Japanese Aerospace Literature This month: *Aerodynamics*

A89-10543 Flow past circular cylinder of finite length placed on ground plane. SHIKI OKAMOTO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, No. 414, 1988, pp. 343-350. 9 Refs.

This paper describes an experimental study of the changes of vortices formation and turbulent wake from a circular cylinder placed on a ground plane. The experiment was carried out in a blow down wind-tunnel having a working section of 500 mm x 5000mm x 2000 mm in size at Reynolds number 25,000 to 47,000. The surface-pressure distributions on the circular cylinder were measured and the drag coefficient was determined from them. The vortices generated in the flow-field around a circular cylinder have also been observed and the velocity defects and turbulent intensities in the turbulent wake behind the circular cylinder were measured. Consequently, it is found that the flowpattern changes rapidly from H/D = 4, while the shedding vortices change from arch type to Karman type.

A89-42110 Computational study of three-dimensional flow around a vehicle-like body. KAZUHIRO TSUBOI and KUNIO KUWAHARA, AIAA Paper 89-1885 presented at the AIAA 20th Fluid Dynamics, Plasma Dynamics and Lasers Conference, Buffalo, NY, June 12-14, 1989. 10 pp. 12 Refs.

Flow around a vehicle-like body in the proximity of a ground at a high Reynolds number (Re = 4.3 x 10 to the 6th) is investigated. Numerical solutions to the three-dimensional unsteady incompressible Navier-Stokes equations have been obtainedfor two distinct ground conditions (moving and fixed). The computational results reproduce successfully the experimental data. Furthermore, it is found that the unsteady behavior of the aerodynamic forces depends on the ground condition. Extensive flow visualization of the computational results has clearly shown that the unsteady behavior of the wake structure is the origin of the unsteadiness of the forces.

A89-33422 Effect of rounding side-corners on aerodynamic forces and turbulent wake of a cube placed on a ground plane. SHIKI OKAMOTO and NAOTO UEMURA, *Preprints of 11th Symposium on Turbulence,* Rolla, MO, Oct. 17-19, 1988, (A89-33402 13-34). Rolla, MO, University of Missouri-Rolla, 1988, pp. A30-1 to A30-10. 8 Refs.

The flow past a cube with rounded side-corners placed on a ground plane was studied in a wind turnnel at a Reynolds number of 4.74 x 10 to the 4th. The distributions of velocities and turbulence intensities in the turbulent wake of the cube were measured, and compared with those of a two-dimensional cylinder. It is shown that the drag coefficient decreases rapidly in the range 2R/D = 0–0.3, and that the Strouhal number of the arch-vortex shedding increases with the corner radius.

A89-33100 On a method for solving integral equations of lifting-surface theory for oscillating high-speed propellers. TERUO ICHIKAWA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 37, No. 420, 1989, pp. 47-51. 11 Refs.

A lifting-surface theory of oscillating high-speed propellers has been formulated earlier by the author in a form of integral equations. In this paper, a method for solution of these integral equations is proposed. An adjoint variational principle, equivalent to the integral equations for direct and reverse flows, as well as to the Kutta conditions in both the flows, is derived. It is shown that the generalized aerodynamic forces acting on the propeller blades will be computed advantageously by applying a Rayleigh-Ritz type method tothe variational principle.

A89-32879 Unsteady aerodynamic forces acting on vibrating cascade blades in a three-dimensional flow field. KUNIYUKI IMANARI, and SHIYOJIRO KAJI, *JSME International Journal, Series II* (ISSN 0914-8817), Vol. 32, Feb. 1989, pp. 57-62.

The vortex-lattice method was used to calculate the unsteady aerodynamic forces for a cascade with a steady loading distribution in the spanwise direction and vibration in an arbitrary mode. The effect of blade twist on unsteady aerodynamic forces was studied; at a lower reduced frequency, the effect was primarily attributed to the nonuniform distribution of steady loading. The unsteady aerodynamic characteristics in the panel mode were studied; this higher-order mode became unstable at a relatively high frequency.

A89-23980 Criticism of the Desmarais method for kernel function computation. SHIGENORI ANDO and MICHIYO KATO, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 31, Nov. 1988, pp. 161-170. 8 Refs.

The Desmarais (1982) method for computing the incomplete Struve-function in the unsteady lifting surface kernel function is examined. A specific example of the method is tested. It is found that the Desmarias method becomes erroneous near the x-axis. Also, it is suggested that the method violates general numerical rules by treating parts of the singularities of the kernel function numerically instead of analytically. It is concluded that, although the Desmarais method reduces computation time by about 30 pct, it should not be applied to discrete lifting surface methods in which some of the control and loading points are close together.

A89-22630 Evaluation of the Desmarais' method for computing subsonic kernel function. SHIGENORI ANDO and MICHIYO KATO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, No. 418, 1988, pp. 529-534. 8 Refs.

A representative of Desmarais' (1982) method is investigated. Itis found that Desmarais' method becomes erroneous in proximity to the X-axis. Moreover, it treats some parts of the singularities of the kernel function numerically, which is a violation of general numerical rules.

A89-10544 An experimental study on aerodynamic performance of Lippisch-type GEW (Ground Effect Wing). FUMIHARU OTAGIRI, SHIGENORI ANDO, TORU NOHISA, HIROSHI TAKASAKI, and TATSUYA TSUJIMOTO, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, No. 414, 1988, pp. 351-356. 9 Refs.

Experimental research on some aerodynamic performance of Lippisch-type Ground Effect Wing is presented. This type has a reverse-Delta wing with some cathedral angles (CA) along the leading edge. Based upon the comparison between experiment I(CA = 16. 3 deg) and II (CA = 8.1 deg), it is concluded that there are some increments of L/D caused from the ground effect both in experiment I and II, but the latter has higher C(L) than the former, caused by a modification of the model I.

A89-20130 Unsteadiness in oblique incident shock wave/turbulent boundary layer interaction region. MASANORI HAYASHI, SHIGERU ASO, and ANZHONG TAN, *Kyushu University, Technology Reports* (ISSN 0023-2718), Vol. 61, Aug. 1988, pp. 457-463. 9 Refs.

Systematic studies on unsteadiness in the oblique incident shock wave/turbulent boundary layer interaction region are conducted at a nominal Mach number of 4, Reynolds number of about 1.4 x 10 to the 7th based on the distance from the flat plate leading edge, and under cold wall condition with shock generator wedge angle from 4.5 to 9 degrees. The boundary layer in the interaction region varies from attached to separated as thewedge angle increases. When boundary layer is attached, there is a peak standard deviation of wall pressure near the incident point of the shock wave. As boundary layer begins to separate, a second peak appears and when separation becomes significant, a third peak exists near the reatttachment point.

A89-16548 Flow fields visualization around an isolated rotor in thevertical autorotation and their application to performance prediction. TOMOARI NAGASHIMA, TAKEICHIRYO HIROSE, and *MASAYUKI OKAMOTO, Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, No. 415, 1988, pp. 380-388. 12 Refs.

A simplified wake model representing dominant tip and root helical vortices by definite numbers of the circular ringvortices is proposed. Numerical analyses of the flow fields are carried out. The numerical results are in good agreement with those obtained during visualization and wake surveys using a hot wire anemometer.

A88-54186 Potential pressure field by stator/downstream strut interaction. HIDEKAZU KODAMA and SUSUMU NAGANO, ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 pp. 8 Refs. (ASME Paper 88-GT-54).

An analytical and experimental study of the potential pressure field caused by the stator/downstream strut interaction is presented. A small disturbance theory employing anactuator disk model is found to accurately predict the forward propagation of downstream pressure perturbations. The experimental results have validated the calculation method of stator tailoring which shields the upstream field from the effect of the downstream struts.

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.

A88-36700 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.

A90-16105 A study on surge and rotating stall in axial compressors - A summary of the measurement and fundamental analysis method. HIROSHI ISHII and YASUSHIGE KASHIWABARA, *JSME International Journal, Series II* (ISSN 0914-8817), Vol. 32, Nov. 1989, pp. 583-590. 5 Refs.

In multistage axial compressors used for gas turbine engines, it is important to understand unsteady behaviors such as surge and rotating stall. The purpose of this study is to develop a practical analytical method for both surge and rotating stall in axial compressors. In this paper, firstly, some characteristics of the unsteady phenomena in axial compressors derived from the measurements of test compressors are summarized. Secondly, a numerical method for the unsteady phenomena is described, assuming incompressible flow. A feature of the method is solving the fluid equations by Galerkin's method with the circumferential flow distortion expressed in the form of a high-order Fourier series. Finally, the usefulness of the method, using some results from parameter-vary computations and comparisons with the measured results in a 3-stage test compressor, is examined.

A90-12238 Numerical calculation of unsteady aerodynamic forces for two-dimensional supersonic oscillating cascades by finite element method. KUO-CHENG YANG and MASANOBU NAMBA, *Kyushu University, Technology Reports* (ISSN 0023-2718), Vol. 62, June 1989, pp. 239-246. 7 Refs.

Calculation by a finite element method has been conductedto study unsteady aerodynamic forces for two-dimensional oscillating cascades in supersonic flows. In the case of lightly loaded cascades, unsteady aerodynamic forces are dominated by the effect of displacement of an oblique shock reflection point, destablizing a translational blade motion at some interblade phase angles. In the case of moderately or highly loaded cascades with a normal shock in the blade passage also the unsteady pressure is locally high near the shock position, but the translational blade motion is generally stablized.

A90-12219 Numerical calculation of unsteady aerodynamic forces for three-dimensional subsonic oscillating cascades by a finite element method. NOBUHIKO YAMASAKI, MASANOBU NAMBA, and KUO-CHENG YANG, *Kyushu University, Faculty of Engineering Memoirs* (ISSN 0023-6160), Vol. 49, March 1989, pp. 1-15. 5 Refs.

This paper presents a finite element method formulation to calculate unsteady aerodynamic force for three-dimensional oscillating cascades in subsonic flows. Three-dimensional small unsteady perturbations superimposed on a spanwise uniform steady flow are treated. Numerical calculations have been conducted to investigate the three-dimensional effects upon unsteady aerodynamic force for various combinations of the reduced frequency, interblade phase angle, mean angle of attack, camber, thickness, aspect ratio and vibration mode.

A90-11873 Finite element method for unsteady three-dimensional subsonic flows through a cascade oscillating with steady loading. NOBUHIKO YAMASAKI, MASANOBU NAMBA, and KUO-CHENG YANG, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 32, Aug. 1989, pp. 51-66. 5 Refs.

The paper presents a finite element method formulation to calculate unsteady aerodynamic force for three-dimensional oscillating cascades in subsonic flows. Three-dimensional small unsteady perturbations superimposed on a spanwise uniform steady flow are treated. Numerical calculations have been conducted to investigate the three-dimensional effects upon unsteady aerodynamic force for various combinations of the interblade phase angle, mean angle of attack, camber, thickness, aspect ratio and vibration mode.

A90-11793 Unsteady aerodynamic characteristics of oscillating cascadewith tip clearance. TOSHINORI WATANABE and SHOJIRO KAJI, *Unsteady aerodynamics and aeroelasticity of turbomachines and propellers; Proceedings of the Fourth International Symposium,* Aachen, Federal Republic of Germany, Sept. 6-10, 1987 (A90-11776 02-02). Aachen, Federal Republic of Germany, Rheinisch-Westfaelische Technische Hochschule Aachen, 1988, pp. 405-435. 8 Refs.

The present experimental and theoretical study of the aerodynamics of oscillating linear cascades with tip clearances has proceeded by obtaining chordwise and spanwise blade direction pressure measurements as tip clearances were varied from 0.056 to 2.8 percent of blade-span. Tip clearance is experimentally found to strongly influence the distribution of unsteady aerodynamic forces along the blade span;under steady aerodynamic loading, however, tip-clearance influence is suppressed. The bladetip vortex increases the absolute value of the steady aerodynamic force in the tip region. Vortex lattice method-based calculations have yielded the unsteady aerodynamic forces acting on oscillating blades with tip clearances.

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.

A89-51678 Theoretical study on the unsteady aerodynamic characteristics of an oscillating cascade with tip clearance - In the case of a nonloaded cascade. TOSHINORI WATANABE and SHOJIRO KAJI, *JSME International Journal, Series II* (ISSN 0914-8817), Vol. 32, Aug. 1989, pp. 368-374. 9 Refs.

This paper describes a theoretical analysis based on potential flow. By use of the vortex lattice method, calculations were performed to obtain unsteady aerodynamic forces acting on oscillating blades with tip clearances. Calculated damping forces in the case of large tip clearance showed good agreement with the experimental data. When the clearance was small, however, a discrepancy was found between the experimental and analytical results. This discrepancy was thought to be ascribable to the viscous effect of the flow near the blade tips. To explain the experimental data it was necessary to apply a model such that each blade should retain finite circulation at the extremity of its tip. From the calculated results for various reduced frequencies it was confirmed that aerodynamic characteristics found in the experimental study could be applied equally to the wide range of reduced frequencies.

A89-41835 A time-accurate iterative scheme for solving the unsteady compressible flow equations. KENICHI MATSUNO, AIAA Paper 89-1992 presented at the 9th AIAA Computational Fluid Dynamics Conference, Buffalo, NY, June 13-15, 1989, Technical Papers (A89-41776 18-02). Washington, DC, American Institute of Aeronautics and Astronautics, 1989, pp. 602-611. 17 Refs.

A second-order time-accurate scheme has been extended to an arbitrary kth-order time-accurate scheme with high-order accuracy in both time and space. The second-order scheme is shown to be suitable for unsteady flow computations. Although the kth-order form of the algorithm is essentially iterative at each time step, the scheme is theoretically kth-order accurate in time without any iteration. It is noted that the iterations at each time step improve the numerical accuracy and robustness of the algorithm.

A89-41799 Turbulence models for 3D transonic viscous flows. YOKO TAKAKURA, SATORU OGAWA, and TOMIKO ISHIGURO, AIAA Paper 89-1952 presented at the 9th AIAA Computational Fluid Dynamics Conference, Buffalo,NY, June 13-15, 1989, Technical Papers (A89-41776 18-02). Washington, DC, American Institute of Aeronautics and Astronautics, 1989, pp. 240-248. 18 Refs.

Computation of three-dimensional transonic viscous flows around the ONERA-M6 wing is performed by using the Harten-Yee TVD scheme with modification of geometrical treatment in order to seek better turbulence models. The models used here are the Jones-Launder (k-epsilon) model and the subgrid-scale model in the large eddy simulation (LES), and for comparison with the Baldwin-Lomax model. The diagonalization of flow equation system including a two-equation model necessary to perform the TVD scheme and the improvement accompanied by extending the LES to compressible flow problems are presented, and then the utilities of both models in compressible flow problems with shock waves have been investigated. The k-epsilon model and the LES work well in the large reverse flow problem by adjusting the coefficients comparedwith the Baldwin-Lomax model.

A89-36009 Acoustic emission from interaction of a vortex ring with a sphere. T. MINOTA, T. MURAKAMI, and T. KAMBE, *Fluid Dynamics Research* (ISSN 0169-5983), Vol. 3, No. 1-4, Sept. 1988, pp. 357-362. 7 Refs.

Acoustic waves emitted by a vortex ring interacting with a fixed solid sphere are studied experimentally and theoretically. The experiments are carried out for two kinds of vortex-sphere arrangement: (1) a vortex ring passes over the sphere, and (2) a vortex ring passes by the sphere. The vortex motion is examined optically by means of a photosensor system, and the pressure signals of the emitted wave are detected by 1/2-inch microphones in the far field. In the first case, the measured diameter of the vortex ring after passing the sphere increases from its initial diameter. The observed acoustic wave is dominated mainly by a dipole emission, and some contribution from a quadrupole radiation is present. In the second case, the emitted wave is characterized by a rotating dipole emission in which the dipole axis rotates as the vortex position changes relative to the sphere.

A89-19927 Experimental study on unsteady aerodynamic characteristics of an oscillating cascade with tip clearance. TOSHINORI WATANABE and SHOJIRO KAJI, *JSME International Journal, Series II* (ISSN 0914-8817), Vol. 31, Nov. 1988, pp. 660-667.

An experimental study was conducted for revealing unsteady aerodynamic characteristics of oscillating cascades with tip clearance. To obtain aerodynamic forces acting on blades, the surface pressure was measured in both the chordwise and spanwise directions. To evaluate the aerodynamic forces due to oscillations of arbitrary interblade phase angle, the method of influence coefficients was adopted. Tip clearances were changed from 0.056 to 2.8 percent of the blade span. The aerodynamic blade loading was also changed. Results show that the tip clearance has a strong influence on the distribution of unsteady aerodynamic forces along the blade span: when tip clearance exists, aerodynamic damping forces decrease considerably over a large portion of the blade span. However, when steady aerodynamic loading acts on theblades, the influence of tip clearance is suppressed. The tip vortex increases the absolute value of the unsteady aerodynamic force in the region near the blade tip.