Japanese Aerospace Literature
This month: *Transonic Flows*

A96-27253 High resolution schemes for the compressible Navier–Stokes equations and their applications. H. DAIGUJI, X. YUAN, S. YAMAMOTO, and K. ISHIZAKA (Tohoku Univ., Sendai, Japan), *The recent developments in turbulence research; Proceedings of the Sino-Japan Workshop on Turbulent Flows*, Tsinghua Univ., Beijing, China, 1994 (A96-27252 06-34), Beijing, International Academic Publishers, 1995, pp. 3–21. 15 Refs. Documents available from Aeroplus Dispatch.

High resolution schemes of the compressible Navier–Stokes equations suitable for the direct numerical simulation of turbulent flows are presented. The delta-form implicit equations using the fourth-order compact MUSCL-type TVD scheme are efficiently solved by the LU SGS algorithm. Some calculated results of three-dimensional compressible mixing layer flows and three-dimensional transonic turbine nozzle flows are shown. The present schemes are very effective for the transonic flows with weak discontinuities. (Author)

A96-26176 Behavior of shock waves in transonic cascades during high-frequency blade pitching oscillation. I. FUJIMOTO, T. HIRANO (Takushoku Univ., Japan), S. ISHII (Nihon Univ., Japan), and H. TANAKA (Tokai Univ., Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, 1995, Proceedings. Vol. 2 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. II-201–II-208. 6 Refs. Documents available from Aeroplus Dispatch.

An accurate photographing and image processing system for capturing the high-speed periodic motion of shock waves in unsteady transonic flow cascades is developed using a video camera with a moderate frame rate, instead of a high-speed video camera. The feasibility of generating successive pictures in one period whose frequency is up to 500 Hz is confirmed. The behavior of the shock waves is clarified in the range up to 200 Hz. Although the amplitude of the shock wave displacement does not change much within the range of the present experiment, the phase lag relative to the blade oscillation reaches around pi/2 as the blade oscillation frequency increases to 200 Hz. (Author)

A96-26162 Effects of inlet passage width contraction of low solidity cascade diffusers on performance of transonic centrifugal compressor. H. HAYAMI (Kyushu Univ., Kasuga, Japan) and A. UMEMOTO (Toto Co., Technology Div., Kitakyushu, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, 1995, Proceedings. Vol. 2 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. II-99–II-102. 5 Refs. Documents available from Aeroplus Dispatch.

Low solidity circular cascades have been applied successfully as part of the diffuser system of a transonic centrifugal compressor. Three types of diffusers with and without an inlet passage width contraction or a pinch upstream of the cascade were tested. An appropriately contracted diffuser realized a high compressor efficiency at high rotor speed by the decrement in input power. The effects of a passage width contraction on surge and choke are also discussed. The choke occurred at the throat of the cascades of a pinched-type diffuser at less flow than the inducer choke flow, in spite of a low solidity cascade. The pinched diffuser had a stabilizing effect on the diffuser characteristics, but only a small amount of gain in the surge margin was obtained, owing to the change in impeller characteristics. (Author)

A96-26151 Navier–Stokes analysis of unsteady transonic flows through gas turbine cascades with coolant ejection. T. TANUMA (Toshiba Corp., Yokohama, Japan), S. YAMAMOTO, and H. DAIGUJI (Tohoku Univ., Sendai, Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, 1995, Proceedings. Vol. 2 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. II-25–II-32. 16 Refs. Documents available from Aeroplus Dispatch.

An implicit time-marching higher-order accurate finite-difference method for solving the two-dimensional compressible Navier–Stokes equations is applied to the numerical analyses of unsteady transonic viscous flows through gas turbine cascades with trailing edge coolant ejection. The unsteady aerodynamic mechanisms associated with the interaction between the trailing edge vortices and shock waves, and the effect of coolant ejection, are evaluated. (Author)

A96-26125 Effect of tip clearance in three-dimensional cascade flow analysis. O. NOZAKI, K. KIKUCHI, A. TAMURA (National Aerospace Lab., Chofu, Japan), K. SHIMIZU, Y. MIYAKE (Mitsubishi Heavy Industries, Ltd., Aichi, Japan), and T. WATANABE (Tokyo Univ., Japan), *Yokohama International Gas Turbine Congress*, Yokohama, Japan, 1995, Proceedings. Vol. 1 (A96-26107 06-37), Tokyo, Japan, Gas Turbine Society of Japan, 1995, pp. I-135–I-142. 7 Refs. Documents available from Aeroplus Dispatch.

The three-dimensional transonic flow fields of a turbine stage have been analyzed by computational solutions of Navier–Stokes equations employing an implicit finite deference method with a high-accuracy upwind scheme. Numerical solutions were compared for different approaches to deal with tip clearance flow. Experimental data were also introduced for verifying the computation. The turbine stage model trader consideration consists of inlet guide vanes and rotor blades. Two approaches were examined for dealing with the flow through tip clearance. These approaches have been applied to the turbine for a certain flow condition to evaluate their advantages. In this paper the numerical approaches are illustrated and discussed, with a comparison of the resultant flow fields as well as overall characteristics with experimental data. (Author)

A96-25496 Genetic optimization of target pressure distributions for inverse design methods. S. OBAYASHI (Tohoku Univ., Sendai, Japan) and S. TAKANASHI (National Aerospace Lab., Chofu, Japan), *AIAA Journal* (ISSN 0001-1452), Vol. 34, No. 5, 1996, pp. 881–886. Previously cited in issue 09, Accession No. A95-36505. 21 Refs. Documents available from Aeroplus Dispatch.

A genetic algorithm has been applied to optimize target pressure distributions for inverse design methods. Pressure distributions around airfoils are parameterized by B-spline polygons, and the airfoil drag is minimized under constraints on lift, airfoil thickness, and other design principles. Once target pressure distributions are obtained, corresponding airfoil/wing geometries can be computed by an inverse design code coupled with a Navier–Stokes solver. Successful design results were obtained for transonic cases with and without a shock wave. (Author)

A96-22055 Visualization of boundary-layer transition on transonic airfoils using liquid crystal coatings. N. SUDANI, M. NOGUCHI, H. KANDA, M. SATO, and Y. ISHIDA (National Aerospace Lab., Chofu, Japan), *Flow visualization VII; Proceedings of the 7th International Symposium on Flow Visualization*, Seattle, WA, 1995 (A96-22001 05-35), New York, Begell House, Inc., 1995, pp. 538–543. 7 Refs. Documents available from Aeroplus Dispatch.

The objectives of this study are to establish a new technique for visualization of transition on airfoils using temperature-sensitive liquid crystals and to investigate the applicability of the liquid crystal coatings to suction surfaces for laminar flow control. Visualization results are presented for two-dimensional supercritical airfoil models with a clean surface and a natural laminar-flow airfoil model with a slotted surface around the midchord. (Author)

N95-34521 Numerical solutions of inviscid and viscous flows about airfoils by TVD method. H. R. KHEIRANDISH, G. BEPPU, and J. NAKAMICHI (National Aerospace Lab., Tokyo, Japan), National Aerospace Lab., Special Publication of National Aerospace Lab., pp. 135–140 (SEE N95-34505 12-02). Documents available from Aeroplus Dispatch.

The need to properly compute steady and unsteady viscous flows surrounding airfoils at transonic speeds remains an outstanding problem in fluid dynamics. In transonic flow where viscous effects such as shock-boundary interactions and separation are dominant, methods based on the Navier–Stokes equations are needed. Calculations of unsteady transonic flow about oscillating airfoils where flutter, dynamic stall, buffet and moving shock waves on these surfaces change the entire flow fields and aerodynamic characteristics, are still stiff problems that stimulate more work and studies to be done. To simulate these problems correctly a robust computer program is needed. This report shows the works have been done up to now, i.e., developing a computer program and verifying it by applying to steady viscous and inviscid flow calculations and inviscid flow about an oscillating airfoil. (Author)

A95-44714 Aerodynamic instability of transonic cascade with shock movement. T. SHIRATORI (Tokyo Metropolitan Inst. of Technology, Hino, Japan) and Y. NOGUCHI (Salford, Univ., United Kingdom), *ISABE—12th International Symposium on Air Breathing Engines*, Melbourne, Australia, 1995, Proceedings. Vol. 1 (A95-44654 12-07), Washington, DC, American Inst. of Aeronautics and Astronautics, 1995, pp. 644–654. 9 Refs. Documents available from Aeroplus Dispatch.

A numerical study to investigate the aerodynamic instability of the transonic cascade with shocks and the role of shock behavior has been carried out. The pitch oscillating two-dimensional transonic cascade which consists of double-circular arc airfoils with 5% thickness is evaluated. The shock behavior and the aerodynamic instability are numerically analyzed at various exit static pressures and frequencies. The numerical results indicate that the shock movement on the suction surface acts as an aerodynamically unstable factor at the relatively high reduced frequencies, and the shock movement on the pressure surface acts as an unstable factor at the low reduced frequency. The results also indicate that the pitching transonic cascade with shocks becomes aerodynamically unstable due to the passage shock movement when the pitching axis is moved forward at relatively high frequencies and the pitching axis is moved backward at low frequencies with an interblade phase angle of 180 deg. (Author)

A95-42795 Elastic deflection effects on transonic aerodynamics of a flutter wing model with control surfaces. K. SAITOH, M. HASHIDATE, H. MATSUSHITA, and T. KIKUCHI (National Aerospace Lab., Tokyo, Japan), *AIAA 1st Aircraft Engineering, Technology, and Operations Congress*, Los Angeles, CA, 1995, p. 7. 14 Refs. Documents available from Aeroplus Dispatch.

Normal direction deflections of an elastic wing are measured by detecting an image on a wind tunnel wall reflected from a laser light target embedded on a wing and processing the video signal obtained. This measurement system allows for the easy and precise measurement of the elastic deformation of the wing. Computing the pressure distribution on the wing surface by a three-dimensional full potential USTF3 code, taking into account the mean elastic deflection of the wing measured above, cleared the elastic deformation effects on the transonic aerodynamics. Dynamic elastic deformation of the wing during flutter is also acquired by processing the high-speed video data which shows that the phase difference between the bending and torsion components change, spanwise. At the outboard wing station, the torsion component leads to bending, which promotes flutter, while at the middle part, the torsion and the bending component go in phase, which leads to flutter suppression. (Author)

A95-40615 Temperature measurement in transonic duct with swept-back bump by laser-induced fluorescence method. M. INOUE, M. MASUDA, M. FURUKAWA, T. MURAISHI, and Y. TAKAHASHI (Kyushu Univ., Fukuoka, Japan), *Modern techniques and measurements in fluid flows; Proceedings of the 2nd International Conference on Fluid Dynamic Measurement and Its Applications (IFCDMA)*, Tsinghua Univ., Beijing, China, 1994 (A95-40601 11-35), Beijing, China, International Academic Publishers, 1994, pp. 153–157. 19 Refs. Documents available from Aeroplus Dispatch.

The laser-induced fluorescence method is developed to investigate the three-dimensional transonic flow with complicated shock wave-boundary layer interaction. This diagnostic system uses an argon-ion laser with seeded iodine as fluorescence material, and is applied to a rectangular duct with a swept-back bump. The temperature distributions in the duct are obtained, and the structure of the flow field is clarified including the curved shock wave and the boundary-layer separation.

A95-40262 An experimental study of transonic flow behavior over a deformable wing section. M. MAKINO and A. MINEO (Nihon Univ., Funabashi, Japan), *1st Asian-Pacific Conference on Aerospace Technology and Science*, Hangzhou, China, 1994, Proceedings (A95-40201 11-31), Beijing, International Academic Publishers, 1994, pp. 463–467. Documents available from Aeroplus Dispatch.

In transonic flow the flow field around a wing section is so sensitive to the shape of its outline that the flow condition changes greatly by slight deformation of the wing surface. In the present experiment the wind tunnel model is a hollow wing, the outer plate of which is made of an aluminum alloy plate suitable in thickness, and the curvature of the wing surface can be changed smoothly and continuously by regulation of the air pressure inside the wing in the flow at a fixed Mach number. On the upper surface of the wing model, 13 static pressure holes line up in the stream direction. The pressure distribution on the surface was measured in Mach numbers 0.60–0.98. At the same time the color video was taken by schlieren method to observe the shock wave patterns. (Author)

A95-38474 Transonic wind-tunnel flows about a fully configured model of aircraft. Y. TAKAKURA (Tokyo Noko Univ., Japan), S. OGAWA, and Y. WADA (National Aerospace Lab., Tokyo, Japan), *AIAA Journal* (ISSN 0001-1452), Vol. 33, No. 3, 1995, pp. 557–559. Previously cited in issue 20, Accession No. A93-48207. 10 Refs. Documents available from Aeroplus Dispatch.

The transonic flows about a fully configured model of an ONBEA-M5 aircraft within the Japanese National Aerospace Laboratory (NAL) transonic wind tunnel are numerically solved to investigate the reliability of numerical solutions. The multidomain technique is used to solve the flow field around the complicated configuration. A simple model is presented to estimate the outflow/inflow effects at the perforated wall of the transonic wind tunnel. The results show good coincidence with the experimental data of NAL wind-tunnel tests with regard to local C(p) distributions on the main wing and total forces C(L) and C(D).

A95-36506 Applications of genetic algorithm to aerodynamic shape optimization. K. YAMAMOTO and O. INOUE (Tohoku Univ., Sendai, Japan), *AIAA 12th Computational Fluid Dynamics Conference*, San Diego, CA, 1995, Collection of Technical Papers. Pt. 1 (A95-36501 09-34), Washington, DC, American Inst. of Aeronautics and Astronautics, 1995, pp. 43–51. 15 Refs. Documents available from Aeroplus Dispatch.

This paper presents an aerodynamic shape optimization method based on a genetic algorithm with the compressible Euler or Navier–Stokes equations. A new algorithm to represent aerodynamic configurations is proposed to find optimum aerodynamic configurations efficiently. We solve three aerodynamic shape optimization problems. First, an inverse problem is solved to understated the basic character and to examine the possibility of the genetic algorithm. Second, a drag minimization problem is solved to find a streamlined body. Finally, the lift/drag ratio maximization problem in a transonic flow is solved, and the optimized configuration is compared with a supercritical airfoil. The results show that the genetic algorithm is powerful and robust in solving aerodynamic shape optimization problems. (Author)

A95-35758 Research and development of two-stage fan component in HYPR project (Super/Hypersonic Transport Propulsion System). M. SUZUKI and N. KUNO (Mitsubishi Heavy Industries, Ltd., Komaki, Japan), *AIAA, ASME, SAE, and ASEE 31st Joint Propulsion Conference and Exhibit*, San Diego, CA, 1995, p. 8. Documents available from Aeroplus Dispatch.

The design and experimental rig test of a two-stage transonic axial-flow fan component for turbofan engine in a super/hypersonic transport propulsion system are described. Engine tests incorporating this fan component were performed, enabling a comparison of rig test results with engine test data. The overall performance is found to be acceptable for demonstrator engine use.

A95-22434 Unsteady analysis of transonic helicopter rotor noise. T. AOYAMA (National Aerospace Lab., Chofu, Japan), K. KAWACHI (Tokyo, Univ., Japan), S. SAITO (National Aerospace Lab., Mitaka, Japan), and J. KAMIO (Tokyo, Univ., Japan), *19th European Rotorcraft Forum*, Como, Italy, 1993, Proceedings. Vol. 1 (A95-22426 05-01), Amsterdam, The Netherlands, National Aerospace Lab., 1993, pp. B2-1–B2-12. 17 Refs. Documents available from Aeroplus Dispatch.

A combined CFD/extended Kirchhoff's equation method has been developed to analyze the high-speed impulsive (HSI) noise of a helicopter rotor. The method solves Euler equations to yield the pressure distributions around a rotor blade. To predict the HSI noise, the behavior of shock wave should be evaluated precisely; the present CFD code used predicts the shock wave by using a higher-order upwind scheme. In case of a forward flight condition, the Newton iterative method is used to get unsteady solutions. The Kirchhoff's equation, extended for moving surfaces, is then used to find the acoustic pressures by using the Euler solutions on the Kirchhoff surface in which all the acoustic sources are enclosed. The HSI noise of a nonlifting hovering rotor is calculated, and good agreement is obtained between calculated and experimental results. The comparison between HSI noise levels of two types of advanced tip shape and a conventional rectangular tip shape are also presented for nonlifting hovering conditions. (Author)

A95-21181 Transonic wind-tunnel flows about a fully configured model of aircraft. Y. TAKAKURA (Tokyo Noko Univ., Japan), S. OGAWA, and Y. WADA (National Aerospace Lab., Tokyo, Japan), *AIAA Journal on Disc* (ISSN 0001-1452), Vol. 1, No. 1, 1995. Previously cited in issue 20, Accession No. A93-48207. 10 Refs. Documents available from Aeroplus Dispatch.

The transonic flows about a fully configured model of aircraft named ONERA-M5 within the Japanese National Aerospace Laboratory (NAL) transonic wind tunnel are numerically solved to investigate the reliability of numerical solutions. The multidomain technique is used to solve the whole flow field around the complicated configuration. In each domain the grid is generated by an algebraic method and the thin-layer Navier–Stokes equations are solved by the improved Chakravarthy–Osher TVD scheme. A simple model is presented to estimate the outflow/inflow effects at the perforated wall of the transonic wind tunnel. The results obtained by the present methods show good coincidence with the experimental data of the NAL wind-test tunnel with regard to local distributions on the main wing and total forces.

A94-29369 Temperature measurement of transonic nozzle flow by laser-induced fluorescence method. M. INOUE, M. MASUDA, T. MURAISHI, and Y. HYAKUTAKE (Kyushu Univ., Fukuoka, Japan), *Flow visualization VI; Proceedings of the 6th International Symposium*, Yokohama, Japan, 1992 (A94-29328 09-35), Berlin and New York, Springer–Verlag, 1992, pp. 525–529. 6 Refs. Documents available from Aeroplus Dispatch.

To measure the spatially- and temporally-resolved temperature and velocity in a transonic turbine and compressor, the laser-induced fluorescence (LIF) method was developed for the flowfield with atmospheric pressure. The temperature distribution was obtained from the fluorescence intensity of the seeded iodine excited with an argon-ion laser, and the velocity was measured by the Doppler shift of the spectral peak of the fluorescence. (Author)