A90-39515 A self-similar solution to boundary layer equations (Ob odnom avtomodel'nom reshenii uravnenii pogranichnogo sloia). G. I. BURDE, *PMTF—Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Mar.–Apr. 1990, pp. 71–75. 7 Refs.

The Falkner-Skan equation and its analog for axisymmetric boundary layers formed on thin bodies of revolution in longitudinal flow are examined. In particular, a case is considered in which the Falkner-Skan equation and its axisymmetric analog can be solved in closed form.

A91-37195 A rapidly converging method for solving Euler equations (Bystroskhodiashchiisia metod resheniia uravnenii Eilera). I. L. SOFRONOV, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 31, April 1991, pp. 575–591. 13 Refs.

A new method is proposed for improving the convergence of numerical schemes for solving problems of steady state nonviscous flow. A two-dimensional Lax-Wendroff difference scheme and its modification, corresponding to the proposed method, are developed. Test problems are solved for different flow regimes.

A91-17179 Increasing the stability of a counterflow implicit scheme with three-point scalar factorization for the Euler equation (Povyshenie ustoichivosti protivopotochnoi neiavnoi skhemy s trekhtochechnymi skaliarnymi progonkami dlia uravnenii Eilera). V. E. KOZLOV, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 30, Oct. 1990, pp. 1596–1599. 7 Refs.

A method is proposed whereby the stability of calculations in counterflow implicit schemes with three-point factorization is improved by modifying the calculation steps that involve the consideration of the local directions of perturbation propagation. The modification proposed here does not lead to an increase in the required memory and in the number of arithmetic operations per one time step. A calculation example is presented.

A90-39519 The problem of supersonic flow past a thin wing of finite span with fully subsonic leading edges (K zadache obtekaniia sverkhzvukovym potokom tonkogo kryla konechnogo razmakha s polnost'iu dozvukovymi perednimi kromkami). N. F. VOROB'EV, *PMTF—Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Mar.–Apr. 1990, pp. 105–111. 7 Refs.

The problem of supersonic flow past a slightly curved wing with fully subsonic leading edges is solved by assuming a zero perturbation potential on the basis plane outside the wing projection plane. The problem is reduced to an integral Volterra equation of the second kind, and the possibility of solving this equation by the method of successive approximations is demonstrated. The solution has the form of a series whose terms are multiple integrals of known functions.

A90-37816 The use of contact transformations of the inhomogeneous Monge-Ampere equation in one-dimensional gas dynamics (Primenenie kontaktnykh preobrazovanii neodnorodnogo uravneniia Monzha-Ampera v odnomernoi gazodinamike). S. V. KHABIROV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 310, No. 2, 1990, pp. 333–336. 6 Refs.

An approach to solving equations of one-dimensional gas dynamics is proposed which provides an alternative to the use of Euler and Lagrange coordinates. The approach uses Martin's substitution, which leads to the inhomogeneous Monger-Ampere equation. In this case, there are equations of state for which the contact symmetries of the equation form an infinite pseudogroup. The approach makes it possible to obtain solutions that are dependent on arbitrary functions and to write an infinite number of new conservation laws.

A90-42992 New solutions for two-dimensional stationary Euler equations (Novye resheniia dvumernykh statsionarnykh uravnenii Eilera). O. V. KAPTSOV, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 54, May-June 1990, pp. 409-415. 10 Refs.

A generalized variable separation method is used to obtain new particular solutions for the current function describing two-dimensional stationary motions of an ideal fluid. Flow line patterns are presented. The proof of the stability of some of the solutions is based on Arnold's (1966) theorem.

A91-55252 Discontinuous flow past a step whose height is much greater than the thickness of the lower sublayer of the interaction region (Otryvnoe obtekanie ustupa, vysota kotorogo mnogo bol'she tolshchiny nizhnego podsloia oblasti vzaimodeistviia). S. I. CHERNYSHENKO, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), July–Aug. 1991, pp. 25–30. 8 Refs.

Flow past a small step is investigated analytically in the context of the theory of boundary layer interaction with supersonic flow. The height of the step is assumed to be much greater than the lower sublayer thickness but much less than the boundary layer thickness. It is shown that such a flow can be calculated with sufficient accuracy using the Batchelor model.

A91-15434 Velocity calculation in the discrete vortex method (O vychislenii skorostei v metode diskretnykh vikhrei). I. K. LIFANOV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 313, No. 6, 1990, pp. 1399–1402.

The mathematical aspects of the calculation of velocities at the sites of discrete vortices in the discrete vortex method are examined. In particular, it is shown that the use of the discrete radius alone in the calculation of the tangential component produces an error when a free discrete vortex (or the point at which the velocity is calculated) is located very close to the vortex layer location curve relative to the discrete step. A model is proposed for the construction of vortex sheets of free vortices shed by an airfoil using the discrete vortex method.

A90-39514 Boundary layer stability in the case of transonic external flow (Ob ustoichivosti pogranichnogo sloia pri transzvukovykh skorostiakh vneshnego potoka). O. S. RYZHOV and I. V. SAVENKOV, *PMTF—Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Mar.–Apr. 1990, pp. 65–71. 15 Refs.

The classical theory of free interaction predicts the stability of direct waves propagating in the incoming flow direction in the case of supersonic flow velocities. The available equations for the transonic range, however, are not applicable to stability problems for viscous flows, although they do predict correctly flow separation. Here, an additional analysis of the initial system of Navier-Stokes equations is carried out in order to preserve the terms determining the loss of boundary layer stability in the transonic region.

A90-34672 A numerical method for calculating supersonic flows of a viscous gas (Chislennyi metod rascheta sverkhzvukovykh techenii viazkogo gaza). S. G. KARATAEV and V. N. KOTEROV, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 30, April 1990, pp. 586–600. 9 Refs.

A numerical method for calculating simplified stationary Navier-Stokes equations is proposed which employs the variables 'current function-orthogonal complement'. For solving a system of difference equations, a modified version of the global iteration method is proposed which significantly accelerates the convergence of the iteration process. Examples of calculations are presented, and the results are compared with the results of the asymptotic theory of local separated flows.

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A92-12423 A numerical simulation of separated flows around bodies. SHIGERU ASO and ATSUHIRO SAKAMOTO, *Kyushu University, Technology Reports* (ISSN 0023-2718), Vol. 64, Aug. 1991, pp. 249–255. 12 Refs.

Dynamic stall phenomena have been investigated numerically by solving incompressible Navier-Stokes equations by a third-order upwind-scheme in order to reveal the flow structure and mechanism of dynamic stall. At first, in order to examine the validity of the calculations separated flows around circular cylinder are calculated. The results show excellent agreements with the experiments. Also, separated flows around a wing section at fixed attack angle are calculated and the results show excellent agreements with experiments which are conducted by the present authors. Finally, separated flows around oscillating airfoil in pitch are calculated by using moving mesh system. The flow conditions are selected from the experiments. The calculated separated region is small in pitching-up process and it becomes large in a pitching-down process. Quite different characteristics of flow patterns between a pitching-up and pitching-down processes are obtained.

A92-11701 Numerical simulations of axisymmetric accretion flows. HIROSHI KOIDE, TAKUYA MATSUDA, and EIJI SHIMA, *Royal Astronomical Society, Monthly Notices* (ISSN 0035-8711), Vol. 252, Oct. 15, 1991, pp. 473–481. 25 Refs.

Properties of axisymmetric accretion flow on to a gravitating compact object from a uniform flow are studied by performing pure hydrodynamic calculations. At first a comparison is made between a numerical solution and an analytic solution based on a ballistic orbit theory, and it is found that the analytic solution is an extremely good approximation even for Mach numbers as low as 1.4. Next, results are presented for Mach numbers of 0.6, 1.4, 2.4, 5, and 10, and for a ratio of specific heats of 5/3. The accretion rate, the stand-off distance of the bow shock, and the stagnation point on the rear axis are computed based on various boundary conditions. An empirical formula for the accretion rate is proposed. It is found that the flow is not completely in steady state but a dome-like shock is formed quasi-periodically in front of the compact object for higher Mach number cases. It is argued that this shock perturbs the flow, leading to the destruction of axisymmetry of the flow eventually.

A92-17502 Supersonic inlet flow computation. SHIN-ICHI KURODA, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 31, July 1991, pp. 227–229. 10 Refs.

Supersonic inlet plays the role of partial or whole air-compression process in supersonic/hypersonic air-breathing engines and is a key factor of the engine performance. The ultimate purpose of the present study is to clarify the complex supersonic inlet flow structure by using the computational fluid dynamics (CFD) and thereby contribute to the development of the inlet. In the present paper, a preliminary computation is performed for the flowfield about the experimental inlet model which is designed at Mach number 3.0 and has a bleed chamber. To handle the complex body configuration, a zonal method with slightly overlapped grid is adopted. The Fortified Navier-Stokes approach is used as the interface scheme, which connects each zone with high accuracy and permits the movement of discontinuities across the zonal boundary.

A92-17501 CFD application to 2D/3D flow fields in Scramjet engine. TOSHIRO FUJIMORI, MASAFUMI KAWAI, TAKAKO SUZUKI, YASUNORI ANDO, and YASUNORI OHMORI, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 31, July 1991, pp. 221–226. 12 Refs.

CFD plays a major role in the research and development of hypersonic flight vehicles on the premise that numerical approaches provide simulations of various conditions, including supersonic combustion for which no ground test capability exists. The 2D/3D CFD codes have been developed to simulate the supersonic/hypersonic turbulent reacting flow in supersonic combustion ramjet (Scramjet) engines. The TVD scheme is used to capture shocks, and a finite reaction-rate mode of hydrogen-air combustion is utilized. The current results for the components of Scramjet engines are presented; i.e., inlet, combustor and nozzle by using the CFD codes. Validation of these results are compared with existing experimental and computational results.

A92-15637 Unsteady Navier-Stokes simulation of transonic cascade flow using an unfactored implicit upwind relaxation scheme with inner iterations. M. FURUKAWA, T. NAKANO, and M. INOUE, Presented as Paper 91-GT-223 at the 36th ASME, International Gas Turbine and Aeroengine Congress and Exposition, Orlando, FL, June 3–6, 1991. 8 pp. 10 Refs.

An implicit upwind scheme is developed for Navier-Stokes simulations of unsteady flows in transonic cascades. The two-dimensional, Reynolds-averaged Navier-Stokes equations are discretized in space using a cell-centered finite-volume formulation and in time using the Euler implicit method. The inviscid fluxes are evaluated using a highly accurate upwind scheme based on a TVD formulation with the Roe's approximate Riemann solver, and the viscous fluxes are determined in a central differencing manner. The algebraic turbulence model of Baldwin and Lomax is employed. To simplify grid generations, a zonal approach with a composite zonal-grid system is implemented, in which periodic boundaries are treated as zonal boundaries. A time-linearization of the inviscid fluxes evaluated by the Roe's approximate Riemann solver is presented in detail. No approximate factorization is introduced, and unfactored equations are solved by a pointwise relaxation method. To obtain time-accurate solutions, 30 inner iterations are performed at each time step. Numerical examples are presented for unsteady flows in a transonic turbine cascade where periodic unsteadiness is caused by the trailing-edge vortex shedding.

A91-50379 Breakdown of frozen motion of vorticity field and vorticity reconnection. SHIGEO KIDA and MASANORI TAKAOKA, *Physical Society of Japan Journal* (ISSN 0031-9015), Vol. 60, July 1991, pp. 2184-2196. Research supported by MOESC. 23 Refs.

The perpendicular components to vorticity of the Laplacian of vorticity multiplied by the kinematic viscosity represents the rate of breakdown due to viscous effects of the frozen motion of vortex lines with fluid particles, whereas the parallel component represents the deviation of the stretching rates of vortex and fluid line elements. The spatial distributions of high-value regions of these two components and vorticity are compared in detail in several analytical and numerical flows. It is found that the parallel component takes large negative values typically inside high-vorticity regions. On the other hand, the absolute value of the perpendicular compound is large where the high-vorticity regions are interacting, which suggests that this component may serve as a good measure of the degree of vorticity reconnection.

A91-38893 Wave number space dynamics of enstrophy cascade in a forced two-dimensional turbulence. KOJI OHKITANI, *Physics of Fluids A* (ISSN 0899-8213), Vol. 3, June 1991, pp. 1598–1611. 24 Refs.

Enstrophy cascade in two-dimensional turbulence is studied with an emphasis on the influence of the coherent vortices on the inertial range spectrum. Temporal intermittency of enstrophy cascade is also examined and compared with that of passive scalar cascade and with intristic stochasticity. The vorticity field is decomposed into elliptic (e) and hyperbolic (h) regions through Weiss' conditional sampling method. The 1/k law of the enstrophy spectrum associated with the h region extends with the dissipation wave number, while the humplike spectrum associated with the e region does not. Asymptotic recovery of the 1/k law is suggested in the inviscid limit. The wave number characteristic to the enstrophy spectrum of the first Liapunov vector is also traced on the (k-t) plane. It is found that, when the peak wave number lies in the inertial subrange, enstrophy dissipation is likely to be large.

A92-21719 Direct numerical simulation of a suddenly-started mixing shear layer. TOSHI FUJIWARA and XIAO WANG, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 34, Nov. 1991, pp. 121–130. 6 Refs.

Numerical solutions for a forced temporally-developing 2D mixing shear layer are presented. Small perturbations with subharmonic and fundamental modes are superimposed on the unidirectional freestream to show the physics of roll-up and pairing of vortices. The phenomena of rolling up, pairing, splitting, and re-pairing processes of large-scale structures are determined, and the evolution of vorticity distribution is demonstrated in terms of vortex pattern.

A92-17503 Numerical simulation for various flowfields of aero-engine components. KOJI MATSUNAGA, YASUNORI ANDO, ATSUSHIGE TANAKA, and HIDEMI TOH, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 31, July 1991, pp. 230–237. 12 Refs.

Advances in aero-engine performance and economy are achieved by a fusion of many individual efforts in technology. Significant advances in the evolution and rationalization of aerodynamic technology appear in the development and utilization of CFD. CFD demonstrates valuable applications and is an essential complement to testing and experimentation. A brief review is presented of the current status and the future of CFD on the aero-engine development including: (1) 3D compressible Navier-Stokes computation for turbine-vane configurations; (2) incompressible Navier-Stokes computation for gas turbine combustor; and (3) Euler and Navier-Stokes computations for some ducts, stator/downstream strut interaction and swan-neck duct.

A92-15356 Computation of the potential flow through cascades using the conformal mapping and the singularity method. SHUJI TANAKA, SUSUMU MURATA, and KAZUO KURATA, *JSME International Journal, Series II* (ISSN 0914-8817), Vol. 34, Nov. 1991, pp. 423–430. 9 Refs.

A numerical analysis of a 2D incompressible potential flow through cascades of airfoils with arbitrary profiles is presented. An airfoil row in the physical plane is first transformed into a near-circle row using a simple mapping function, and then the singularity method is applied in the mapped plane. A cascade of thin or practical airfoils can be transformed into a near-circle row with sufficiently smooth contour through the proposed procedure. The results are found to be in good agreement with the exact solutions for a cascade of flat plates or specified airfoils by Gostelow, in which the numerical error for the typical cascade configuration is as low as 0.2 percent.

A92-15330 A robust flow calculation technique with multiple finite control volumes. E. MORISHITA, *Chinese Journal of Aeronautics* (ISSN 1000-9361), Vol. 4, May 1991, pp. 121–125.

The control-volume method describes the forces which act on the system, but not necessarily the wall pressure of the system. An attempt is made to develop a control volume method which makes it possible to obtain the wall pressure of the control volume. The 2D inviscid incompressible steady duct flow is considered. The conservation equations in integral form are discretized for a control volume. The circulation along the control surface is expressed as a nonlinear function of the vertical velocity component at the inlet and is set equal to zero for the inviscid flow. The equation is solved by the Newton method, and the other aerodynamic properties can be obtained. The calculated results are compared to the experiment and the agreement is found to be satisfactory.

A91-44828 Numerical simulation for nonstationary Mach reflection of a shock wave—A kinetic-model approach. D. Q. XU and H. HONMA, *Shock Waves* (ISSN 0938-1287), Vol. 1, March 1991, pp. 43–49. 16 Refs.

A numerical simulation was performed for the process of formation of single Mach reflection on a wedge by solving a BGK type kinetic equation for the reduced distribution function with a finite-difference scheme. The calculations were carried out for a shock Mach number 2.75 and wedge angle 25 deg in a monatomic gas, which corresponds to the conditions of single Mach reflection in the classical von Neumann theory. The calculations were performed for both diffuse and specular reflection of molecules at the wall surface. It is concluded that the diffuse reflection of molecules at the wall surface or the existence of the viscous or thermal layer is an essential factor for a nonstationary process at the initial stage of Mach reflection.

A91-37780 A comparison between computation and experiment for flows around airfoil with slat and flap. MICHIRU YASUHARA, YOSHIAKI NAKAMURA, and WEI JIA, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 33, Feb. 1991, pp. 218–233. 10 Refs.

The flows about an airfoil with a slat and a flap are investigated experimentally and numerically. The experiment measures aerodynamic coefficients and velocity distributions in the neighborhood of the slat slot exit and visualizes the flow field for various attack angles and flap angles, which include two cases: open and closed slat slot. The Reynolds number of the experiments is 160,000. A numerical simulation is conducted under the same conditions as the experiment, and comparison between experiment and calculation shows good agreement for aerodynamic coefficients, flow patterns, and velocity distributions, especially in the region influenced by the slat slot jet. Control of a flow separation by the jet is significant for improving the flow situation around an airfoil at large attack angles.

A91-55143 Straining effects and vortex reconnection of solutions to the 3-D Navier-Stokes equation. MASANORI TAKAOKA, *Physical Society of Japan Journal* (ISSN 0031-9015), Vol. 60, Aug. 1991, pp. 2602–2612. 18 Refs.

Superimposed a time-dependent irrotational straining flow, a class of exact solutions to the 3D incompressible Navier-Stokes equation is slightly generalized, which represents time-evolution of various configurations of straight jets. In particular, since the vorticity depends on two spatial variables, two-dimensional aspects of the dynamics and strain effects to the vortex structure, such as vortex reconnection, can be investigated with these solutions. The time developments of circulation, energy and enstrophy are also examined and compared with numerical results of turbulence.

A91-52920 A universal cubic interpolation solver for compressible and incompressible fluids. T. YABE, *Shock Waves* (ISSN 0938-1287), Vol. 1, Aug. 1991, pp. 187–195. 10 Refs.

A universal numerical solver commonly usable for compressible and incompressible fluids is proposed. The method approaches the MAC algorithm at very high sound speed and continuously approaches the algorithm for compressible fluid with decreasing sound speed. The advection term is treated by the CIP algorithm which was previously proposed. A single program is applied to one- and two-dimensional shock-tube problems, and two-dimensional liquid flow inside a cavity at high Reynolds number.

A91-52819 Fundamental studies in rarefied gas dynamics—Theory, numerical analysis, and experiment. YOSHIO SONE and TAKU OHWADA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 39, No. 450, 1991, pp. 328–341. 62 Refs.

Studies of rarefied gas dynamics on the basis of the Boltzmann equation are discussed. The numerical analysis of Couette, Poiseuille, and thermal transpiration flows is described. Evaporation and condensation characteristics are investigated.

A91-50378 Unified numerical procedure for compressible and incompressible fluid. TAKASHI YABE and PEI-YUAN WANG, *Physical Society of Japan Journal* (ISSN 0031-9015), Vol. 60, July 1991, pp. 2105–2108. 8 Refs.

A unified numerical procedure is proposed as a solver both for compressible and incompressible fluids. The method approaches the MAC algorithm at very high sound speed and continuously approaches the algorithm for compressible fluid with decreasing sound speed. The advection term is treated by a CIP algorithm which gives quite accurate and less diffusive results. This unified procedure is tested both by one-dimensional shock-tube problem and two-dimensional cavity flow at high Reynolds number.

A91-48805 Computational fluid dynamics and computers. SATORU OGAWA and YOKO TAKAKURA, *Fujitsu Scientific and Technical Journal* (ISSN 0016-2523), Vol. 27, Summer 1991, pp. 222–232. 35 Refs.

This paper describes the participation of CFD and computers. First, the history and outline of CFD are briefly explained. Next, advanced researches (computations of transonic flow with large separation, supersonic flow around complex configurations, supersonic flow with combustion, and hypersonic flow of real gas) in the computation laboratory of the National Aerospace Laboratory are shown. Finally, turbulence and the future problems of CFD are described as impacted by computer performance.

A91-46822 Numerical simulation of outer flow around an ACV by discrete vortex methods. RYUICHI HAYASHI, TERUHIKO KIDA, and ZENSABURO YASUTOMI, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 39, No. 448, 1991, pp. 258–267. 23 Refs.

Two discrete vortex methods are used to compute the outer flow around an air cushion vehicle (ACV). The flow patterns for a two-dimensional ACV and the flow model are discussed. A numerical computational model of the three-dimensional ACV is also demonstrated.

A91-46198 Topology of a computed incompressible three-dimensional separated flow field around a high-angle-of-attack cone-cylinder. KOJIRO SUZUKI, *Computers and Fluids* (ISSN 0045-7930), Vol. 19, No. 3–4, 1991, pp. 315–334. 18 Refs.

The concept of 'topology' of a continuous vector field is introduced to numerical studies on the structure of a three-dimensional separated flowfield. In this paper, the flow structure is regarded as the topological properties of the streamlines and described as a composition of finite types of basic elements correlated with some typical flow features. The present topological studies are made in four vector fields defined in the flow around a body with regard to some physical aspects. All possible basic elements are formulated as a critical point or line in each vector field by use of the eigenvalues and eigenvectors for a local velocity gradient tensor. The former represents the quantitative topological properties and the latter determines the direction of a critical line. The method used to identify these basic elements from numerical flow data is also presented. Computational studies on a separated flowfield around a high-angle-of-attack cone-cylinder demonstrate that the present topological approaches have great potential for revealing the essential properties of flow phenomena with three-dimensional separation.

A91-47908 Statistics of velocity difference vs statistics of dissipation in isotropic turbulence. IWAO HOSOKAWA and KIYOSHI YAMAMOTO, *Physical Society of Japan Journal* (ISSN 0031-9015), Vol. 60, June 1991, pp. 1852–1855. 17 Refs.

From the data of a 3D numerically simulated isotropic turbulence, it is found that the statistics of longitudinal velocity difference in distance r is different from that of the velocity scale derived from dissipation averaged over a domain of scale r, and then intermittency exponents can hardly be related with exponents of structure functions.The probability distributions in both statistics are comparatively studied from the viewpoint of scale-similarity and modeling to involve multifractality.

A91-46200 The compact CIP (cubic-interpolated pseudo-particle) method as a general hyperbolic solver. TAKASHI YABE, PEI-YUAN WANG, TAKEO ISHIKAWA, TAKAYUKI AOKI, and GYO SAKAGUCHI, *Computers and Fluids* (ISSN 0045-7930), Vol. 19, No. 3–4, 1991, pp. 421–431. 11 Refs.

A new universal solver is proposed for general hyperbolic equations: multi-dimensional, linear and nonlinear equations with dissipative and dispersive terms. The scheme uses piecewise cubic polynomial interpolation inside meshes. The physical quantity and its spatial derivative are advanced in time according to the given equation. The scheme not only describes a sharp discontinuity with only one mesh but also reproduces the traveling wave train in the dispersive media. The extension to higher dimensions is straightforward.

A91-43062 Double linearization theory for prediction of mean loading effect on cascade flutter. I—Two-dimensional subsonic cascade. II—Two-dimensional supersonic cascade. M. NAMBA and K. TOSHIMITSU, *Journal of Sound and Vibration* (ISSN 0022-460X), Vol. 147, June 8, 1991, pp. 203–231, 233–254. 30 Refs.

This paper presents an improved mathematical formulation of the double linearization theory for predicting the mean loading effect upon the unsteady aerodynamic force for 2D vibrating cascades on subsonic flows, which is developed on the basis of methods of Namba (1975), Namba and Minami (1980), and Namba et al. (1984) for compressible flows. The new formulation takes into account the effect of equivalent unsteady mass sources due to the motion of blades with a steady fluid density jump between the upper and the lower surfaces of blades. The new formulation is extended by including predictions of the mean loading effect for the case of a supersonic cascade.

A91-40782 Direct simulations of three-dimensional flows using generalized vector potential method. H. TOKUNAGA, N. SATOFUKA, and K. YOYEDA, Presented as Paper 91-1610 at the 10th AIAA Computational Fluid Dynamics Conference, Honolulu, HI, June 24–27, 1991, Technical Papers (A91-40701 17-34). Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 937-946. 17 Refs.

A method for solving three-dimensional incompressible viscous flows is presented in the generalized coordinate. The vorticity, the scalar and the vector potential are introduced. The governing equations consist of the vorticity transport equations, the Laplace equation for the scalar potential and the Poisson equations for the vector potential. The vorticity transport equations are solved by the higher order method of lines. The higher order modified differential quadrature method is applied to the discretization of the elliptic equations and the reduced algebraic equations are treated using the Gauss-Seidel and the Jacobi method. The higher order multigrid methods used for the convergence acceleration. The present method is applied for the direct simulations of three-dimensional flows in a straight square duct and a curved circular duct as well as the transient turbulent flow in a channel.

A91-31493 Subgrid-scale modeling of compressible turbulent flows. AKIRA YOSHIZAWA, *Physics of Fluids A* (ISSN 0899-8213), Vol. 3, April 1991, pp. 714–716. 11 Refs.

A subgrid-scale (SGS) model for compressible turbulent flows is presented in the combination of the mass-weighted filtering procedure with the theoretical results from a two-scale DIA. This model consists of the filtered equations for mass, momentum, and internal energy as well as the equation for the intensity of SGS density fluctuation. In this model, the effects of fluid compressibility appear through the intensity of SGS density fluctuation and the divergence of the grid-scale velocity. The model with the SGS density fluctuation neglected leads to the simplest compressible version of the Smagorinsky model.

A91-28830 An upwind finite element scheme for high-Reynolds-number flows. MASAHISA TABATA and SHOICHI FUJIMA, *International Journal for Numerical Methods in Fluids* (ISSN 0271-2091), Vol. 12, Feb. 20, 1991, pp. 305–322. 28 Refs.

A new upwind finite element scheme for the incompressible Navier-Stokes equations at high Reynolds number is presented. The idea of the upwind technique is based on the choice of upwind and downwind points. This scheme can approximate the convection term to third-order accuracy when these points are located at suitable positions. From the practical viewpoint of computation, the algorithm of the pressure Poisson equation procedure is adopted in the framework of the finite element method. Numerical results of flow problems in a cavity and past a circular cylinder show excellent dependence of the solutions on the Reynolds number. The influence of rounding errors causing Karman vortex shedding is also discussed in the latter problem.