Japanese Aerospace Literature
This month: *Turbulent Boundary Layers*

A96-22089 Flow oscillation induced by normal shock wave/turbulent boundary-layer interaction in a supersonic diffuser. Y. MIYAZATO, M. KASHITANI, and K. MATSUO (Kyushu Univ., Fukuoka, 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. 853–858. 10 Refs. Documents available from Aeroplus Dispatch.

The flow oscillations induced by normal shock wave/turbulent boundary-layer interaction in a supersonic diffuser are experimentally investigated by flow visualization using the schlieren method and by static pressure measurements both on the duct centerline and on the wall surface. Downstream-convected pressure disturbance is observed on the duct centerline in the pseudoshock wave region. Its origin seems to be the instability of the separation shear layer forming the separation bubble beneath the first shock wave in the pseudoshock wave. The downstream-convected velocity of the pressure disturbances is found to be about 116 m/s.

A96-19588 An experiment on transition of three-dimensional boundary layer. T. AZUMA (Osaka City Univ., Japan), *Laminar-turbulent transition; IUTAM Symposium*, Sendai, Japan, 1994, Proceedings (A96-19558 04-34), Berlin, Germany, Springer–Verlag, 1995, pp. 307–314. 6 Refs. Documents available from Aeroplus Dispatch.

The laminar-turbulent transition of a three dimensional boundary layer was studied experimentally using a thin radial liquid-film flow along a stationary and rotating disk, and with a linear stability theory. Because of the very small liquid-film thickness of the flow, a disturbance growing near the wall produces an uneven liquid surface. Hence, the process of transition and the radius of the point of transition could be easily observed through the features of the liquid surface. It was found that two different types of instability, viscous and inflectional, may appear, and that the weak three-dimensionality of the mean flow suppresses the transition due to viscous-type instability, whereas the strong one promotes it due to inflectional-type instability. (Author)

A96-19580 'Vortex dynamics' of a vortex ring introduced into a laminar boundary layer. H. MAEKAWA, H. TAKAMI (Univ. of Electro-Communications, Chofu, Japan), and T. NISHIOKA (Hitachi Co., Ltd., Ibaraki, Japan), *Laminar-turbulent transition; IUTAM Symposium*, Sendai, Japan, 1994, Proceedings (A96-19558 04-34), Berlin, Germany, Springer–Verlag, 1995, pp. 221–228. 10 Refs. Documents available from Aeroplus Dispatch.

The motion of a single vortex ring introduced in a laminar boundary layer was observed by means of flow visualization. The turbulent flow evolving from the vortex ring depends on the initial configuration of the vortex ring in a laminar boundary layer. The initial evolution process is strongly dependent on the direction of circulation of the vortex ring in the layer. Furthermore, the turbulent region evolving from the primary vortex was investigated using pseudo-synchronized hot-wire measurements. Breakdown of the vortex ring in a laminar boundary layer leads to high fluctuation velocity fields within the turbulent bloblike structure. (Author)

A96-19550 An application of differential-geometrical methods in statistics to a turbulent flow field. I. NAKAMURA, Y. TSUJI, and T. ZUSUKI (Nagoya Univ., Japan), *10th Symposium on Turbulent Shear Flows*, Pennsylvania State Univ., University Park, 1995, Proceedings. Vol. 3 (A96-19391 04-34), University Park, PA, Pennsylvania State Univ., 1995, pp. P3-13–P3-16. 7 Refs. Documents available from Aeroplus Dispatch.

PDF's have been applied to the field of analysis and statistics of turbulence. It was shown by Amari (1985) that the PDF can be related to the geometry called the differential-geometrical methods in statistics. In this method a family of PDF's is regarded as one information element which constructs a manifold, and then the Riemann metric is introduced naturally. In this paper, the Kullback-Leibler divergence is computed in a turbulent boundary layer, which is an important quantity to define the metric in the manifold. (Author)

A96-19484 The chaotic and fractal structure in the turbulent boundary layer on a spinning cylinder in a quiescent fluid. Y. UEKI (Nagano Technical College, Japan) Y. TSUJI, and I. NAKAMURA (Nagoya Univ., Japan) *10th Symposium on Turbulent Shear Flows*, Pennsylvania State Univ., University Park, 1995, Proceedings. Vol. 2 (A96-19391 04-34), University Park, PA, Pennsylvania State Univ., 1995, pp. 17-13–17-18. 7 Refs. Documents available from Aeroplus Dispatch.

The behavior of chaos and fractality are investigated for the turbulent shear flow around a rotating cylinder in a quiescent flow. In the intermittent region, the chaos of generalized type III is confirmed for the present flow, which is somewhat more complex than the flat plate flow. The fractal property of an isovelocity set which is defined by the instantaneous streamwise velocity signal is obtained. The aim is to provide further evidence for the fractal property for the complex flow and to investigate which physical and dynamical quantities siginificantly affect the fractal property of an isovelocity set. The instantaneous Reynolds stress is found to be a key factor of this fractal property, as is conceived for the flat plate boundary layer. (Author)

A96-19467 Structure of a wall jet over a riblet surface. S. YAMASHITA (Gifu Univ., Japan), and Y. INOUE (Suzuka College of Technology, Mie, Japan), *10th Symposium on Turbulent Shear Flows*, Pennsylvania State Univ., University Park, 1995, Proceedings. Vol. 2 (A96-19391 04-34), University Park, PA, Pennsylvania State Univ., 1995, pp. 14-1–14-6. 23 Refs. Documents available from Aeroplus Dispatch.

Measurements are presented of a wall jet over a riblet surface, in which the reduction of the skin friction and the modification of the turbulent structure near the wall are investigated. The reduction of the local skin-friction by the riblets is about 11% maximum. Turbulent energy spectra and PDF's for the streamwise velocity fluctuation are shown on the riblet and flat surfaces. The VITA technique is utilized to analyze the coherent structure. Two-point space-time correlation coefficients are measured in the wall-normal and spanwise directions and the integral scales are computed. These results make clear the alternation of the turbulent structure near the wall by the riblets, showing the weakened sweep, decreased turbulent-energy production, increased integral scale in the spanwise direction, and so on. The spanwise spectra are calculated from the time-averaged two-point spanwise correlation, they clarify the noticeable difference in the near-wall turbulent structure in wall jets from turbulent boundary layers or channel flows. It is suggested that the optimum size of the riblet is related to the spanwise structure. (Author)

A96-19453 Properties in a relaminarizing turbulent boundary layer under a favorable pressure gradient. M. ICHIMIYA (Tokushima, Univ., Japan), *10th Symposium on Turbulent Shear Flows*, Pennsylvania State Univ., University Park, 1995, Proceedings. Vol. 2 (A96-19391 04-34), University Park, PA, Pennsylvania State Univ., 1995, pp. 11-7–11-12. 18 Refs. Documents available from Aeroplus Dispatch.

The behavior of the turbulent boundary layer on a flat plate in a relaminarizing process with flow acceleration due to a convergence of the sectional area is experimentally investigated. Statistical properties are measured and the turbulent structure is examined in detail. In the relaminarizing process, low-amplitude fluctuating portions appear intermittently in the velocity signal. In the retransitional process an irregular velocity fluctuation appears intermittently, then it grows and gradually becomes a turbulent condition. The turbulent energy dissipation decreases in the relaminarizing process and increases in the retransitional process. The distribution of skewness factor indicates how the fluctuating velocity tends to take a largely negative value with motion of this kind so readily appearing. In the relaminarizing process, vorticity increases in the large eddy and decreases in the small eddy. The small eddies become coarse, and the contribution from the high wave number decreases. (Author)

A96-19425 Secondary flow and stability effects of Coriolis force on turbulent boundary layer in a rotating channel. H. S. KOYAMA (Tokyo Denki Univ., Japan), K. KITAGAWA (Shin-Etsu Handotai Co., Ltd., Annaka, Japan), and K. CHEN (East China Univ. of Technology, Shanghai, China), *10th Symposium on Turbulent Shear Flows*, Pennsylvania State Univ., University Park, 1995, Proceedings. Vol. 1 (A96-19391 04-34), University Park, PA, Pennsylvania State Univ., 1995, pp. 8-7–8-12. 14 Refs. Documents available from Aeroplus Dispatch.

Turbulent boundary layer developing in a rotating rectangular channel of low aspect ratio was investigated by using a specially designed rotating wind tunnel. Mean velocity and Reynolds stress components were measured by using straight and slanted hot-wire sensors and a transmission system of electrical signals from a rotating apparatus to the stationary system. Aspect ratio of the channel was changed from 1:3.5 to 1:7 by inserting a partition plate between the side walls of the channel. The secondary flow effect and the stability effect of the Coriolis force on the turbulence structure are remarkable in the suction side boundary layer. For example, Reynolds stress-uv-bar decreases considerably and the phenomenon of negative production of turbulent energy was observed, unlike what is expected in normal boundary layer without rotation. (Author)

A96-18286 Experimental study of horseshoe vortex at wing/body junction with attack angle by triple hot-wire. T. SHIZAWA, S. HONAMI (Tokyo, Science Univ., Japan), and M. YAMAMOTO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), *AIAA 34th Aerospace Sciences Meeting and Exhibit*, Reno, NV, 1996, p. 12. 10 Refs. Documents available from Aeroplus Dispatch.

This paper presents an experimental study focused on the structure of a horseshoe vortex at a wing/body junction. A flat wing is established on the flat wall where the two-dimensional turbulent boundary layer is fully developed. An attack angle of the wing is changeable from +15 to −15 deg every 5 deg. The reference velocity is 16.2 m/s, the boundary layer thickness at the leading edge of the wing is about 22 mm, and the Reynolds number based on the radius of curvature is 24,000. Total pressure was measured by a three-hole Pitot probe, and turbulence intensity was measured by a normal hot-wire anemometer. Three components of mean velocity and six components of Reynolds stress were measured simultaneously by a specially designed triple hot-wire. The pressure loss at the downwash side of the vortex is small, but it takes a large value at the upwash side. The loss is large at the suction side of the wing. The vortex center shifts from the wing in the downstream direction at the suction side. The location where the Reynolds stress takes a negative value does not correspond to the region of the negative mean velocity gradient at the upstream location. (Author)

A96-18022 Fluctuating wall pressures in a Mach 5 crossing shock/turbulent boundary layer interaction including asymmetric effects. K. TANI (National Aerospace Lab., Kakuda, Japan) and D. S. DOLLING (Texas, Univ., Austin), *AIAA 34th Aerospace Sciences Meeting and Exhibit*, Reno, NV, 1996, p. 15. 24 Refs. Documents available from Aeroplus Dispatch.

Fluctuating wall pressure measurements have been made in a relatively weak double fin-induced shock wave/turbulent boundary layer interaction. Measurements were made along the centerline and at nine spanwise stations between the fin leading edge (entrance) and the throat. The wall pressure standard deviation on centerline increases by a factor of about eight between the entrance and throat, although as a fraction of the local mean wall pressure it is essentially constant with a value of about 0.03. Cross correlations of pressure signals upstream of separation are similar to those of undisturbed flow, little correlation is observed between signals measured upstream and downstream of separation. The latter can be explained in terms of the flowfield structure predicted by computations reported in the literature. Small asymmetries in model geometry do not generate any obvious flow structural asymmetries. (Author)

A96-17334 Satellite monitoring of oceanic turbulence around Japan islands. T. NISHIMURA, T. KOBAYASHI (Tokyo, Science Univ., Noda, Japan), S. TANAKA, and T. SUGIMURA (Remote Sensing Technology Center of Japan, Tokyo), *Advances in Space Research* (ISSN 0273-1177), Vol. 16, No. 10, 1995, pp. 137–140. 7 Refs. Documents available from Aeroplus Dispatch.

Based on kinematic features of the coherent structure dominant in the oceanic turbulence around the Japanese islands, obtained from NOAA/AVHRR monitoring, the Kuroshio behavior was discussed. Most eddies shed from cusped capes on the Pacific Coast increase the turbulent boundary layer and form an organized coherent structure of mesoscale eddies interlocked in the Shikoku-Basin. Some eddies shed from the Cape Shionomisaki, however, trap part of the Kuroshio watermass and deviate it coastward, leading to a decay of the boundary layer. The formed coherent structure induces the basin-scale Kuroshio variability, which has usually been described through the meandering and nonmeandering phenomena of the Kuroshio path. (Author)

A96-16202 Reynolds stress distribution around a large-scale coherent vortex in a turbulent boundary layer. H. MAKITA (Toyohashi Univ. of Technology, Japan) and K. SASSA (Kochi Univ., Japan), *Advances in turbulence V; Proceedings of the 5th European Turbulence Conference*, Siena, Italy, 1994 (A96-16146 03-34), Dordrecht, The Netherlands, Kluwer Academic Publishers (Fluid Mechanics and its Applications. Vol. 24), 1995, pp. 346–350. 10 Refs. Documents available from Aeroplus Dispatch.

The distributions of the Reynolds stress produced by the large-scale coherent vortex at an arbitrary stage of its streamwise development are obtained. Detailed distributions of the Reynolds stress components around the artificial large-scale coherent vortex and the streamwise evolution of their integrated values are given. Most of the Reynolds stress was produced by the organized motions, the outflow, and the inrush. The contribution of the random component was not negligible anywhere inside the large-scale vortex. The large-scale coherent vortex plays an active role in momentum transfer at the growth and self-preserving stages, but only a passive one at the decay stage.

A96-12484 Three-dimensional mixing flow field in supersonic flow induced by injected secondary flow through a traverse circular nozzle. S. ASO, S. MAEKAWA, M. TAN-NOU, S. OKUYAMA (Kyushu Univ., Fukuoka, Japan), Y. ANDO, and Y. YAMANE (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), *Shock waves at Marseille I: Hypersonics, shock tube and shock tunnel flow; Proceedings of the 19th International Symposium on Shock Waves*, Marseille, France, 1993 (A96-12460 01-02), Berlin and New York, Springer–Verlag, 1995, pp. 163–170. 16 Refs. Documents available from Aeroplus Dispatch.

Shock wave/turbulent boundary layer interaction regions induced by gaseous secondary flows injected into supersonic flows through circular nozzles have been experimentally and computationally investigated. In the experiments the flowfields are visualized by the schlieren method, oil flow technique, and surface pressure, spatial total pressure distributions are measured in the whole interaction region. The total pressure ratio is varied and the changes of the flowfield are investigated for circular injection. The detailed flow structures in three dimensional mixing flow structures have been revealed. Especially, the surface oil patterns show a quite complicated flow in the interacting region with primary and secondary separations. Also, quite interesting Pitot pressure fields are revealed. The same flowfields have been simulated by solving Navier–Stokes equations with turbulent modeling. Surface pressure and spatial Pitot pressure distributions show quite good agreement with experiments. The results suggest that the numerical code is quite useful for supersonic mixing flows. (Author)

A96-12479 Aerodynamic heating in three-dimensional bow shock wave/turbulent boundary layer interaction region. S. MAEKAWA, S. ASO, S. NAKAO (Kyushu Univ., Fukuoka, Japan), K. ARASHI (Churyo Engineering Co., Ltd., Nagoya, Japan), K. TOMIOKA (NASDA, Tokyo, Japan), and H. YAMAO (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan), *Shock waves at Marseille I: Hypersonics, shock tube and shock tunnel flow; Proceedings of the 19th International Symposium on Shock Waves*, Marseille, France, 1993 (A96-12460 01-02), Berlin and New York, Springer–Verlag, 1995, pp. 133–138. 4 Refs. Documents available from Aeroplus Dispatch.

Aerodynamic heating phenomena in the shock wave/turbulent boundary layer interaction region are one of the most important research tasks and this subject demands further investigation. To explain these phenomena, we investigate the bow shock wave/turbulent boundary layer interaction region induced by a blunt body, that is to say, the model case of the internal flow between a main rocket body and an auxiliary rocket booster. In this study, selecting as the main parameter the distance from the flat plate to the blunt body, the effect of the height is investigated by use of oil flow technique, surface pressure measurements, and surface heat flux measurements. The results show that the distance has a major impact on the interaction region. Moreover, this parameter influences the flow behavior. (Author)

N95-32994 A note on separation prediction of two-dimensional turbulent boundary layer. I. TANAKA, and K. MA, Osaka Univ., Osaka (Japan). Dept. of Naval Architecture and Ocean Engineering. *Its Technology Reports of the Osaka University*, Vol. 45, Nos. 2205–2216, pp. 95–99. Documents available from Aeroplus Dispatch.

Based on the two-dimesional turbulent boundary layer theory developed by Tanaka and Himeno, a simple prediction method of the separation of the two-dimensional turbulent boundary layer with the pressure gradient is presented. The effectiveness of this method is investigated by applying it to several cases of published data from previous experiments. This method is shown to be applicable for practical prediction purposes. (Author (revised))

N95-29712 Experimental studies on boundary-layer transition on a reentry vehicle at transonic and supersonic speeds. K. SUZUKI, and T. ABE, Tokyo Univ. (Japan). Inst. of Space and Astronautical Science. Documents available from Aeroplus Dispatch.

The boundary-layer transition on the EXPRESS reentry capsule at transonic and supersonic speeds is studied experimentally by the wind tunnel tests. For the diagnostic of the turbulent transition of the boundary layer, the China-clay method is used. The experimental results clarify that when the freestream Mach number increases, the transition point moves downstream on the body surface and the distance between the beginning of the transition and its completion to the fully turbulent flow becomes larger. The effects of the freestream Mach number on the location of the boundary-layer transition are described successfully in terms of two nondimensional quantities, that is, the transition Reynolds number and the local Mach number at the boundary-layer edge. The oil-flow pictures reveal that in the transonic regime, the separation bubble is formed at the junction between the blunt nose and the conical part of the body and therefore the transition begins behind the reattachment point of the separation bubble. The effects of the turbulent transition on the aerodynamic characteristics of the reentry body are investigated by using the technique of the boundary-layer trip and the experimental results show that the aerodynamic characteristics of the EXPRESS reentry vehicle are not sensitive to the boundary-layer transition. (Author)

A95-44706 A study of three-dimensional supersonic mixing flow phenomena induced by helium gas injection through circular nozzle. S. ASO, M. TANNOU, S. MAEKAWA (Kyushu Univ., Fukuoka, Japan), Y. ANDO,Y. YAMANE (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), and M. FUKUDA (National Aerospace Lab., Tokyo, Japan), *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. 564–573. 17 Refs. Documents available from Aeroplus Dispatch.

Shock wave/turbulent boundary layer interaction regions induced by secondary flows of helium gas injected into supersonic flows through circular nozzles were experimentally and computationally investigated. In the experiments, the flow fields were visualized by the schlieren method and an oil flow technique. Detailed flow structures in three-dimensional mixing flow have been observed. In particular, the surface oil patterns show quite complicated flow in the interacting region with primary and secondary separations. Due to helium injection, spatial mass fraction distributions are measured at two cross sections downstream of the nozzle. The results suggest that flow mixing with helium gas is better, as compared with N_2 gas. Also, the same flow fields were simulated by solving Navier–Stokes equations with turbulent modeling. Almost reasonable mixing flow structure is reconstructed in the calculations. The results suggest that the numerical code is quite useful for supersonic mixing flows. (Author)

A95-41063 Organized motions of a turbulent boundary layer. Y. KOBASHI and M. ICHIJO (Hokkaido Inst. of Technology, Sapporo, Japan), *6th Asian Congress of Fluid Mechanics*, Singapore, 1995, Proceedings. Vol. 1 (A95-41024 11-34), Singapore, Nanyang Technological Univ., 1995, pp. 344–347. 13 Refs. Documents available from Aeroplus Dispatch.

Two rows of vortices are used for the study of organized motions of the outer layer of a turbulent boundary layer. Velocity distribution of the layer and the speed of moving structures agree fairly well with the results obtained so far. Burst structures of the inner layer are found to be caused by the interaction between rows of vortices. The origin of turbulence in the outer layer is also discussed. (Author)