolution with attendant formation of H_4TiO_4, and the Fe_2O_3 equivalent of $Fe(OH)_3$ impurity resulting from corrosion of the steel walls. Although 600 discharge pulses appreciably enlarged the 0.065-0.250 mm fractions and almost wiped out the 2.0-3.0 mm fractions, this positive effect of electrohydraulic treatment was by far outweighed by both dissolution and contamination of rutile. References 4: all Russian.

2415/9835

UDC 621.791.44:(669.71+666.3/.7):539.4

Dependence of Mechanical Strength of Oxide-Metal Joints on Parameters of Pressure Welding Under Vacuum

18420168e Kiev AVTOMATICHESKAYA SVARKA in Russian No 5, May 87 (manuscript received 6 Aug 86) pp 74-77

[Article by Yu. V. Naydich, corresponding member, UkSSR Academy of Sciences, I. I. Gab, engineer, V. S. Zhuravlev, candidate of technical sciences, and D. I. Kurkova, engineer, Institute of Materials Science Problems, UkSSR Academy of Sciences, Yu. N. Yevplov, engineer, Strength Problems Institute, UkSSR Academy of Sciences]

[Abstract] An experimental study of the pressure welding under vacuum of A0115M pyroceramic (67% SiO_2, 21% Al_2O_3, 6% TiO_2, 4% Li_2O, 1% Na_2O, 1% K_2O) and class-100 silicate porcelain (72.15% SiO2, 23.19% Al_2O_3, 0.45% Fe_2O_3, 0.35% TiO_2, 0.5% CaO, 0.16% MgO, 1.63% Na_2O, 0.57% K_2O), as well as KI quartz glass and L-I leucosapphire, to AD1 aluminum alloy and VT1-0, VT6S and VT16S titanium alloys was made for a determination of the optimum process parameters, welding being done with interlayers of A5 and A7 aluminum alloys or commercially pure aluminum. The surfaces of the pyroceramic and porcelain were finished to a class R_α = 0.08-0.04 μm roughness and the interlayers in the form of platelets or washers were treated with ethanol for degreasing and removal of the oxide surface film, whereupon welding was done under a vacuum of $6 \cdot 10^{-3}$ Pa. Welding specimens were tested in an SD-4 machine for flexural strength at a loading rate of 1 MPa/s. The test results and microstructural examination of fractures indicate that the strength of such joints depends nonmonotonically on the welding pressure P, the welding temperature T, and the length of holding time τ under pressure. Maximum strength of all joints was recorded after welding under a pressure P = 5 MPa (T = 630°C, τ = 20 min), at a temperature T = 620 ± 10°C (P = 5 MPa, τ = 20 min) and for τ = 20-40 min (P = 5 MPa, T = 630°C). Such joints up to 100 mm wide were found to withstand service temperatures up to 500°C. References 6: all Russian.

2415/9835 - END -

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