Soviet Aerospace Literature
This month: *Computational Fluid Dynamics*

A89-35495 Potential models of transonic flows (O potentsial'nykh modeliakh transzvukovykh techenii). IU. B. LIFSHITS and A. A. SHAGAEV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 304, No. 6, 1989, pp. 1315-1319. 6 Refs.

The paper considers the development of potential models for transonic flows, where the Zhukovskii-Chaplygin condition guarantees uniqueness of the solution. The proposed method is used to calculate transonic flow past wing profiles. In particular, the pressure-coefficient distribution is shown for the NACA 0012 profile at a freestream Mach number of 0.8 and an angle of attack of 1.25 deg.

A89-35451 Calculation of the far hypersonic wake of a body moving in the presence of quasi-equilibrium chemical processes (Raschet dal'nego giperzvukovogo sleda za telom, dvizhushchimsia v usloviiakh okoloravnovesnogo protekaniia khimicheskikh protsessov). E. M. BIKART, *Leningradskii Universitet, Vestnik, Matematika, Mekhanika, Astronomiia* (ISSN 0024-0850), Oct. 1988, pp. 37-42. 11 Refs.

An implicit three-layer difference scheme with Newton-type linearization is used to calculate the characteristics of a viscous turbulent far wake of a body in the presence of quasi-equilibrium chemical processes. A matrix method is used to solve the set of algebraic equations obtained after linearization. Calculation results are presented for flight conditions at an altitude of 30 km for a blunt cone moving at 7.4 km/sec.

A89-34642 Third order compact schemes in high Reynolds number viscous flow computation. A. I. TOLSTYKH, BAIL V; Proceedings of the Fifth International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods, Shanghai, People's Republic of China, June 20-24, 1988 (A89-34626 14-64). Dublin, Ireland, Boole Press, Ltd., 1988, pp. 345-350. 6 Refs.

The difficulties associated with the numerical simulation of high Reynolds number flows are presently addressed by a solution-dependent coordinate transformation for adaptive grid generation in conjunction with a class of noncentered third-order compact schemes. The 'stretching' of thin boundary layers with compact third-order upwind differencing approximations has been used in the numerical simulation of several kinds of separated flows; attention is given to the simple illustrative case of shock wave-boundary layer interaction.

A89-34636 Calculations of the unsteady external viscous fluid flows at large Reynolds numbers. V. A. GUSHCHIN, BAIL V; Proceedings of the Fifth International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods, Shanghai, People's Republic of China, June 20-24, 1988 (A89-34626 14-64). Dublin, Ireland, Boole Press, Ltd., 1988, pp. 155-159. 14 Refs.

The physical factors-splitting method is presently used to calculate unsteady separated incompressible viscous flows past a circular cylinder, on the basis of the Navier-Stokes equations. The hybrid finite-difference scheme of the method is constructed by combining central-difference and upwind schemes. The resulting scheme is of second-order accuracy in its space variables, has minimal scheme dissipation, and works over a broad range of Reynolds numbers; it may be used to calculate flat, axisymmetrical and three-dimensional homogeneous and nonhomogeneous fluid flow problems with free surfaces. Results obtained for the flow around circular cylinders are discussed.

A89-34078 Heat transfer in a laminar semiinfinite jet for different initial velocity profiles (Teploobmen v laminarnoi poluogranichennoi strue pri razlichnykh nachal'nykh profiliakh skorosti). V. N. KOROVKIN and IU. A. SOKOVISHIN, *Promyshlennaia Teplotekhnika* (ISSN 0204-3602), Vol. 11, No. 1, 1988, pp. 29-31. 5 Refs.

The evolution of a plane laminar jet of a viscous incompressible fluid along a solid nonporous surface with a fixed temperature is modeled numerically. The problem is treated in a non-self-similar formulation. Velocity and temperature evolution patterns are obtained, as are dependences of the principal flow parameters on the longitudinal coordinate, Prandtl number, and initial conditions.

A88-48744 Flow of a viscous gas through a cylindrical channel in the presence of a supercritical pressure gradient and three-dimensional heat release (Istechenie viazkogo gaza cherez tsilindricheskii kanal pri sverkhkriticheskom perepade davleniia i nalichii ob'emnogo teplovydeleniia). A. A. KOROTEEV, *Akademiia Nauk SSSR, Sibirskoe Otdelenie, Izvestiia, Seriia Tekhnicheskie Nauki* (ISSN 0002-3434), June 1988, pp. 27-34.

A full two-dimensional system of Navier-Stokes equations is used to develop a computational model for solving the nonlinear problem of viscous gas flow in a channel in the presence of intense internal heat release. Some characteristic properties of the flow are identified, such as the presence of a sonic surface penetrating the channel, the presence of a maximum flow heating point inside the channel, and a well pronounced decrease in flow rate in comparison with a flow without heat release. It is shown that, with an accuracy sufficient for engineering calculations, gas flow through short channels at low Reynolds number is adequately described by an approximate one-dimensional model.

A89-34077 Heat transfer in a laminar boundary layer on a curved surface (Teplootdacha v laminarnom pogranichnom sloe na krivolineinoi poverkhnosti). A. A. KHALATOV and A. A. AVRAMENKO, *Promyshlennaia Teplotekhnika* (ISSN 0204-3602), Vol. 11, No. 1, 1988, pp. 19-23. 6 Refs.

A method is proposed for calculating heat transfer in a laminar boundary layer on a surface with longitudinal curvature. Similarity equations for the Nusselt number are obtained which allow for the surface curvature. The equations can be used for calculating heat transfer over a wide range of Prandtl numbers, for constant and variable curvature, and also in the boundary layer separation layer.

A89-34043 Energy dissipation rate for a viscous fluid with a tangential stress condition at the boundary flow line (Skorost' dissipatsii energii viazkoi zhidkosti s usloviem dlia kasatel'nogo napriazheniia na granichnoi linii toka). A. G. PETROV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 304, No. 5, 1989, pp. 1082-1086. 8 Refs.

The Helmholtz theorem yields an exact lower bound on the dissipation rate of flow for fluids of different viscosities with the same velocity at the boundary. It is shown here that, for the same tangential stress at the boundary, it is possible to obtain an exact upper bound on the dissipation rate for fluids of different viscosities. A proof for the corresponding theorem is presented, and flow of a viscous fluid inside a spherical drop in the path of viscous gas flow is considered as an example.

A89-32281 Entry of a free expanding gas jet into a round opening in a transverse obstacle (Vkhod svobodno rasshiriaiushcheisia gazovoi strui v krugovoe otverstie v poperechnoi pregrade). A. M. BISHAEV, E. F. LIMAR, S. P. POPOV, and E. M. SHAKHOV, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 29, Feb. 1989, pp. 277-285. 6 Refs.

Results of a numerical solution are presented for an axisymmetric problem concerning the impingement of a free expanding jet of a monoatomic gas on a plane transverse obstacle separating the gas jet from a vacuum and having a circular opening at the jet axis. The obstacle may be either infinitely thin or have a finite thickness. The problem is solved on the basis of Euler equations and a model kinetic equation. In the limit of a continuum, a steady oscillation regime is observed for moderate distances between the obstacle and the nozzle exit section.

A89-31311 Grid characteristic method in external gas dynamics. LEONID TURCHAK, Computational fluid dynamics; Proceedings of the International Symposium, Sydney, Australia, Aug. 23-27, 1987 (A89-31301 12-34). Amsterdam, North-Holland, 1988, pp. 177-190. 13 Refs.

Inviscid flowfields near blunt bodies traveling at supersonic speeds in perfect gas atmosphere are discussed. Considerationis given to steady two-dimensional and three-dimensional flows near bodies in a nonuniform oncoming stream, including some separated flows, unsteady axisymmetric flows near bodies in a uniform oncoming stream with a time-dependent velocity, and diffraction of plane or spherical shocks on bodies traveling with supersonic speeds. The solution of these problems are obtained numerically using the grid characteristic method.

A88-38847 Analytical study of friction and heat transfer in the vicinity of a three-dimensional critical point at low and moderate Reynolds numbers (Analiticheskoe issledovanie treniia i teploobmena v okrestnosti trekhmernoi kriticheskoi tochki pri malykh i umernnykh chislakh Reinol'dsa). I. G. BRYKINA and V. V. RUSAKOV, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Mar.-Apr. 1988, pp. 143-150. 10 Refs.

Hypersonic three-dimensional flow of a viscous gas past blunt bodies at low and moderate Reynolds numbers is investigated analytically with allowance for slip effects and a temperature discontinuity at the surface. Equations of a three-dimensional viscous shock layer are solved by the integral method of successive approximations and by the finite difference method near the critical point. An analytical solution to the problem is obtained to a first approximation. An analysis of the solution yields a simple formula which reduces the calculation of heat flux toward a three-dimensional critical point to the calculation of heat flux toward an axisymmetrical critical point.

A89-31305 Numerical algorithms for solving the Euler and Navier-Stokes equations on the basis of the splitting up method. V. M. KOVENIA, A. S. LEBEDEV, and S. G. CHERNYI, Computational fluid dynamics; Proceedings of the International Symposium, Sydney, Australia, Aug. 23-27, 1987 (A89-31301 12-34). Amsterdam, North-Holland, 1988, pp. 67-85. 21 Refs.

The numerical simulation of two- and three-dimensional viscous and inviscid flows on the basis of the gasdynamics equations and the parabolic approximation of the Navier-Stokes equations is discussed in an analytical review. Topics addressed include the formulation of a predictor-corrector-type difference scheme, marching algorithms for steady-flow problems, and the method of global iterations. Typical results are presented in extensive graphs and characterized in detail.

A89-30105 Calculation of unsteady viscous flows with highly inhomogeneous regions (Raschet nestatsionarnykh viazkikh techenii s oblastiami sil'nykh neodnorodnostei). A. S. KISELEV, A. N. KONDRATENKO, and A. V. PANASENKO, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 29, Jan. 1989, pp. 104-109. 14 Refs.

Three implicit difference schemes of splitting type are used to calculate the unsteady flows of a viscous heat-conducting gas with highly inhomogeneous regions (boundary layer, shock wave, or mixing zone). A numerical solution is obtained to the problem of an arbitrary discontinuity near a limiting plane. The results obtained demonstrate the effectiveness of the proposed approach.

A89-34040 Stability of nonaxisymmetric jets (Ustoichivost' neosesimmetrichnykh strui). V. A. VOSTRIAKOV, S. IA. GERTSENSHTEIN, and A. IA. RUDNITSKII, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 304, No. 5, 1989, pp. 1065-1069. 14 Refs.

The problem of the stability of nonaxisymmetric jets is investigated analytically for the case of the arbitrary dependence of velocity on two spatial variables. The stability analysis is carried out on the basis of linearized Navier-Stokes equations. The problem is reduced to a system of two equations for two unknowns, and a solution is then found by using the Bubnov-Galerkin method.

A89-31309 Completely conservative difference schemes. IU. I. SHOKIN, Computational fluid dynamics; Proceedings of the International Symposium, Sydney, Australia, Aug. 23-27, 1987 (A89-31301 12-34). Amsterdam, North-Holland, 1988, pp. 135-155. 23 Refs.

The theoretical basis of numerical simulation techniques for gasdynamics problems is explored analytically, with a focus on methods which conserve the most important properties of the approximated differential equations completely. The derivation of a family of completely conservative difference schemes is given in detail; in these schemes, the thermodynamic properties are determined using two layers, while the impulse equations are three-layered. The applicability of the results to splitting methods is indicated.

A89-23690 Asymptotic structure of nonviscous perturbations in a thin shock layer (Asimptoticheskaia struktura neviazkikh vozmushchenii v tonkom udarnom sloe). V. R. GUSHCHIN and A. V. FEDOROV, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Nov.-Dec. 1988, pp. 72-79. 8 Refs.

Different kinds of nonviscous three-dimensional short-wave perturbations in a thin shock layer of an ideal gas with arbitrary transverse velocity and temperature distributions are investigated by the WKB method. Simple analytical expression of dispersion relations are obtained for neutral perturbations. The results of an asymptotic analysis are compared with direct numerical calculations for a simple shock layer model.

A89-23689 Resonance interaction of wave packets in a boundary layer (O rezonansnom vzaimodeistvii volnovykh paketov v pogranichnom sloe). M. B. ZEL'MAN and B. V. SMORODSKII, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Nov.-Dec. 1988, pp. 67-71. 12 Refs.

In an effort to analyze the nonlinear evolution of a perturbation induced by an instantaneous point source, attention is given to the interaction of a two-dimensional wave train of variable carrier frequency with pairs of three-dimensional low-frequency packets. The possibility of the sequential parametric excitation of pulsations over the full range of frequency parameters is established, which can explain the acceleration of the transition process under conditions of pulsed boundary layer excitation.

A89-23688 A semiempirical method for calculating separated turbulent flow in a conical (Laval nozzle in the reexpansion mode Poluempiricheskii metod rascheta turbulentnogo otryvnogo techeniia v konicheskom sople Lavalia na rezhime pererasshireniia). T. I. MALIK and R. K. TAGIROV, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Nov.-Dec. 1988, pp. 60-66. 15 Refs.

A mathematical model describing separated flow in a nozzle is developed with allowance for the effect of the wall boundary layer and pressure variation along the separation zone inside the nozzle. The effect of geometrical and gasdynamic parameters on the separated flow pattern is investigated numerically. The results obtained are presented in graphic form.

A89-21593 A study of organized structures in the near-wall region of a turbulent boundary layer on a plastically deformed surface (Issledovanie organizovannykh struktur v pristennoi zone turbulentnogo pogranichnogo sloia na plastichno deformiruemoi poverkhnosti). O. A. LIKHACHEV, *PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Sept.-Oct. 1988, pp. 66-73. 24 Refs.

The dimensions of strips forming on a plastically deformed surface in the presence of a turbulent boundary layer are analyzed statistically. It is assumed that a transverse periodic structure is formed as a result of the presence of coherent formations in the near-wall region of the boundary layer in the form of longitudinal counterrotating vortex pairs. A self-similar lognormal distribution function is obtained for the structure size. A theoretical model is constructed which describes the interaction between coherent structures. The period between successive fluid ejections is related to the external and internal scales of the boundary layer.

A89-27348 Numerical solution of the problem of the expansion of a high-temperature gas volume (Chislennoe reshenie zadachi o razlete vysokotemperaturnogo ob'ema gaza). V. P. KOROBEINIKOV and A. K. SHARIPOV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 303, No. 6, 1988, pp. 1323-1326. 9 Refs.

The problem of the decomposition of a volume of a high-temperature radiating gas is investigated theoretically as part of a study of the qualitative and quantitative characteristics of gas expansion and radiative heat transfer for different parameters of the initial perturbation. Equations of radiative gas dynamics are integrated numerically; equations of radiation transfer are written in the diffusion approximation with allowance for radiation selectivity. Examples of spatial-temporal gas characteristics and changes in the integral light flux from the heated region with time are presented.

A89-26164 A nonstationary invariant solution to gas dynamics equations describing gas expansion to a vacuum (Nestatsionarnoe invariantnoe reshenie uravnenii gazovoi dinamiki, opisyvaiushchee rastekanie gaza do vakuuma). S. V. KHABIROV, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 52, Nov.-Dec. 1988, pp. 967-975. 6 Refs.

An invariant solution to gas dynamics equation is considered which is based on a one-dimensional subgroup valid for a polytropic gas with a special adiabatic exponent. The expands to a vacuum over an infinite period of time. New solutions are obtained which describe one-dimensional flows from a source into a vacuum and gas focusing inside a sphere or a cyylinder with shock waves. The discussion included the expansion of a mass of gas with an arbitrary boundary and gas expansion in the presence of contact discontinuity.

A89-23691 Motion of a dusty gas in the initial section of a plane channel and a circular pipe (Dvizhenie zapylennogo gaza v nachal'nom uchastke ploskogo kanala i krugloi truby). A. N. OSIPTSOV, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Nov.-Dec. 1988, pp. 80-87. 11 Refs.

The transition from uniform to nonuniform impurity distribution over the cross section of a duct (pipe) in the case of flow of a gas with suspended particles is investigated analytically using a two-continuum model of a dusty gas. The expression for momentum exchange between the phases includes the Saffman force, which accounts for transverse particle migration. Four characteristic flow regions are shown to be formed in the initial section at large Reynolds numbers. Equations describing the motion of the mixture in each of these regions are obtained using the method of matched expansions.

A89-18671 Mathematical modeling of laminar and turbulent supersonic flow past convex-concave bodies (Matematicheskoe modelirovanie laminarnogo i turbulentnogo sverkhzvukovogo obtekaniia tel vypuklo-vognutoi formy). A. M. GRISHIN and O. I. POGORELOV, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), Sept.-Oct. 1988, pp. 138-145. 12 Refs.

Laminar and turbulent supersonic flow past two convex-concave bodies is analyzed on the basis of Navier-Stokes equations. For laminar flow, the effect of the Reynolds number on the shock layer structure, pressure distribution, and heat flux is investigated. For turbulent flow, the calculated results are compared with the calculations and experimental data of recent studies. It is shown that, in the separation region, the pressure distributions on the body and the position and shape of the shock wave based on the Navier-Stokes equations are found to be in better agreement with experimental data than results based on the Euler and viscous shock layer equations.

A89-13157 Numerical study of nonstationary subsonic flows of a viscous gas in a plane duct with a sudden expansion (Chislennoe issledovanie nestatsionarnykh dozvukovykh techenii viazkogo gaza vo vnezapno rasshiriaiushchemsia ploskom kanale). A. T. FEDORCHENKO, *Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza* (ISSN 0568-5281), July-Aug. 1988, pp. 32-41. 17 Refs.

Nonlinear processes associated with instability evolution in nonstationary subsonic viscous gas flows in ducts with an axisymmetric sudden expansion are investigated numerically over a wide range of characteristic parameters, with allowance made for acoustic-vortex interactions. Sonic self-excitation effects are identified in the case of a jet flowing into the expansion, and approximate formulas are obtained for the stationary conditions of self-excitation. The effect of initial mean velocity profiles on flow evolution is evaluated. Finally, an analysis is made of the characteristics of formation and interaction of coherent structures.

A89-11568 Nonlinear stability of a stratified shear flow in the regime with an unsteady critical layer. S. M. CHURILOV and I. G. SHUKHMAN, *Journal of Fluid Mechanics* (ISSN 0022-1120), Vol. 194, Sept. 1988, pp. 187-216. 9 Refs.

Previous work on the nonlinear development of disturbances to a weakly supercritical stratified shear flow is extended to model an unsteady critical layer appearing in the region of resonance of the wave. The nonlinear term is nonlocal in time, and an evolution equation with cubic and quintic nonlinearity is derived which is used to study the evolution of an initially small disturbance. Where the wave amplitude is small enough, cubic nonlinearity is shown to dominate. For larger amplitudes, quintic nonlinearity dominates and an explosive regime occurs.