Soviet and Japanese Aerospace Literature

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Soviet Aerospace Literature
This month: *Fracture Mechanics of Composite Materials*

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. 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.

A90-15648 Elastic and thermoelastic characteristics of composites reinforced by unidirectional layered fibers (Uprugie i termouprugiekharakteristiki kompozitov, armirovannykh odnonapravlennymi sloistymi voloknami). S. K. KANAUN and L. T. KUDRIAVTSEVA, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 53, Sept.-Oct. 1989, pp. 798-807. 11 Refs.

The thermoelasticity problem for a medium containing an isolated cylindrically inhomogeneous inclusion is analyzed for the case of constant external stresses and temperatures. The problem is solved using an approach proposed in a previous study (Kanaun and Kudriavtseva, 1986). An efficient computational algorithm is proposed for the case of cylindrically layered fibers. The interaction between the fibers in the composite is described using the effective (self-consistent) field method. Tensors of the effective elastic moduli and linear expansion coefficients are obtained for composites reinforced by cylindrically layered fibers. Formulas are presented for estimating microstress concentrations at the fibers.

A89-51026 Consideration of the effectof a free boundary on the stability of a periodic series of fibers in a semiinfinite elastic matrix (Vrakhuvannia vplivu vil'noi granitsi na stiikist' periodichnogo riadu volokon u pruzhnii napivneskinchennii matritsi). IU. M. LAPUSTA, *Akademiia Nauk Ukrains'koi RSR, Dopovidi, Seriia—A Fiziko-Matematichni ta Tekhnichni Nauki* (ISSN 0002-3531), May 1989, pp. 34-37. 8 Refs.

A method is proposed for solving the problem of stability loss of an infinite series of fibers in a semiinfinite matrix with allowance for the effect of the free boundary under compression in the fiber direction. The analysis uses three-dimensional linearized equations and a piecewise homogeneous medium model for nonlinearly elastic transversally isotropic incompressible matrix materials and fibers in the context of the theory of highly elastic subcritical deformations.

A90-15564 Fracture mechanics of materials under compression along cracks (Review) -Structural materials (Mekhanika razrusheniia materialov pri szhatii vdol' treshchin /Obzor/ -Konstruktsionnye materialy). A. N. GUZ' and V. M. NAZARENKO, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Oct. 1989, pp. 3-19.

Results of recent research related to the fracture mechanics of materials under compression along macrocracks are reviewed. The results reviewed here have been obtained using exact linearized formulations for a wide range of common composite and plastic materials; a comparison is made with the results obtained using approximate approaches. In particular, attention is given to cracks in a single plane in an infinite composite; surface delaminations in composites under compression along surface macrocracks; layered composites with isotropic layers; composites stochastically reinforced by short ellipsoidal fibers; and the compression of a composite along periodic parallel dilaminations.

A90-15558 Phenomenological and structural approaches in the fracture mechanics of fiber composites (Fenomenologicheskii i strukturnyi podkhody v mekhanike razrusheniia voloknistykh kompozitov). IU. V. SUVOROVA and V. S. DOBRYNIN, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Sept.-Oct. 1989, pp. 861-868. 22 Refs.

A method for modeling damage accumulation in polymer-matrix fiber composites is proposed which uses a combination of the structural and phenomenological approaches. By using this method, the possible changes in the fracture mechanisms of carbon fiber composites due to changes in the loading rate are determined. It is found that the transition from fracture related to gradual damage accumulation to fracture resulting from the propagation of a macrocrack is due to changes in load redistribution within the material structure. The applicability limits of phenomenological models of the hereditary type describing the deformation and fracture of composites are defined.

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.

A90-18085 Modes of failure of materials under the dynamic loading. IU. V. SUVOROVA, *Journal de Physique (Colloque C3), Supplement* (ISSN 0449-1947), Vol. 49, Sept. 1988, pp. C3-295 to C3-299.

A model to evaluate the failure mechanisms of materials under various loading rates is proposed. The dependence of strength on loading rate is experimentally shown to be nonmonotonic, the phenomenon described by the model. The limits to applying phenomenological equations for each of the mechanisms are also indicated.

A90-15556 Structuraltheory 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.

Longterm 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.

A90-15553 Problems in the mechanics of composite materials with curved structures—A model of a piecewise homogeneous medium (Problemy mekhaniki kompozitnykh materialov s iskrivlennymi strukturami—Model' kusochno-odnorodnoi sredy). A. N. GUZ' and S. D. AKBAROV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Sept.-Oct. 1989, pp. 788-798. 24 Refs.

Approaches using a piecewise homogeneous medium model and three-dimensional equations of deformable body mechanics in the mechanics of composites with curved structures are examined. Specific numerical results are presented which characterize the effect of the curvature of the reinforcement elements on stress distribution in such composites.

A90-15551 Anisotropy of the viscoelastic properties of layered metallorganic composites (Anizotropiia viazkouprugikh svoistv sloistykh metalloorganoplastikov). G. M. MAGOMEDOV, Z. R. RADZHABOV, G. P. MASHINSKAIA, and A. B. AIVAZOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Sept.-Oct. 1989, pp. 771-775.

Theanisotropy of the viscoelastic properties of layered metallorganic composites was investigated by the torsional vibration method. It is found that, under torsional bending, the outer layers of the composite are responsible for the main contribution to the formation of the viscoelastic properties. It is further found that the anisotropy of composite properties increases with the transition of the polymer matrix from the glassy state to the viscoelastic state as a result of an abrupt decrease in the contribution of the matrix to the formation of composite properties. The results obtained also provide evidence for the anisotropy of the mechanical glass transition temperature of the polymer matrix due to changes in the component contributions to the formation of composite properties associated with a change in the angle between the specimen and reinforcement axes.

A89-54658 Exact solution for a twophase composite of stochastic structure in the plane elasticity problem (Tochnoe reshenie dlia dvukhfaznogo kompozita stokhasticheskoi struktury v ploskoi zadache teorii uprugosti). A. A. KUPRIENKO, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela* (ISSN 0572-3299), July-Aug. 1989, pp. 73-78. 18 Refs.

The effective elasticity moduli of a twophase composite of stochastic structure are determined for the case of statistical equivalence of phase distribution in the isotropy plane. Solutions to the plane elasticity problem are presented for isotropic phases and for three constants of a composite formed by transversally isotropic components. Cases in which self-consistent solutions coincide with the exact solutions are examined.

A89-54587 A version of the linear theory of composite shells allowing for transverse shear and reduction (Variant lineinoi teorii kompozitnykh obolochek, uchityvaiushchii deformatsii poperechnogo sdviga i obzhatie). V. K. IVANOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), July-Aug. 1989, pp. 682-687. 7 Refs.

A version of the linear theory of composite shells is presented which includes transverse shear, crosssectional reduction, and nonlinear displacement distribution over the shell thickness. Equilibrium equations in forces and moments are supplemented by equations eliminating the discrepancy between transverse stresses determined by integrating three-dimensional elasticity equations and Hooke law. The accuracy of the solutions depends on the number of the resolved discrepancies.

A89-49156 Stability of a noncircular cylinder in a matrix in the case of small deformations (Ob ustoichivosti nekrugovogo tsilindra v matritse pri malykh deformatsiiakh). DZH. A. MUSAEV, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, June 1989, pp. 27-31. 7 Refs.

The stability of a noncircular cylinder in a matrix is analyzed for the case of small subcritical deformations using a model of a piecewise homogeneous medium in the context of a three-dimensional linearized elasticity theory. The stability of an elliptical cylinder in an elastic matrix is examined with reference to a specific example.

A89-51020 Integral elasticity equations for a multiply connected region with inclusions (Integral'nye uravneniia teorii uprugosti dlia mnogosviaznoi oblasti s vkliucheniiami). D. IA. BARDZOKAS, V. Z. PARTON, P. S. TEOKARIS, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 53, May-June 1989, pp. 485-495. 23 Refs.

An infinite multiply connected region is considered which contains curvilinear cracks, holes, arbitrary inclusions, and rectilinear reinforcing stringers. A system of equations describing the stressed state of such a composite medium is obtained on the basis of a general formulation. The problem is solved using complex potentials and the theory of singular integral equations.

A89-50852 Deformation and strength of rod structural elements reinforced by a boron/epoxy composite at cryogenic temperatures (Deformirovanie i prochnost' sterzhnevykh elementov konstruktsii, armirovannykh epoksidnym boroplastikom, pri kriogennykh temperaturakh). N. K. KUCHER and M. P. ZEMTSOV, *Kosmicheskaia Nauka i Tekhnika* (ISSN 0321-4508), No. 3, 1988, pp. 9-17. 9 Refs.

The stress-strain state and loadbearing capacity of rod structural elements made of D16T aluminum alloy and reinforced by a unidirectional boron/epoxy composite are investigated at 293 and 77 K. In particular, attention is given to the mechanism by which the stress is transmitted from the metal to the composite and to the effect of cooling on the deformability and strength of the reinforced rod elements. A method for predicting the load bearing capacity of reinforced rods of this type is proposed.

A89-50839 Regular structures with extremal elastic properties (Reguliarnye struktury s ekstremal'nymi uprugimi svoistvami). S. B. VIGDERGAUZ, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela* (ISSN 0572-3299), May-June 1989, pp. 59-65. 11 Refs.

In an earlier study (Gibianskii and Chekaev, 1987), the potential energy of an arbitrary twophase periodic composite has been estimated for extremestiffness media. It has been shown that the estimated potential energy is achieved in laminated matrix composites one of whose phases is absolutely stiff or is absent altogether (a porous material). In the present study, it is found that this solution to the optimization problem is not unique: the same energy is also characteristic of composites with a simpler structure in which second phase inclusions in the form of finite grains are located within an orthogonal lattice.

A89-50838 Fundamental solution of a biperiodic three-dimensional elasticity problem (Fundamental'noe reshenie dvoiakoperiodicheskoi trekhmernoi zadachi teorii uprugosti). A. L. KALAMKAROV, B. A. KUDRIAVTSEV, and V. Z. PARTON, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Tverdogo Tela* (ISSN 0572-3299), May-June 1989, pp. 44-50. 8 Refs.

An exact analytical fundamental solution that is biperiodic with respect to two coordinates is obtained for the three-dimensional elasticity problem. The results of the study can be used in solving biperiodic three-dimensional elasticity problems by the boundary element method and, particularly, local problems associated with the asymptotic analysis of the three-dimensional elasticity problem for a curved thin inhomogeneous (composite) layer with rapidly oscillating thickness and periodic structure. As the period tends to infinity, the solution is reduced to the known Kelvin fundamental solution.

A89-48914 Determination of the elastic characteristics of radially-spirally reinforced carbon/carbon composites (Opredelenie uprugikh kharakteristik uglerod-uglerodnykh kompozitnykh materialov s radial'no-spiral'noi skhemoi armirovaniia). V. V. VASIL'EV and A. N. EGORCHENKOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May-June 1989, pp. 547-549. 6 Refs.

A method for determining the elastic constants of carbon/carbon composites with a three-dimensional radial-spiral structure is proposed which combines the testing of thick-walled cylinders and with the testing of coupons cut from the same cylinders. The method proposed here is supported by test results obtained for composite cylinders under complex loading.

A89-48904 Elasticity and fracture of triorthogonally reinforced media. II-Shear (Uprugost' i razrushenie triortogonal'no armirovannykh sred. II-Sdvig). G. A. VANIN, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), MayJune 1989, pp. 431-436.

A shear theory is proposed for a medium triorthogonally reinforced by bunched filaments, with cracks in filament bunches and at the filament-matrix interface. A method is also developed for correlating experimental data with theoretical shear modulus calculations. It is found that the growth of interface cracks leads to a multiple decrease of the effective elastic moduli.

A89-47953 Calculation of shallow shells of revolution made of fiber composites with an elastoplastic matrix (K raschetu pologikh obolochek vrashcheniia iz KVM s uprugoplasticheskim sviazuiushchim). IA. G. ANTSILEVICH, B. G. MAIOROV, and S. B. CHEREVATSKII, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 1, 1989, pp. 9-12.

The large deformations of a filament-wound shell of revolution are investigated analytically. The analysis allows for the possibility of the plastic deformations and fracture of the matrix and fiber-matrix debonding. A program for solving the problem on a computer is developed, and computation results are presented.

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.

A89-48907 Strength of composites susceptible to edge delamination (Prochnost' plastikov, sklonnykh k kromochnomu rassloeniiu). IU. IU. PEROV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May-June 1989, pp. 448-454. 10 Refs.

Edge stresses in laminated composites are determined in accordance with an approximate theory which uses static equivalents of interlaminar stresses, and good agreement with experimental data is demonstrated. The effect of the self-strengthening of laminates susceptible to edge delamination is investigated. It is shown that the strength of composite laminates can be increased by up to 40 percent through the inversion of the plies. Experimental data are presented on the deformation of the free edge of inverted and noninverted laminates.

A89-48902 Stress-strain state in the matrix of stochastically reinforced composites (Napriazhennodeformirovannoe sostoianie v matritse stokhasticheski armirovannykh kompozitov). B. P. MASLOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), May-June 1989, pp. 396-402. 8 Refs.

A method is proposed for the three-dimensional study ofstress and strain concentrations in the matrix of composites reinforced by spheroidal inclusions. The method is based on the use of tensor operators specified at the inclusion-matrix interface and on the effective modulus theory for stochastically reinforced composites. A glass fiber reinforced composite is examined as an example.

A89-44688 Fracture theory for layered composites with ashear crack (K teorii razrusheniia sloistykh kompozitov s treshchinoi sdviga). V. E. SADYKHOV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 305, No. 6, 1989, pp. 1331-1334.

The Keldysh-Sedov (1950) method is used to solve the problem of stress distribution in the direction of the possible propagation of a boundary shear crack which has ruptured the first layer of a twolayer strip and has penetrated its second layer. An expression for the stress intensity factor is obtained, and the asymptotic form of the stress intensity factor is determined for a crack approaching the free boundary of the twolayer strip. Approximate expressions are also presented for the stress intensity factor at the moment when the crack crosses the interface.

A89-42617 Strength and fatigue life of layered composite materialswith a central crack (Prochnost' i dolgovechnost' sloistykh kompozitnykh materialov s tsentral'noi treshchinoi). V. D. KULIEV, A. B. KAPLUN, and N. E. SADYKHOV, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 25, Mar.Apr. 1989, pp. 23-35. 12 Refs.

The paper is concerned with the fracture behavior of layered composites formed symmetrically with respect to a layer containing a central crack and subjected to static and cyclic loading. A solution is first obtained for the case where the crack surfaces are loaded by a normal stress. The solution is then used to analyze the fatigue fracture of the composite under certain assumptions.

A89-42414 Experimental methods for estimating the edge effect (Eksperimental'nye metody otsenki kromochnogo effekta). V. A. POLIAKOV and IU. IU. PEROV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Mar.-Apr. 1989, pp. 318-331. 43 Refs.

The existing experimental methods for studying effects associated with large stress gradients at the edges of composite materials, such as microdelaminations, edge swelling, and interlaminar crack propagation under tensile loading, are reviewed. The discussion is illustrated by test results obtained for homogeneous and hybrid composites with carbon, organic, and glass fiber reinforcements. The effect of the layup pattern and layer dispersity on the composite strength is examined.

A89-40514 Modification of high-viscosity thermoplastics during the forming of structural composites (Modifitsirovanie vysokoviazkikh termoplastov v protsessakh formirovaniia konstruktsionnykh plastikov). V. A. DOVGIALO, R. S. KROTOVA, V. A. LAPITSKII, and E. V. PISANOVA, *Akademiia Nauk BSSR, Doklady* (ISSN 0002-354X), Vol. 33, April 1989, pp. 347-350. 6 Refs.

The modification of thermally stable thermoplastic matrix materials by thermoset oligomers of similar chemical compositions is investigated as a way of improving the processability of these materials. The mechanisms of the modifying effect of oligomer additives, involving changes in the structure and properties of the polymer matrix, are examined with particular reference to glass fiber composites based on an aromatic polysulfone modified by epoxy sulfone oligomers.

A89-37511 Modeling of the elastoplastic behavior of randomly inhomogeneous composite materials (Modelirovanie uprugoplastricheskogo povedeniia sluchainoneodnorodnykh kompozitnykhmaterialov). M. I. GAI, V. G. OSHMIAN, and L. I. MANEVICH, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 305, No. 1, 1989, pp. 75-78. 11 Refs.

An attempt is made to extend percolation models, whichare successfully used to describe the elastic deformation of real composites, to the region of higher deformations. To expand the class of materials considered, use is made of the deformation theory of plasticity. The model proposed here is shown to provide an adequate description of the general deformation characteristics of randomly inhomogeneous composites under simple loading conditions as well as their transformation with increasing filler content.

A89-37401 Fracture of composites under compression along periodic parallel circular delaminations (Razrushenie kompozitov pri szhatiivdol' periodicheski razmeshchennykh parallel'nykh krugovykh rassloenii). A. N. GUZ', V. M. NAZARENKO, and S. M. NAZARENKO, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, March 1989, pp. 3-10. 35 Refs.

The initial stage of the fracture of composites with a periodic system of parallel macrocracks under conditions of uniform compression along the cracks is investigated using a fracture criterion based on a linearized stability theory for deformable bodies. The composites are modeled by a medium with normalized anisotropic body characteristics. The axisymmetric problem for a composite with normalized characteristics of a transversally isotropic material is analyzed as an example. It is shown that the consideration of the effect of delaminations leads to a significant reduction in critical compression stresses corresponding to the onset of fracture.

A89-35616 A study of the temperature dependence of the strength and fracture characteristics of a thermoplastic-matrix carbon composite (Issledovanie temperaturnoi zavisimosti prochnosti i osobenno-stei razrusheniia ugleplastika s termoplastichnoi matritsei). G. S. GOLOVKIN, V. P. DMITRENKO, V. M. VASILEVSKII, N. A. MALIAVINA, and N. E. IVANOVA, *Problemy Prochnosti* (ISSN 0556-171X), Feb. 1989, pp. 37-42.

The temperature dependence of the axial and transverse tensile and compressive force of a carbon/polycaproamide composite is investigated experimentally in the temperature range 20-423 K. It is found that the temperature dependence of the strength characteristics is largely determined by the stress-strain state in the material and by relaxation processes in the matrix phase. The use of transverse compressive strength data for estimating the shear strength of the composite is suggested.

A89-35489 Analysis of high-modulus cross-reinforced composite shells (Raschet vysokomodul'nykh perekrestno armirovannykh kompozitnykh obolochek). V. Z. PARTON, A. L. KALAMKAROV, and A. G. KOLPAKOV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Jan.-Feb. 1989, pp. 129-135. 10 Refs.

Cross-reinforced composite shells with high-modulus reinforcement fibers are analyzed using a mean shell model developed by using an asymptotic method for averaging periodic structures. Explicit analytical expressions are obtained for the complete set of the effective stiffness moduli of high-modulus reinforced shells with fibers of elliptical and circular cross sections. The deformation behavior of the fibers and the matrix is analyzed at the microscopic level. The effect of matrix fracture in the case of dense fiber packing is examined.

A89-26092 Nonlinear deformation effects in composites with a regular system of fine cracks (Nelineinye effekty deformirovaniia kompozitov s reguliarnoi sistemoi melkikh treshchin). S. A. NAZAROV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Nov.-Dec. 1988, pp. 1052-1059. 11 Refs.

The effect of crack propagation on the tension diagramis examined for the case of a simple isotropic composite with a regular system of cracks. It is shown that allowing for the brittle stable growth of fine cracks leads to nonlinearities in the tension diagram, with a region of hardening observed prior to fracture. For cracks of equal length, quasi-three-dimensional fractureof the material is observed. In accordance with the model proposed here, nonuniformity of the effective elastic characteristics of the composite or effective deformation fields leads to the localization of nonlinearly elastic tension and of the fracture zone.

A89-26053 Ultrasonic shadow method for determining the depth of defects in composite products (Ul'trazvukovoi tenevoi metod opredeleniia glubiny zaleganiia defektov v izdeliiakh iz kompozitov). V. V. IGNAT'EVSKII, IU. G. KUTIURIN, A. I. POTAPOV, D. A. RAPOPORT, and V. V. RIABOV, *Defektoskopiia* (ISSN 0130-3082), No. 12, 1988, pp. 19-23. 6 Refs.

An ultrasonic shadow method for determining the depth of defects in composite products is proposed which is based on measuring the defect transit time between two pairs of transmitters and receivers whose acoustic axes have different angles relative to the surface of the product being tested. An experimental implementation of the method is described, and test results are presented for a hollow cylindrical specimen (internal diameter, 960 mm; length, 800 mm) of a multilayer plastic, with individual layers 0.4-0.8 mm thick and a total wall thickness of 30 mm.

A89-35486 Relationship between the structure, fracture energy, and strength of fiber composites (Sviaz' struktury, energoemkosti razrusheniia i prochnosti voloknistogo kompozita). V. S. KRIVOBODROV and A. M. LEKSOVSKII, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Jan.-Feb. 1989, pp. 29-35. 13 Refs.

The effect of structural characteristics on the strength and fracture mode of fiber composites is investigated analytically using a criterion relating the formation of a main crack to the fracture energy content. Expressions are obtained which relate the critical stresses to the interface shear strength and fiber volume fraction. It is shown that the model proposed here can be generalized to the case of multicomponent reinforcement.

A89-30038 Development of a fracture theory for composites in triaxial and biaxial compression (O postroenii teorii razrusheniia kompozitnykh materialov pri trekhosnom i dvukhosnom szhatii). A. N. GUZ', *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Jan. 1989, pp. 36-43. 11 Refs.

A fracture theory for composites loaded in triaxial and biaxial compression is developed for the case where fracture results from stability loss in the composite structure. The properties of the material are described using the continuum approximation and the principal equations of three-dimensional linearized stability theory for deformable bodies. The analysis is carried out with particular reference to the brittle and ductile fracture of composite materials with polymer and metallic matrices.

A89-27265 A study of damage accumulation in a fiber composite using a numerical experiment (Issledovanie protsessa nakopleniia povrezhdenii v voloknistom kompozite metodom chislennogo eksperimenta). I. N. ZHDANOVA and D. N. KARPINSKII, *Zhurnal Tekhnicheskoi Fiziki* (ISSN 0044-4642), Vol. 58, Nov. 1988, pp. 2266-2269. 6 Refs.

Under loading, fiber composites undergo a long stage of three-dimensional fracture (multiple fiber fractionation), with fiber ruptures leading to structural changes in the matrix whose dimensions are comparable with the distance between fibers. The interaction between damage centers and their effect on damage accumulation in a loaded fiber composite is examined here with reference to a specific example. The analysis allows for the effect of neighboring fiber overloading due to cracks in the matrix caused by fiber rupture.

A89-27397 Modeling of the imperfectly elastic properties of composite materials (Modelirovanie nesovershenno-uprugikh svoistv kompozitnykh materialov). V. G. DUBENETS, *Problemy Prochnosti* (ISSN 0556-171X), Dec. 1988, pp. 81-86.

Governing equations for a quasi-homogeneous composite material are obtained which allow for the microstructure and imperfectly elastic properties of the components. The equations are intended for the mathematical modeling of structures exposed to dynamic loading.

A89-27381 Fracture toughness of carbon-composite structural elements (Treshchinostoikost' ugleplastikovykh elementov konstruktsii). A. E. USHAKOV, *Fiziko-Khimicheskaia Mekhanika Materialov* (ISSN 0430-6252), Vol. 24, Nov.-Dec. 1988, pp. 81-87.

The paper is concerned with some aspects of using linear composite fracture mechanics in analytical and experimental studies of the fracture toughness and residual strength of structural elements made from carbon composites. Particular attention is given to methodological problems associated with the use of a two-parametric model of composite fracture mechanics and equations for determining the critical stress intensity factor with allowance for the variability of composite fracture modes. A comparison is made between analytical and experimental results obtained for carbon plastics with different layup patterns.

A89-21484 Proof of a continuum fracture theory for the compression of metal-matrix layered composites (Obosnovanie kontinual'noi teorii razrusheniia pri szhatii sloistykh kompozitnykh materialov s metallicheskoi matritsei). A. N. GUZ' and I. A. GUZ', *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 24, Nov. 1988, pp. 9-16. 11 Refs.

By using an approach previously proposed for brittle fracture mechanics, a continuum fracture theory under compression is developed for the case of ductile fracture of metal-matrix layered composites. The theory is proved for the plane problem for layered composites consisting of alternating layers of a metal matrix and a filler. The proof is based on results obtained in the context of a piecewise homogeneous medium using a three-dimensional linearized stability theory for elasticplastic bodies under small subcritical deformations.

A89-26262 Strength and defects of composites. A. A. BERLIN, S. L. BAZHENOV, A. M. KUPERMAN, and E. S. ZELENSKII, *Composite materials and structures; Proceedings of the International Conference,* Madras, India, Jan. 6-9, 1988 (A89-26251 09-39). New Delhi, Tata McGrawHill Publishing Co., Ltd., 1988, pp. 121-126. 9 Refs.

The effects of stress concentrators on the strength of composites with elastic and plastic matrices can differ significantly; stress concentration is substantially lower in the case of a plastic matrix than an elastic one. For a given matrix type, the greater the fiber modulus of elasticity, the higher the stress concentration, and the more plastic the matrix must be in order to maintain the level of the material's sensitivity to such defectrelated parameters as fracture energy.

A89-26097 Effect of secondary cracks on the stability and growth of delaminations in composite structures (Vliianie vtorichnykh treshchin na ustoichivost' i rost otsloenii v konstruktsiiakh iz kompozitov). G. KH. MURZAKHANOV and V. N. SHCHUGOREV, *Mekhanika Kompozitnykh Materialov* (ISSN 0203-1272), Nov.-Dec. 1988, pp. 1120-1124. 5 Refs.

Analytical and experimental data are presented on the growth of edge delaminations in composites in the presence of secondary cracks in the delamination region. The stability of the delaminations and secondary cracks is analyzed in the sense of Euler (elastic stability) and Griffith (fracture mechanics). The theoretical treatment is based on multiparametric fracture mechanics models.

A89-35665 Delayed fractureof a block of a viscoelastic composite material with a plane disk-shaped crack (Dlitel'noe razrushenie massiva iz viazkouprugogo kompozitsionnogo materiala s ploskoi krugovoi treshchinoi). A. A. KAMINSKII and S. A. KEKUKH, *Prikladnaia Mekhanika* (ISSN 0032-8243), Vol. 25, Feb. 1989, pp. 66-75. 6 Refs.

The paper is concerned with the slow subcritical growth of a plane disk-shaped macrocrack of the normal tearing type in a block of a composite material consisting of system of mutually orthogonal rectilinear isotropic elastic fibers and an isotropic viscoelastic matrix. Expressions are obtained which determine the safe level of external loads, crack growth kinetics, and the life of the composite block.

A89-21596 Stress-strain state of layered composite shells (Napriazhenno-deformirovannoe sostoianie obolochek iz sloistykh kompozitov). G. M. KULIKOV, *PMTF Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Sept.-Oct. 1988, pp. 157-162. 11 Refs.

A nonlinear version of the theory of multilayer anisotropic shells in which the order of the resolvent system of differential equations depends on the number of layers is developed in arbitrary curvilinear coordinates. Local effects in cross-reinforced cylindrical shells are investigated. The results obtained are compared with results based on linear elasticity theory and two refined theories for Timoshenko shells.

Japanese Aerospace Literature
This month: *Fracture Mechanics of Composite Materials*

A90-18391 Near-threshold transverse fatigue crack growth characteristics of unidirectionally continuous fiber reinforced metals. K. HIRANO, *Proceedings of the 4th Japan-U.S. Conference on Composite Materials,* Washington, DC, June 27-29, 1988, (A90-18351 06-24). Lancaster, PA, Technomic Publishing Co., Inc., 1989, pp. 633-642. Research supported by MITI. 10 Refs.

Transverse fatigue crack growth tests under both Mode I and mixed mode (Mode I, II) loading conditions were conducted on unidirectional continuous SiC (CVD) fiber reinforced 6061 Al alloy matrix composite over a wide range of fatigue crack growth rates covering the threshold stress intensity factor range. The transverse fatigue crack growth characteristics were evaluated on the basis of linear elastic fracture mechanics. The fatigue crack growth mechanism was also investigated based on fractographic examinations. It is found that the transverse fatigue crack growth characteristics were successfully presumed from both that of the matrix metal and fracture toughness.

A90-15721 Thermal shock fracture behaviour of ZrO2 based ceramics. M. ISHITSUKA, T. SATO, T. ENDO, and M. SHIMADA, *Journal of Materials Science* (ISSN 0022-2461), Vol. 24, Nov. 1989, pp. 4057-4061. 17 Refs.

Thermal shock fracture behavior of alumina, mullite, silicon carbide, silicon nitride and various kinds of zirconia-based ceramics, such as magnesia partially stabilized zirconia (Mg-PSZ), yttria and ceria-doped tetragonal zirconia polycrystals (Y-TZP and Ce-TZP), Y-TZP/Al2O3 composites and yttria-doped cubic stabilized zirconia (Y-CSZ), was evaluated by the quenching method using water, methyl alcohol and glycerin as quenching media. Thermal shock fracture of all materials seemed to proceed by the thermal stress due to convective heat transfer accompanied by boiling of the solvents under the present experimental conditions. Thermal shock resistance of zirconia-based ceramics increased with increasing the fracture strength, but that of Y-TZP and Y-TZP/Al2O3 composites was anomalously lower than the predicted value.