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Russian and Japanese Aerospace Literature

During 1997 the *AIAA Journal* will carry selected abstracts on leading research topics from Russian 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 Computational Fluid Mechanics from Russia and Stress–Strain Mechanics from Japan.

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Russian Aerospace Literature
This month: *Computational Fluid Mechanics*

A96-36926 Optimal nozzle profiling for 'Orel-2-1' Transport System; 1996. A. BOROVIKOV (CIAM Research and Development Center, Ltd., Moscow, Russia), V. GAVRILIOUK, A. KHOKHLOV (Computational Aerodynamics Systems Co., Moscow, Russia), A. LANSHIN (CIAM, Moscow, Russia), A. SOBATCHKINE (Moscow State Aviation Inst., Russia), and V. SOKOLOV (NPO 'Molnija', Moscow, Russia), *AIAA, ASME, SAE, and ASEE 32nd Joint Propulsion Conference and Exhibit*, Lake Buena Vista, FL, 1996, p. 10. 10 Refs. Documents available from Aeroplus Dispatch.

The problem of optimal nozzle design for the OREL-2-1 prospective Russian aerospace transport system is considered. The nozzle scheme consists of two contours: the upper one is an airbreathing propulsion engine and the lower one a ramjet. We describe the performance of the propulsion system throughout the flight mission range from subsonic to hypersonic flight velocities. The performance of the OREL-2-1 nozzle is described for the two engine cycles and the influence of ambient flow. The geometry of some parts of the airbreathing and ramjet nozzles are varied during changes of the operational modes and flight conditions. The optimal configuration of the nozzle system is defined by special engineering design methods, with a consequent set of parametric numerical investigations. Jet separation effects are essential for the chosen nozzle scheme, consisting of parts of variable geometry in the throat regions of two engine channels. Losses for different flight and operation condition are presented for the chosen nozzle configuration. (Author)

A96-36489 Two temperature chemical kinetics in gas dynamics; 1996. S. A. LOSEV (Moscow State Univ., Russia), *AIAA 27th Fluid Dynamics Conference*, New Orleans, LA, 1996, p. 12. 48 Refs. Documents available from Aeroplus Dispatch.

The problems of macroscopic description of thermal nonequilibrium reacting gas are considered. The vibrational temperature concept for real gas under these conditions is justified using results of collision dynamics numerical solutions. The complex of the developed models for nonequilibrium factor to simulate two-temperature dissociation and chemical exchange reactions is analyzed. Supersonic cooling flows, combustion and laser or microwave energy added gas are two-temperature chemical kinetics application areas distinct from frequently discussed strong shock waves. (Author)

A96-36458 The mathematical basis for description of the disturbances in interacting boundary layers; 1996. E. TERENT'EV (Russian Academy of Sciences, Computing Center, Moscow, Russia), *AIAA 27th Fluid Dynamics Conference*, New Orleans, LA, 1996, p. 13. 24 Refs. Documents available from Aeroplus Dispatch.

The disturbances in a two-dimensional boundary layer under high Reynolds number are considered. For mathematical description, the triple deck theory is used. In the framework of this theory, the classical stability problem is considered. A full investigation of the dispersion relation was made. It involves putting in order all roots, finding all branching points of the roots, and describing the topology of roots. These results were used for solving three problems: the start of harmonic vibrator, periodic blowing and suction, and development of initial vorticity in a boundary layer. For these problems, all the saddle points of the first (unstable) root of the dispersion relation were determined, and families of saddle points for the function ϕ, describing the disturbance growth rate, were studied. It is shown that, for describing wave pockets, we need only two families of these points. (Author)

A96-36457 Shock waves/turbulent boundary-layer interactions—Fundamental studies and applications; 1996. A. A. ZHELTOVODOV (Russian Academy of Sciences, Inst. of Theoretical and Applied Mechanics, Novosibirsk, Russia), *AIAA 27th Fluid Dynamics Conference*, New Orleans, LA, 1996, p. 28. 105 Refs. Documents available from Aeroplus Dispatch.

The paper presents a review of the results of researches of two- and three-dimensional shock wave/turbulent boundary-layer interactions. Collaborative experimental and theoretical (computational) investigations of simplified test models, such as compression corners, forward- and backward-facing steps, cavities, swept compression corners, one and two fins mounted on a flat plate, are considered. Specific stages of two-dimensional and three-dimensional separation development are analyzed in the vicinity of normal and oblique shock waves. Incipient separation criterions are specified on the basis of experimental studies and classical free interaction theory. Solutions of the Reynolds-averaged Navier–Stokes equations, incorporating algebraic Baldwin-Lomax turbulence model, two-equation Wilcox k-ϵ model, Jones-Launder k-ϵ model and its modifications, proposed by Rodi, Chien and Knight, as well as the full Reynolds Stress Equation (RSE) model developed by Knight are compared with experimental data for various test configurations. (Author)

A96-33833 Flow correction in multidimensional hyperbolic and parabolic problems (Korrektsiya potokov v mnogomernykh zadachakh giperbolicheskogo i parabolicheskogo tipov; 1996). V. I. PINCHUKOV, *Zhurnal Vychislitel'noj Matematiki i Matematicheskoj Fiziki* (ISSN 0044-4669), Vol. 36, No. 4, 1996, pp. 26–40. In Russian. 23 Refs. Documents available from Aeroplus Dispatch.

Correction algorithms for explicit schemes of arbitrary degree of approximation for parabolic equations and hyperbolic symmetrical systems of equations are described. The resulting schemes are identical to the initial ones, with smooth functions without extrema, and satisfy the maximum principle. A scheme for solving Navier–Stokes equations is described. Results of flow calculations near bodies of revolution with a forward separation region are presented.

A96-29641 The W-modification of the Godunov method and its application to two-dimensional unsteady flows of a dusty gas (W-modifikatsiya metoda S. K. Godunova i ee primenenie dlya dvumernykh nestatsionarnykh techenij zapylennogo gaza; 1996). E. I. VASIL'EV, *Zhurnal Vychislitel'noj Matematiki i Matematicheskoj Fiziki* (ISSN 0044-4669), Vol. 36, No. 1, 1996, pp. 122–135. In Russian. 20 Refs. Documents available from Aeroplus Dispatch.

A new modification of the Godunov method, characterized by improved accuracy, is proposed for two-dimensional conservation laws. The monotonic nature of the proposed scheme in the linear scalar case is demonstrated. A generalization of the scheme to the flow of two-phase media in the Euler formulation is presented. Also included are results of a numerical experiment concerned with the interaction between a shock wave and a dust cloud.

A96-28203 Adaptive-harmonic grid generator; 1996. S. A. IVANENKO (Russian Academy of Sciences, Computing Center, Moscow, Russia), *Numerical grid generation in computational field simulations; Proceedings of the 5th International Conference*, Mississippi State Univ., Mississippi State, 1996. Vol. 1 (A96-28186 07-64), Mississippi State, MS, Mississippi State Univ. 1996, pp. 167–176. 35 Refs. Documents available from Aeroplus Dispatch.

Elliptic grid generation techniques guaranteeing one-to-one mapping are discussed. The generalization of Winslow's (1981) method based on the theory of harmonic maps between surfaces is presented. The resulting adaptive-harmonic grid generator guarantees construction of nondegenerate structured grids in arbitrary domains of complex shape. Extensions to the case of surface and three-dimensional grid generation are discussed. (Author)

A96-25505 Self-similar viscous incompressible flow along an unbounded corner; 1996. V. I. VASILIEV (Central Inst. of Aviation Motors, Moscow, Russia), *AIAA Journal* (ISSN 0001-1452), Vol. 34, No. 5, 1996, pp. 946–952. 9 Refs. Documents available from Aeroplus Dispatch.

The self-similar viscous flow of incompressible fluid along the right-angle unbounded corner with nonzero streamwise pressure gradient is considered. The corner layer equations for this case are derived, and their asymptotic series are analyzed. It is shown that self-similar corner layer equations have two solutions, even at a zero streamwise pressure gradient. The numerical procedure for the integration of corner layer equations is developed, and numerical calculations are performed at several values of power exponent for a streamwise pressure gradient distribution. (Author)

A95-44778 Simulation of working processes and performance for turbojet engines using 3D mathematical model; 1995. M. Y. IVANOV, R. Z. NIGMATULLIN, and P. TCHASTON (Central Inst. of Aviation Motors, Moscow, Russia), *ISABE 12th International Symposium on Air Breathing Engines*, Melbourne, Australia, 1995, Proceedings. Vol. 2 (A95-44654 12-07), Washington, DC, American Institute of Aeronautics and Astronautics, 1995, pp. 1355–1365. 14 Refs. Documents available from Aeroplus Dispatch.

We present the results of steady and transient working process simulations for different types of turbojet engines, using high level two- and three-dimensional mathematical models of whole flow passage for full engines. The models are based on solutions of unsteady two- and three-dimensional conservation laws of mass, momentum and energy and includes viscous losses, axial and tip clearance leakages, and selection or blowing out of cooling air. We use high order accuracy implicit monotone method for integration of Euler and Navier–Stokes equations and special gas dynamic simulations of main physical peculiarities for real gas turbine passage flows. Typical examples of bypass flow passage simulation on steady and transient regimes are presented. (Author)

A95-42793 Calculation method for supersonic/hypersonic flows over configurations with blunt leading edges; 1995. N. V. VOEVODENKO (TsAGI, Zhukovski, Russia), *AIAA 1st Aircraft Engineering, Technology, and Operations Congress*, Los Angeles, CA, Sept. 1995, p. 9. 7 Refs. Documents available from Aeroplus Dispatch.

A combined numerical method, based on successive calculation of the flow regions near the blunt leading edge and center of a wing, is proposed on the assumption that the angle of attack and the relative thickness and bluntness radius of the leading edge are small. The flow in the neighborhood of the wing leading edge is assumed to be identical to that on the windward surface of a slender body coinciding in shape with the nose of the wing, and is numerically determined in accordance with a paper by Sychev (1960). The flow parameters near the center of the wing are calculated within the framework of the hypersonic small-disturbance theory (Hayes, 1947). In both regions the gas motion equations are integrated by Godunov's method. A comparative analysis of the calculation results for elliptic wings makes it possible to estimate the region of the method's applicability. This method was used for calculations on an aerospace plane model, and the calculation results are compared with the results of other numerical methods. (Author)

A95-38849 A Godunov's method modification for prediction of supersonic reacting turbulent jets; 1995. A. V. RODIONOV (Central Research Inst. of Machine Building, Kaliningrad, Russia), *La Recherche Aerospatiale* (ISSN 0034-1223), No. 4, 1995, pp. 263–276. 5 Refs. Documents available from Aeroplus Dispatch.

The paper is devoted to prediction of chemically reacting supersonic turbulent jets on the basis of the parabolized Navier–Stokes equations. The jets exit from an axisymmetric nozzle into a subsonic flow. A new Godunov's method modification is proposed to calculate this problem with high efficiency. (Author)

A95-36292 Reusable launch vehicle propulsion based on the RD-0120 engine; 1995. N. S. GONCHAROV, V. A. ORLOV, V. S. RACHUK, A. V. SHOSTAK (Chemical Automatics Design Bureau, Voronezh, Russia), and R. STARKE (Aerojet, Sacramento, CA), *AIAA, ASME, SAE, and ASEE 31st Joint Propulsion Conference and Exhibit*, San Diego, CA, 1995, p. 11. 4 Refs. Documents available from Aeroplus Dispatch.

Due to its high performance and advanced analytically and experimentally based reusability, the RD-0120 liquid oxygen/hydrogen engine, designed and manufactured by the Chemical Automatics Design Bureau (CADB), is one of the key candidates for reusable launch vehicles. This high pressure (3170 psia chamber pressure), high performance (455.5 lbf-s/lbm vacuum delivered Isp, 441,000 lbf vacuum thrust) staged combustion engine has had a complete success on both flights of the Energia heavy lift launch vehicle. During development, the engine demonstrated the characteristics of long life, power margin, throttling, and endurance that are required for low cost reliable reusable propulsion systems. The bipropellant RD-0120 engine can also be readily converted to a reliable, low cost tripropellant engine by replacement of the fuel-rich preburner and addition of a kerosene turbopump. This paper describes the operability and reusability of the existing RD-0120 engine and further improvements.

A95-35181 Internal 'shock' formation in the laminar boundary layer due to supercritical subcritical transition; 1995. I. I. LIPATOV (TsAGI, Zhukovsky, Russia), *AIAA 26th Fluid Dynamics Conference*, San Diego, CA, 1995, p.11. 37 Refs. Documents available from Aeroplus Dispatch.

The flows in unsteady hypersonic boundary layers are investigated. It is shown that the boundary layer may be supercritical (supersonic in average) or subcritical (subsonic in average). The flow regime is defined by the upstream perturbations propagation possibility. This phenomenon leads to the change in the heat transfer, pressure, and skin friction distributions, therefore modifying the integral aerodynamic and thermal characteristics of hypersonic vehicles. The perturbations propagation processes are described by a hyperbolic system of equations, which has a full set of characteristics (subcharacteristics). It is shown that the supercritical subcritical transition may lead to 'shock' formation. This 'shock' has many common features with the usual gasdynamic shock wave, but has a different inner structure. In this report two examples of supercritical subcritical transition are presented. The first example is the transition in the laminar wake behind a flat plate of finite length and is characterized by non-local strong viscous-inviscid interaction. The second one takes place near a strongly cooled surface and is characterized by local strong viscous-inviscid interaction. For the last regime, a new fundamental hyperbolic equation is derived which describes the 'shock' formation. Numerical results describing the pressure and other function distributions in flows with strong interaction are presented. (Author)

N95-21081 A flamelet model for turbulent unpremixed combustion. V. R. KUZNETSOV, *AGARD, Application of Direct and Large Eddy Simulation to Transition and Turbulence*, p. 10 (SEE N95-21061 06-34). Documents available from Aeroplus Dispatch.

Combustion theory is an applied science which is syntheses of several fundamental theories such as chemistry, heat and mass transfer theory, hydrodynamics, turbulence, etc. Now the knowledge of these theories is adequate to make calculations for practical purposes. However some difficulties still remain unresolved. The most important one is associated with the steep dependence of chemistry on temperature. As a result chemistry is confined to very thin zones (flamelets). Hence very large memory and speed of computers are needed to resolve flamelets in DNS. This difficulty is aggravated by the large number of intermediate species. The use of turbulence closures does not help since one has to assume that eddy diffusivities of reacting species and their pdf's (which are needed to average chemistry rates) are the same as that of conserved scalar. There are several examples indicating that these assumptions may lead to significant errors. Therefore there is a need to develop some new approach. (Author)

A95-31669 Pseudospectral algorithms for Navier–Stokes simulation of turbulent flows in cylindrical geometry with coordinate singularities; 1995. V. G. PRIJMAK (Russian Academy of Sciences, Inst. for Mathematical Modeling, Moscow, Russia), *Journal of Computational Physics* (ISSN 0021-9991), Vol. 118, No. 2, 1995, pp. 366–379. 34 Refs. Documents available from Aeroplus Dispatch.

The present novel family of algorithms for incompressible three-dimensional Navier–Stokes equations in cylindrical geometry is evaluated for stability, accuracy, and efficiency in the illustrative case of turbulent-flow calculations for an infinite circular pipe. The algorithms are based on 1) Galerkin trigonometric approximation for uniform variables and 2) implicit and predictor-corrector time-advancement schemes. Advantages and disadvantages are assessed for four Navier–Stokes algorithms. A technique is presented which is applicable to exhaustive a priori estimates of algorithm accuracy and stability in the linear approach.

N95-19023 Simulation of steady and unsteady viscous flows in turbomachinery. G. KRUPA, *AGARD, Mathematical Models of Gas Turbine Engines and their Components*, p. 39 (SEE N95-19017 05-07). Documents available from Aeroplus Dispatch.

A Navier–Stokes code has been used to compute the viscous turbulent cascade flows. The numerical method employs implicit high-order accurate Godunov scheme and a two equation (q-ω) turbulence model based on the integration to the wall. The generation of the O-H grid system for viscous cascade flow simulations is discussed. Numerical solutions were obtained for two- and three-dimensional turbine cascade flows and two-dimensional unsteady rotor-stator interactions. Available experimental data are used for verification of the computed results. (Author)

N95-19022 Application of multicomponent models to flow passage simulation in multistage turbomachines and whole gas turbine engines. R. Z. NIGMATULLIN, *AGARD, Mathematical Models of Gas Turbine Engines and their Components*, p. 17 (SEE N95-19017 05-07). Documents available from Aeroplus Dispatch.

Some features of used numerical algorithms for gas turbine engines components flow simulation are considered. Among them are topology of computational grids in two- and three-dimensional cases for flow passages of complex geometry, details of realization of conservative scheme at joints of different grids. In S(sub 2)-calculations it is necessary to consider the problem of inlet and outlet angles; in Euler calculation the ways of accounting for viscous loss effects are briefly described. Examples of calculations of flow through by-pass engine components are presented. (Author)

N95-19019 Solution of Navier–Stokes equations using high accuracy monotone schemes. V. G. KRUPA and M. J. IVANOV, *AGARD, Mathe-*

matical Models of Gas Turbine Engines and their Components, p. 16 (SEE N95-19017 05-07). Documents available from Aeroplus Dispatch.

Numerical monotone methods for integration of the Reynolds averaged Navier–Stokes equations are presented. These methods employ finite volume formulation, implicit high-order accuracy Godunov type scheme and two-equation (q-ω) turbulence model, based on integration up to the wall. To illustrate the typical peculiarities of these methods the computations of viscous flows in curvilinear ducts, around two-dimensional airfoils and three-dimensional shock-wave boundary layer interaction are considered. Available experimental data are used for verification of the computed results. (Author)

N95-19018 On the CFD monotone high accuracy methods. M. J. IVANOV, V. G. KRUPA, and R. Z. NIGMATULLIN, *AGARD, Mathematical Models of Gas Turbine Engines and their Components*, p. 9 (SEE N95-19017 05-07). Documents available from Aeroplus Dispatch.

Some theoretical fundamentals of monotone high accuracy methods are presented. The conditions for the construction of monotone, total variation diminishing (TVD) and following difference schemes are described. The peculiarities of high accuracy and implicit methods design are given. The typical results of numerical solutions illustrate the principle features of developed computational techniques. (Author)

A95-28672 Mathematical models and topological methods in wing aerodynamics (Matematicheskie modeli i topologicheskie metody v aehrodinamike kryla; 1995). S. K. BETYAEV and O. P. BRYSOV, *PMTF — Prikladnaya Mekhanika i Tekhnicheskaya Fizika* (ISSN 0869-5032), Vol. 36, No. 1, 1995, pp. 40–47. In Russian. 19 Refs. Documents available from Aeroplus Dispatch.

The use of topological methods in wing aerodynamics and the fundamentals of the asymptotic wing theory are reviewed. In particular, attention is given to the existing mathematical models for wings of large and small aspect ratios. For slender wings of small aspect ratio at small angles of attack, linear theories have been developed for both subsonic and supersonic flow. The validity and applicability limits of the existing models are assessed. Results of wind tunnel tests are presented for five different wing models, including delta wings of two different sweep angles (30 and 60 deg), parabolic wings (15 and 25 mm long), and a rectangular wing (30 mm long).

A95-24940 Symbolic-numerical method for the stability analysis of difference schemes on the basis of the catastrophe theory; 1995. E. V. VOROZHTSOV, B. Y. SCOBELEV, and V. G. GANZHA (Russian Academy of Sciences, Novosibirsk, Russia), *Journal of Computational Physics* (ISSN 0021-9991), Vol. 116, No. 1, 1995, pp. 26–38. 36 Refs. Documents available from Aeroplus Dispatch.

A combination of symbolic and numerical computations is proposed for the stability analysis of difference initial-value problems approximating initial-value problems for systems of hyperbolic- or parabolic-type partial differential equations. The present method is based on the Fourier method. Examples of the stability analyses are presented for a number of difference-initial value problems. It is shown that the present method is an efficient means for determining the necessary stability conditions for difference schemes.

A95-21647 Comparative numerical testing of one- and two-equation turbulence models for flows with separation and reattachment; 1995. M. SHUR, M. STRELETS, L. ZAJKOV (Federal Scientific Center 'Applied Chemistry,' St. Petersburg, Russia), A. GULYAEV, V. KOZLOV, and A. SEKUNDOV (Central Inst. of Aviation Motors, Moscow, Russia), *AIAA 33rd Aerospace Sciences Meeting and Exhibit*, Reno, NV, Jan. 1995, p. 32. 28 Refs. Documents available from Aeroplus Dispatch.

Numerical testing of three turbulence models proposed recently by Secundov and co-workers, by Spalart and Allmaras, and by Menter is carried out for the two-dimensional backward/forward-facing step benchmark flows that were studied experimentally and involved a wide range of Reynolds numbers, opposite wall angles, and step geometry. A grid refinement study is carried out for all the models and test cases to make sure that grid-independent results are obtained. On the basis of detailed comparison of the numerical results with the experimental data and also with similar results obtained in the framework of the well-known low Reynolds number k-ϵ model by Chien, the strengths and weaknesses of each model are determined. (Author)

A94-29435 Numerical simulation of nonstationary jets of the viscous gas; 1994. N. M. BULGAKOVA (Russian Academy of Sciences, Inst. of Thermophysics, Novosibirsk, Russia), *Rarefied gas dynamics—Experimental techniques and physical systems; 18th International Symposium on Rarefied Gas Dynamics*, Univ. of British Columbia, Vancouver, Canada, 1992, Technical Papers (A94-29402 09-34), Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1994, pp. 352–362. 8 Refs. Documents available from Aeroplus Dispatch.

The evolution of the viscous, axisymmetric, underexpanded jets issuing from a nozzle into the ambient gas is explored. The appearance of vortical structures was observed near the nozzle exit. The jet evolution is shown to occur in two ways, depending on the density ratio: with the return flow in front of the jet wnd without one. The program is applied to simulate a plume forming during the interaction of laser pulsed radiation with a substance. Significant pressure pulsations occurred on the irradiated target. The pulsation amplitude dependences on pressure ratio, temperature ratio, and geometric sizes are obtained.

A95-18931 Numerical investigation of the 3D effects for space flow through a turbomachine stage; 1995. V. I. GNESIN, S. V. ERSHOV, and A. V. RUSANOV (National Academy of Sciences of Ukraine, Inst. for Problems in Machinery, Kharkov), *5th International Conference of Fluid Mechanics—ICFM5*, Cairo, Egypt, 1995, Proceedings. Vol. 2 (A95-18906 03-34), Giza, Egypt, Cairo Univ., 1995, pp. 443–452. 9 Refs. Documents available from Aeroplus Dispatch.

Two numerical models of the three-dimensional inviscid compressible flow through a turbine stage are considered. Both models are based on the integration of the Euler equations by using Godunov's finite-difference schemes. A comparison of the present calculation results with the experimental data of other authors confirms the reliability of the numerical methods. To estimate the influence of the blade compound lean on the steady and unsteady cascade characteristics, an investigation has been carried out with both numerical models. (Author)

A95-18930 Calculation and measurement of the three-dimensional flow in axial compressor cascades, with and without end-bends; 1995. M. L. UGRYUMOV, Y. A. SKOB, V. A. MENSHIKOV (Kharkov Aviation Inst., Ukraine), and V. I. PISMENNIJ (Zaporozhye Machine-Building Bureau Progress, Ukraine), *5th International Conference of Fluid Mechanics—ICFM5*, Cairo, Egypt, 1995, Proceedings. Vol. 2 (A95-18906 03-34), Giza, Egypt, Cairo Univ., 1995, pp. 433–442. 5 Refs. Documents available from Aeroplus Dispatch.

A three-dimensional axial compressor blade design system is described. A three-dimensional computational fluid dynamics code, coupled iteratively with an integral boundary layer method, and a compressor cascade optimization technique are proposed for the design of end-bend compound curved compressor blade cascades with controlled-diffusion airfoils. The experimental models consist of two groups of cascades with different blade aspect ratios. Each group includes three sets of cascades with different kinds of blades. Three-dimensional viscous flow computation and experimental data for the design of compressor cascades are obtained. These results demonstrate that the end-bend causes a reduction of the secondary loss if the cascade has an obtuse corner angle of end walls on the blade suction side. (Author)

A95-18926 Implicit monotonic difference schemes of splitting of the second order of accuracy for solving the Euler and Navier–Stokes equations; 1995. N. N. BELAEV, and V. K. KHRUSHCH (Dnepropetrovsk State Univ., Ukraine), *5th International Conference of Fluid Mechanics—ICFM5*, Cairo, Egypt, 1995, Proceedings. Vol. 2 (A95-18906 03-34), Giza, Egypt, Cairo Univ., 1995, pp. 369–377. 3 Refs. Documents available from Aeroplus Dispatch.

This paper introduces a new algorithm for solving the Navier–Stokes and Euler equations. The Euler and Navier–Stokes equations are written in the form of increments in solution for the finite time step of integration. The analytical solutions of the Euler and Navier–Stokes equations with the frozen matrices of the convective and diffusion fluxes are used in balance relations. The final solution is written in the form of a linear sum of the one-dimensional equations of splitting, and when the summation takes place the coefficients are chosen to provide the absolute stability and monotonic calculation on the time coordinate. (Author)

A95-17523 Self-consistent shock capturing in finite difference calculations of gasdynamic flows (Samosoglasovannoe vydelenie razryvov pri skvoznykh raschetakh gazodinamicheskikh techenij); 1994. V. F. KAMENETSKIJ and A. Y. SEMENOV, *Zhurnal Vychislitel'noj Matematiki i Matematicheskoj Fiziki* (ISSN 0044-4669), Vol. 34, No. 10, 1994, pp. 1489–1502. 15 Refs. Documents available from Aeroplus Dispatch.

New self-consistent shock capturing algorithms are proposed which can be used in the numerical solution of one-dimensional and axisymmetric gasdynamic problems. The self-consistent shock capturing procedure proposed here employs special self-adjusting grids which automatically trace discontinuities formed in gasdynamic flow. The efficiency of the approach is illustrated by examples.

A95-15471 An implicit iterative scheme for calculating flows of a nonviscous incompressible fluid (Neyavnaya iteratsionnaya skhema dlya rascheta techenij vyazkoj neszhimaemoj zhidkosti; 1994). V. I. KOPCHENOV and D. A. NIKIFOROV, *Zhurnal Vychislitel'noj Matematiki i Matematicheskoj Fiziki* (ISSN 0044-4669), Vol. 34, Nos. 8–9, 1994, pp. 1335–1343. In Russian. 10 Refs. Documents available from Aeroplus Dispatch.

The compact approximation method is used to develop a higher-order implicit scheme employing the Gauss–Seidel iterative method. The advantages of this scheme over the approximate factorization algorithm are demonstrated. Calculations of flow in a square cavity up to Re 4000 are presented. The efficiency of the algorithm proposed here, when used with essentially nonuniform grids, is demonstrated.

Japanese Aerospace Literature
This month: *Stress–Strain Mechanics*

A96-33758 Optimum design of 3-D truss structure considering control with stress constraint at initial deformed state. Y. TADA and S. MITA (Kobe Univ., Japan), *IUTAM Symposium on Optimization of Mechanical Systems*, Stuttgart, Germany, 1995, Proceedings (A96-33726 08-31), Dordrecht, The Netherlands, Kluwer Academic Publishers (Solid Mechanics and Its Applications. Vol. 43), 1996, pp. 309–316. 4 Refs. Documents available from Aeroplus Dispatch.

As a simultaneous optimization problem of structure and control, cross-sectional areas of a three-dimensional truss structure are optimized with consideration of the ^^ minimization of the structural weight and its control cost under the stress constraint at the initial deformed state. A quadratic performance index as in the optimal regulator theory is adopted as a control cost, and it is minimized with structural weight fixed at a constant value in order to obtain a Pareto optimum solution of the two-objective problem. The optimization is carried out by the energy-ratio method, and the stress constraint is treated by the stress-ratio method. (Author)

A96-31543 Shape and stress control analysis of prestressed truss structures; 1995. K. KAWAGUCHI, Y. HANGAI (Tokyo Univ., Japan), S. PELLEGRINO (Cambridge Univ., U.K.) and H. FURUYA (Nagoya Univ., Japan), *5th International Conference on Adaptive Structures*, Sendai, Japan, 1994, Proceedings (A96-31526 08-31), Lancaster, PA, Technomic Publishing Co., Inc., 1995, pp. 184–193. 15 Refs. Documents available from Aeroplus Dispatch.

Space truss systems are light and effective structural systems and are used for various structural purposes, such as long span roof structures or space reflectors, etc. In some applications, notwithstanding their high redundancy, high accuracy is required to realize their shape and predetermined distribution of prestress. In this paper, a simple analytical scheme for shape and stress control of general truss structures is presented. The scheme is based on the linear force method of analysis. (Author)

A96-26222 Design and test of an air-cooled ceramic nozzle for a power generating gas turbine; 1995. S. YOSHINO, T. TSUCHIYA, Y. FURUSE (Tokyo Electric Power Co., Japan), R. CHIKAMI, Y. KASAI, Y. TSUKUDA (Mitsubishi Heavy Industries, Ltd., Takasago, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, 1995, Proceedings. (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. III-169–III-176. Documents available from Aeroplus Dispatch.

A trial to apply ceramics to the first-stage nozzle vanes of a 1500°C class gas turbine has been carried out. The temperatures of ceramic nozzle vanes were estimated to exceed the tolerance temperature level, therefore the utilization of a small amount of a cooling air has been studied to reduce the temperatures of the ceramic nozzle vanes. The inner face of the nozzle is cooled by air impingement and this air is discharged and mixed into the main gas flow through cooling slits located at the trailing edge of the nozzle. A series of cascade tests were carried out for the designed air-cooled Si_3N_4 nozzle vanes under intermediate pressure and 1500°C conditions. After these tests, full-pressure tests were conducted at an average temperature of 1500°C. They included both steady state and transients of emergency shutdown. This paper presents the results of these cascade tests. (Author)

A96-26206 Detective method of fracture origin in ceramic turbine wheel by photographing fracture moment; 1995. M. HIEI (Toyota Motor Corp., Shizuoka, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, Oct. 1995, Proceedings. Vol. 3 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. III-59–III-63. 3 Refs. Documents available from Aeroplus Dispatch.

The design of strength for ceramic turbine wheels has been carried out by FEM. It is still necessary, however, to detect a fracture origin to study the correlation between the calculated values of stress and fracture of wheels. However, it is difficult to detect the fracture origin of the ceramic wheels by inspecting the fragments since they break into small pieces. Two detection methods of fracture origin of the ceramic turbine wheels are reported in this study. One is the method to take photographs at a fracture moment, and the other is to observing the fracture surface by restoration of wheel using photographs. (Author)

A96-26201 Stress rupture behavior of a silicon nitride under combustion gas environment; 1995. M. KAJI, T. ONO, M. HIGASHI, and A. KOKAJI (Kyocera Corp., Kagoshima, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, Oct. 1995, Proceedings. Vol. 3 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. III-21–III-28. 15 Refs. Documents available from Aeroplus Dispatch.

Stress rupture testing of silicon nitride material was performed under a combustion gas environment. The dominant mechanism of the rupture was creep and it was independent of the environment at each temperature tested. Water vapor had quite a few effects on the rupture time of the present material. Oxidation, however, enhanced the creep deformation. At 1200 and 1300°C, the fracture origins were large grains and the rupture was caused by internal stresses around the grains. At 1400°C, the rupture was mainly caused by creep damages. A master rupture curve by Larson-Miller parameter was applied for a life time prediction in a practical sense and it worked. This result also supports the idea that creep mechanism is responsible for the rupture. The prediction was also performed in a theoretical sense. Eshelby's equivalent inclusion method was used. The predicted rupture time was in good agreement with the experimental result. (Author)

A96-26198 Damage analysis and evaluation of material degradation for first-stage nozzle of gas turbine; 1995. N. ISOBE, S. SAKURAI, and M. KUNIHIRO (Hitachi Ltd., Ibaraki, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, Oct. 1995, Proceedings. Vol. 3 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. III-1–III-5. 5 Refs. Documents available from Aeroplus Dispatch.

A cracking analysis for the first-stage nozzle of a 25 MW class gas turbine is presented. Cracks initiated in the nozzle concentrate around the corner between the outer wall and blade. The crack shape is very shallow due to stress gradients in the blade cross section. A crack growth analysis in depth was carried out by approximating the stress profile as a quadratic curve. The predicted crack growth curve coincided with inspection data to within a factor of 1.2 scatter band. To evaluate the material degradation, a small punch test was conducted. The fracture energy obtained in the test shows good correlation with the variation of crack density. A residual life assessment method consisting of crack growth estimation based on the maximum surface crack length and evaluation of material degradation by small punch method is proposed. (Author)

A96-26127 Development of 300-kW-class ceramic gas turbine (CGT301); 1995. M. TATSUZAWA, T. SAKIDA, and Y. YONEKUBO (Ishikawajima-Harima Heavy Industries Ltd., Tokyo, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, Oct. 1995, Proceedings. Vol. 1 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. I-147–I-152. 4 Refs. Documents available from Aeroplus Dispatch.

The 300-kW-class ceramic gas turbine (CGT301) is a recuperated single-shaft ceramic gas turbine for cogeneration use. Ceramic parts are used in the hot section of the engine, such as turbine blades and nozzle vanes, combustor liners, heat exchanger elements, and gas path parts. For development of the engine component, i.e., compressor, combustor, turbine, and heat exchanger, the required structural reliability and the target efficiency of each component were attained in the component rig tests. This paper presents the component development and the test results of the ceramic gas turbine at a TIT of 1200°C. (Author)

A96-26119 Advanced materials under development in AMG project for future gas-generator; 1995. M. HIROMATSU (Research Inst. of Advanced Material Gas-Generator Tokyo, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, Oct. 1995, Proceedings. Vol. 1 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. I-95–I-100. 2 Refs. Documents available from Aeroplus Dispatch.

The Advanced Material Gas-Generator Project was initiated by a joint investment from a Japanese governmental organization and 14 Japanese companies in 1993. Advanced composite materials selected as candidates for future high-performance gas-generator components are under development in the program. This paper outlines this project and presents results from the initial two and half years of the program, focusing on design and analysis study and manufacturing process development of advanced materials. Advanced materials described in this paper are high temperature polymer matrix composites, MMCs, intermetallic compounds, and ceramic matrix composites. (Author)

A96-25466 Nanoscale evaluation of structure and surface potential of gated field emitters by scanning Maxwell-stress microscope; 1995. J. ITOH. Y. NAZUKA, T. INOUE, H. YOKOYAMA, S. KANEMARU, and K. SHIMIZU (Electrotechnical Lab., Tsukuba, Japan), *Japanese Journal of Applied Physics, Part 1* (ISSN 0021-4922), Vol. 34, No. 12B, 1995, pp. 6912-6915. Documents available from Aeroplus Dispatch

Both the structural and surface potential images of gated field emitters (GFEs) were measured using a scanning Maxwell-stress microscope in air. Si cone-shaped and Mo disk-edge GFEs were measured. The experimental results clearly revealed differences in the surface potential for various materials and irregularities in the GFE structures which were too small to be

found by conventional SEM observations. It was also found that the surface potential of Si was rather flat even in the emitter tip apex. (Author)

A96-24972 Description of internal damage in FRP laminates by continuum damage mechanics; 1996. Y. KANAGAWA, S. MURAKAMI, Y. LIU Q. BAI, and K.TANAKA (Nagoya Univ., Japan), *Japan Society of Materials Science, Journal* (ISSN 0514-5163), Vol. 45, No. 2, 1996, pp. 206–211. In Japanese. 14 Refs. Documents available from Aeroplus Dispatch.

The effects of matrix microcracks on elastic moduli of FRP laminates and their modeling by means of continuum damage mechanics are discussed. The anisotropic damage states in FRP laminates are described by a damage variable of second rank tensor. The damage models, based on the strain equivalence and strain energy equivalence principle respectively, are developed to describe the relations between the damage variable and the elastic moduli of FRP laminates. The two damage models for matrix cracks of lamina are formulated and extended to the damage models for laminates by making use of classical laminate theory. Finally, the proposed models are applied to predict the change in elastic moduli induced by matrix microcracks in laminates. Comparison with experimental results shows that both of the suggested models can reasonably describe the anisotropic effects of matrix microcracks on elastic moduli of FRP laminates. In case of GFRP laminates under uniaxial tension, the model based on strain energy equivalent principle is shown to give some better description of the damage influence than that based on strain equivalent principle. (Author)

A96-22654 Optimization for the bake-hardenability of Al-Mg-Si alloys; 1996. M. YANAGAWA, S. OHIE (Kobe Steel Ltd., Japan), and M. ABE (Kobelco Research Inst., Inc., Kobe, Japan), *Japan Institute of Light Metals*, Journal (ISSN 0451-5994), Vol. 46, No. 1, 1996, pp. 27–32. In Japanese. 25 Refs. Documents available from Aeroplus Dispatch.

Effects of Mg, Si content, additional elements and pre-aging temperatures on the bake-hardenability of Al-Mg-Si alloys were investigated by tensile tests and an electron microscope. The 0.2% proof stress obtained by the short time aging at 170°C increased with increasing Mg_2Si content, and it became higher with the following ascending order: pseudobinary system alloys, excess Mg alloys, excess Si alloys. The pre-aging at 100°C was more effective in increasing the bake-hardenability of the alloys than that at room temperature. The additions of Ag, Cu, Zn, and Sn on the bake-hardenability of the Al-0.8 pct Mg_2Si-0.5 pct Si alloy were ineffective, on the contrary the addition of Mn or Cr was effective. The Al-0.8 pct Mg_2Si-0.5 pct Si-0.1 pct Mn (or 0.1 pct Cr) alloy was found to be the most appropriate for automobile body panels. (Author)

N96-12966 A study of design of a high field and high current density superconducting magnet by Nb_3Sn superconductors. M. UMEDA, *Electrotechnical Lab.*, Tokyo (Japan). Page: 84P. Documents available from Aeroplus Dispatch.

A design method for large-scale, high-field superconducting magnets having a higher current density is established. The three main areas of the research are as follows: (1) superconductors that have a large current capacity; (2) adjusting superconducting properties and electromagnetic support; and (3) magnet stability during mechanical disturbances. The first area involves multifilamentary composite Nb_3Sn superconductors that have a large current capacity, which is required in large-scale and high-field superconducting magnets. The second research field involves reinforcement problems of electromagnetic force for superconducting magnet. The third research field involves magnet stability during mechanical disturbances, such as friction between conductors and insulators or among conductors. The paper presents a synthetic design that considers the strain effect and strain limit, the optimization of reinforcement, and the protection against mechanical disturbances on large-current superconductors composed of fine, twisted filamentary structures. The manufacturing and testing of a superconducting pancake-coil type magnet that uses a 3kA-class Nb_3Sn superconductor processed by solid-liquid diffusion method are also described. (Derived from text)

A96-19384 Interfacial debonding behavior of mullite/SiC continuous fiber composite; 1995. Y. YAMADE, Y. KAWAGUCHI (Sumitomo Metal Industries, Amagasaki, Japan), N. TAKEDA, and T. KISHI (Tokyo, Univ., Japan), *American Ceramic Society, Journal* (ISSN 0002-7820), Vol. 78, No. 12, 1995, pp. 3209–3216. 24 Refs. Documents available from Aeroplus Dispatch.

Mullite/SiC continuous fiber composites were fabricated by hot-pressing under different processing conditions. The interfacial shear strength was measured during the pull-out test, and the effect of fabrication conditions on interfacial debonding behavior was discussed. The debonding length during the pull-out test was quantitatively evaluated using acoustic emission. The interfacial shear strength was evaluated by stress analysis. The control of interfacial shear strength was achieved by controlling the hot-press temperature. An increase of load was found during the pull-out process after complete debonding. In order to explain the increased load, a new model is presented. (Author)

A96-19007 Stress and failure analysis for cross-plied curved composite laminates; 1996. N. WATANABE (Tokyo Metropolitan Inst. of Technology, Japan) and T. OKADA (National Aerospace Lab., Tokyo, Japan), *AIAA Journal on Disc* (ISSN 1081-0102), Vol. 1, No. 2, 1996. AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, and AIAA/ASME Adaptive Structures Forum, La Jolla, CA, April 1993, Technical Papers. Pt. 3, pp. 1820–1828. 9 Refs. Documents available from Aeroplus Dispatch.

The two-dimensional FEM is used to analyze cross-plied curved composite laminates for stress and failure. The strength for the in-plane failure of each layer is predicted using the Tsai-Wu criterion, and the maximum radial stress criterion is employed for a delamination. It is shown that the simultaneous increase of these two strengths should be possible by the shift of the 90-deg ply to the middle and by the shift of the neutral surface of the laminate to the outer direction.

A96-15998 On newly developed assumed stress finite element formulations for geometrically and materially nonlinear problems; 1995. W. SEKI (Bridgestone Corp., Yokohama, Japan) and S.N. ATLURI (Georgia Inst. of Technology, Atlanta), *Finite Elements in Analysis and Design* (ISSN 0168-874X), Vol. 21, No. 1–2, 1995, pp. 75–110. 48 Refs. Documents available from Aeroplus Dispatch.

Newly developed assumed stress hybrid elements are presented. The elements are applicable for geometrically as well as materially nonlinear problems with or without volume constraints. Variational principles using unsymmetric stresses and rotations are adopted as the basis of the formulations. The variational principles are modified through a regularization term to eliminate every stress term at element level. Two types of four-noded quadrilateral plane element formulations are derived through direct discretizations of the variational principles with proper suggestions for the shape functions. The first one has three independent fields displacements (velocities), rotations (spins), and unsymmetric (Biot) stress fields. In the second one, the hydrostatic pressure field is added as an independent field, to account for volume constraints. It is confirmed that better solutions can be obtained by rather small numbers of stress parameters. (Author)

A96-13288 Stress and failure analysis for cross-plied curved composite laminates; 1995. N. WATANABE (Tokyo Metropolitan Inst. of Technology, Japan) and T. OKADA (National Aerospace Lab., Tokyo, Japan), *AIAA Journal* (ISSN 0001-1452), Vol. 33, No. 12, 1995, pp. 2433–2435. Previously cited in issue 13, Accession No. A93-34056. 9 Refs. Documents available from Aeroplus Dispatch.

The two-dimensional FEM is used to analyze cross-plied curved composite laminates for stress and failure. The strength for the in-plane failure of each layer is predicted using the Tsai-Wu criterion, and the maximum radial stress criterion is employed for a delamination. It is shown that the simultaneous increase of these two strengths should be possible by the shift of the 90-deg ply to the middle and by the shift of the neutral surface of the laminate to the outer direction.

A96-11256 Photoviscoelastic method for time dependent stress and strain analysis under non-proportional loading; 1995. J. GOTOH, H. HORIE, M. TAKASHI (Aoyama Gakuin Univ., Tokyo, Japan) and A.MISAWA (Kanagawa Inst. of Technology, Atsugi, Japan), *1995 SEM Spring Conference on Experimental Mechanics and Exhibit*, Grand Rapids, MI, 1995, Proceedings (A96-11243 01-31), Bethel, CT, Society for Experimental Mechanics, Inc., 1995, pp. 234–241. 8 Refs. Documents available from Aeroplus Dispatch.

A computer-aided technique based on the diagonal summation theorem is effectively utilized to perform simultaneous measurement of the time variation of isochromatics and the principal direction of birefringence. The authors attempt to develop a convenient method for photoviscoelastic analysis under nonproportional quasi-static or dynamic loading condition. (Author)

A95-45305 Stress analysis and optimum design for three-dimensional composite materials; 1995. A. YOKOYAMA (Mie Univ., Tsu, Japan), K. NAGAI (Mitsubishi Heavy Industries, Ltd., Nagoya Aerospace Systems Works, Japan), Z. MAEKAWA, and H. HAMADA (Kyoto Inst. of Technology, Japan), *Materials challenge diversification and the future; Proceedings of the 40th International SAMPE Symposium and Exhibition*, Anaheim, CA, 1995. Book 1 (A95-45236 12-23), Covina, CA, Society for the Advancement of Material and Process Engineering (Science of Advanced Materials and Process Engineering Series. Vol. 40), 1995, pp. 892–902.13 Refs. Documents available from Aeroplus Dispatch.

Three-dimensional fiber reinforced composite materials produced by impregnating the resin to the woven fabric are superior to the interlaminar strength, impact strength, and capability of forming complex shapes. They are also tailored materials, so we can obtain the required material properties by deciding the three-dimensional fiber construction appropriately. In this report, we propose an optimum design method for three-dimensional composite materials. Weight minimization problems subjected to the elastic moduli or

the failure loads are considered. Strength analyses are performed using the stress averaging method which gives efficient calculation, and the genetic algorithm is applied in the optimization. Calculation is executed for the 5-axis woven CFRP three-dimensional composite, and the validity of the present design method is discussed. (Author)

A95-44919 Fracture toughness of structural ceramics under biaxial stress state by anticlastic bending test 1995. T. ONO and M. KAJI (Kyocera Corp., Kagoshima, Japan), *ASME, International Gas Turbine and Aeroengine Congress & Exposition*, Houston, TX, June 1995, 17 p. 18 Refs. Documents available from Aeroplus Dispatch.

Mixed-mode fracture of structural ceramics under biaxial stress state was investigated by an anticlastic bending test using the controlled surface flaw technique. The stress state of the anticlastic bending specimen is biaxial. This test enables the study of fractures under pure mode I, pure mode II, or any combination of mode I and mode II loading. To discuss the experimental results, a parameter 'T' was introduced to the modified maximum hoop stress criterion. This parameter represents frictional effects of crack interfaces on the mixed-mode fracture and can be obtained experimentally. Relative magnitudes of mode I and mode II stress intensity factors and the directions of non-coplanar crack extension angles were predicted using the parameter 'T'. Reasonable agreement with the experimental results was obtained. (Author)

A95-42709 Analysis of single-layered corrugated core sandwich plate by homogenization method—On the application of homogenization method to composite structures with only planar periodicity; 1995. N. TAKANO, M. ZAKO (Osaka Univ., Suita, Japan) and N.KIKUCHI (Michigan Univ., Ann Arbor), *Japan Society of Materials Science, Journal* (ISSN 0514-5163), Vol. 44, No. 502, 1995, pp. 905–910. 8 Refs. Documents available from Aeroplus Dispatch.

The effectiveness of the homogenization method for the analysis of composite materials has been shown since it was first introduced in the 1970s. As this method is applicable to periodic problems only, however, some important engineering problems remain unsolved. Those problems are, for instance, honeycomb sandwich plates and panels with reinforcing ribs, which are not periodic in the thickness direction. Here, the application of the homogenization method to those problems is discussed. As a practical example, stress analysis of single-layered corrugated core sandwich plates is presented. A method to homogenize its complicated geometry to a simple solid model, to get the homogenized material constants, and to calculate the microscopic stress is proposed. (Author)

A95-42220 Stress analysis of sandwich plate by the homogenization method; 1995. N. TAKANO, M. ZAKO (Osaka Univ., Japan) and N. KIKUCHI (Michigan Univ., Ann Arbor), *Materials Science Research International* (ISSN 1341–1683), Vol. 1, No. 2, 1995, pp. 82–88. 11 Refs. Documents available from Aeroplus Dispatch.

An outline of the formulation of the homogenization method for the analysis of three-dimensional periodic elastic bodies is presented. The method has been shown to be effective for the analysis of composite materials since it was first introduced in the 1970s. However, since this method is applicable to periodic problems only, some engineering problems remain unsolved. For instance, the method cannot be applied to honeycomb sandwich plates and panels with reinforcing ribs, because these structures are not periodic in the thickness direction. In this paper, the application of the homogenization method to those composite structures is discussed. As a practical example, the stress analysis of a single-layered corrugated-core sandwich plate is presented. A method which homogenizes the complicated geometry to a simple solid model, obtains the homogenized material constants, and which calculates the microscopic stress is proposed.

A95-37290 Suggestion of analytical method of three-dimensional stress analysis for laminated composite structures; 1995. M. ZAKO, T. TSUJIKAMI, and T. KITAMURA (Osaka Univ., Suita, Japan), *Japan Society of Materials Science, Journal* (ISSN 0514-5163),Vol. 44, No. 499, 1995, pp. 390–394. 5 Refs. Documents available from Aeroplus Dispatch.

A new analytical method is proposed to calculate the mechanical behavior of laminated structures. The proposed method is applied to a laminated composite structure as an example. It is shown that the numerical behavior of the composite structure with anisotropic properties under mixed loads of bending and tension can be analyzed by the proposed method even if it has two different moduli of elasticity of bending and tension. In addition, CPU time of FEM based on the proposed method can be reduced remarkably as compared with ordinary FEM. (Author)

A95-35447 FGM compliant design for high efficiency silicon germanium thermoelectric cell; 1995. M. KAMBE, M. ARAI, K. YOSHIDA, and M. UOTANI (Central Research Inst. of Electric Power Industry, Tokyo, Japan), *FGM 94; Proceedings of the 3rd International Symposium on Structural and Functional Gradient Materials*, Swiss Federal Inst. of Technology, Lausanne, Switzerland, 1994 (A95-35401 09-23), Lausanne, Switzerland, Presses Polytechniques et Universitaires Romandes, 1995, pp. 627–632. 6 Refs. Documents available from Aeroplus Dispatch.

Thermoelectric (TE) power conversion systems have been focused upon as candidates for direct energy conversion systems from nuclear energy sources to meet the various power requirements of the next century. In order to achieve high thermal energy density in TE power conversion systems, conduction coupling of TE cells to both hot and cold exchangers is essential. This paper discusses how the challenges of mechanically attaching both ends of the TE cell to a hard structure have been addressed. An attempt was made to adopt FGM-compliant pads of C-Pd-Si_3N_4-C for the hot side, and C-Cu-Si_3N_4-C for the cold side. (Author)

A95-35437 Influence of coating configuration on cyclic thermal shock fracture behavior of plasma sprayed coatings; 1995. M. FUKUMOTO (Toyohashi Univ. of Technology, Japan), T. YAMASAKI (Nippon Sharoy Seizo Co., Ltd., Japan), and I. OKANE (Toyohashi Univ. of Technology, Japan), *FGM 94; Proceedings of the 3rd International Symposium on Structural and Functional Gradient Materials*, Swiss Federal Inst. of Technology, Lausanne, Switzerland, 1994 (A95-35401 09-23), Lausanne, Switzerland, Presses Polytechniques et Universitaires Romandes, 1995, pp. 425–432. 5 Refs. Documents available from Aeroplus Dispatch.

Evaluation of the thermal shock fracture behaviors of plasma-sprayed ceramic coatings is one of the essential problems to be solved in order to obtain the necessary reliability of such coatings for superior heat protection. Though many types of rectangular specimens have been used for thermal shock evaluation, the properties have not always been evaluated correctly because the fracture behavior of these rectangular specimens is strongly affected by the preferential oxidation-induced cracks at the corners of the specimens. More precise evaluation can be anticipated by a disk-shaped specimen, as the preferential fracture due to the specimen's morphology must be inhibited in such a specimen. In the present study, disk-shaped duplex and functionally graded ZrO_2/NiCrAlY coating specimens were prepared by plasma spraying, and the cyclic thermal shock fracture behaviors of the disk-shaped specimens, as well as the effect of the coating configuration on the fracture behavior, were evaluated. Unsteady thermal stress analyses by FEM of the cooling processes of thermal shock cycles were also conducted. (Author)

A95-35433 Thermal shock fracture mechanism of functionally gradient materials as studied by burner heating test; 1995. A. KAWASAKI and R. WATANABE (Tohoku Univ., Sendai, Japan), *FGM 94; Proceedings of the 3rd International Symposium on Structural and Functional Gradient Materials*, Swiss Federal Inst. of Technology, Lausanne, Switzerland, 1994 (A95-35401 09-23), Lausanne, Switzerland, Presses Polytechniques et Universitaires Romandes, 1995, pp. 397–404. 11 Refs. Documents available from Aeroplus Dispatch.

The thermomechanical properties of metal/ceramic functionally gradient materials were evaluated by a burner heating test using an H_2/O_2 combustion flame, which simulated the environment of the heated inner wall of a rocket combustor. Disk-shaped graded samples were used for the test in which the ceramic surface of the sample was heated with the burner flame, and the back surface was cooled with flowing water. The critical temperature of the first crack formation, which was always observed on the ceramic surface during cooling, was determined in the test. The stress distributions in the sample during heating and cooling cycles, calculated by the finite element method, shows the generation of large compressive and tensile stresses during heating and cooling, respectively, which was attributed to the nonelastic deformation of the heated sample surface due to an excess in the compressive stress. The fracture mechanism, in terms of crack formation and spalling in the FGMs, was discussed on the basis of the stress distributions in addition to the fracture mechanics approach. (Author)

A95-26749 Thermal stress analysis for Al honeycomb sandwich plates with very thin CFRP faces; 1995. N. WATANABE and K. TERANISHI (Tokyo Metropolitan Univ. of Technology, Japan), *AIAA/ASME/ASCE/AHS/ASC 36th Structures, Structural Dynamics, and Materials Conference, and AIAA/ASME Adaptive Structures Forum*, New Orleans, LA, 1995, Technical Papers. Pt. 3 (A95-26551 06-39), Washington, DC, American Institute of Aeronautics and Astronautics, 1995, pp. 1955–1963.12 Refs. Documents available from Aeroplus Dispatch.

The thermal stress in sandwich plates composed of very thin CFRP face and Al honeycomb core may often cause a thermal buckling of the face coincident with the periodic pattern of the core. By using our extended homogenization method and the exact honeycomb core model, the magnitude and distribution of the thermal stress are examined and its characteristic is revealed. Next, buckling and post-buckling analyses of the hexagonal laminate with the residual thermal stress are carried out numerically and buckling characteristics are examined. From these analyses it is proved that the most effective term should be the in-plane rigidity of the core and that the lamination or stiffness of the face should have a little less effect. For such sandwich plates, the thermal buckling is expected to occur by the present analysis, and these results are generally coincident with the actual examples. Therefore, the present analysis is considered to be sufficiently effective and accurate. (Author)