trekhmernogo pogranichnogo sloia). IU. IA. GERASIMOV, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 2, 1987, pp. 46-53. 9 Refs.

This paper describes a method which makes it possible to reduce the computation time for three-dimensional boundary layers, by using a computational grid for the integration of the equations of motion which are described by an orthogonal coordinate system connected with outside stream lines. The computational grid is built on the basis of a nonorthogonal coordinate system connected with the body. It is shown that the application of this grid and the formulas derived reduce the time needed for the calculation of a three-dimensional compressible turbulent boundary layer along the wing by more than twice compared with a conventional integration method.

A88-52038　　Using a solution to the inverse problem for aerodynamic surface design (Ispol'zovanie resheniia obratnoi zadachi dlia proektirovaniia aerodinamicheskoi poverkhnosti). L. A. POTAPOVA, IU. N. SVIRIDENKO, and L. L. TEPERIN, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 1, 1987, pp. 106-109.

A method for solving the problem of the aerodynamic design of a lifting surface, with a specified pressure profile and a fixed wing planform, is proposed which allows for the effect of the fuselage, powerplant, and other components on the wing profile shapes. In the design problem for part of a wing, the specified pressure distribution represents a boundary condition for determining profile shapes for the surface being designed. The geometry of the remaining part of the wing and other components is assumed to be known and remains unchanged in the process of the solution.

A88-52094　　Experimental study of flow in the core of a vortex structure (Eksperimental'noe issledovanie techeniia v iadre vikhrevoi struktury). V. L. BAKULIN and A. M. GAIFULLIN, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 4, 1987, pp. 117-119.

The paper presents an experimental study of quasi-conical flow for a parabolically curved wing with a parabolic planform. Two closed recirculation regions not touching the wing were observed at the wing's leading edge. An analysis is made of the effect of nonself-similar factors on the structure of the quasi-conical flow.

A88-52068　　The stability of the supercooled state of a flow in shaped wind-tunnel nozzles (Ob ustoichivosti pereokhlazhdennogo sostoianiia potoka v profilirovannykh soplakh aerodinamicheskikh trub). A. V. CHIRIKHIN, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 3, 1987, pp. 57-68. 16 Refs.

Parametric calculations of the nonequilibrium condensation of nitrogen in shaped nozzles of different scales were used to establish stability criteria for the supercooled state (8-13 K) of the flow. A technique was developed to estimate the size of the stable-supercooling zone and to assess the effect of weak condensation on the gasdynamic properties in the uniform-flow region.

A88-39913　　An error in the theory of conformal mappings of regions that are close to each other and in application to flow past airfoils (Ob odnoi oshibke v teorii konformnykh otobrazhenii blizkikh oblastei i v prilozhenii k obtekaniiu profilia). A. L. GONOR, *Prikladnaia Matematika i Mekhanika* (ISSN 0032-8235), Vol. 52, Mar.-Apr. 1988, pp. 345-348.

The correct value of the boundary derivative for the conformal mapping of the outer periphery of regions that are close to each other is defined. This value is used in a formula for determining the velocity distribution on a contour close to a given airfoil. The correction is introduced in the formula, and examples of the calculation of the velocity distribution on an elliptical airfoil are considered.

A88-32755　　Representation of a surface segment of an airfoil profile in Bezier form (Predstavlenie uchastka poverkhnosti aerodinamicheskogo profilia v forme bez'e). B. KH. PEREL'SHTEIN and S. S. SOLOV'EV, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 3, 1987, pp. 100-102. 5 Refs.

A formalism is developed for describing a segment of the surface of an airfoil profile of the kinematic kind. The approach used here is based on the use of a mathematical model of a surface in the form of the Bezier polyhedron, which makes it possible to use the coordinates of the Bezier polyhedron apex as the variable parameters in the shape optimization procedure. The method proposed here is designed for calculating optimal turbomachine profiles on the basis of three-dimensional gasdynamic models.

A88-37697　　Separation of a supersonic boundary layer ahead of the base of a body (Otryv sverkhzvukovogo pogranichnogo sloia pered donnym srezom kontura tela). M. A. KRAVTSOVA and A. I. RUBAN, *Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki* (ISSN 0044-4669), Vol. 28, April 1988, pp. 580-590. 8 Refs.

The separation of supersonic flow near a corner point on a body is analyzed in the context of the asymptotic theory of the interaction between a laminar boundary layer and the external nonviscous part of flow. Particular attention is given to the transition stage of flow during which a pressure increase in the base region leads to the detachment of the separation point from the corner point and to the displacement of the separation point toward the leading edge of the body. Results of a numerical solution are presented.

A88-33903　　Calculation of the diffusive combustion of a subsonic jet in a supersonic wake (K raschetu diffuzionnogo goreniia dozvukovoi strui v sputnom sverkhzvukovom potoke). I. S. BELOT-SERKOVETS and V. I. TIMOSHENKO, *PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki* (ISSN 0044-4626), Jan.-Feb. 1988, pp. 91-95. 9 Refs.

An approximate method for calculating the parameters of a subsonic injected jet in a supersonic wake in the presence of diffusive combustion is developed on the basis of a model of strong viscous-nonviscous interaction through pressure. An algorithm is presented for integrating boundary layer equations across the viscous flow region in the presence of a flame front. The effect of the molecular weight of the injected jet and diffusive combustion of hydrogen on the pressure in the nonsymmetric near wake of a plate is estimated in relation to injection intensity and hydrogen concentration.

A88-46060　　Asymptotic theory of separated flows (Russian book) (Asimptoticheskaia teoriia otryvnykh techenii). VLADIMIR VASIL'EVICH SYCHEV, ANATOLII IVANOVICH RUBAN, VIKTOR VLADIMIROVICH SYCHEV, GEORGII L'VOVICH KOROLEV, *Moscow, Izdatel'stvo Nauka*, 1987, 256 pp. 163 Refs.

Results of theoretical studies of separation flows of an incompressible fluid at large Reynolds numbers using asymptotic methods are examined. Particular attention is given to problems of self-induced separation in stationary and nonstationary flows, theory of local separations at the leading and trailing edges of thin airfoils, and investigations of the global field structure of flows in the wake of blunt bodies. Numerical methods for solving problems of the interaction between a boundary layer and a potential flow are discussed.

A88-52095　　Calculation of noncirculating flow past arbitrary bodies (Raschet bestsirkuliatsionnogo obtekaniia proizvol'nykh tel). S. M. BELOTSERKOVSKII, I. K. LIFANOV, and A. A. MIKHAILOV, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 5, 1987, pp. 1-10. 8 Refs.

The discrete vortex method is extended to a wide range of problems concerned with the calculation of noncirculating flow past bodies of arbitrary shape with corner points. The basic principles of a calculation method for plane problems are examined. The convergence of a numerical solution to the exact solution is demonstrated.

A88-52079　　Numerical study of viscous swirling flows (Chislennoe issledovanie viazkikh zakruchennykh potokov). A. M. GAIFULLIN and V. F. MOLCHANOV, *TsAGI, Uchenye Zapiski* (ISSN 0321-3429), Vol. 18, no. 4, 1987, pp. 10-16. 8 Refs.

A method for the numerical analysis of the motion of viscous fluid in a swirling steady axisymmetric flow is presented. Examples are introduced, calculating this motion in the presence of recirculating regions near the central line of the vortex. The study is useful in understanding the anomaly known as a 'vortex explosion,' which sometimes occurs during subsonic flow along a wing in a vortex line.

A88-43632　　Solution of a problem concerning flow past a finite-span wing (O reshenii zadachi obtekaniia kryla konechnogo razmakha). Z. KH. NUGMANOV and V. M. ROMANOV, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 1, 1988, pp. 108-110. 7 Refs.

The problem of flow past a finite-span wing is solved by using an approach representing a further development of the basis function method proposed in a previous study (Nugmanov, 1979). In contrast to the original method, the approach presented here involves solving singular integral equations. A significant saving in computational effort is achieved by transforming the kernels of the integral equations. Flow past a rectangular ring with a Zhukovskii profile is calculated as an example.

Japanese Aerospace Literature
This month: *Aerodynamics*

A88-46048　　Some thoughts on power-augmented-ram wing-in-ground (PAR-WIG) effect vehicle. SHIGENORI ANDO, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 31, May 1988, pp. 29-47. 13 Refs.

The PAR (Power-Augmented-Ram) WIG (Wing-in-Ground) effect vehicle is promising as an overwater commuter transport vehicle. Three important requirements, PAR effect, ability of off-ground effect flight, and ability of automatic IGE (in-ground effect) flight, are described. Many useful materials for designing WIG are presented. New concepts are proposed, which contain some new devices. Ability of 'stick-free' IGE flight is

especially desirable, hence the phugoid mode should be suppressed sufficiently.

A88-36698　　Aeroelastic galloping of a square-section cylinder in the Reynolds-number range from 100 to 10,000. YOSHIMASA TOMONARI, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Feb. 1988, pp. 234-242. 7 Refs.

The present study aims to make clearer the aerodynamic mechanism of high-speed, low-frequency galloping, starting spontaneously from rest in a cross-flow direction, to which the linear quasi-steady aerodynamic theory

is applicable. Low Reynolds-number measurements on a square-section cylinder with its front face normal to the uniform flow show that an increase in the Reynolds number approximately from 1,000 to 10,000 brings about a remarkable increase in the magnitude of an aerodynamic force derivative that represents a quasi-steady aerodynamic action to promote galloping. The corresponding change in the flow field is a progressive upstream movement of the laminar-to-turbulent transition position in the free shear layer. It is therefore suggested that turbulence in the free shear layers plays a vital role in the onset of galloping. Related data of surface pressures are also presented.

A88-31193 Aerodynamic characteristics of two-dimensional membrane airfoils. TAKESHI SUGIMOTO and JUNZO SATO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, no. 409, 1988, pp. 36-43. 16 Refs.

A theoretical and experimental investigation has been made of a flow past a two-dimensional inextensible membrane airfoil with slackness. The basic equations based on a linearized invincid theory have been analytically reformulated as a Fredholm integral equation of the second kind with an integral constraint, which has been solved by the degenerate kernel method. The experiment has been made of the measurements of lift, drag, and moment acting on quasi-two-dimensional membranes and the visualization of the flow past them. From the comparison of the analysis and the experiments, the following conclusions are obtained: (1) The linearized inviscid theory can predict fairly well the essential properties of flow around membranes with very small slackness. (2) As the excess length exceeds about five percent of the chord length, viscous effects prevail over the inviscid phenomena. (3) S-shaped membranes exist but exhibit a sustained-oscillation. (Author)

A88-50571 Experimental study of flow past two spheres in oblique arrangement placed on plane boundary. SHIKI OKAMOTO and KATSUHIDE MATSUNAGA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, no. 413, 1988, pp. 280-289. 9 Refs.

This paper describes an experimental study of the mutual interference between two spheres placed on plane boundary. The surface pressure distributions of two spheres were measured for the oblique arrangement of two spheres, and the drag, side-force, and lift coefficients were determined from surface-pressure distributions. The formation of vortices was observed by the method of visualization. The distributions of velocities and turbulent intensities of the flow past two spheres were measured. The experimental results were compared with those for a single sphere and two spheres, in tandem and side-by-side arrangements.

A88-36699 Quasi-one-dimensional aerodynamics with chemical, vibrational and thermal nonequilibrium. RI'ICHI MATSUZAKI, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Feb. 1988, pp. 243-258. 18 Refs.

A set of equations governing a nonequilibrium flow of high-temperature air is formulated. It consists of chemical and vibrational rate equations and an electron energy equation. In the latter equation, the electron temperature may be different from that of the heavy particles. These equations are coupled with global flow equations in a quasi-one-dimensional framework. Numerical solutions are obtained for nonequilibrium nozzle flows and for flows behind normal shock wave. The results give reasonable physical pictures for these flows, and a wide applicability of the present set of equations to nonequilibrium aerodynamic problems is confirmed. The effect of coupling of free electrons and vibrational nonequilibrium is also discussed.

A88-40421 Unsteady aerodynamic heating phenomena in the interaction of shock wave/turbulent boundary layer. MASANORI HAYASHI, SHIGERU ASO, and ANZHONG TAN, *Kyushu University, Faculty of Engineering, Memoirs* (ISSN 0023-6160), Vol. 47, Dec. 1987, pp. 231-239. 10 Refs.

Fluctuations of heat transfer have been measured in the regions of interaction between oblique shock waves and turbulent boundary layers. A new type of heat transfer rate gauge with high spatial resolution and fast response developed in the laboratory was used for the measurements of heat transfer rates. Results are compared with the wall pressure fluctuation measurements performed under the same test conditions. Experiments were made at a nominal Mach number of 4, wall temperature condition of 0.56, and Reynolds number of 1.26×10 to the 7th based on the distance from the flat plate leading edge. When the boundary layer is unseparated, fluctuations of heat transfer get strong near the impinging point of the incident shock; however no intermittency phenomena are observed. When the boundary layer is separated, significant fluctuations of heat transfer are observed throughout the interaction region. Near the separation and the reattachment point, the fluctuations are particularly strong, and near the separation point intermittency of heat transfer is observed.

A88-36700 Addendum to the calculation of transonic potential flow through a two-dimensional cascade. KENJI INOUE and TAKASHI NAKAMURA, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Feb. 1988, pp. 259-261.

A procedure proposed previously for calculating the transonic potential flow through a two-dimensional cascade is reviewed. This procedure is developed further by including a means of obtaining the solution in which a given point on a blade is a stagnation point; the downstream condition is

not given. Consideration is also given to the relationship between the force acting on a blade, the pressure distribution on its surface, the circulation around it, and the upstream and downstream conditions.

A88-26359 Aerodynamic characteristics of the Weis-Fogh mechanism. II - Numerical computations by the discrete vortex method. MICHIHISA TSUTAHARA and TAKEYOSHI KIMURA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 407, 1987, pp. 596-604. 10 Refs.

Aerodynamic characteristics of the Weis-Fogh (1973) mechanism, which is a lift-generating mechanism of hovering flight of small insects, were studied by the discrete-vortex method. Two flat wings were approximated by a finite number of bound vortices, and the unsteady force due to the change of the strengths of these vortices was estimated by a contour of integration including newly introduced nascent vortices. A sufficient lift is generated in all the stages of the wing motion. Especially at the final stage of the closing motion, the moment for closing the wing becomes very large while the lift remains moderate. At the same stage, a jet is produced between the two wings, and a region of high-speed flow also appears in the back side of each wing.

A88-24505 Large motion flight control system design for aircraft by the theory of perfect servo. SHOKICHI KANNO, AKIRA HASHIMOTO, and TATSUO CHUBACHI, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Nov. 1987, pp. 133-149. 9 Refs.

A decoupled and linearized tracking flight control system design for the large motion of aircraft is analyzed as an application of the theory of a nonlinear perfect tracking servo. The nonlinear rigid body dynamics are considered, but the nonlinear aerodynamics are neglected. The nonlinear terms of state equations are estimated and transformed to be added to the input signals of aircraft, and the nonlinearities are canceled. These nonlinear compensations permit the aircraft system to become linear. The precompensators with signal limiters and subcompensators are added, and the nonlinear perfect servo systems are achieved. The transfer matrix of this servo equals I3, even if the signals are saturated. Simulations on a high-speed aircraft show good results.

A88-14000 Wind shear tunnel with inclined wire gauze. HARUO KIMURA and HAMID BASSIRI, *Kyushu University, Faculty of Engineering, Memoirs* (ISSN 0023-6160), Vol. 47, June 1987, pp. 115-124.

For studying experimentally the aerodynamic characteristics of aircraft in wind shear using a conventional wind tunnel in which the aircraft model is set restrained from linear movement, a method for producing the wind shear condition - the flow field with spatial and temporal gradients - in the tunnel is presented. The spatial wind gradient is obtained by an inclined wire gauze installed upstream in the test section, and the temporal variation, which corresponds to the situation experienced by a moving aircraft, is generated by rotating the gauze or by controlling the tunnel stagnation pressure. This method is applied to a blowdown type wind tunnel and its validity is shown.

A88-13546 A design of the cascade for a shock-in-rotor supersonic axial-flow compressor. TAKAAKI HASHIMOTO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 403, 1987, pp. 401-404. 6 Refs.

A design method of the cascade for a shock-in-rotor supersonic axial-flow compressor is presented. The inlet flow is uniform and satisfies simplified radial equilibrium. The flow just before the normal shock is uniform and satisfies simplified radial equilibrium. The supersonic portion between the inlet and the normal shock is designed by using the method of weak wave. In the subsonic portion the flow is quasi-axisymmetric. The shape of mean streamline is assumed to be circular arc. The passage walls are composed of circular arcs. A two-dimensional supersonic cascade which is designed by the method in this report includes the three-dimensional effect by taking into account radial equilibrium conditions.

A87-52359 Study of the flow visualization on the rotary wing with low aspect ratio. SHIGERU SAITO, TADAHARU WATANUKI, YOSHIAKI TAMURA, KOJIRO SUZUKI, KOHICHI SAGAWA et al. IN: *Flow visualization IV; Proceedings of the Fourth International Symposium*, Paris, France, Aug. 26-29, 1986. Washington, DC, Hemisphere Publishing Corp., 1987, pp. 443-448. 12 Refs.

Flow pattern on a rotary wing with low aspect ratio is investigated in the wind tunnel experimentally. The Goettingen-type low speed wind tunnel with 1.5-m diameter is used to simulate the takeoff and landing operating regimes. Four means (oil flow, china-clay, tuft, minituft) of flow pattern visualization on the rotary wing are applied and compared to each other. Photographs are taken to record the phenomena. To analyze the flow pattern on the blade, boundary layer calculations are carried out by the integral method. External flow around a blade is calculated by means of the vortex lattice method. To judge the separation line on the rotary blade, the limiting streamline is used. Comparison between calculations and experiments shows good coincidence.

A88-44654 Expansion series in the Laplace domain of integral functions occurring in the lifting surface theory for nonplanar wings. TETSUHIKO UEDA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, no. 412, 1988, pp. 255-257. 9 Refs.

An exact expansion series of the integral function occurring in the lifting surface theory is presented. The series is applicable to nonplanar

wings treated in the Laplace domain with the nondimensional Laplace variable p as well as the reduced frequency k which corresponds to the imaginary axis of the p-plane.

A88-24847 **Pressure losses and flow field distortion induced by tip clearance of centrifugal and axial compressors.** YASUTOSHI SENOO, *Kyushu University, Research Institute of Industrial Science, Reports* (ISSN 0368-6841), no. 82, 1987, pp. 1-13. 40 Refs.

The flow field near the tip of compressor rotor blades is distorted by leakage through the tip clearance, and the performance of the compressor deteriorates. Empirical equations expressing the pressure loss and the efficiency drop are varied. They are related to the lift coefficient in different ways such as proportional to $C(L)$, $C(L)$ exp 1.5, $C(L)$ sq, or the sum of two terms, depending upon the ways of understanding the mechanics of pressure losses. These methods are examined and compared. Also included is a brief discussion on the optimum value of the tip clearance.

A87-39266 **Basic analyses for optimum propulsion efficiency of a counter rotating ATP (Advanced Turbo Prop).** TOMOARI NAGASHIMA and TAKEICHIRYO HIROSE, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 397, 1987, pp. 102-107. 9 Refs.

To clarify the effects of wake contraction, swirl velocity and mutual interactions on the cruising performances of a counter rotating advanced turboprop fundamental analyses based on the generalized momentum theory were carried out. Assuming a linear interaction scheme, the optimum propulsion efficiency and the wake geometry which minimize the total induced losses for a given thrust were established as solutions of a calculus of variations problems. The optimum combinations of operating parameters such as the thrust sharing ratio, the power sharing ratio and the disk area ratio between fore and aft propellers were also specified, and their dependency upon the axial velocity, the total thrust level and the axial spacing were revealed. It was understood that, in addition to the counter-rotating effect of propellers, the upwash effect of the contracted top propeller wake on the outer part of the bottom propeller disk plays a fundamental role for improving the propulsion efficiency of a counter-rotating advanced turboprop.

A88-13545 **Addendum to the calculation of transonic potential flow through a two-dimensional cascade.** KENJI INOUE and TAKASHI NAKAMURA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 403, 1987, pp. 399, 400. 5 Refs.

Two things to be added to a previously published paper on the calculation of the transonic potential flow through a two-dimensional cascade are stated. The first is a calculation procedure to obtain the solution in which a given point on a blade is a stagnation point without giving the downstream condition. The second is the relation between the force acting on a blade, the distribution of pressure on its surface, the circulation around it, and the up- and downstream conditions.

A88-13544 **Numerical solutions of the Euler equations for the flow field around counter-rotating propellers.** MAKOTO KOBAYAKAWA and MASAHIRO NAKAO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 403, 1987, pp. 398-398. 7 Refs.

In order to investigate the flow field around the ATP through numerical methods for its optimal design, 3D-Euler equations are most prominent. The flow field around counterrotating propellers in advancing 0.8 Mach is obtained. Two spaces including front and rear blades are solved separately. The interaction between both blades are taken into the calculation by the connecting surfaces. The noniterative implicit ADI scheme is used in order to solve Euler equations. The periodic steady and averaged steady solutions are obtained. The latter is simplified by averaging the variables at the connecting surface. This shortens the calculation time to one-third compared with the periodic steady analysis which simulates the relative motion of the blades exactly. Numerical calculations are performed for two counter rotating ATP's with SR-1 and SR-3 blades. Both results show that they are similar to each other, and the propeller efficiencies increase compared with single rotating ATP with same blades.

A88-31195 **The two-dimensional smoke wind tunnel of the Dept. of Aeronautical Engineering of the National Defence Academy.** TAKE-ICHIRYO HIROSE, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, no. 409, 1988, pp. 50-52.

The two-dimensional smoke wind tunnel which was opened in the Dept. of Aeronautical Engineering, The National Defence Academy, Yokosuka, Japan in March 1987 is introduced in this note. The essential points and the new ideas of the design are described, and some pictures showing the flow field are presented.

A88-29375 **Effects of wind distribution over aircraft on the longitudinal equations of motion in wind shear conditions.** HARUO KIMURA and HAMID BASSIRI, *Kyushu University, Faculty of Engineering, Memoirs* (ISSN 0023-6160), Vol. 47, Sept. 1987, pp. 193-205. 8 Refs.

This paper derives the longitudinal equations of motion for an aircraft incorporating the wind shear terms in which the effect of wind distribution over the aircraft is taken into account. The aerodynamic forces and moment being dependent on the motion relative to the atmosphere, pertinent use of wing and tail relative velocities is emphasized. For simplicity, only the variation of horizontal atmospheric winds with altitude is considered. It is shown by a simple numerical example that - depending on the severity

of atmospheric movement - the wind distribution over the aircraft has a distinguishable effect on the moment, and therefore the stability.

A88-14248 **A study of a multi-layered thin film heat transfer gauge and a new method of measuring heat transfer rate with it.** MASANORI HAYASHI, AKIRA SAKURAI, and SHIGERU ASO, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Aug. 1987, pp. 91-101. Translation. Previously cited in issue 10, pp. 1378, Accession no. A86-25228. 13 Refs.

A new method of measuring heat transfer rate with high spatial resolution and fast response is developed to be used in wind tunnels with long flow duration. For the development of the new method a multilayered thin-film heat transfer gage is proposed. The principle of the sensor is based on measuring the temperature gradient across a thin heat-resistant layer of SiO with two thin film resistance thermometers on its upper and lower surfaces. These thin films and the heat-resistant layer are deposited by the vacuum evaporation technique. The design considerations, the accuracy of the sensor, the frequency response, and the calibration technique are discussed. The sensor is applied to the measurement of the heat transfer rate in a turbulent boundary layer on a flat plate at Mach number 4, Tw/TO = 0.64, and Re = 1.4 x 10 to the 7th, and shows high sensitivity and fast response. It also shows excellent durability.

A87-49324 **An experimental investigation of aerodynamic drag of peripheral jet GEM with a forward-facing intake.** FUMIHARU OTAGIRI, SHIGENORI ANDO, and HIRONARI NOHARA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 400, 1987, pp. 270-275. 6 Refs.

The 'interference thrust' suggested by Ando et al. (1961) has been confirmed by a series of experimental investigations in the laboratory. However, the models used in those experiments are considerably simplified ones in comparison with existing GEMs in practical operation. The purpose of the present work is to complete a series of experimental investigations by using more practical model configuration. In order to achieve both satisfactory separation of the parasite drag from the momentum drag and a good intake efficiency, a forward-facing intake is adopted. The results of this experiment present a better proof of 'interference thrust'.

A88-26358 **Quasi-conical aerodynamic loadings due to kinked planform wings.** KYOKO NITTA, SHIGENORI ANDO, and SETSUYA KINUGAWA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 407, 1987, pp. 586-595. 10 Refs.

Aerodynamic loadings over kinked-planform wings are investigated using lifting-surface theories. In using conventional mode methods, kinked edges of the planform should be rounded in some way. The effects of roundings on loadings are investigated through BIS-QS, which is a discrete method developed in the authors' laboratory. Another discrete method, DLM, is used supplementarily. Two kinds of roundings are used. It is found that the influence of roundings remains spanwise considerably far from the rounded region. Conventional mode methods are thus less efficient than discrete methods for investigating kinked-planform wings. Modified aerodynamic loading (MAL) is introduced to be kept free from the conventional square-foot edge-singularities. It is noteworthy that quasi-conical distributions of MAL appear near kinks. Thus the well known peculiar loadings of swept-back, or forward-swept wings can be explained essentially and naturally. This quasi-conical MAL would serve for rapid convergence of mode methods in lifting-surface theory.

A87-48291 **An experimental investigation of the stability of converging cylindrical shock waves in air.** K. TAKAYAMA, H. KLEINE, and H. GROENIG, *Experiments in Fluids* (ISSN 0723-4864), Vol. 5, no. 5, 1987, pp. 315-322. 27 Refs.

An experimental study was made of the stability of converging cylindrical shock waves. The experiments were conducted on annular shock tubes equipped with a double exposure holographic interferometer in the Stosswellenlabor, RWTH Aachen, and in the Institute of High Speed Mechanics, Tohoku University, Sendai, for shock Mach numbers of 1.1 to 2.1 in air. By comparing these two different shock tube experiments, it is found that in the former facility the mode-three instability is predominant at the center of convergence, whereas the mode-four instability appears in the latter setup. The instabilities are denoted in this way because the shock and the flowfield behing it reveal a remarkable triangular and quadrangular symmetry, respectively. It is concluded that the converging cylindrical shock wave is always unstable and sensitive to the structure of the annular shock tube. The applicability of holographic interferometry to this kind of shock wave research is also demonstrated.

A87-39265 **A new concept of surface-airplane (Power-Augmented Ram Wing).** SHIGENORI ANDO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 397, 1987, pp. 91-101. 12 Refs.

The PAR (Power Augmented Ram) Wing concept is presented. It will be useful for over-water transport to carry passengers, cargos, and/or cars. It is much faster than ships, while it requires no runway, in contrast to airplanes. The PAR concept makes the fuselage-shape 'aero-configured' rather than 'hydro-configured', and so decreases the parasite-drag significantly. An empirical formula is found for the effective aspect ratio which is applicable to various kinds of ground effect wings. The present PAR concept has a variable geometry wing, in front of which tiltable

turboprop engines are installed. Untill the take-off speed is exceeded, the wing is swept-forward with extended full span flaps (the outer ones are differential flaps). In cruising condition, the wing becomes unswept. If the sea-state is bad, the vehicle can fly off-ground effect with unswept wing. Special devices are proposed for the tip-floats, which improve aerodynamic efficiency and which alleviate loads due to wave-impacts.

A87-39264 Measurements of heat-transfer coefficients in the interaction regions between oblique shock waves and turbulent boundary layers with a multi-layered thin film heat transfer gauge. MASANORI HAYASHI, AKIRA SAKURAI, and SHIGERU ASO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 397, 1987, pp. 85-90. 11 Refs.

A new type of thin-film heat transfer gauge is applied to the measurement of heat-transfer coefficients in the interaction regions of oblique shock waves and fully developed turbulent boundary layers, for wind tunnels with long flow duration. Experiments have been performed under the conditions of Mach number = 4, total pressure = 1.2 MPa, $T(w)/T(o)$ = 0.59-0.65, Reynolds number = 13-15 million, and incident shock angles from 17.8 to 22.8 deg. Flow fields are visualized by the schlieren technique. Both distributions of surface pressure and heat-transfer coefficient are measured throughout the interaction regions by scanning the shock generator parallel to the free stream. Owing to the high spatial resolution of the new sensor, complicated features of the aerodynamic heating in the interaction regions are revealed.

A87-49321 Subsonic flow region on blunted cones in supersonic flow. TAKASHI TANI, NORIO ARAI, KOETSU TAKEHANA, HIDEO SEKINE, and NAOKI HIROSE, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 400, 1987, pp. 253-259. 6 Refs.

The article investigates both experimentally and numerically the complicated flow around the blunted cone of semiapex angle 20-45 degrees at Mach number 1.4-3.0. Especially emphasized is the structure of the subsonic flow region on the cone surface that is caused by the transition from the overexpanded flow at the nose to the recompression on the cone. Both results are in good agreement with each other. Consequently, it is shown that the numerical analysis of inviscid flow is very practical for such a complicated flow.

A87-46240 J85 surge transient simulation. Y. SUGIYAMA, W. TABAKOFF, and A. HAMED, *IN: Proceedings of the 8th International Symposium on Air Breathing Engines, Cincinnati, OH, June 14-19, 1987* (AIAA Paper 87-46176). American Institute of Aeronautics and Astronautics, 1987, pp. 568-578. 25 Refs.

Surge transient flow phenomena and unsteady compressor operating-point excursion during surge in J85 turbojet engine, are analyzed using a one-dimensional model which is capable of simulating surge disturbance propagations throughout an entire turbojet engine. Unknown stalled compressor stage characteristics are represented by parameters and predicted through the parametric study in such a way that the overall computed results must agree with surge data, such as hammer over-pressures at the compressor face and reduced burner-pressures. The prediction resulted in the stalled characteristics with faster responses and larger pressure-ratio deterioration compared to low speed compressors. Surge hammer over-pressures are found to have a triangle shape in time-space (engine axis) domain. Different stall methods result in different compressor operating-point excursion, in which mass flows through compressor reduce to almost zero in roughly 10 to 20 milliseconds, and thus affect surge transient flow phenomena such as levels of peak hammer over-pressures at the intake duct and high temperatures in the compressor.

A87-42623 A simple theory on hovering stability of one-ducted-fan VTOL. SHIGENORI ANDO, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 29, Feb. 1987, pp. 242-250. 8 Refs.

Flying Platforms supported by ducted fan(s), such as the Hiller VZ-1, are the safest and simplest aircraft. The height of vehicle CG (center-of-gravity) from the ducted-fan aerodynamic-center should be selected quite carefully, from stability and control viewpoints. A simple theory is presented for the longitudinal motion. It is found that the vehicle is stable only in a small range of CG. The stable CG range is located above the duct, the height of which depends on the duct lip radius. A simple philosophy is presented to make the vehicle safe against horizontal gusts.

A87-39267 Interference of two spheres placed on a plane boundary. SHIKI OKAMOTO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 35, no. 397, 1987, pp. 108-116. 11 Refs.

This paper describes an experimental study of the interference of two spheres placed on a plane boundary. The experiment was carried out in a wind-tunnel having a working section of 500 mm x 500 mm x 2000 mm in size at Reynolds number of 4740. The surface-pressure distributions of two spheres at various relative positions were measured, and the drag, lift and side-force coefficients were determined from the surface-pressure distributions. The experimental results were compared with those of a single sphere.

A87-34852 Response of a helicopter penetrating the tip vortices of a large airplane. AKIRA AZUMA, KEIJI KAWACHI, and SHIGERU SAITO, *Vertica* (ISSN 0360-5450), Vol. 11, no. 1-2, 1987, pp. 65-76. 15 Refs.

The dynamic response of helicopters penetrating a pair of trailing vortices of a jumbo jet is analyzed. The rotor aerodynamic forces which are fully coupled with the body motion with six degrees of freedom are calculated by using the local momentum theory (LMT). The wake vortices of the jumbo jet are assumed to be a frozen gust and are disturbed by the blade motion. The time histories of the dynamic behaviors of the helicopter as well as the blade motion are presented for the various parameters such as the distance between the helicopter and the jumbo jet, the type of helicopter rotor, and the flight path angle with respect to the trailing vortex of the jumbo jet.

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