Soviet and Japanese Aerospace Literature

Throughout 1991 the *AIAA Journal* will carry selected abstracts on leading research topics from the Soviet aerospace literature and, as space permits, from similar Japanese literature. The topics will be chosen and the abstracts reviewed for pertinency by *AIAA Journal* editors. This month features Fracture Mechanics from the USSR and Japan.

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Soviet Aerospace Literature This month: *Fracture Mechanics*

A91-22177 Further results on rectilinear line cracks and inclusions in anisotropic medium. V. V. TVARDOVSKII, *Theoretical and Applied Fracture Mechanics* (ISSN 0167-8442), Vol. 13, July 1990, pp. 193–207. 9 Refs.

The Fredholm integral equations of the second kind are obtained for a system of arbitrarily spaced and oriented cracks and embedded in a two-dimensional infinite anisotropic solid for the first and second fundamental problems. The stress intensity factors K1 and K2 are derived; they are expressed in quadratures from the specified boundary conditions and the corresponding solutions of the integral equations. Numerical calculations are performed for specific crack configurations where the algorithm employed gave high convergence.

A91-19905 A theoretical method of determining the limiting state of a plate with a hole (Teoreticheskii sposob opredeleniia predel'nogo sostoianiia plastiny s otverstiem). N. M. BORODACHEV and IU. I. KAZARINOV, *Problemy Prochnosti* (ISSN 0556-171X), Oct. 1990, pp. 3–7. 11 Refs.

A new approach to the calculation of the limiting state of finite plates weakened by a hole is presented which is based on the combined use of the strength criteria of crack mechanics and continuum mechanics. The method proposed here makes it possible to determine the effective stress at the plate ends corresponding to the fracture of the structural element and the critical size of the limiting stress zone near the hole. Calculations for a plate with a hole are presented as an example. The maximum discrepancy between the experimental data and the calculations does not exceed 9 percent.

A90-19180 Improving the mechanical properties of titanium aluminide (Povyshenie mekhanicheskikh svoistv aliuminida titana). S. M. BARINOV, S. B. MASLENKOV, P. I. ANDRIASHVILI, and N. N. BUROVA, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 309, No. 2, 1989, pp. 344–346. 14 Refs.

The objective of the study was to increase the fracture toughness and strength of TiAl alloys with a view to structural applications. To achieve this, TiAl was alloyed by small amounts of elements that displace the embrittling impurities from the grain boundaries by the competition mechanisms and also by elements that tend to form thermodynamically stable disperse refractory phases. Complex microalloying of TiAl made it possible to increase the fracture toughness of the material to 38-43 MPa sq rt of m; the compressive strength of the alloyed specimens was 1760-200 MPa. Structural changes responsible for the improved mechanical properties of the TiAl alloys are examined.

A91-18300 Discussion on surface crack growth criteria under cycling loading. I. V. VARFOLOMEEV and V. A. VAINSHTOK, *International Journal of Fracture* (ISSN 0376-9429), Vol. 46, Nov. 15, 1990, pp. R25–R33. 17 Refs.

The use of local, averaged, and effective stress intensity factors as criteria characterizing surface crack growth is discussed together with the conditions for transferring the fatigue crack-growth properties from standard specimens to structural components of the same thickness in order to predict the shape of the surface cracks. Plates made of pressure vessel 15Kh2MFA steel are used as standard specimens. The surface cracks, initiated using an electro-spark technique, are monitored during cyclic-loading tests. The surface flaw propagation is studied using a two-dimensional model. The fatigue crack-growth rate is found to vary within the Paris region of the fatigue curve. In predicting the surface-crack shape, the use of the effective stress intensity factor is found to give the best results in comparison with the overestimated or underestimated values obtained using the averaged or the local factors, respectively.

A91-15454 Fracture of a unidirectional ribbon-reinforced composite with an elastoplastic matrix under compression (Razrushenie odnonapravlennogo lentochnogo kompozita s uprugoplasticheskoi matritsei pri szhatii). A. N. GUZ' and DZH. A. MUSAEV, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 26, May 1990, pp. 3–8. 19 Refs.

The stability of unidirectional ribbon-reinforced composites with an elastoplastic matrix is investigated analytically for low filler concentrations using a piecewise homogeneous medium model in the context of a three-dimensional linearized stability theory for deformable bodies at low subcritical deformations. The loss of stability of the structure is used as the fracture criterion. The strength limits of ribbon-reinforced composites are determined under compression along the reinforcement.

A91-13600 Fragmentation of a composite material and fiber breakup under dynamic loading (Fragmentatsiia kompozitsionnogo materiala i droblenie volokon pri dinamicheskom nagruzhenii). V. V. KOBELEV, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 54, July–Aug. 1990, pp. 695–699. 14 Refs.

A relatively simple model is proposed which describes, in qualitative terms, the dynamic fracture of a fiber composite material. The model is based on an analysis of energy and momentum conservation laws during the fragmentation of composites. Expressions are obtained which relate the size of fragments to their shape, deformation rate, density, and new surface formation energy. Model predictions are compared with experimental data for a boron/aluminum composite.

A91-12012 Nonlinear plane elasticity theory and its application to physically and geometrically nonlinear crack mechanics (Nelineinaia ploskaia teoriia uprugosti i ee primenenie k fizicheski i geometricheski nelineinoi mekhanike treshchin). K. F. CHERNYKH, *Uspekhi Mekhaniki - Advances in Mechanics* (ISSN 0137-3722), Vol. 12, No. 4, 1989, pp. 51–75. 11 Refs.

For an elastic potential of a special kind, corresponding to a prestressed material (infinitely linearly elastic), an exact nonlinear elasticity solution is obtained for base boundary value problems, such as a plane with a rectilinear crack and a plane with a linear solid inclusion. The asymptotic behavior of the stresses is determined, as is the configuration of the deformed contour of the crack. The asymptotic form of stresses is also examined for an elastic potential of a more general kind. The exact solutions obtained here are compared with linear elasticity solutions.

A91-11970 Structure, material properties, and fracture specifics of hot-pressed boron carbide ceramics (Struktura, fiziko-mekhanicheskie svoistva i osobennosti razrusheniia goriachepressovannoi keramiki na osnove karbida bora). O. N. GRIGOR'EV, V. V. KOVAL'CHUK, V. V. ZAMETAILO, R. G. TIMCHENKO, D. A. KOTLIAR et al., *Poroshkovaia Metallurgiia* (ISSN 0032-4795), July 1990, pp. 38–43. 12 Refs.

The microstructure, material properties, and break-up specifics of single-phase and heterophase boron-carbide ceramics are studied. B4C-SiC, B4C-TiB2, and B4C-ZrB2, formed during the process of heating under pressure are explained as due to the interactions between boron carbide, oxides, and carbon. Components such as FeB and SiB6 are considered a result of the impurities in the starting mixture. It is shown that single-phase boron carbide ceramics have heterogeneous porous microstructure and low crack resistance and that heterophase ceramics show improved material properties. Two types of fracture have been observed, i.e., transcrystal and intercrystal, and a transition from transcrystal to intercrystal fracture is found to occur at a critical grain-size diameter of approximately 3 microns, irrespective of the single-phase or heterophase condition.

A90-50839 The accuracy of effective characteristics in composite mechanics (O tochnosti effektivnykh kharakteristik v mekhanike kompozitov). B. E. POBEDRIA, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May-June 1990, pp. 408–413. 14 Refs.

The mathematical aspects of composite mechanics are briefly reviewed, and accurate effective characteristics of composite mechanics are defined. Methods of determining the effective characteristics are discussed with particular reference to elastic and linear viscoelastic inhomogeneous media. Formulas are obtained which can be used for determining stresses and strains in composites and for establishing fracture criteria.

A90-50828 An experimental study of the effect of local impact loading on the interlayer strength of composites (Eksperimental'noe issledovanie vliianiia lokal'nogo udarnogo nagruzheniia na mezhsloinuiu prochnost' kompozitov). V. V. BOLOTIN, A. E. EFIMOV, N. S. MEZENTSEV, and V. N. SHCHUGOREV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Jan.-Feb. 1990, pp. 48–51. 10 Refs.

The effect of local impact loading on the specific work of interlayer fracture is investigated in the context of multiparametric fracture mechanics for three composites, a typical glass textolite and unidirectional organic and carbon fiber composites. In particular, the effect of the impactor energy and velocity, load-bearing layer thickness, and matrix layer of the target on the delamination size and the specific work of fracture is determined. The energy used for the fracture and delamination growth is estimated in relation to the full impactor energy.

A90-48262 Fracture of layered composites under surface impact (Razrushenie sloistykh kompozitov pri poverkhnostnom udare). V. V. BOLOTIN, A. A. GRISHKO, and V. N. SHCHUGOREV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.–Apr. 1990, pp. 225–230. 15 Refs.

The fracture of layered composites under surface impact is investigated using a computational experiment, with allowance made for the essential inhomogeneity and nonlinear properties of the composites associated with plastic deformations and microdamage in the composite. Consideration is given to the interaction of deformation waves both with layer boundaries and with free boundaries formed as a result of fracture. The contribution of secondary deformation waves produced as a result of reflection from the layer boundaries and composite cracking is estimated.

A89-52829 Cyclic creep and fracture of TsM-6 and TsM-10 molybdenum alloys at high temperatures (Tsiklicheskaia polzuchest' i razrushenie molibdenovykh splavov TsM-6 i TsM-10 pri vysokikh temperaturakh). V. V. BUKHANOVSKII, V. K. KHARCHENKO, V. S. KRAVCHENKO, E. P. POLISHCHUK, G. N. ALEKSEENKO et al., *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1989, pp. 37–42. 20 Refs.

The cyclic creep and low-cycle fatigue characteristics of rolled sheets of TsM-6 and TsM-10 molybdenum alloys were investigated at 1500 and 1750 C under trapezoidal loading. Empirical expressions are obtained which relate the steady state creep rate to the number of cycles to fracture and maximum cycle stress. It is shown that, for TsM-6 alloy at 1500 and 1750 Cand for TsM-10 at 1500 C, these relations can be adequately described on the basis of experimental data obtained under long-term static loading using concepts of equivalent stresses and the hypothesis of linear damage summation.

A90-48263 Fracture of an obliquely reinforced organic fiber composite under axial loading (Razrushenie kosougol'no armirovannogo organoplastika pri osevom nagruzhenii). IA. A. ANDERSON, V. A. LIMONOV, and V. P. TAMUZH, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.-Apr. 1990, pp. 231–236. 20 Refs.

A model is presented for calculating the strength of a spirally wound composite subjected to axial static or cyclic loading. Based on an analysis of the moment stresses generated after matrix cracking in the layers, a criterion is proposed for delamination. It is shown that the layer-by-layer analysis of fracture with allowance for delamination produces results that are in satisfactory agreement with experimental data.

A90-45083 Stability of reversible cracks (Ob ustoichivosti obratimykh treshchin). V. V. BOLOTIN, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela* (ISSN 0572-3299), May–June 1990, pp. 102–109. 7 Refs.

Reference is made to earlier studies (Bolotin, 1983, 1987) in which a general approach was developed to the mechanics of solids with cracks based on the principle of virtual displacements for mechanical systems with unilateral constraints. This approach is consistent with the concept of irreversible, nonhealing cracks. Here, it is shown how this theory can be expanded to make it applicable to reversible cracks. In the analysis, slow crack evolution and loading processes are treated as a sequence of contiguous states of equilibrium.

A90-27301 Ductile fracture of cylindrical bodies with axial cracks loaded by internal pressure (Viazkoe razrushenie tsilindricheskikh tel s aksial'nymi treshchinami, nagruzhennykh vnutrennim davleniem). A. IA. KRASOVSKII, I. V. ORYNIAK, and V. M. TOROP, *Problemy Prochnosti* (ISSN0556-171X), Feb. 1990, pp. 16–20. 16 Refs.

The paper is concerned with the problem of determining the critical pressure of the ductile fracture of a cylinder with an axial crack. Specific formulas are obtained for a thin-walled shell and thick-walled cylinders. The results obtained are in good agreement with full-scale test data.

A90-23441 Modeling of the fracture of composite bodies by the numerical/analytical potential method (Modelirovanie protsessov razrusheniia sostavnykh tel chislenno-analitiche skim metodom potentsiala). IU. V. VERIUZHSKII, D. R. GIGINEISHVILI, and A. N. SNITKO, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Nov.–Dec. 1989, pp. 1024–1030. 8 Refs.

By using the numerical/analytical potential method, a procedure has been developed for determining the stress-strain state of composite bodies. The interaction between reinforcement rods and a solution based on epoxy resins is investigated with allowance for friction and slip. Crack formation and stress distributions in element contact zones are simulated on a computer for different classes of reinforcement rods.

A90-23440 Delamination-type fracture of composite structures (Razrushenie konstruktsii iz kompozitnykh materialov po tipu rassloenii). A. N. VORONTSOV, G. KH. MURZAKHANOV, and V. N. SHCHUGOREV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Nov.–Dec. 1989, pp. 1007–1023. 81 Refs.

The available literature on the interface fracture mechanics of composite structures is reviewed in a systematic manner. In particular, attention is given to stability problems for compressed elastic elements of composite materials, including rods, plates, and shells with delamination-type defects. Examples of applications of multiparametric fracture mechanics, combined with damage accumulation theory, to the calculation of the stability and endurance of structures with interlayer defects are presented. Equilibrium dimensions and growth kinetics are determined for ellipsoidal delaminations in a spherical shell under cyclic loading.

A90-20403 Three-dimensional nonaxisymmetric stability problems for highly elastic layered composite materials (Prostranstvennye neosesimmetrichnye zadachi teorii ustoichivosti sloistykh vysokoelasticheskikh kompozitnykh materialov). I. A. GUZ', *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Nov. 1989, pp. 26–31. 5 Refs.

The paper is concerned with three-dimensional nonaxisymmetric elasticity problems for highly elastic multilayer composites, consisting of two alternating layers of filler and matrix materials, loaded in uniform biaxial compression. The analysis is based on the extension of the three-dimensional linearized stability theory for deformable bodies in the case of finite subcritical deformations to highly elastic incompressible materials. It is proved that the characteristic equation corresponding to three-dimensional nonaxisymmetric problems reduces to a characteristic equation corresponding to three-dimensional axisymmetric problems. Thus, all the results previously obtained for axisymmetric problems are equally applicable to the nonaxisymmetric problems considered here.

A90-43015 A scheme for the construction of a unified theory of fracture (Skhema postroeniia edinoi teorii razrusheniia). A. G. IVANOV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 310, No. 4, 1990, pp. 866–870. 15 Refs.

A scheme is proposed which makes it possible to define the weight of various strength criteria and to describe strong scale effects as well as the dynamic plasticity peak and the dependence of brittleness on L. This scheme also allows a unified treatment of brittle fractures under static loads and extremely high dynamic loads, as well as of fractures in the deep-plasticity range under high strain rates.

A90-17276 Limiting equilibrium of composite structures with delaminations (Granichna rivnovaga kompozitsiinikh struktur iz rozsharuvanniami). B. L. PELEKH and O. S. MACHUGA, *Akademiia Nauk Ukrains'koi RSR, Dopovidi, Seriia A—Fiziko Matematichni ta Tekhnichni Nauki* (ISSN 0002-3531), Sept. 1989, pp. 55–58. In Ukrainian. 12 Refs.

An approach to the modeling of the limiting equilibrium of composite structures subjected to interphase shear fracture is proposed which is based on the assumption of the limiting of tangential interface stresses by the adhesion strength. The limiting state is described on the basis of a deformation criteria representing a generalization of the delta(k) model. The approach is illustrated for the case of adhesively bonded half-planes of different materials.

A90-17209 Description of the behavior of small fatigue cracks (Opisanie povedeniia malykh ustalostnykh treshchin). S. SAEHN, M. SCHAPER, and P. SELIGER, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 25, Sept.–Oct. 1989, pp. 18–22. 17 Refs.

A fatigue fracture model is proposed which provides a quantitative description of the growth of small surface cracks with allowance for the anomalous material properties in the surface layer. The analytical relations of the model include cyclic fracture toughness characteristics determined by standard methods using specimens with long cracks. This makes it possible to analyze the evolution of small cracks without any special experimental studies.

A90-15557 Catastrophes in the fracture mechanics of composites with cracks (Katastrofy v mekhanike razrusheniia kompozitov s treshchinami). G. P. ZAITSEV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Sept.–Oct. 1989, pp. 840–850. 8 Refs.

A study is made of the potential energy functions of a composite with a crack. The type of catastrophe is determined as a function of the level of composite analysis, type of defect, and loading conditions. It is shown that the potential energy and limiting stress function of composites are described by elementary catastrophes of the fold, crease, and swallowtail types. Some additional characteristics of composite fracture are established using the method of catastrophes.

A90-15556 Structural theory of the long-term strength of reinforced plastics (Strukturnaia teoriia dlitel'noi prochnosti armirovannykh plastikov). A. M. SKUDRA and M. R. GURVICH, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Sept.–Oct. 1989, pp. 833–839. 23 Refs.

Long-term strength criteria for layered reinforced composites are proposed which describe material fracture resulting from matrix fracture, fiber rupture, or fiber-matrix debonding. Based on an analysis of the long-term stress-strain state and possible fracture mechanisms, structural conditions are developed for the long-term strength of unidirectionally reinforced layers. Attention is also given to the effect of the geometry, properties, and volume fraction of the structural components on changes in the strength of the composite with time. The analytical relations obtained here are supported by experimental data for glass, carbon, and boron fiber composites.

A90-14437 A fiber composite fracture model (Model' razrusheniia voloknistogo kompozita). V. V. KOBELEV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 308, No. 2, 1989, pp. 290–294. 9 Refs.

A model describing the deformation of a two-phase fiber composite material is proposed which reduces to the Hedgepeth-Van Dyke model when the stiffness of the matrix is neglected (i.e., k tends to zero). The deformation equations are solved using the Fourier method, and conditions for crack growth within the matrix are defined. Two principal types of cracks that can grow in a brittle two-phase composite are identified.

A90-14392 Fracture mechanics of materials under compression along cracks (Review)—High-elasticity materials (Mekhnika razrusheniia materialov pri szhatii vdol' treshchin /Obzor/—Vysokoelasticheskie materialy). A. N. GUZ' and V. M. NAZARENKO, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Sept. 1989, pp. 3–32. 99 Refs.

Recent studies concerned with fracture mechanics under conditions of compression along cracks are reviewed with emphasis on work based on exact linearized formulations. Results relevant to high-elasticity materials are presented in detail. Attention is given to plane problems under uniaxial and biaxial compression, cracks in infinite material located in one plane, surface cracks parallel to the free boundary, half-spaces with a group of surface cracks, and internal parallel interacting cracks. The use of approximate approaches based on applied beam, plate, and shell theories for the class of problems considered here is discussed.

A90-41443 Quantitative fractography, self-similarity and fractal nature of metal fatigue fracture. V. S. IVANOVA, S. A. KUNAVIN, and A. A. SHANIAVSKII, *Advances in fracture research; Proceedings of the Seventh International Conference on Fracture* (ICF7), Houston, TX, Mar. 20-24, 1989. Vol. 6 (A90-41276 18-39). Oxford, England and Elmsford, NY, Pergamon Press, 1989, pp. 3677–3687. 13 Refs.

An approach to metal fracture analysis is proposed which combines the fracture mechanics approach with synergistic fracture analysis. The approach takes into account bifurcation points that are essential for quantitative fractographic analysis and for the prediction of fatigue striation spacing at bifurcation points. The synergistic analysis of metal fracture demonstrates the fractal nature of fatigue striations.

A90-12392 Relationship between the mechanical and thermophysical characteristics of materials during fracture (Zavisimost' mezhdu mekhanicheskimi i teplofizicheskimi kharakteristikami materialov pri razrushenii). G. N. TRET'IACHENKO and B. S. KARPINOS, *Problemy Prochnosti* (ISSN 0556-171X), Sept. 1989, pp. 22–27. 22 Refs.

Based on thermodynamic principles and dimensionality theory methods, expressions are obtained in relative form for solids which relate the enthalpy and relative volume to the heat of melting and fracture energy under single loading. The relationships provide a satisfactory description of fracture conditions during the melting of various chemical elements, oxides, nitrides, and salts and also during the single loading of various structural materials over a wide temperature range. Results obtained for 1Kh18N9T, 0Kh20N16, and 35KhMA steels and AMg6 and D20 alloys are used as an example.

A90-42913 Fracture criterion for metal specimens with stress raisers based on the mean stress theory (O kriterii razrusheniia metallicheskikh obraztsov s kontsentratorami na osnove teorii srednikh napriazhenii). V. I. IVANIUTENKO, A. A. KRITSUK, A. G. RAFAILOV, V. I. REZNICHENKO, V. S. RUSETSKII et al., *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 26, Feb. 1990, pp. 113–117. 8 Refs.

Results of a study of the tensile strength of statically loaded aluminum alloy specimen with a central hole are reported. The parameters of a fracture model based on the mean stress theory, are determined experimentally and used for the theoretical calculation of the strength of specimens with symmetrical U-shaped notches. A comparison with experimental results shows that this approach yields better results than Neuber's interpolation formulas allowing for the nonlinear deformation of materials in the stress raiser region prior to fracture.

A90-32645 Scale effects in the impact fracture and explosion kinetics of solids and the problem of strongly nonequilibrium process modeling (Masshtabnye effekty v kinetike udarnogo razrusheniia i vzryva tverdykh tel i problema modelirovaniia sil'no neravnovesnykh protsessov). A. S. BALANKIN, A. A. LIUBOMUDROV, and I. T. SEVRIUKOV, *Zhurnal Tekhnicheskoi Fiziki* (ISSN 0044-4642), Vol. 59, Dec. 1989, pp. 102–105. 25 Refs.

Knowledge of the scale effect in impact fracture and explosion kinetics is essential for the adequate modeling of processes developing in solids under impact loading, such as deformation, fracture, thermal explosion, and detonation. It is shown that body dimensions, geometry, and boundary conditions have a noticeable effect on the kinetic phase transitions and the type of the dissipative structures formed. The concept of scale phase transitions is examined.

A90-30448 Fracture of thermal protection coatings of varying structure and thickness (Razrushenie teplozashchitnykh pokrytii razlichnoi konstruktsii i tolshchiny). G. E. BRAILOVSKII, B. A. LIASHENKO, O. V. TSYGULEV, V. V. GRABIN, and N. I. GRECHANIUK, *Problemy Prochnosti* (ISSN 0556-171X), March 1990, pp. 96–102. 8 Refs.

The creep behavior of EI868 alloy at constant temperature and under thermal cycling was investigated as a function of the type of the thermal protection coating. It is shown that the creation of a thermal barrier in the form of a multilayer NiCrAlY composite increases the life of the alloy in both cases of thermal loading. An increase in the thickness of the ceramic layer changes the failure mode of the coating and the material as a whole. Crack formation in the ceramic layer is described quantitatively by an exponential expression.

A89-48908 Numerical modeling of the fracture of multilayer composite shells (Chislennoe modelirovanie protsessov razrusheniia mnogosloinykh obolochek iz kompozitov). A. S. SAKHAROV, A. V. GONDLIAKH, S. L. MEL'NIKOV, and A. N. SNITKO, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May–June 1989, pp. 459–465. 20 Refs.

An approach to the numerical modeling of the fracture behavior of composite shells is developed using a refined deformation model for multilayer shells allowing for the inhomogeneity of transverse shear distribution across the ply stack. The stress-strain state of multilayer shell structures is analyzed using a moment scheme, a version of the finite element method. The strength of the ply materials is estimated on the basis of phenomenological criteria. The physically and geometrically nonlinear problem is solved using an iteration algorithm based on a modified version of the Newton-Kantorovich method.

A89-35464 Microfractographic fracture characteristics of pseudo-alpha titanium alloys in the case of stress corrosion cracking in acid media (Mikrofraktograficheskie osobennosti razrusheniia titanovykh psevdo-alpha-splavov pri korrozionnom rastreskivanii v kislykh sredakh). IA. M. SPAS, I. N. LEVINA, G. V. CHUMALO, and A. A. TRUFANOV, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 25, Jan.–Feb. 1989, pp. 63–67. 13 Refs.

The paper reports the results of a fractographic study of the stress corrosion cracking behavior of several pseudo-alpha titanium alloys, including medium-strength Ti-Al-Ni and Ti-Al-Ni-Zr alloys, high-strength Ti-Al-V-Zr alloys, and commercial low alloys AT3 (medium strength) and AT6 (high strength). It is shown that the additional alloying by zirconium reduces the embrittling effect of acid media. It is also shown that, in acid chloride solutions and hydrogenating media, the embrittling effect of hydrogen is more pronounced in the case of high-strength alloys contaminated by more than 0.1 mass pct of oxygen.

A89-52844 Nonlinear theory of brittle fracture (K nelineinoi teorii khrupkogo razrusheniia). MR. LE KHAN CHAU, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 307, No. 2, 1989, pp. 321–323. 8 Refs.

A mathematical model is proposed which describes the brittle fracture of a nonlinearly elastic body that does not have any initial cracks. The main idea of the approach is based on the following variational principle: the full energy of an elastic body attains a stationary value only in the equilibrium configuration. The inclusion of discontinuous configurations modeling a body with cracks into the set of all possible configurations makes it possible to apply this principle to the fracture theory. Thus, the development of a mathematical model of a fracturing body is reduced to the specification of its full energy for all possible configurations including the discontinuous ones.

A89-50848 A study of the effect of microcracks on fracture kinetics and shock wave structure in metals (Issledovanie vliianiia mikrotreshchin na kinetiku razrusheniia i strukturu udarnykh voln v metallakh). O. B. NAIMARK and V. V. BELIAEV, *Problemy Prochnosti* (ISSN 0556-171X), July 1989, pp. 46–53. 32 Refs.

The characteristics of formation of stress wave fronts in solids with microcracks are analyzed using a deformation model. It is shown that the splitting of a shock wave into an elastic precursor and a plastic wave is a result of a kinetic transition with respect to a parameter characterizing the microcrack orientation mode. The kinetics of the disperse-microscopic fracture transition is investigated. The relationship between the self-similarity of the fully developed fracture process and the dynamic branch spall effect is discussed.

A89-48905 Microfracture localization in a fiber composite (Lokalizatsiia mikrorazrushenii v voloknistom kompozite). V. S. KRIVOBODROV and G. N. GUBANOVA, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May–June 1989, pp. 437–443. 5 Refs.

A dimensionless microfracture localization parameter is introduced which characterizes the homogeneity of microfracture accumulation within a fiber composite. It is shown that this parameter can be determined experimentally from the data on the acoustic emission of the signal sources and theoretical calculations based on a fracture model. Results obtained for a carbon fiber composite are presented as an example.

A89-42412 Estimation of the fracture of composite plates with openings (Otsenka razrusheniia plastin iz kompozitnykh materialov s otverstiiami). B. D. ANNIN and V. N. MAKSIMENKO, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.–Apr. 1989, pp. 284–290. 10 Refs.

A method is proposed for estimating the ultimate strength of composite materials with free and pin-loaded holes. The approach proposed here is based on the integral equation method and principles of linear fracture mechanics. The advantages of the method are demonstrated by comparing results obtained for several problems with finite element solutions and experimental data.

A90-30394 Modeling of crack formation processes and fracture of multilayer composites—A vector model of a composite material (Modeliuvannia protsesiv trishchinoutvorennia i ruinuvannia bagatosharovikh kompozitsiinikh materialiv—Vektorna model' kompozitsiinogo materialu). M. V. DELIAVS'KII, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 26, Jan.-Feb. 1990, pp. 22–26. 6 Refs.

The fracture mechanism of compressed panels under conditions of creep is determined based on an analysis of test data, and a deformation criterion is proposed. It is shown that prior creep significantly reduces the load-bearing capacity of a panel during subsequent short-term loading. An explanation is presented for the loss of stability of thin-walled panels and rods under creep.

A89-48906 Relation between interphase interaction and fracture surface characteristics of fiber-reinforced thermoplastics (Vzaimosviaz' mezhfaznogo vzaimodeistviia s kharakteristikami poverkhnostei razrusheniia voloknisto-armirovannykh termoplastov). A. I. SVIRIDENOK, A. IA. GRIGOR'EV, V. V. MESHKOV, and T. K. SIROTINA, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May–June 1989, pp. 444–447. 8 Refs.

A method for studying fracture surfaces is proposed which is based on the selective estimation of surface irregularity parameters at different scales. The characteristics of phase interactions are found to correlate with the statistical characteristics of the fracture surface. The correlations established here can be used for determining the structure of materials and for increasing the strength of materials by optimizing the statistical characteristics of fracture surfaces.

A89-42484 Surface effect on the brittle strength of solid bodies (Vliianie poverkhnosti na khrupkuiu prochnost' tverdykh tel). P. K. KHODZHER, *PMTF—Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Mar.–Apr. 1989, pp. 175–179. 12 Refs.

Surface defects have been shown to have a significant effect on the brittle strength of solid specimens. In the present work, the risk factors associated with bulk and surface defects are determined, and the fundamental relationship between their parameters and the size of the body is established. The neutralization of surface defects is also considered.

A89-42411 Effect of the degree of reinforcement on the strength and fracture characteristics of unidirectional fiber composites (Vliianie stepeni armirovaniia na prochnost' i kharakter razrusheniia odnonapravlennykh voloknitov). A. F. ERMOLENKO and V. D. PROTASOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.–Apr. 1989, pp. 276–283. 5 Refs.

A study is made of the possibility of identifying mechanical processes from their acoustic images recorded in a limited frequency range. The approach proposed here is based on the comparison of the spectra in terms of the mean energy and median frequency. Acoustic emission scattering ellipses are plotted for fracture mechanisms of different types. A process identification criterion is proposed.

A89-35664 Evaluation of the fracture toughness of a material based on the deformation diagram (Ob otsenke treshchinostoikosti materiala na osnove diagrammy deformirovaniia). L. P. KHOROSHUN, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Feb. 1989, pp. 59–66. 7 Refs.

A new criterion for evaluating the brittleness and fracture toughness of materials is proposed which is based on a piecewise linear approximation of the deformation diagram. The plane problem of the fracture of a body with a cylindrical cavity under uniform biaxial tension is analyzed as an example. The correlation between the fracture toughness criterion proposed here and the fracture toughness of aluminum alloys and steels is examined.

A89-34087 Structural characteristics and strength of zirconium reinforced by tungsten and molybdenum fibers (Osobennosti struktury i prochnost' tsirkoniia, armirovannogo vol'framovymi i molibdenovymi voloknami). L. R. VISHNIAKOV, V. P. MOROZ, V. A. PISARENKO, A. B. SAMELIUK, *Poroshkovaia Metallurgiia* (ISSN 0032-4795), Feb. 1989, pp. 76–79. 10 Refs.

A study is made of the structure and fracture characteristics of a zirconium-matrix composite reinforced by 80-100-micron-diameter tungsten and molybdenum fibers (volume fraction, 25-30 percent). It is shown that, at high temperatures (950 C), the composite retains its high strength despite the interaction between fibers and the matrix. The high strength and ductility of the composite makes it an attractive structural material.

Japanese Aerospace Literature This month: *Fracture Mechanics*

A90-46059 A method of fatigue life prediction for composite materials - In case of prediction based on the extension mode. MASARU ZAKO, TETSUYA TSUJIKAMI, and HIROYUKI YOSHIZAWA, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, June 1990, pp. 701–705.

A technique for predicting the fatigue life of laminated composites is developed on the basis of linear fracture mechanics and evaluated experimentally by means of cyclic tests on (+/-30)s, (+/-45)s, and (+/-60)s CFRP plates. The derivation of the governing equations is outlined, and the theoretical predictions are compared with measurement data in extensive tables and graphs. Good general agreement is demonstrated in most cases, and it is shown that fatigue life depends mainly on (1) the ultimate tensile and shear strength of the matrix and (2) the initial crack length (estimated from data on the size of voids and defects). Poor prediction accuracy is obtained in the case of the (+/-30)s laminates in the long-life regime, where fracture involves a combination of shear and tensile modes.

A90-33684 Stress intensity factor analysis by combination of boundary element and finite element methods. N. MIYAZAKI, T. IKEDA, and T. MUNAKATA, *Engineering Fracture Mechanics* (ISSN 0013-7944), Vol. 36, No. 1, 1990, pp. 61–70. 15 Refs.

A version of the boundary element method is proposed for calculating the stress intensity factors of two-dimensional crack problems including mixed mode ones. In this method, finite elements are only allocated around a crack tip, and boundary elements are used to discretize the rest of a structure. The virtual crack extension method is applied to the finite elements to obtain the stress intensity factors, together with the method for the separation of displacement components into mode I and mode II for mixed mode crack problems. The analyses are performed not only for single mode crack problems but also for mixed mode crack problems. It is found that large-sized finite elements around the crack tip can be used for straight crack problems and to select the crack extension value from the wide range of values.