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Abstracts of Papers to Appear in Future Issues

IMPLICIT SOLVERS FOR UNSTRUCTURED MESHES. V. Venkatakrishnan. *Computer Sciences Corporation, NAS Applied Research Branch, NASA Ames Research Center, Moffett Field, California 94035, U.S.A.*; Dimitri J. Mavriplis. *Institute for Computer Applications in Science and Engineering, NASA Langley Research Center, Hampton, Virginia 23665, U.S.A.*

Implicit methods are developed and tested for unstructured mesh computations. The methods are used to solve the compressible Navier–Stokes equations to steady state. The approximate system which arises from the Newton-linearization of the nonlinear evolution operator is solved by using the preconditioned GMRES (generalized minimum residual) technique. Three different preconditioners, namely, the incomplete LU factorization (ILU), block diagonal factorization, and the symmetric successive over-relaxation (SSOR) are investigated. The preconditioners have been optimized to have good vectorization properties. SSOR and ILU themselves are studied as iterative schemes. The various methods are compared over a wide range of problems. Ordering of the unknowns, which affects the convergence of these sparse matrix iterative methods, is also investigated. Results are presented for inviscid and turbulent viscous calculations on single and multi-element airfoil configurations using globally and adaptively generated meshes.

NEW ALGORITHMS FOR ULTRA-RELATIVISTIC NUMERICAL HYDRODYNAMICS. V. Schneider, U. Katscher, D. H. Rischke, B. Waldhauser, and J. A. Maruhn. *Institut für Theoretische Physik der Universität Frankfurt, 6000 Frankfurt am Main, Germany*; C.-D. Munz. *Institut für Neutronenphysik und Reaktorforschung, Kernforschungszentrum Karlsruhe, 7500 Karlsruhe, Germany.*

Two new transport algorithms for solving the one-dimensional relativistic hydrodynamic equations of motion are discussed. One of them, *relativistic HLLE*, is based on the HLLE upwind scheme, while the other is a relativistic adaptation of some kinds of flux corrected transport (FCT) algorithms. A comparison with other numerical methods used in relativistic hydrodynamics including fully implicit techniques is given. Emphasis is put on the dependence of the results on the relativistic gamma factor and on the adiabatic exponent entering the ideal gas equation of state. Future applications of the algorithms are particularly in the field of ultra-relativistic heavy ion collisions that require transport methods not critically dependent on the Lorentz gamma or the equation of state.

NUMERICAL CHAOS, SYMPLECTIC INTEGRATORS, AND EXPONENTIALLY SMALL SPLITTING DISTANCES. B. M. Herbst. *Department of Applied Mathematics, University of the Orange Free State, Bloemfontein 9300, South Africa*; Mark J. Ablowitz. *Program in Applied Mathematics, University of Colorado, Boulder, Colorado 80309-0526, U.S.A.*

Two discrete versions of Duffing's equation are derived as reductions of discretizations of the nonlinear Schrödinger (NLS) equation. Inheriting the properties of the NSL discretizations, one is shown to be integrable and, using a Mel'nikov type analysis, the other discretization is shown to be nonintegrable. Arguments are given why it is possible for the nonintegrable scheme to restore the homoclinic orbit at an exponentially fast rate which is faster than the order of the approximation, as $h \to 0$. This suggests why there can be fundamental differences between symplectic and nonsymplectic discretizations of certain continuous Hamiltonian systems.

TRANSITION TO CHAOS IN AN OPEN UNFORCED 2D FLOW. Thomas H. Pulliam. *CFD Branch, NASA Ames Research Center, Ames, Iowa 50010, U.S.A.*; John A. Vastano. *Center for Turbulence Research, Stanford University, Stanford, California 94305, U.S.A. and NASA Ames Research Center, Ames, Iowa 50010, U.S.A.*

Unsteady low Reynolds number flow past a two-dimensional airfoil is studied numerically. The purpose is to (1) determine the bifurcation sequence leading from simple periodic flow to complex aperiodic flow as the Reynolds number is increased, (2) identify and quantify the chaos present in the aperiodic flow, and (3) evaluate the role of numerics in modifying and controlling the observed bifurcation scenario. The full two-dimensional Navier–Stokes equations are solved for a NACA 0012 airfoil at $M_\infty = 0.2$, $\alpha = 20°$, and $\mathrm{Re} < 4000$. The Navier–Stokes code ARC2D in an unsteady time-accurate mode is used for most of the computations. For each Reynolds number studied, the asymptotic behavior of the flow is studied using time delay reconstructions, Poincaré sections, and frequency decompositions. The system undergoes a period-doubling bifurcation to chaos as the Reynolds number is increased from 800 to 1600, with windows of periodic behavior in the chaotic regime past 1600. The observed chaotic attractors are further characterized by estimates of the fractal dimension and partial Lyapunov exponent spectra. Tests are made on the effects of varying mesh resolution, added artificial dissipation, and order of spatial or temporal accuracy of the numerical method. It is shown that the observed chaos does not arise due to numerical effects alone, but is a true solution of the model system. Local Lyapunov exponent analysis is used to determine the physical mechanism behind the period-doublings.

A CONSERVATIVE STABLE SMOOTHNESS-ENHANCING FREE-LAGRANGIAN METHOD. V. M. Hazins and V. V. Svetsov. *Institute for Dynamics of Geospheres, Russian Academy of Sciences, Moscow 117 979, Russia.*

In this paper a two-dimensional free-Lagrangian method for modeling compressible fluid flows is presented. Within the traditional general approach, combining a flexible reconnected triangular mesh with a finite difference algorithm, several new important numerical techniques are developed to enhance stability and smoothness of the method. Characteristic features of the method are a new technique of additional mesh connections and a way of mapping variables from nodes to zones and back. A finite difference scheme is chosen to conserve different forms of energy. The implicit discrete equations are solved by a special iterative procedure. Four numerical examples, including flows with relatively complex internal structure, are considered.

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THE TREATMENT OF SPURIOUS PRESSURE MODES IN SPECTRAL INCOMPRESSIBLE FLOW CALCULATIONS. Timothy N. Phillips and Gareth W. Roberts. *Department of Mathematics, University of Wales, Aberystwyth, Aberystwyth SY23 3BZ, United Kingdom.*

Algorithms for the transient and steady state simulation of incompressible Newtonian and non-Newtonian flows are described for the primitive variable formulation of the governing equations. Spectral approximations are used for the spatial discretization. Attention is given to the satisfaction of the incompressibility constraint and the determination of the pressure. Spurious pressure modes are removed by means of a singular value decomposition. The corresponding velocity field is divergence-free at all the collocation points. Numerical results are presented for Newtonian flow in a regularized driven square cavity and for non-Newtonian flow in a planar channel and in a journal bearing for a realistic range of material parameters.

A DIVERGENCE-FREE CHEBYSHEV COLLOCATION PROCEDURE FOR INCOMPRESSIBLE FLOWS WITH TWO NON-PERIODIC DIRECTIONS. Ravi K. Madabhushi, S. Balachandar, and S. P. Vanka. *University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, U.S.A.*

The enforcement of divergence-free condition in the interior and on the boundaries of an incompressible flow with two non-periodic directions is discussed for a Chebyshev collocation formulation. An influence matrix technique along with a correction methodology is used to satisfy the continuity equation everywhere in the domain. Details of implementing this procedure in a collocation method are presented. An efficient solution procedure based on matrix diagonalization has been used to solve the resulting full matrices. Two test problems, (a) flow in a driven square cavity, and (b) fully-developed laminar flow in a square duct subject to a three-dimensional perturbation, are studied. Run-time statistics (CPU, memory, MFLOPS) of the solution procedure are presented for representative grid sizes.

THE APPLICATION OF PRECONDITIONING IN VISCOUS FLOWS. Y.-H. Choi. *Sverdrup Technology, Inc., NASA Lewis Research Center, Cleveland, Ohio 44135, U.S.A.*; C. L. Merkle. *Department of Mechanical Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, U.S.A.*

A time-derivative preconditioning algorithm that is effective over a wide range of flow conditions from inviscid to very diffusive flows and from low speed to supersonic flows has been developed. The algorithm uses a preconditioning matrix that introduces well-conditioned eigenvalues while simultaneously avoiding nonphysical time reversals for viscous flows. The resulting algorithm also provides a mechanism for controlling the inviscid and viscous time step parameters at very diffusive flows, thereby ensuring rapid convergence for very viscous flows as well as for inviscid flows. Computational capabilities are demonstrated through computation of a wide variety of problems. Convergence rates are shown to be accelerated by as much as two orders of magnitudes, while providing solutions that are identical to those obtained without the preconditioning method.

DENSITY-CONSERVING SHAPE FACTORS FOR PARTICLE SIMULATIONS IN CYLINDRICAL AND SPHERICAL COORDINATES. Wilhelmus M. Ruyten. *University of Tennessee-Calspan, Center for Space Transportation and Applied Research, UTSI Research Park, Tullahoma, Tennessee 37388-8897, U.S.A.*

It is shown that, in cylindrical and spherical coordinates, particle-to-grid weighting based on conventional particle-in-cell (PIC) and cloud-in-cell (CIC) shape factors results in non-uniform grid densities even for uniform particle distributions. Instead, alternative, density-conserving weighting schemes are discussed, including modified PIC and CIC weighting.

NOTES TO APPEAR

COMPUTATION OF THE IDEAL-MHD CONTINUOUS SPECTRUM IN AXISYMMETRIC PLASMAS. Stefaan Poedts and Elisabeth Schwarz. *Max-Planck-Institut für Plasmaphysik, Boltzmannstrasse 2, D-8046 Garching bei München, Germany.*

SPHERICAL BESSEL TRANSFORMS. Brian A. Pettitt, Werner Danchura, and Donna Labun. *Department of Chemistry, University of Winnipeg, Winnipeg, Manitoba, Canada R3B 2E9.*

PROPERTIES OF COLLOCATION THIRD-DERIVATIVE OPERATORS. William J. Merryfield and Bernie Shizgal. *Department of Chemistry and Department of Geophysics and Astronomy, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1.*