Japanese Aerospace Literature
Jet Flow

A93-54086 Observation of fluctuation of 2D-nozzle flows. TOMOYUKI NAKAMURA and YOKICHI SUGIYAMA, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol. 2,* Tokyo, Japan, Sept. 20–24, 1993, (A93-53976 23-07) Washington, American Institute of Aeronautics and Astronautics, 1993, pp 1128–1133 (ISABE 93-7110)

In order to determine the fluctuation of 2D nozzle flows, instantaneous flow visualization was carried out using flashing sheet beam for three types of scale models, a boat-tail model, an internal-aerodynamic model, and a transparent model Both the boat-tail and internal-aerodynamic models made of stainless steel with adjustable nozzle-flaps were tested for exhaust-jet-flow visualization at jet velocities as high as Mach 1 4, and the transparent model was tested for internal-flow visualization at jet velocity of approximately 10 m/s Results show that entrainment of ambient air takes place in an unsteady 3D manner, a smaller aspect ratio enhances the entrainment, and inlet whirl spreads the jets at high speed but it just rotates middle portion of the jets at low speed, resulting in an S-like section flow-pattern in downstream.

A93-54046 DSMC method for transverse gas injection into a supersonic air flow. T. NAKAE, S. TERAMOTO, and T. NAGASHIMA, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol. 2,* Tokyo, Japan, Sept 20-24, 1993, (A93-53976 23-07). Washington, American Institute of Aeronautics and Astronautics, 1993, pp. 728–733 5 Refs. (ISABE 93-7070.

Transverse fuel injection from a wall slit into a supersonic air flow has been investigated by applying the direct simulation Monte Carlo (DSMC) method. The DSMC method has been developed for rarefied gas dynamics and it is still restrictive to carry out a continuum gas flow simulation in a full-scale model. The present calculation results, however, reveal many of the characteristic flow features associated with the transverse injection such as the bow/separation shock waves, the recirculations before/after the injection slit, whence it is concluded that DSMC method can be successfully applied and will be a good alternative of the other numerical methods based upon the Navier-Stokes equations in the investigation of the present gas injection problem, yielding more physical/microscopic insights into the shock wave structure and the gas mixing/diffusion in the flow field.

A93-54045 Tandem transverse hydrogen gas injection into a supersonic airflow. S. NOGUCHI, H ITOH, Y KOTANI, and T. NAGASHIMA, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol 2,* Tokyo, Japan, Sept. 20–24, 1993, (A93-53976 23-07) Washington, American Institute of Aeronautics and Astronautics, 1993, pp 719–727. 6 Refs (ISABE 93-7069).

Hydrogen gas has been injected transversely into Mach 1.8 airflow from two circular sonic injectors which are mounted flush and placed in tandem along the center line of the bottom wall plate of a test section Both cold and hot (i e , atmospheric and heated to max 1460 K stagnation temperature) air flow conditions were tested. In the cold flow experiments, detailed measurements were successful, and the tandem injection results showed a marked difference from the single injection results in the pattern of shock waves and the distribution of pressure and hydrogen concentration near the injector region. Upon changing the injection pressure ratio between the two injectors, it has been revealed that a prior injection upstream of the main injection would be beneficial in terms of the total pressure loss in the air flow and the hydrogen concentration near the injector region while maintaining the mixing performance. The flow features showed in general little difference as the air flow temperature was raised until the hydrogen burning was observed; then the results became inevitably more qualitative than quantitative. Contrary to expectations from the cold flow tests, a prior injection of cold hydrogen has resulted in quenching the main injector flame

A93-50219 Development of a fuel rich methane-air burner. T. HASHIMOTO, T YOSHINO, T TAKAKUSAKI, N. ARAI, N. TERAMAE, N. KOBAYASHI, A KATAOKA, and M HASATANI, 29th AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, Monterey, CA, June 28–30, 1993. 5 pp. 6 Refs (AIAA Paper 93-2476).

Lately, it has become clear that several new energy conversion systems are needed in order to use fossil fuel more efficiently. Included among these are technologies which will develop an advanced high-efficiency energy conversion system using a gas turbine, operating at higher temperatures and higher pressures To develop this system, a new burner with low emission of nitrogen oxides is indispensable. This paper discusses a fuel rich methane-air burner which produces (a) a distinctly low level of nitrogen oxide emission and (b) combustion gas containing few oxygen mole fractions. The burner is small in scale because of limitations in the gas supply system, and employs a coaxial injector owing to higher combustion chamber pressures in the specifications (4 MPa). Design materials, such as characteristics of stable ignition and flame stability, are studied experimentally using several geometrical parameters and several operating conditions. Characteristics under lean fuel condition is also examined As a result, stable combustion characteristics are obtained for an equivalence ratio between 0 7 and 1.5.

A93-54026 Ignition and combustion performance of a scramjet combustor with a fuel injection strut. GORO MASUYA, TOMOYUKI KOMURO, ATSUO MURAKAMI, NOBORU SHINOZAKI, AKIHIRO NAKAMURA, MOTOHIDE MURAYAMA, and KATSURA OHWAKI, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol 1,* Tokyo, Japan, Sept 20–24, 1993, (A93-53976 23-07) Washington, American Institute of Aeronautics and Astronautics, 1993, pp 533–542 27 Refs. (ISABE 93-7050)

Ignition and combustion performance of a scramjet combustor with a fuel injection strut was experimentally investigated. A vitiation air heater supplied Mach 2.5 airstream to the combustor at stagnation conditions of 800-2200 K and 1 0 MPa. In order to select strut configuration which does not produce major disturbance in the flowfield, five strut models with different leading edge geometry were tested without fuel injection The nonreacting flowfields were also investigated by computation with a 2D Navier-Stokes code Using a less flow-disturbing strut, combustion and ignition tests were conducted Pitot pressure and gas composition survey was carried out to deduce mixing and combustion efficiencies It was found that mixing and combustion with a less flow-disturbing strut was considerably worse than those previously studied with a more flow-disturbing strut Autoignition and forced ignition with plasma torches were tested for hydrogen fuel at the room temperature Ignition characteristics of fuel injected parallel and perpendicular to the airstream were quite different The plasma igniters could successfully ignite both parallel and perpendicular fuel jets without noticeable time delay between both sides of the strut.

A93-54025 A study of self-ignition of methane-hydrogen mixture fuel injected into high enthalpy supersonic airstreams. H. TAGUCHI, S TOMIOKA, H NAGATA, M KONO, and Y. UJIIE, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol 1,* Tokyo, Japan, Sept. 20–24, 1993, (A93-53976 23-07) Washington, American Institute of Aeronautics and Astronautics, 1993, pp 525–532 14 Refs (ISABE 93-7049).

In order to attain combustion of methane fuel in supersonic airstreams of relatively low temperature, hydrogen fuel was added to the fuel as a ignition promoter In experiments, rectangular combustor with backward step was adopted, and the methane-hydrogen mixture fuel was injected into supersonic airstreams The region where the self-ignition occurs was confirmed by high speed direct photographs, and self-ignition characteristics were investigated with parameters of equivalence ratio and fraction of hydrogen in the fuel. The injection form was refined with use of the obtained results to attain self-ignition with low fraction of hydrogen The combustion of methane-hydrogen mixture fuel was compared with that of hydrogen fuel by using wall static pressure distributions and OH/CH emission images of the flame. It is confirmed that the combustion of methane fuel in the airstreams is obtained by addition of hydrogen fuel, and it is argued that the self-ignition in refined injection form is obtained under same conditions as that of hydrogen fuel, independently of the fraction of hydrogen in total injected fuels The static pressure distribution and the flame shape in methane-hydrogen mixture fuel case were similar to those in hydrogen fuel case

A93-44374 Three-dimensional calculation of a hydrogen jet injection into a supersonic air flow. A K. HAYASHI and MASAHIRO TAKAHASHI, 13th Dynamics of gaseous combustion; International Colloquium on Dynamics of Explosions and Reactive Systems, Nagoya, Japan, July 28–Aug 2, 1991, Technical Papers (A93-44349 18-25) Washington, American Institute of Aeronautics and Astronautics, Inc , 1993, pp 402–412 8 Refs

Three-dimensional, Reynolds averaged, full Navier-Stokes equations with an algebraic eddy viscosity model of Baldwin and Lomax are integrated to simulate a secondary hydrogen jet transversely injected into a supersonic air flow. The second-order implicit Harten-Yee type total variation diminishing (TVD) scheme and the second-order central difference scheme are used to difference the convective and viscous terms, respectively. The numerical results are investigated to understand the three-dimnensional flowfield of the interaction between the main and injected flows. The results show the three-dimensional phenomena such as a secondary vortex underneath the primary vortex The recirculations are predicted at several places, some of which are not detected in the two-dimensional calculation.

A93-40430 Study of mixing flow field of a jet in a supersonic cross flow. I - Experimental facilities and preliminary experiments. KAZUHIKO TOSHIMITSU, YUZO INOKUCHI, NOBUHIKO YAMASAKI, and MASANOBU NAMBA, *Kyushu University, Technology Reports* (ISSN 0023-2718), Vol 65, No. 6, Dec 1992, pp. 631–636 3 Refs

The interaction of a jet with a supersonic cross flow is one of the important fluid dynamics problems concerned with supersonic combustion ramjet engines This paper describes a supersonic wind tunnel which has been newly constructed for measuring a density distribution of such a mixing flow field In particular, an optical system of this experimental facility comprises a Mach-Zehnder interferometer and an image processor system Furthermore, some results of Mach-Zehnder and schlieren visualization experiments are presented

A93-54022 Noise reduction of supersonic heated jet with jet mixing enhancement by tabs. H KOBAYASHI, H OINUMA, M MINODA, and E OUTA, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol 1,* Tokyo, Japan, Sept. 20-24, 1993, (A93-53976 23-07). Washington, American Institute of Aeronautics and Astronautics, 1993, pp. 501–510 Research supported by MITI. 9 Refs. (ISABE 93-7046)

Effects of jet gas temperatures on underexpanded supersonic jet noise reduction by small size tabs has been experimentally investigated, using a supersonic jet noise test facility operated in an anechoic room. The small size tab in comparison with ones used previously by other investigators was selected, based on test results of underexpanded supersonic cold jet noise reduction for acquiring tabs with a large noise reduction level per percent jet thrust loss. The far-field jet noise spectra and directivity were measured from the conical covergent nozzles operated with the two tabs and without tabs, in super-critical jet operating conditions of the maximum jet Mach number 1.684 and in jet gas temperature conditions varied from 303 k to 773 k for each jet operating condition. In the cases of high jet gas temperature, the tabs efficiently eliminate the screech tone noise as well as reduce broadband shock associated noise, by the maximum 7 dB in overall sound pressure level

A93-54016 ' Isothermal flow characteristics behind V-shape gutter with and without injection. YUJI IKEDA, SHIGEO HOSOKAWA, MASASHI MINATO, and TSUYOSHI NAKAJIMA, *Proceedings of the 11th ISABE - International Symposium on Air Breathing Engines, Vol 1,* Tokyo, Japan, Sept 20–24, 1993, (A93-53976 23-07) Washington, American Institute of Aeronautics and Astronautics, 1993, pp. 449–456 18 Refs. (ISABE 93-7040)

Three-dimensional flow characteristics behind the V-gutter with and without jet injection were investigated by LDV measurements. The difference of reverse flows with and without injection was measured in order to specify the flow characteristics for flame holding The injected jet spread as an elliptical shape The reverse flow region at low equivalence ratio was a continuous circular-ring shape, while the combination of these reverse flow regions was yielded with increase of equivalence ratio. The reverse flow ratio was almost proportional to the jet flow rate, that is, equivalence ratio Three typical flow characteristic parameters were proposed in order to specify the flame holding and mixing characteristics at different equivalence ratio.

A93-53801 Characteristics of liquid jet atomization across a high-speed airstream. III - Breakup process of liquid jet and internal structure of spray. TETSUYA ODA, HIROYUKI HIROYASU, and KEIYA NISHIDA, *Japan Society of Mechanical Engineers, Transactions B* (ISSN 0387- 5016), Vol. 59, No 560, April 1993, pp 1408–1413 7 Refs.

To elucidate deformation and breakup processes of a liquid jet across an airstream, tomograms of the liquid jet were taken by means of the laser light sheet method In this method, fluorescent dye, Eosine-Y, was contained in the injected water, and the liquid jet was illuminated by the Nd·YAG laser light sheet There are two types of atomization mechanisms In the first mechanism, a horizontal section of the liquid column is distorted into a bow shape, and there exists a cavity without drops behind the liquid column Small drops are produced at both tips of the bow. The continuous length and the width of the liquid column were measured from the tomograms. In the second mechanism, in which velocities of both the airstream and the injecting liquid are low, the liquid column is distorted in a snakelike shape and drops are produced near the tip of the liquid column

A93-51638 Blue flame combustion in a jet-mixing-type spray combustor. HIROYUKI HIROYASU, MASATAKA ARAI, KAORU NAKAMORI, and SHINJI NAKASO, Aerothermodynamics in combustors, IUTAM Symposium. National Taiwan Univ., Taipei, June 3–5, 1991, Selected Papers (A93-51626 22-25). Berlin and New York, Springer-Verlag, 1992, pp 185–196. 9 Refs

A new combustion system called a jet-mixing-type combustor was designed to obtain a blue flame from a kerosene spray A spray was injected by a conventional-type swirl atomizer into the combustor and combustion air was introduced through a baffle plate with 16 inlet holes The basic mechanism of this combustion method was revealed as a rapid mixing of the air and the spray, which was achieved by a high-speed air jet Combustion characteristics including combustion stability, temperature distribution and exhaust emissions were compared with a conventional swirl-type combustor. NO and THC emission levels exhausted from this blue flame combustor were lower than those exhausted from the swirl-type combustor

A93-23365 Effect of the coherent vortex on combustion in a jet diffusion flame. S NODA, *31st AIAA, Aerospace Sciences Meeting and Exhibit,* Reno, NV, Jan. 11–14, 1993 9 pp. 13 Refs. (AIAA Paper 93-0457).

This paper is concerned with a role of coherent vortices in a jet diffusion flame The combination of the Mach-Zehnder and the schlieren methods was employed to make clear an effect of the coherent vortices on combustion A simultaneous measurement of temperature and OH emission intensity was also applied. These experiments have revealed that an effect of small roll-up vortices inside the flame (center vortices) is restricted just near the flame base and an effect of large toroidal vortices outside the flame (boundary vortices) extends over a wider region through mixing with the surrounding air. However, the comparison between the flames on a nozzle and a pipe burner has shown that the center vortices work for the stabilization of both the attached and lifted flames

A93-50524 A study of a direct-injection stratified-charge rotary engine for motor vehicle application. RYOJI KAGAWA, SYUNKI OKAZAKI, NOBUHIRO SOMYO, and YUJI AKAGI, SAE, International Congress and Exposition, Detroit, MI, Mar. 1–5, 1993. (ISSN 0148-7191), 11 pp. 6 Refs (SAE Paper 930677).

A study of a direct-injection stratified-charge system (DISC), as applied to a rotary engine (RE) for motor vehicle usage, was undertaken. The goals of this study were improved fuel consumption and reduced exhaust emissions. These goals were thought feasible due to the high thermal efficiency associated with the DISC-RE. This was the first application of this technology to a motor vehicle engine Stable ignition and ideal stratification systems were developed by means of numerical calculations, air-fuel mixture measurements, and actual engine tests. The use of DISC resulted in significantly improved fuel consumption and reduced exhaust emissions The use of an exhaust gas recirculating system was studied and found to be beneficial in NOx reduction.

A93-45512 Shock wave/turbulent boundary layer interactions induced by gaseous secondary flows injected into supersonic flow through slot and circular nozzles. S. ASO, S. OKUYAMA, and Y. ANDO, Shock waves, Proceedings of the 18th International Symposium, Sendai, Japan, July 21–26, 1991. Vol. 1 (A93-45451 19-34) Berlin and New York, Springer-Verlag, 1992, pp. 705–710. 10 Refs.

The complex flowfields induced by a gaseous secondary flow injected into a supersonic flow have been studied experimentally. A gaseous nitrogen jet is injected normally into the external flow through slotted and circular nozzles mounted on a flat plate model. Experiments are conducted under the following conditions: the free stream Mach number of 3 8, total pressure of 1.2 MPa, the Reynolds number of 2.0 x 10 exp 7 In the flowfields, the widths of the slotted nozzles and the pressure ratio Pc/P0 (Pc: total pressure of secondary flow, P0· total pressure of free stream) are used as primary parameters. In the interacting flow, barrel shock waves and Mach disk are observed clearly As the total pressure ratio or the thickness of the nozzle is increased, the separation region, the extent of the interaction region, the extent of the interaction region and of their shock structures become significantly large.

A93-44348 Numerical simulation of pulsed jet plume combustion. MANABU HISHIDA, and A. K. HAYASHI, 13th Dynamics of heterogeneous combustion and reacting systems, International Colloquium on Dynamics of Explosions and Reactive Systems, Nagoya, Japan, July 28–Aug. 2, 1991, Technical Papers (A93-44339 18-25). Washington, American Institute of Aeronautics and Astronautics, Inc , 1993, pp 343–361. 8 Refs.

Pulsed jet plume combustion is numerically simulated using time-dependent, axisymmetric, full Navier-Stokes equations in conjunction with the mass, energy, and species conservation equations for a hydrogen-air mixture. Numerical results are obtained for temperatures of 1000 and 1500 C. It is found that, at lower temperatures, the reaction occurs in the center region of the ringed hydrogen cloud, but does not affect the flowfield because of the long induction period due to the low reaction rate. At higher temperatures, the reaction occurs at the interface between the hydrogen plume and the surrounding air due to high reaction rates.

A93-34779 Turbulent magnetohydrodynamic dynamo for accretion disks using the cross- helicity effect. AKIRA YOSHIZAWA, and NOBUMITSU YOKOI, *Astrophysical Journal, Part 1* (ISSN 0004-637X), Vol. 407, No 2, April 20, 1993, pp. 540–548 22 Refs.

Accretion disks are studied using the concept of the turbulent magnetohydrodynamic (MHD) dynamo. Under this concept, the effect of cross helicity (magnetic-field/velocity correlation function) plays a key role as does the effect of turbulent viscosity and anomalous resistivity In the presence of the cross helicity, the rotational motion of the disk can generate the toroidal magnetic field. The magnetic field produces the thrust for launching the jet which, in turn, induces the poloidal magnetic field under the cross-helicity effect The close relationship between the magnetic field and the plasma velocity is a primary feature of the cross-helicity dynamo

A92-54092 Mach 3 wind tunnel test of mixed compression supersonic inlet. AKIRA MURAKAMI, RYOJI YANAGI, SHIGEMI SHINDO, KIMIO SAKATA, SHINJI HONAMI, ATSUSHIGE TANAKA, and KAZUO SHIRAISHI, *28th AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit,* Nashville, TN, July 6-8, 1992 7 pp. Research supported by Agency of Industrial Science and Technology and New Energy and Industrial Technology Development Organization. 7 Refs. (AIAA Paper 92-3625).

Two supersonic inlet models, designed in a 2D mixed compression configuration with a multishock system, were tested in a Mach 4 supersonic wind tunnel at the National Aerospace Laboratory in Japan. The first model was a fixed geometry with an 8-shock system, and the second one was a variable geometry with a 5-shock system and isentropic compression surfaces. The design Mach number for both models was 3 Pressure measurements and flow visualization, applying Schlieren method, oil-flow and vapor screen techniques, were conducted in the tests Pressure recovery performance, stability of the shock associated flows, and the basic feature of the internal flows were investigated Importance of establishing the shock systems and eliminating the shock-induced boundary layer separations were notified for the aerodynamic performance of the model from the test results A consideration for the passage design of subsonic diffusers was also discussed.