Japanese Aerospace Literature This month: *Supersonics*

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.

A88-40375 Heat flux on the surface of a wedge in Mach reflection and regular reflection of shock waves. MASANORI HAYASHI, SHIGERU ASO, YOSHIHARU TANAHASHI, and AKIRA YAMASHITA, *Kyushu University Technology Reports* (ISSN 0023-2718), Vol. 61, Jan. 1988, pp. 59-65. 5 Refs.

Measurements of transient temperature and pressure rise on a surface of wedge in a shock tube have been carried out for the case where the incident oblique shock waves on the surface reflect under the conditions of shock Mach numbers 1.34-2.75, with wedge angles of 35.0-48.0 degrees. The heat flux on the surface has been calculated by using the temperature rise. It is known that there are four patterns for the shock reflections. In this paper, these shock reflection patterns have been visualized by the Schlieren method. Finally, it is shown that each flow pattern exhibits characteristic changes of the surface temperature, heat flux and pressure rise with time, and these variations are influenced by the slipstream.

A88-39389 Ruby-laser scattering diagnostics of a supersonic plasma flow for low-pressure plasma spraying. RYOUTA HIDAKA, TSUTOMU OOKI, KOUICHI TAKEDA, KATSUYUKI KONDO, HIROSHI KANDA et al., *Japanese Journal of Applied Physics, Part 2* (ISSN 0021-4922), Vol. 26, Oct. 1987, pp. L1724-L1726.

Truly reliable measurements of electron temperature and density in a plasma flow for low-pressure plasma spraying were performed for the first time, using incoherent Thomson scattering of ruby-laser light. The results indicate the characteristic feature of a supersonic nozzle flow, namely, successive appearance of oblique shock-wave heating (about 1 eV) and compression (4 x 10 to the 21st/cu m), and subsequent cooling (about 0.2 eV) and rarefaction (1 x 10 to the 21st/cu m).

A88-22324 Ignition mechanism of scram jet fuel using silane. KOICHI HAYASHI, A. TOSHI FUJIWARA, and KENJI SUGIMOTO, *AIAA, 26th Aerospace Sciences Meeting,* Reno, NV, Jan. 11-14, 1988. 8 pp. 15 Refs. (AIAA Paper 88-0437).

Silane is added to oxyhydrogen combustion to understand its additivity effect in an application of scramjet combustion. A shock tube is used to measure the ignition delay time of the stoichiometric oxyhydrogen mixture with and without 25 percent silane to the hydrogen concentration in the temperature range of 880-1600 K and the pressure range of 1.7-5.1 atm. The results show that the effect of silane addition is strong at the low to medium temperature (880-1300 K) and weak at the high temperature where oxyhydrogen ignition dominates. The slope of ignition delay time versus temperature is different at the medium to high temperature (1000-1600 K) than it is at the low temperature (800-1000 K). A preliminary mechanism of the silane-oxyhydrogen system is developed and numerical simulation of experimental results is performed using the developed mechanism.

A88-26185 Supersonic expansion of a dusty gas around a sharp corner. H. MIURA and I. I. GLASS, *Royal Society (London), Proceedings, Series A—Mathematical and Physical Sciences* (ISSN 0080-4630), Vol. 415, no. 1848, Jan. 8, 1988, pp. 91-105. 12 Refs.

Steady supersonic flows around a corner are studied theoretically for a dusty gas in which the gas and the particles make a significant exchange of momentum and heat. Perfect-gas theory for the dusty gas in an equilibrium limit is used to examine the nature of the flow far from the corner. The maximum flow-deflection angle is found to be increased by the presence of the particles. The equations of motion are solved numerically to study the transition of the flow from a frozen state at the corner to a near-equilibrium state at infinity. The differences in nonequilibrium properties of the flow between the cases of large and small deflection angles of the corner are discussed. Numerical results for large deflection angles show that the gas expands excessively after it enters a pure-gas region which forms along the wall surface. In every case, diffusive flow patterns arise around the effective wavehead and wavetail in the far field. It is shown analytically that the length of the diffusive flow domain increases in proportion to the square root of the distance from the wall.

A87-46186 A study on the flows to aft-inlets of a missile in supersonic flight at an angle of attack. S. KOIDE and Y. SUGIYAMA, *Proceedings of the 8th International Symposium on Air Breathing Engines,* Cincinnati, OH, June 14-19, 1987, (A87-46176 20-07). New York, American Institute of Aeronautics and Astronautics, 1987, pp. 94-101. 9 Refs.

In order to investigate the flow conditions to aft-inlets of a rocket ramjet engine for a missile in supersonic flight at an angle of attack, three-dimensional rotational inviscid flow fields downstream of the eccentric shock wave cone are numerically analyzed in a range of attack-angles of 0 to 20 deg and flight Mach numbers of 2 to 5. The shock wave cone is found to be more eccentric with the strongest shock wave on windward near the vertex, as the angle of attack increases, resulting highly-pronounced rotationality in the downstream flows. The flow incidence angles to the inlets locating on sideward of the body significantly increase compared to those at other positions due to the cross flow around the body. There exists a critical angle-angle for local stagnation pressures at the upper leeward inlet to suddenly deteriorate, caused by the low energy air flows through the strong wave on windward near the vertex, which is found to be affected by the inlet axial location and the free-stream Mach number.

A88-36695 Numerical simulation of a supersonic flow CO chemical laser using a leaky stream tube approach. WATARU MASUDA and MOTOSHI TOHYAMA, *Japan Society for Aeronautical and Space Sciences Transactions* (ISSN 0549-3811), Vol. 30, Feb. 1988, pp. 201-210. 8 Refs.

A leaky stream tube approach is used to simulate a supersonic flow CO chemical laser. Downstream of the nozzle exits, the flow field is divided into three stream tubes: two stream tubes for the dissociated products of CS2 diluted in Ar and for O2 and the third one located between these two. It is shown that the dependence of the small signal gain coefficient on most parameters obtained by the leaky stream tube analysis resembles that obtained under the instantaneous mixing assumption. Since the gain is lowered considerably, it is necessary to account for the mixing process so that the laser performance can be estimated precisely.

A87-37699 Visualization and numerical simulation of supersonic microjets. K. TESHIMA and M. SOMMERFELD, *Experiments in Fluids* (ISSN 0723-4864), Vol. 5, no. 3, 1987, pp. 197-200. Research supported by Kyoto University.

Very narrow supersonic jets expanding from a small size convergent-divergent nozzle are visualized by the laser induced fluorescence method and simulated numerically using the piecewise linear method. Good agreement between the experiment and the numerical result is obtained in the jet structure, i.e., the shape of the barrel shock, the location of its reflection point on the axis, and the shape of the jet boundary.

A87-35408 Nozzle flows of gas-particle mixtures. R. ISHII, Y. UMEDA, and K. KAWASAKI, *Physics of Fluids* (ISSN 0031-9171), Vol. 30, March 1987, pp. 752-760. 13 Refs.

A numerical analysis of supersonic nozzle flows of gas-particle mixtures is described. A time-dependent technique is applied to solve a two-phase inviscid flow through an axially symmetric nozzle. The two-step MacCormack algorithm is used for the gas-phase flow and the method of characteristics is applied to the particle-phase flow. Attention is mainly focused on the location of the limiting particle streamline. The numerical results are compared with the theoretical results obtained previously and also with experiments.

A87-50011 Two-dimensional focusing of a supersonic free jet by a rectangular orifice. KOJI TESHIMA, *Physics of Fluids* (ISSN 0031-9171), Vol. 30, July 1987, pp. 1899-1901. 6 Refs.

Supersonic free jets issuing from rectangular orifices have been observed by using a laser-induced fluorescence technique. Anisotropy of expansion in two directions, the orifice length (z) and width (y), apparently occurs in the jet structure at a large pressure ratio (between reservoir and vacuum chambers); the jet spreads in the y direction whereas it converges in the z direction. This effect is enhanced by interaction of lateral shocks from both ends of the orifice when a small aspect ratio orifice is used. Under a flow condition whereby the shocks reflect normally on the axis, the jet becomes very thin in the z direction.

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.

A89-47010 Mach 4 testing of scramjet inlet models. TAKESHI KANDA, TOMOYUKI KOMURO, GORO MASUYA, KENJI KUDO, ATSUO MURAKAMI et al., AIAA Paper 89-2680 presented at the AIAA, ASME, SAE, and ASEE, 25th Joint Propulsion Conference, Monterey, CA, July 10-13, 1989. 9 pp. 6 Refs.

Six scramjet inlet models were tested in a Mach 4 wind tunnel. Wall pressure was measured, pitot pressure was measured at the throat, and schlieren photographs were taken. Parameters of these models are side plate sweep angle, contraction ratio, and cowl geometry. The shock pattern inside one of the models as shown by schlieren photographs coincides with calculations. Both mass capture ratio and total pressure recovery are 50 - 70 percent. There seems to be an optimum sweep angle and an optimum cowl length for maximum total pressure recovery.

A89-47006 A comparison of scramjet engine performances of various cycles. TAKESHI KANDA, GORO MASUYA, YOSHIO WAKAMATSU, NOBUO CHINZEI, and AKIO KANMURI, AIAA Paper 89-2676 presented at the AIAA, ASME, SAE, and ASEE, 25th Joint Propulsion Conference, Monterey, CA, July 10-13, 1989. 10 pp. 19 Refs.

An airframe-integrated hydrogen fueled scramjet engine is assumed in order to compare engine performances of various engine cycles: an expander cycle, a staged-combustion cycle, a coolant-bleed cycle, and a gas-generator cycle. Each engine was regeneratively cooled by liquid hydrogen. Effects of flight Mach number, flight dynamic pressure, and fuel injection-to-air dynamic pressure ratio were examined as related to propellant feed-line power balance. The system pressure of the closed loop cycle becomes high, while the specific impulse of the open loop cycle becomes low, when the flight Mach number, the flight dynamic pressure, or the fuel injection to air dynamic pressure are high, i.e., when the fuel injector manifold pressure is high. Of the four cycles, the coolant-bleed cycle shows the most well-balanced performance.

A89-46927 Effectiveness of plasma torches for ignition and flameholding in scramjet. YUKINORI SATO, MASAMI SAYAMA, KATSURA OHWAKI, GORO MASUYA, TOMOYUKI KOMURO et al., AIAA Paper 89-2564 presented at the AIAA, ASME, SAE, and ASEE, 25th Joint Propulsion Conference, Monterey, CA, July 10-13, 1989. 9 pp. 6 Refs.

A plasma torch with a feed stock of air or oxygen was studied experimentally to determine its effect on ignition and flameholding in a scramjet combustor. Consideration was given to fuel injection from one orifice, from four orifices on one wall, and from all nine orifices on both walls. This plasma torch was capable of stable operation without any support gas. In the case of single wall injection, the plasma torch ignited the fuel jet located directly downstream and the flame formed ignited adjacent fuel jets. In double wall injection, ignition of the fuel injected from the wall opposite the plasma torch was unsuccessful.

A89-46600 Performance analysis of scramjet engines. YOSHIHARU TSUJIKAWA, YUJIRO TSUKAMOTO, and SHOICHI FUJII, *Osaka Prefecture, University, Bulletin, Series A - Engineering and Natural Sciences* (ISSN 0474-7844), Vol. 37, no. 1, 1988, pp. 1-13. 5 Refs.

The quasi-one-dimensional model for the flow through a scramjet engine is proposed, and the performance of the components is analyzed thermodynamically. In the analysis, there are severe difficulties in the combustor due to problems such as turbulent diffusion and mixing at supersonic speed. For the combustion reaction, a global hydrogen-air combustion model with two-step reaction schemes is introduced.

A89-45460 Numerical analysis of gas-particle two-phase flows. R. ISHII, Y. UMEDA, and M. YUHI, *Journal of Fluid Mechanics* (ISSN 0022-1120), Vol. 203, June 1989, pp. 475-515. 39 Refs.

A numerical analysis of axisymmetric gas-particle two-phase flows is presented in which the gas phase is treated as a continuous medium and the particle phase is treated partly as a discrete medium. The particle cloud is divided into a large number of small clouds, and the particles in each cloud are assumed to have the same velocity and temperature. Results obtained for underexpanded supersonic free-jet flows and supersonic flows around a truncated cylinder of gas-particle mixtures reveal that the flow characteristics of the gas-particle mixtures are widely different from those of dust-free gas at many points.

A89-12890 Multiple shock wave and turbulent boundary layer interaction in a rectangular duct. H. SUGIYAMA, J. ZHANG, F. ABE, and H. TAKEDA, *Shock tubes and waves—Proceedings of the Sixteenth International Symposium,* Aachen, Federal Republic of Germany, July 26-31, 1987 (A89-12876 03-34). Weinheim, Federal Republic of Germany, VCH Verlagsgesellschaft mbH, 1988, pp. 185-191. 11 Refs.

The effects of the locations of pseudoshock waves in straight square ducts in which the flows are choked at the duct exits on the structure and oscillation phenomena of pseudoshock waves were investigated. The experiments were conducted at the duct-entrance Mach-infinity numbers between 1.72 and 1.88, and the duct length to width ratios (L/D) between 20.6 and 23.6. It was found that the location of a pseudoshock wave moves in a downstream direction with decreasing L/D ratios and increasing Mach-infinity values. As the location of pseudoshock waves moves, the shape of the pseudoshock waves changed from the lambda-type pseudoshock wave, which oscillates with an amplitude of about 0.2 D and low frequencies below 40 Hz, to the X-type wave, which oscillates more regularly with an amplitude of 0.3 D, low frequencies less than 70 Hz, and high frequencies of about 150 to 250 Hz. (I.S.)

A89-44975 A simple theory of aerospaceplane. RYOJIRO AKIBA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 37, no. 423, 1989, pp. 202-204.

Simplified equations of energy and momentum conservation lead to a closed form expression of effective exhaust velocity of an air-breathing engine which characterizes an aerospace plane. Following features of hypervelocity propulsion are disclosed. First, the intake air is effective as an oxygen carrier, a momentum carrier, and an energy carrier, depending on the flight velocity. Second, actual thermochemical values allow only hydrogen to be the fuel of an aerospace plane. Third, the efficiency of energy utilization for intake air must exceed 90 percent in order to reach near an orbital speed.

A89-38387 Scramjet combustion with an aid of silane. KENJI SUGIMOTO, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22-27, 1988, Vol. 2 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 2595-2600. 8 Refs.

The effect of substituting 25-percent silane for hydrogen on the combustion of a stoichiometric H2-O2 mixture at 823-1617 K is investigated in shock-tube experiments simulating conditions in a scramjet engine. The ignition delay time is determined on the basis of monochromator/PMT detection of OH emission, and the results are presented in extensive graphs. Silane is found to improve the H2 combustion, significantly at temperatures up to about 1200 K but only slightly at higher temperatures. The accuracy of theoretical combustion models is shown to be good at low temperatures but only fair at high temperatures.

A89-38386 Standing oblique detonation held by a wedge (in supersonic combustion ramjet engines). AKIKO MATSUO, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22-27, 1988, Vol. 2 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 2589-2594. 6 Refs.

The feasibility of generating a standing oblique detonation wave (SODW) on a blunt two-dimensional wedge is investigated by means of numerical simulations based on the Euler equations for an exothermally reacting gas. The derivation of the model and its numerical implementation via a fully implicit TVD finite-difference scheme are outlined, and results are presented graphically for premixed stoichiometric O2-H2 (diluted in 70-percent Ar/He) passing over a circularly blunted wedge of apex half-angle 30 deg at inlet Mach numbers 6 and 10. At Mach 6, increasing the radius of the blunting circle changes the SODW from detached (between the bow shock and the reaction front) to attached and unsteady. At Mach 10, however, the SODW remains steady and attached. The applicability of the present results to the design of scramjet engines is indicated.

A89-38125 Highly-resolved flowfield induced by Mach reflection. TADAYOSHI SUGIMURA and TOSHI FUJIWARA, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22-27, 1988, Vol. 1 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 743-748. 5 Refs.

The interaction between the chemical reaction and shear flow behind a Mach reflection shock is examined, focusing on the ignition mechanism caused by the interaction. Using the two-dimensional Euler equations where the incident Mach number is 3, the flow around a forward-facing step is solved, neglecting the chemical reaction. It is found that, by increasing the resolution, the flowfield is changed to generate a more conspicuous shear layer behind the first Mach reflection from the upper surface of the forward-facing step.

A89-38124 Numerical simulation of supersonic flows past a spaceplane. SUSUMU TAKANASHI, KISA MATSUSHIMA, and KOZO FUJII, *Proceedings of the 16th International Symposium on Space Technology and Science,* Sapporo, Japan, May 22-27, 1988, Vol. 1 (A89-38031 16-12). Tokyo, AGNE Publishing, Inc., 1988, pp. 731-742. 13 Refs.

Supersonic flows past a research model of a spaceplane are simulated numerically. A single block O-C grid is generated around the model and the Reynolds-average thin-layer Navier-Stokes equations are solved using the implicit finite difference method based on an upwind TVD scheme. The predicted lift, drag, and moment are compared with experimental data, showing fairly good agreement.

A89-31513 Characteristics of combustion-driven CO2 gasdynamic laser. I - Influence of expansion ratio of a supersonic nozzle. TADAHARU WATANUKI, EIJI OGURA, YASUHIRO MIZOBUCHI, SHIGERU SATO, and HIROTOSHI KUBOTA, *Japan Society for Aeronautical and Space Sciences Journal* (ISSN 0021-4663), Vol. 36, no. 419, 1988, pp. 550-557. 12 Refs.

The characteristics of a combustion-driven CO2 gasdynamic laser (GDL) for use as a radiation heating simulator for reentry of a planetary probe and AOTV are experimentally and theoretically obtained. In the present GDL system, CO2 produced in the combustion of liquid C6H6 with gaseous O2 is used as the lasing medium associated with the energy-pumping gaseous N2. The influence of gas components on the small-signal gain is investigated using four expansion ratios (5, 7.5, 10, and 15) which have common throat height 1.0 mm. The experimental results show that the small-signal gain increases as the nozzle expansion ratio increases and that the maximum gain obtained is 0.2/m at expansion ratios 10 and 15.