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Abstracts of Papers to Appear

Weak ψ–ω Formulation for Unsteady Flows in 2D Multiply Connected Domains. M. Biava, D. Modugno, L. Quartapelle, and M. Stoppelli. Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano, Via La Masa 34, 20158 Milan, Italy.

This paper describes a variational formulation for solving the time-dependent Navier–Stokes equations expressed in terms of the stream function and vorticity around multiple airfoils. This approach is an extension to the case of multiply connected domains of the weak formulation based on explicit viscous diffusion recently proposed by Guermond and Quartapelle. In their method the momentum equation was interpreted as a dynamical equation governing the evolution of the (weak) Laplacian of the stream function, while the Poisson equation for the latter was used as an expression to evaluate the distribution of the vorticity. Time discretizations with the viscous term made explicit were used, leading to the viscosity being split from the incompressibility, similarly to the primitive variable fractional-step method. In the present work the multiconnectedness is addressed by introducing an influence matrix to determine the constant values of the stream function on the airfoils in a noniterative fashion. The explicit treatment of the viscous term leads to an influence matrix rooted in the harmonic problem instead of in the biharmonic problem occurring in methods enforcing integral conditions on the vorticity, such as the Glowinski–Pironneau method. The influence matrix changes at each time step or is constant depending on whether a semi-implicit or fully explicit treatment is adopted for the nonlinear term. The resulting split method is implemented using a first-order Euler backward difference or a second-order BDF scheme and linear finite elements. Numerical results are given and compared with the solutions obtained by means of the biharmonic formulation for multiply connected domains.

Consistent Boundary Conditions for Multicomponent Real Gas Mixtures Based on Characteristic Waves. Nora Okong'o and Josette Bellan. Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, MS125-109, Pasadena, California 91109-8099.

Previously developed characteristic-wave-based boundary conditions for multicomponent perfect gas mixtures are here extended to real gas mixtures. The characteristic boundary conditions are derived from the one-dimensional wave decomposition of the Euler equations, and the wave amplitude variations are determined from the prescribed boundary conditions on the flow variables. The viscous conditions are applied separately. For multidimensional simulations, the boundary conditions for each coordinate direction are applied additively. These boundary conditions are tested on a representative two-dimensional problem—the propagation of an incompressible vortex by a supersonic flow with outflow conditions specified as nonreflecting—solved using a high-order finite-difference scheme. Simulations conducted for a heptane–nitrogen mixture flow with strong real gas effects display excellent, nonreflective wave behavior as the vortex leaves the computational domain, verifying the suitability of this method for the multidimensional multicomponent real gas flows computed.

A Pressure-Based Method for Turbulent Cavitating Flow Computations. Inanc Senocak and Wei Shyy. Department of Aerospace Engineering, Mechanics and Engineering Science, University of Florida, Gainesville, Florida 32611.

A pressure-based algorithm is presented for turbulent cavitating flow computations. Single-fluid Navier–Stokes equations cast in their conservative form, along with a volume fraction transport equation, are employed. The flow field is computed in both phases with the vapor pressure recovered inside the cavity via a mass transfer

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model. A pressure–velocity–density coupling scheme is developed to handle the large density ratio associated with cavitation. While no temperature, and hence Mach number, effect is considered in the cavitation model, the resulting pressure–correction equation shares common features with that of high-speed flows, exhibiting a convective–diffusive type, instead of only a diffusive type. Furthermore, similar to high-speed cases, upwinded density interpolation in mass flux computations also aids convergence of the cavitating flow computations. The nonequilibrium effect in the context of the k-ε turbulence model, the grid distribution, and the choice of convection schemes have been computationally examined in projectile flows. While satisfactory predictions in wall pressure distribution can be made with variations in grid resolution and parameters in the cavitation model, other aspects, such as the density distribution and detailed streamline characteristics, are found to exhibit higher sensitivity to them.

A Numerical Method to Simulate Radio-Frequency Plasma Discharges. E. P. Hammond,* K. Mahesh,† and P. Moin.* *Department of Mechanical Engineering, Stanford University, Stanford, California 94805; and †Department of Aerospace Engineering and Mechanics, University of Minnesota, Minneapolis, Minnesota 55455.

A fully conservative and efficient numerical algorithm is developed for fluid simulations of radio-frequency plasma discharges. Results are presented in one and multiple dimensions for a helium discharge. The algorithm produces accurate results even on fairly coarse grids without the use of numerical dissipation. The proposed electron flux discretization is more accurate and efficient than two of the most commonly used discretizations: low-order upwinding (M. S. Barnes, T. J. Colter, and M. E. Elta, 1987, *J. Appl. Phys.* **61**, 81) and Scharfetter–Gummel (D. L. Scharfetter and H. K. Gummel, 1969, *IEEE Trans. Electron Devices* **ED-16**, 64).

Exponential Time Differencing for Stiff Systems. S. M. Cox and P. C. Matthews. School of Mathematical Sciences, University of Nottingham, University Park, Nottingham NG7 2RD, UK.

We develop a class of numerical methods for stiff systems, based on the method of exponential time differencing. We describe schemes with second- and higher-order accuracy, introduce new Runge–Kutta versions of these schemes, and extend the method to show how it may be applied to systems whose linear part is nondiagonal. We test the method against other common schemes, including integrating factor and linearly implicit methods, and show how it is more accurate in a number of applications. We apply the method to both dissipative and dispersive partial differential equations, after illustrating its behavior using forced ordinary differential equations with stiff linear parts.