

# Soviet and Japanese Aerospace Literature

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## Soviet Aerospace Literature This month: Aerospace Alloys and Properties

**A88-23938** Effect of a gas medium and aging temperature on the gas saturation and mechanical properties of VT23 titanium alloy (Vliianie gazovoi sredy i temperatury starenia na gazonasyshchenie i mekhanicheskie svoistva titanovogo splava VT23) A. I. KHOREV, A. T. PICHUGIN, M. N. ZIMA, S. G. BULGAKOVA, and I. S. DERKACH, *Fiziko-Khimicheskaya Mekhanika Materialov* (ISSN 0430-6252), Vol. 23, Nov.-Dec. 1987, pp. 39-42.

Plane specimens (1 mm thick) of VT23 titanium alloy were aged at various temperatures in air, vacuum, and argon to determine the effect of temperature and the gas medium on the gas saturation and mechanical properties of the alloy. It is found that, during aging in the temperature range 673-823 C, gas saturation of the specimens is negligible even in air. It is also found that the effect of the gas medium on the strength characteristics of the alloy is only slight.

**A88-18030** Effect of microalloying by boron on the structure and properties of tungsten (Vliianie mikrolegirovaniia borom na strukturu i svoistva vol'frama) I. O. TOLSTOBROV and K. B. POVAROVA, *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Sept.-Oct. 1987, pp. 121-124.

It is shown experimentally that the microalloying of vacuum-arc-melted tungsten by boron significantly improves its workability and low-temperature ductility, with the cold temperature brittleness of the grain body decreasing by 100-120 C. The characteristics of recrystallization processes in W-B alloys are examined. The formation of secondary borides during strain aging is found to inhibit collective recrystallization processes up to 1900 C.

**A88-18029** Stability of the structure and mechanical properties of rapidly solidified aluminum (O stabil'nosti struktury i mekhanicheskikh svoistv bystrozakristallizovannogo aluminia) O. V. ABRAMOV, B. A. AREF'EV, I. A. GAL'CHENKO, V. V. KULESHOV, V. O. ABRAMOV et al., *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Sept.-Oct. 1987, pp. 117-120. 6 Refs.

The stability of the fine structure and mechanical properties of rapidly solidified AD1 aluminum is investigated experimentally as a function of aging and extrusion temperature. It is shown that compacted rapidly solidified aluminum has a mean subgrain size of 0.5-1 micron when compacted at 20-200 C and 1.5-2 microns when compacted at 300 C. The size of coherent scattering zones is shown to increase following compaction, with a simultaneous decrease of the mechanical characteristics of

the specimens. Recrystallization of the compacted material starts at 200-250 C.

**A88-18026** Physicomechanical properties of W-Re coatings (Fiziko-mekhanicheskie svoistva W-Re-pokrytii) I. V. LAKHOTKIN, M. A. KHUSAINOV, and A. I. KRASOVSKII, *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Sept.-Oct. 1987, pp. 71-75. 11 Refs.

Mechanical test results are presented for W-Re coatings obtained from a mixture of rhenium and tungsten hexafluorides with hydrogen. In the brittle fracture region, the strength of W-Re deposits of varying composition is shown to increase with test temperature and Re content. The brittle transition temperature of W-Re deposits is 300-500 C lower than that of fluoride tungsten. The strengthening of tungsten through heterophase alloying by rhenium is particularly pronounced in the temperature range 800-1400 C and is observed up to 2100 C. The ductility of W-Re coatings strength of coatings up to 0.25 mm thick and their fracture behavior are similar to those of compact materials. However, the structural and phase inhomogeneity and a high level of internal stresses reduce the ductile characteristics of the coatings, resulting in greater brittleness in comparison with compact materials.

**A88-21773** Deformation and strength of VT14 alloy in a complex stressed state (Deformirovanie i prochnost' splava VT14 pri slozhnom napriazhennom sostoianii) A. F. KHAKIMOV, N. M. KUL'CHITSKII, and B. I. KOVAL'CHUK, *Problemy Prochnosti* (ISSN 0556-171X), Nov. 1987, pp. 70-72. 5 Refs.

The mechanical properties of VT14 titanium alloy in a biaxial stressed state are investigated as a function of the structural state of the alloy using experimental data obtained for thin-walled tubular specimens loaded by an axial force and internal pressure. Four groups of specimens, corresponding to four different heat treatment schedules, have been tested. It is found that the heat treatment conditions affect not only the dimensions of a region defined by a limiting curve but also the shape of the curve.

**A88-16010** Densification of metals with increased pressures and temperatures A. F. BELOV and V. V. NIKOLENKO, *IAF, 38th International Astronautical Congress*, Brighton, England, Oct. 10-17, 1987. 4 p. (IAF Paper 87-310).

Hot isostatic pressing (HIP) is applied to cast steels and aluminum, titanium, and nickel-base alloys to eliminate porosity and to improve their structure and mechanical properties. It is shown that the HIP treatment of

steel castings improves their ultimate tensile and yield strengths by up to 30 percent, with a factor of 3 improvement in plastic properties and a factor of 2 improvement in low-cycle fatigue strength. Rotating components which are usually capable of withstanding not more than 20,000 rpm during whirling tests can endure up to 50,000 rpm after HIP treatment. HIP treatment also helps in the healing of weld defects and substantially improves ultrasonic test capability.

**A88-14674** Characteristics of the structure of a P/M nickel-based alloy after stepped aging and creep (Osobennosti struktury granuliromogo splava na nikel'noi osnove posle stupenchatogo starenia i polzuchestii) R. R. ROMANOVA, A. N. UKSUSNIKOV, V. I. EREMENKO, O. KH. FATKULLIN, and A. F. BELOV, *Akademiia Nauk SSSR, Izvestiia, Metallurgii* (ISSN 0568-5303), Sept.-Oct. 1987, pp. 152-157. 16 Refs.

The structure and the dislocation substructure of a nickel-based P/M alloy, EP741, are investigated experimentally after various stepped aging treatments and creep. It is found that, from the earliest stages of creep to fracture, plastic deformation involves the following two mechanisms: cutting of coherent particles by sliding dislocations and bypassing of particles in the sliding plane in accordance with the Orowan mechanism. The large values of time to fracture observed experimentally are due to an increase in the stability of the hardening phase against coagulation at test temperatures resulting from particle size and distribution optimization during stepped aging.

**A88-14642** Effect of sintering conditions on the structure and mechanical properties of aluminum-based P/M alloys (Vliianie uslovii spekania na strukturu i mekhanicheskie svoystva poroshkovykh splavov na osnove aluminia) V. A. BRODOV, A. V. ZHIL'TSOV, I. P. MELASHENKO, and A. B. ALT'MAN, *Poroshkovaia Metallurgii* (ISSN 0032-4795), Sept. 1987, pp. 29-34. 21 Refs.

The shrinkage, structure, and physicomechanical properties of Al-4.4 pct Cu and Al-4.4 pct Cu-0.5 pct Mg P/M alloys are investigated as a function of sintering conditions in the temperature range 595-635 C. It is shown, in particular, that an increase in the holding time at 615 and 635 C leads to increased porosity; sintering of Al-Cu alloys at temperatures above 595 C results in a noticeable coarsening of the structure. Alloying with magnesium has no noticeable effect on the structure of the Al-Cu alloys.

**A87-31947** A method for determining the thermal conductivity of composite materials at high temperatures (Ob odnom metode opredeleniia temperaturoprovodnosti kompozitsionnykh materialov pri vysokikh temperaturakh) V. I. ZISKIN, A. V. CHOBA, V. V. PASICHNYI, and G. A. FROLOV, *Teplofizika Vysokikh Temperatur* (ISSN 0040-3644), Vol. 24, Nov.-Dec. 1986, pp. 1156-1160. 6 Refs.

A method for determining the thermal conductivity of composite materials is proposed which is based on the experimental measurement of the distance covered by the phase transition isotherms of the low-melting component on the surface of a material. Calculations are made of the temperature dependence of the thermal conductivity coefficient of a tungsten-copper pseudoalloy (10 percent Cu) in the temperature range 1000-3000 K. The method can be extended to materials that do not have a low-melting component; in this case, a small amount of such a component can be applied to the surface of the material.

**A88-21907** Physicomechanical properties and fracture of detonation-sprayed coatings (Fiziko-Mekhanicheskie svoystva i razrushenie detonatsionnykh pokrytii) V. K. FEDORENKO, I. U. V. MIL'MAN, V. KH. KADYROV, R. K. IVASHCHENKO, and O. V. IVASHCHENKO, *Poroshkovaia Metallurgii* (ISSN 0032-4795), Nov. 1987, pp. 88-94. 8 Refs.

The effect of structural and phase changes occurring in detonation sprayed coatings on the physicomechanical properties of the coatings is examined with reference to experimental results for detonation-sprayed coatings of Kh20Ni80 nichrome strengthened by WC-Co particles and NKHl nichrome alloyed by aluminum and boron. It is found that the increases monotonically with temperature up to 2000 C, whereas the ductility of tungsten reaches a maximum at 1200 C.

**A88-17725** A study of the behavior of lattice dislocations in grain and phase boundaries during the annealing of a nickel alloy (Issledovanie povedeniia reshetochnykh dislokatsii v granitsakh zeren i faz pri otzhibe nikel'evogo splava) G. N. ALESHIN and R. Z. VALIEV, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), Vol. 64, Aug. 1987, pp. 383-389. 25 Refs.

The stability of lattice dislocations in the boundaries of the grains and phases of ZhS6KP nickel alloy is investigated experimentally by heating thin-foil specimens of the alloy directly in the column of an electron microscope. It is found that the relaxation temperature of boundary-trapped lattice dislocations is the same for any intraphase and interphase boundaries in the alloy. An increase in grain size from 2 to 50 microns leads to an increase in relaxation temperature by about 100 C. In twin and interphase semicoherent boundaries, no dislocation spreading is observed in the temperature range studied (up to 700 C).

**A87-53822** Formation of stable structures in high-alloy nickel-base P/M alloys M. A. SURIKOVA, V. N. PLECHEV, and E. E. NIKOL'SKAIA, *Powder Metallurgy International* (ISSN 0048-5012), Vol. 19, Aug. 1987, pp. 18-21.

Regularities of forming thermally stable structures of nickel-base P/M alloys with 65 Vol. pct or more of the strengthening gamma-prime-phase

have been revealed. The up to 1150 C stable duplex structure with the phase ratio gamma:gamma-prime of roughly 1:1 and a grain size of approximately 1 micron, which is being developed in hot extrusion, allows the superductility effect to be achieved at the subsequent deformation of extruded bars.

**A87-53543** Mechanical properties and structure of rapidly quenched TiCu-TiNi alloys (Mekhanicheskie svoystva i struktura bystrozakalennykh splavov TiCu-TiNi) N. M. MATVEEVA, I. U. K. KOVNERISTYI, L. A. MATLAKHOVA, Z. G. FRIDMAN, and M. A. LOBZOV, *Akademiia Nauk SSSR, Izvestiia, Metallurgii* (ISSN 0568-5303), July-Aug. 1987, pp. 97-100. 7 Refs.

The mechanical properties and structure of rapidly quenched TiCu-TiNi alloys are investigated in the Ni concentration range 5-40 at. pct. It is shown that, depending on the composition, TiCu-TiNi alloys cooled from the molten state at 5 x 10 to the 6th C/s may solidify either as amorphous or crystalline systems. A nickel concentration of 25 at. pct is a limit above which amorphous solidification does not occur. The amorphous alloys have a sufficiently high tensile strength (1000-1800 MPa) and a high hardness; the hardness of the alloys depends only slightly on their composition.

**A88-11406** Laser modification of thermally sprayed coatings (Modifikatsiia gazotermicheskikh pokrytii izlucheniem lazera) A. A. UGLOV, A. D. FOMIN, A. O. NAUMKIN, P. I. U. PEKSHEV, I. U. SMUROV et al. *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), July-Aug. 1987, pp. 78-82.

Experimental results are reported on the modification of thermally sprayed coatings on steels and aluminum alloys using pulsed YAG and CW CO2 lasers. In particular, results obtained for self-fluxing Ni9CrBSi powders, ZrO2 ceramic, and titanium are examined. It is shown that the laser treatment of thermally sprayed coatings significantly improves their physicomechanical properties; it also makes it possible to obtain refractory coatings on low-melting substrates with good coating-substrate adhesion.

**A88-11348** A theoretical and experimental study of the plastic deformation of sintered composites. I - An analysis of the conditions of the simultaneous deformation of heterogeneous composite phases (Teoreticheskoe i eksperimental'noe issledovanie protsessov plasticheskoi deformatsii spechennykh kompozitsionnykh materialov. I - Analiz uslovii sovместnoi deformatsii raznorodnykh faz kompozitsionnogo materiala) S. S. KIPARISOV, I. A. KILANSKII, and V. E. PEREL'MAN, *Poroshkovaia Metallurgii* (ISSN 0032-4795), Aug. 1987, pp. 17-23. 6 Refs.

The conditions of the simultaneous deformation of the heterogeneous phases of a composite material with essentially different strength characteristics are analyzed using the concepts of mechanics. The dependence of the shear stress on the compressive stress is demonstrated, and it is shown that the extent of this dependence is largely determined by the ratio of the strength characteristics of the components of the composite, phase contact area per unit volume, and relative orientation of property discontinuity surfaces and slip planes. The possibility of increasing the shear strength of a composite to that of the harder phase is demonstrated experimentally for Cu-Nb and Al-Nb composites.

**A88-11229** Estimation of thermal stresses and their effect on the properties of titanium-matrix fiber composites (Otsenka termicheskikh napriazhenii i ikh vliianie na svoystva voloknistykh kompozitsionnykh materialov s titanovoi matritsei) A. S. LAVRENKO, V. E. OL'SHANETSKII, and G. I. DUDNIK, *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1987, pp. 60-64. 10 Refs.

Axial thermal stresses in the components of a titanium-matrix composite reinforced by molybdenum fibers are investigated as a function of temperature, with allowance made for the dependence of the yield strength of the matrix alloy on the composite thermal loading rate. It is found that internal stresses have a direct effect on the short-term strength of the composite, whose value is always less than the rule-of-mixtures value at test temperatures below 600 C. It is thought, however, that the presence of thermal stresses is not the factor responsible for composite fracture under cyclic loading.

**A87-47589** Dynamic recrystallization of a magnesium alloy (Dinamicheskaia rekristallizatsiia magnieevogo splava) N. G. ZARIPOV, A. R. VAGAPOV, and R. O. KAIBYSHEV, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), Vol. 63, April 1987, pp. 774-781. 15 Refs.

The dynamic recrystallization of a commercial magnesium alloy, MA14, is investigated experimentally in the temperature range 250-500 C at a deformation rate of 0.0043 per s. It is found that dynamic recrystallization in the alloy studied is characterized by substantial inhomogeneity, correlated with the inhomogeneity of multiple slip. Partially recrystallized MA14 alloy exhibits superplastic behavior when the recrystallized grains make up at least 40 percent of the alloy volume. The highest degree of recrystallization is achieved at 450 C.

**A87-42046** Strength of sintered heterophase TiN-Cr materials at room and high temperatures (Prochnost' spechennykh geterofaznykh materialov TiN-Cr pri komnatnoi i vysokikh temperaturakh) F. F. EGOROV, E. N. IVANOV, O. V. BAKUN, V. P. SMIRNOV, and V. V. ZAMETAILO, *Poroshkovaia Metallurgii* (ISSN 0032-4795), April 1987, pp. 96-100. 7 Refs.

The strength and fracture behavior of sintered TiN-Cr materials at room and high temperatures is investigated as a function of the contents of

the principal components, phase composition, and porosity. It is shown that the temperature dependence of the strength characteristics of the material is nonmonotonic, with a maximum depending on the amount of the binder (high-alloy chromium). The yield strength of the material is largely determined by the binder content, its distribution, and porosity.

**A87-41751** The effect of low-energy ion implantation on the mechanical properties of titanium and iron alloys (Vliianie nizkoenergeticheskoi ionnoi implantatsii na mekhanicheskie svoistva splavov titana i zheleza) V. O. VAL'DNER, V. P. KVIADARAS, G. A. ERMAKOV, V. F. TERENT'EV, N. A. MAKHLIN et al. *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Mar.-Apr. 1987, pp. 18-24. 15 Refs.

The effect of low-energy (5-10 kW) ion implantation on the hardness and strength characteristics of plane specimens of a low-carbon (0.17 pct C) steel and VT1-0 titanium under static and repeated tensile loading is investigated experimentally. The dose dependence of the surface hardness of the steel is characterized by the presence of a saturation region, with the highest increase in hardness observed in the range (1-4)  $\times 10$  to the 18th ions/sq cm. Surface modification by nitrogen ions increases the fatigue strength of steel and titanium specimens by 23 and 36 percent, respectively.

**A87-41906** Cyclic creep and the effect of vibrations on the inelastic deformation rate in materials (Tsiklicheskaia polzuchest' i vliianie vibratsii na skorost' razvitiia neuprugikh deformatsii v materialakh) T. S. VOZNYI, *Problemy Prochnosti* (ISSN 0556-171X), March 1987, pp. 35-38. 6 Refs.

The effect of high-frequency bending vibrations on the cyclic creep of titanium (TS, OT4-0, and VT14) and aluminum (AK8 alloys) is investigated experimentally under conditions of repeated static tension. For all the materials tested, the superposition of vibration increases the rate of plastic deformation, the increase being almost an order of magnitude in the case of TS alloy. It is found that there exists a linear relationship between the fatigue life and the cyclic creep rate at the stage of steady-state creep.

**A87-38999** Metal glasses (Stekloobraznye metally) ALEKSEI IAKOVLEVICH BELEN'KII, *Priroda* (ISSN 0032-874X), Feb. 1987, pp. 80-88.

Methods of producing amorphous alloys of various systems (e.g., Pd-Si, Fe-B, Ni-P, Ni-Nb, Ni-Ta, Co-Gd, Fe-Gd, Mg-Zn, and Ca-Al) are briefly discussed, and the atomic structure and properties of such alloys are examined. In particular, attention is given to anomalies in the low-temperature behavior of amorphous alloys, their electrical and magnetic properties, strength, ductility, and corrosion stability. Some applications of metal glasses are mentioned.

**A87-36111** Properties of porous tungsten-copper and molybdenum-copper pseudoalloys (Svoistva poristykh vol'fram-mednykh i moliбdenovnykh psevdosplavov) A. V. EGOROV, A. G. KOSTORNOV, V. A. KOSHELEV, G. N. MELNIKOVA, A. V. PUSTOGAROV et al. *Poroshkovaia Metallurgii* (ISSN 0032-4795), Feb. 1987, pp. 47-50. 6 Refs.

Experimental data are presented on the viscous and inertial coefficients of hydraulic resistance, heat conductivity, and heat transfer coefficients of W-Cu and Mo-Cu pseudoalloys (15-36.8 pct Cu) in the porosity range 0.49-0.84. The experimental data support the extremal nature of the dependence of the heat transfer coefficient on porosity, with a maximum at 0.45-0.50. It is shown that Koh's empirical relationship for porous metals can be used to calculate the heat conductivity of pseudoalloys.

**A88-11228** Effect of heat treatment on the mechanical properties and fracture characteristics of sheet molybdenum alloys (Vliianie termicheskoi obrabotki na mekhanicheskie svoistva i kharakter razrusheniia listovykh moliбdenovykh splavov) V. V. BUKHANOVSKII, N. G. KARTYSHOV, E. P. POLISHCHUK, V. K. KHARCHENKO, and M. I. CHIKUNOV, *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1987, pp. 53-57. 11 Refs.

Experimental data are presented on the effect of the temperature of annealing (1223-2273 K) on the grain size, mechanical properties, and cold brittleness threshold of rolled sheets of TsM-6 and TsM-10 molybdenum alloys. It is found that an increase in annealing temperature is accompanied by a monotonic decrease in yield strength, this effect being particularly pronounced at the annealing temperature corresponding to the temperature region of primary recrystallization. It is also found that the ductility of molybdenum alloys is strongly affected by oxygen and carbon redistribution between the bulk of the grain and grain boundaries.

**A88-11227** Creep behavior of a coated niobium alloy under stepped changes in stress and temperature (Polzuchest' niobievogo splava s pokrytiem pri stupenchatom izmenenii napriazheniia i temperatury) I. U. A. EREMIN, L. V. KAIDALOVA, P. B. KUZNETSOV, and O. V. TSYGULEV, *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1987, pp. 50-53. 7 Refs.

Plane specimens of a niobium alloy, with and without a thermally sprayed protective coating, were tested in creep at three levels of stress (30, 40, and 50 MPa) and temperature (900, 1150, and 1400 C). The rheological behavior of the specimens is analyzed by representing creep strains in the form of a sum of components each of which is described by a system of finite and ordinary differential equations. The equations are shown to provide an adequate description of the experimentally observed creep behavior of the alloy.

**A87-51120** Anisotropy of the structure and mechanical properties of low-alloy tungsten (Anizotropiia struktury i mekhanicheskikh svoistv malolegirovannogo vol'frama) I. U. N. PODREZOV, O. G. RADCHENKO, N. G. DANILENKO, V. V. SKOROKHOV, V. V. PANICHKINA et al. *Poroshkovaia Metallurgii* (ISSN 0032-4795), July 1987, pp. 78-84. 10 Refs.

The relationship between the structure and mechanical properties of a tungsten alloy with rhenium (2 pct) and a tungsten alloy with additions of yttrium and hafnium oxides is investigated experimentally. In particular, attention is given to the effect of anisotropy resulting from rolling on the mechanical properties of the alloys in three mutually perpendicular directions. It is shown that the addition of elements increasing the ductility of the grain body improves the mechanical properties of the rolled material in the longitudinal and transverse directions, whereas the addition of oxide particles decreases the susceptibility of the material to delamination.

**A87-46064** Effect of laser diffusion heat treatments on the structure and properties of titanium and its alloys (Vliianie lazernoi khimiko-termicheskoi obrabotki na stroenie i svoistva titana i ego splavov) I. U. M. LAKHTIN, I. A. D. KOGAN, D. P. SHASHKOV, L. A. TEPUOVA, and N. S. IUDINA, *Akademiia Nauk SSSR, Izvestiia, Metall* (ISSN 0568-5303), May-June 1987, pp. 161-166. 8 Refs.

The characteristics of the formation of a hardened layer on titanium alloys during laser diffusion heat treatments are investigated experimentally using samples of commercial titanium VT1-0, pseudo-alpha alloys AT-3 and AT-6, and an alpha-beta alloy, VT-22. It is shown that a maximum increase in the hardness of alpha and alpha-beta titanium alloys, without a substantial loss of ductility, is produced by laser carbosilicizing and carboboriding. These treatments also increase the high-temperature (500 C) strength of titanium and its alloys, which is explained by the formation of a complexly alloyed alpha-prime solid solution strengthened by borides or silicides.

**A87-47427** Effect of chromium content on the friction properties of titanium-chromium alloys (Vliianie soderzhanii khroma na triboekhnicheskie svoistva titano-khromovykh splavov) A. M. PETROVA and V. V. POLOTAI, *Poroshkovaia Metallurgii* (ISSN 0032-4795), May 1987, pp. 51-56. 8 Refs.

An experimental study is made of the mechanical properties and wear resistance of Ti-Cr powder metallurgy alloys containing 10-35 percent Cr. It is shown that an optimum combination of mechanical properties is obtained in alloys containing 15-20 percent Cr. The wear resistance of the alloys increases with the amount of chromium in the titanium matrix due to the formation of TiCr<sub>2</sub> intermetallic and oxide films, which act as solid lubricants under friction.

**A88-21770** Effect of elevated temperatures on the deformation and fracture resistance of AK4-1 alloy under plane stress conditions (Vliianie povyshennykh temperatur na soprotivlenie deformirovaniu i razrusheniiu splava AK4-1 v usloviakh ploskogo napriazhennogo sostoiianiia) A. A. LEBEDEV, B. I. KOVAL'CHUK, N. M. KUL'CHITSKII, and A. F. KHAKIMOV, *Problemy Prochnosti* (ISSN 0556-171X), Nov. 1987, pp. 47-50.

The effect of elevated temperatures (20-350 C) on the deformation resistance, yield, and strength characteristics of AK4-1 aluminum alloy is investigated experimentally under conditions of uniaxial and complex stressed state. As temperature increases, the regular limiting surfaces of the alloy corresponding to the deformation criterion are found to transform to singular surfaces corresponding to the maximum tangential stress criterion. It is also found that the anisotropy of the strength characteristics of the material decreases with increasing temperature.

**A88-19597** An approach to the estimation of the cyclic creep characteristics of materials under multifactor loading (Ob odnom podkhode k otsenke kharakteristik tsiklicheskoii polzuchestii materiala pri mnogofaktornom nagruzhenii) A. N. BADAIEV, M. V. BAUMSHTEIN, and V. D. MAN'KO, *Problemy Prochnosti* (ISSN 0556-171X), Oct. 1987, pp. 35-39. 7 Refs.

A complex phenomenological approach involving the use of experimental design techniques is proposed for estimating the performance of materials under conditions of multifactor loading. With reference to results obtained for EI826 alloy, it is shown that the principle of superposition of static and cyclic loading can be used in the case of cyclic creep under conditions of high-temperature multifactor loading. The limiting state of materials under conditions of high-temperature multifactor loading can be determined by using functional relations and equivalent stresses.

**A87-35861** The effect of oxygen and nitrogen impurities on the mechanical properties and low-cycle fatigue of VT1-0 and PT-3V alloys (Vliianie primesei kisloroda i azota na mekhanicheskie svoistva i malotsiklovuiu ustalost' splavov VT1-0 i PT-3V) A. A. TRUFANOV, V. I. A. GONCHAROV, V. P. RUDENKO, V. I. MIKHAILOV, V. A. SHER et al. *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 23, Jan.-Feb. 1987, pp. 32-35. 8 Refs.

An experimental study is made of the effect of oxygen (0.13-0.45 wt pct) and nitrogen (0.04-0.45 wt pct) impurities on the mechanical properties and low-cycle fatigue behavior of the alpha titanium alloy VT1-0 and the pseudo-alpha alloy PT-3V in air and a 3.0-percent NaCl solution at room temperature. The tensile strength of VT1-0 alloy is found to increase by 32 percent as its oxygen content increases to 0.45 pct; the ductility and the

impact toughness of the alloy decrease. The effect of nitrogen is similar to that of oxygen. In the case of PT-3V alloy, the tensile strength remains practically constant in the oxygen concentration range 0.17-0.23 pct, and ductile properties remain stable over the full concentration range. The impact toughness of the alloy, however, decreases by 65 percent. In both alloys, an increase in oxygen and nitrogen contents produces a decrease in low-cycle fatigue life.

**A87-34347 Crystalline structure of a welded joint in VT23 titanium alloy (Kristallicheskaia struktura svarnogo soedineniia splava titana VT23)** A. A. BABAREKO, I. V. EGIZ, and M. A. KHOREV, *Akademiia Nauk SSSR, Izvestiia, Metallogy* (ISSN 0568-5303), Jan.-Feb. 1987, pp. 100-106. 5 Refs.

The welding of plates and sheets of VT23 titanium alloy leads to the formation of strong phase inhomogeneity in the welds which cannot be readily removed through heat treatment. It is shown here that an optimal structural equilibrium is achieved after a hardening treatment from 800 C followed by aging at 450 C for 10 hr. The resulting structural state is characterized by a high level of the ultimate tensile strength combined with satisfactory ductility in the weld zone; the strength of the weld metal is equal to that of the base alloy.

**A87-31966 Structure and mechanical properties of specimens of Ni3Al intermetallic synthesized from a mixture of powders (Struktura i mekhanicheskie svoistva obraztsov intermetallida Ni3Al, sintezirovannogo iz smesi poroshkov)** O. A. KASHIN, E. F. DUDAREV, V. I. ITIN, E. G. FEDOROVA, A. R. GAFAROV et al. *Poroshkovaia Metallurgii* (ISSN 0032-4795), Jan. 1987, pp. 71-74. 6 Refs.

A study is made of the structure and mechanical properties of Ni3Al intermetallic produced from a mixture of Ni and Al powders (3:1) by combustion synthesis followed by the compaction of the exothermally heated product. Results of X-ray diffraction analysis and electron probe microanalysis show that the compacts consist of Ni3Al intermetallic having an L1(2) structure with a lattice spacing of 0.35646 nm; the structure of the intermetallic does not change after a 1-hr vacuum anneal at 1400 K. The intermetallic product is shown to have good mechanical properties which can be further improved by alloying.

**A88-24799 High-temperature strength of platinum alloys (Russian book) (Zharoprochnost' platinovykh splavov)** EVGENII ISAEVICH PYTVIN, *Moscow, Izdatel'stvo Metallurgii*, 1987, 201 pp. 64 Refs.

Data are presented on the solid-solution, substructural, and precipitation hardening mechanisms characteristic of platinum and platinum-based alloys and also on the high-temperature strength of platinum-based laminates and platinum alloys with plasma-sprayed ceramic coatings. Included are data on the high-temperature strength characteristics of binary and multicomponent platinum alloys with Pd, Au, Rh, Ru, and Ir in air and in a silicate melt. The effect of alloying and impurity elements, chemical inhomogeneity, temperature, stress, and high-temperature corrosion on the structure and high-temperature strength of platinum alloys is discussed.

**A88-24781 The space metal: All about titanium (Russian book) (Kosmicheskii metall: Vse o titane)** LEONID BORISOVICH ZUBKOV, *Moscow, Izdatel'stvo Nauka*, 1987, 128 pp. 17 Refs.

The history of the discovery and study of titanium, its occurrence in space and on earth, and its applications are discussed in a popular manner. Attention is given to the physicochemical properties of titanium and titanium alloys, geochemistry and mineralogy of titanium, main titanium deposits, titanium mining and concentration of titanium ores, and titanium alloys. The properties and applications of titanium alloys are discussed with particular reference to titanium-based alloys with aluminum, iron, copper, manganese, molybdenum, chromium, and other metals.

**A88-18048 Structural changes in the deep layers of a material following ion-beam modification and the nature of material hardening (Strukturnye izmeneniia giubinnnykh sloev materiala posle modifikatsii ionnymi puchkami i priroda ego uprochneniia)** A. N. DIDENKO, A. E. LIGACHEV, E. V. KOZLOV, I. B. KURAKIN, and I. P. SHARKEEV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 296, no. 4, 1987, pp. 869-871.

Specimens of pure polycrystalline copper, several alloy steels, and a hard alloy, VK-6, were ion-implanted by 40-keV ions of different elements (e.g., N, C, B, Ti, Al, Mg, W, Re, and Pb). The structure of the specimens was then examined by electron diffraction microscopy, and the specimens were tested mechanically. It is found that the hardening effect of the ion-beam treatment is determined not so much by changes in the thin surface layer as by changes occurring in the deeper layers (up to 150 microns), which are characterized by a more developed dislocation structure.

**A87-50903 Changes in the structure and properties of heterophase tungsten alloys during deformation (Izmenenie struktury i svoistv geterofaznykh splavov vol'frama pri deformatsii)** K. B. POVAROVA, I. O. TOLSTOBROV, and E. K. ZAVARZINA, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 6, 1987, pp. 38-41. 10 Refs.

Changes in the structure and properties of a carbide-strengthened tungsten alloy containing 0.08 pct Zr and 0.02 pct C during tensile deformation in the temperature range 300-1700 C are investigated

experimentally. At about 1000 C, the strain aging processes taking place in the recrystallized alloy lead to an abrupt increase in the Ludwik parameters A and n at the first stage of hardening, with a certain increase in tensile strength. The optimum temperature range of deformation for the alloys studied is 1400-1500 C. At these temperatures, the strength of the alloys and its capacity for strain hardening are low, while its ductility after deformation is high due to a decrease of the effective grain size.

**A87-50901 Effect of iron and silicon impurities on the mechanical properties of an Al-Zn-Mg-Cu alloy (Vlianie primesei zheleza i kremniia na mekhanicheskie svoistva splava sistema Al-Zn-Mg-Cu)** I. N. FRIDLINDER, O. A. NOSKOVA, and N. B. KUZNETSOVA, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 6, 1987, pp. 30-32.

A study is made of the mechanical properties of pressed semifinished products of an Al-Zn-Mg-Cu alloy in which the contents of Fe and Si impurities have been reduced from 0.2 to 0.08 pct and from 0.1 to 0.03 pct, respectively. It is shown that the reduction in Fe and Si contents contributes to a significant increase in ductility and resistance to exfoliation corrosion without a noticeable reduction in strength. The impact toughness of the alloy containing 0.08 pct Fe and 0.03 pct Si is a factor of two higher than that of the alloy containing 0.2 pct Fe and 0.1 pct Si.

**A87-40349 Structural transformations in heat-resistant protective coatings on nickel alloys (Strukturnye prevrashcheniia v zharostoikiikh zashchitnykh pokrytiakh na nikelovykh splavakh)** I. G. VEKSLER, V. P. LESNIKOVA, S. I. A. PALEEVA, E. G. LESNIKOVA, and G. F. MIAL'NITSKA, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 4, 1987, pp. 45-50. 9 Refs.

A study is made of the structural and phase transformations occurring in fused slurry aluminosilicide coatings (Al-Si and Al-Nb-Si) and in an electron-beam-deposited Co-Cr-Al-Y coating on EP-539 alloy during high-temperature and corrosion testing and during service. A model is developed which describes the disintegration of these coatings resulting from structural changes due to high-temperature gas corrosion. The role of the martensitic transformation of the beta phase (NiAl) in the deterioration of aluminosilicide coatings is examined.

**A87-40348 Mechanical properties of structural materials under static and dynamic loading (Mekhanicheskie svoistva konstruktsionnykh materialov pri staticheskom i dinamicheskom nagruzhении)** N. N. POPOV, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 4, 1987, pp. 8-10. 6 Refs.

Experimental data are presented on the strength and deformation characteristics of Si3, 20, 45, and 30KhGSA steels and AMts and VT14 alloys. Test results in the strain rate range 0.01-300 per s indicate that the strain rate has a noticeable effect on the strength characteristics of the materials studied (except 30KhGSA steel); the effect of the strain rate on the deformation characteristics of these materials is less pronounced. The results of the study can be useful in developing metal working processes and in designing structures subjected to dynamic loading.

**A87-36074 Structure and properties of cast alloys of the system Mg-Li-Zn (Struktura i svoistva litykh splavov sistema Mg-Li-Zn)** L. V. NIKULIN, S. B. SHEVRIKUKO, and E. V. BELOZEROVA, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 3, 1987, pp. 53-56. 5 Refs.

The structure and strength characteristics of cast Mg-14 pct Li-(1-10) pct Zn alloys are investigated experimentally using specimens produced by permanent-mold casting, specimens solidified under pressure, and die-cast specimens. The hardening mechanisms associated with each casting process are examined. It is shown that the stability of the properties of the ternary alloys is determined not only by their composition but also by the casting process used. Thus, in the case of solidification under pressure, all the alloys investigated have stable properties.

**A87-34361 Structure and properties of the zone adjacent to the weld in titanium high alloys (Struktura i svoistva metalla okoloshovnoi zony svarnykh soedinenii iz vysokolegirovannykh splavov titana)** V. N. MESHCHERIAKOV, I. G. KIRILLOV, and I. V. LIASOTSKII, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 2, 1987, pp. 57-59.

The structure and properties of the zone adjacent to the weld in VT22 and VT23 titanium alloys are investigated experimentally as a function of the weld cooling rate (0.6-600 K/s). An analysis of experimental results shows that, in titanium alloys of martensitic and transition classes, an optimal combination of strength and ductile properties is achieved at low or high weld cooling rates. Since these cooling rates are either impossible or impractical, the mechanical properties of the zone adjacent to the weld in titanium high alloys can be best improved through heat treatment.

**A87-34360 A study of the fracture surface of embrittled VT5 alloy (Issledovanie poverkhnosti razrusheniia okhrupchennogo splava VT5)** B. S. ERMAKOV, N. N. REVIKINA, S. V. MARUSHIN, G. G. KOLCHIN, and A. Z. KEVESH, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), no. 2, 1987, pp. 55-57. 6 Refs.

The fracture surfaces and the surface layers of VT5 titanium alloy (Ti - 5 pct Al) are examined following long-term strength tests in ductile and brittle conditions with a view to determining the factors responsible for the embrittlement of the alloy. In both ductile and brittle conditions, the alloy is



characterized by grain boundary fracture occurring along carbide and carbonitride inclusions and aluminum-rich zones. The embrittlement of VT5 alloy is attributed to aluminum redistribution within the grains during

heat and thermomechanical treatments, which leads to the formation of clusters of a solid solution based on  $Ti(x)Al$  (where  $x$  is equal to or less than 1); the number of the clusters depends on the aluminum content of the alloy.

## Japanese Aerospace Literature This month: *Structural Mechanics*

**A88-24553 Post-buckling behavior of centrally cracked plates under tension** TAKASHI FUJIMOTO and SEINOSUKE SUMI, *JSME International Journal* (ISSN 0913-185X), Vol. 30, Nov. 1987, pp. 1714-1723. 23 Refs.

The postbuckling behavior of centrally cracked rectangular plates subjected to uniaxial tension is analyzed using the FEM, taking into account both geometrical and material nonlinearities. The FEM formulation is based on the total Lagrangian coordinate system and the flow theory of plasticity. The effects of an initial imperfection on buckling deformation are studied in some detail. Postbuckling behavior is discussed in relation to undesirable effects on the fracture of cracked plates. The results of elastic analyses show that the magnitude of the stress-intensity factor increases after buckling. The results of elastic-plastic analyses and experiments show that the residual strength of cracked plates is reduced by the interaction between buckling deformation and plastic deformation at the ends of cracks.

**A88-21216 A basic study of the accuracy estimation of structural analysis by the zooming method - Finite element analysis of the transverse bending of thin flat plates** MASAOKI YOKOYAMA and SHIGERU SASAKI, *JSME International Journal* (ISSN 0913-185X), Vol. 30, Oct. 1987, pp. 1534-1542. 10 Refs.

A finite element analysis of problems related to the transverse bending of thin flat plates has been performed in order to derive an accuracy estimation method for structural analysis using the zooming method. The error characteristics of the bending moment are first obtained for the case of the uniform mesh division of a square plate and a circular plate. An accuracy estimation method is then proposed in which the existence range of the bending moment at a selected point is given as the sum of two errors: the accumulation of relative errors of the gradients on the zooming boundaries, and the relative error of the bending moment at the selected point in the last zooming region. The method is demonstrated by application to 16 problems of various shapes.

**A88-19820 Fatigue fracture toughness and crack propagation rate** YOZO SAWAKI, SHUJI TADA, SHIGEHARU HASHIMOTO, and TADASHI KAWASAKI, *International Journal of Fracture* (ISSN 0376-9429), Vol. 35, Oct. 1987, pp. 125-137. 20 Refs.

The fatigue crack growth rates  $da/dN$ , of two high-strength steels were examined in air at different stress ratios, covering almost the entire range of stress intensity  $\Delta(K)$  from nearly threshold value  $\Delta(K)_{th}$  to final fracture. The fatigue fracture toughness  $\Delta(K)_{fc}$  corresponding to the final fracture in fatigue was also determined. At lower  $\Delta(K)_{fc}$ , higher  $da/dN$  and reduced  $\Delta(K)_{th}$  are found. This correlation was analyzed quantitatively using the four-parameter Weibull function, and the stress-ratio dependency of the fatigue crack propagation curve was accounted for.

**A88-23318 Report of the Institute of Industrial Science - The University of Tokyo** YUTAKA TOI and TADAHIKO KAWAI, *Tokyo, University, Institute of Industrial Science, Report* (ISSN 0040-9006), Vol. 34, No. 1, Sept. 1987, pp. 1-58. 61 Refs.

The rigid bodies-spring models are extended to the discrete limit analysis of general thin-walled structures. The flat rigid plate element is formulated for arbitrarily shaped shell structures. This element consists of triangular rigid plates which are inclined to each other and connected with springs resisting relative displacements. Both geometrical and material nonlinearities are taken into account. The applications to the static and dynamic plastic collapse, the inelastic stability and the crushing problems are described with numerical examples.

**A88-23317 Discrete limit analysis in structural mechanics** YUTAKA TOI and TADAHIKO KAWAI, *Tokyo, University, Institute of Industrial Science, Report* (ISSN 0040-9006), Vol. 33, no. 6, Sept. 1987, pp. 213-274. 42 Refs.

New discrete models, called the rigid bodies-spring models, are described along with their applications to the plastic collapse analysis of solids and structures. For beams, plates, and framed structures, emphasis is placed on the dynamic collapse problems centering around the impulsive collapse, while static as well as dynamic collapse problems are discussed for some of standard shells, such as circular cylindrical and spherical shells. Plastic analysis of two-dimensional solid is also given.

**A88-19199 Probabilistic approach to the certification of fatigue strength of composite structures** TOSHIYUKI SHIMOKAWA, *Japan Society of Materials Science, Journal* (ISSN 0514-5163), Vol. 36, Sept. 1987, pp. 947-953. 11 Refs.

The objective of this study was to investigate the probabilistic certification method for the fatigue strength of composite structures systematically and then to propose the use of the combination of the scatter factor of life and the scatter factor of fatigue strength. The equations

to express the mutual relationship between these two scatter factors and the combination of both factors were derived. Moreover, some calculation examples of the scatter factors were given by using the typical scatter parameters of fatigue life and fatigue strength obtained from the test results of carbon/epoxy laminate specimens. The assumptions made in this study were that: (1) fatigue tests of the composite structures provide an appropriate estimate of the central tendency of fatigue life; (2) the distribution form of fatigue life is the log-normal or two-parameter Weibull distribution; (3) the scatter parameters of fatigue life are known and independent of stress; (4) the shape of the S-N curve is linear on semilogarithmic or double-logarithmic graph paper; and (5) the slope of the S-N curve is known.

**A88-13945 An alternating method for analysis of a group of interacting multiple elliptical cracks in an infinite solid** TOSHIHISA NISHIOKA and YASUFUMI FURUTANI, *JSME International Journal* (ISSN 0913-185X), Vol. 30, Aug. 1987, pp. 1221-1228. 11 Refs.

An efficient alternating method is developed for the analysis of a group of interacting multiple elliptical cracks in an infinite solid. In this alternating method, an analytical solution for an elliptical crack in an infinite solid is used. To save computational time, geometrical symmetries of crack shapes and locations are effectively utilized in conjunction with the symmetry of the analytical solution with respect to the Cartesian coordinate system. Parametric studies on the interaction behavior of multiple coplanar elliptical cracks are made for several examples of problems. The stress intensity factors for those problems are determined efficiently and accurately by the present alternating method.

**A88-13943 Two elastic half-planes bonded through an elastic layer weakened by two identical interface cracks** SHOUETSU ITOU, *JSME International Journal* (ISSN 0913-185X), Vol. 30, Aug. 1987, pp. 1207-1211. 7 Refs.

Stresses around two symmetrically located interface cracks which lie in the composite materials constructed of two elastic half-planes bonded through an elastic layer are examined. To avoid the oscillatory stress singularities near the crack tips, the crack surface displacements are expanded in trigonometrical functions accompanied with the unknown coefficients. A modified version of the Schmidt method is used to determine these coefficients. Numerical calculations are carried out for the stress intensity factors.

**A88-13567 Experimental investigation on interference effect of notch on strength of notched bar with double U-notches of unequal depth and radius** TAMOTSU MAJIMA, HAJIME NAKAZAWA, TAKURO TOBITA, and YOSHIYASU KIMIZUKA, *Japan Society of Materials Science, Journal* (ISSN 0514-5163), Vol. 36, Aug. 1987, pp. 871-877. 6 Refs.

The interference effect of double symmetrical U-shaped notches of unequal notch depth and/or unequal notch radius on the strength was investigated experimentally. The notch pitch range in which the general yield strength is reduced could be predicted by using the upper and lower bound theorems. An X-shaped extension of plastic deformation occurred in the notch pitch range influenced by the interference effect. The notch tensile strength was also reduced by the interference effect, as was the nominal mean stress at the net section at fracture. The magnitude of the reduction of notch strength ratio and notch pitch range due to the interference effect almost equalled that due to the general yield stress ratio. The difference in notch depth has a much stronger influence on the interference effect than the difference in notch radius does.

**A87-50032 Free vibrations of pre-twisted plates (Fundamental Theory)** TSUNEO TSUIJI and TEIYU SUEOKA, *JSME International Journal* (ISSN 0913-185X), Vol. 30, June 1987, pp. 958-962. 7 Refs.

The derivation of fundamental equations needed to investigate the free vibrations of thin pre-twisted plates is presented in this paper. Firstly, the strain-displacement relationships are derived by employing assumptions of the thin shell theory, and their simplified forms are proposed for plates having relatively large length-to-width ratios. Next, the principle of virtual work for the free vibration of the thin pre-twisted plates is formulated. The equation derived will be used to analyze the free vibrations of the thin pre-twisted plates by the Rayleigh-Ritz procedure.

**A87-48074 Dependence of crack acceleration on the dynamic stress-intensity factor in polymers** K. TAKAHASHI and K. ARAKAWA, *Experimental Mechanics* (ISSN 0014-4851), Vol. 27, June 1987, pp. 195-200. MOESC-supported research. 18 Refs.

The caustics method in combination with high-speed photography was employed to study velocity effect on the dynamic-stress-intensity factor of fast cracks in polymethyl methacrylate and in Araldite D. The specimen geometry was so determined that both the accelerating and decelerating crack propagation occurred noticeably in one fracture event. Instantaneous