

A90-14590 Effect of the angle of attack on the efficiency and thrust ratio of axial-flow microturbines with full admission (Vliianie ugla ataki na ekonomichnost' i stepen' reaktivnosti osevykh mikroturbin s polnym vpuskom). N. T. TIKHONOV and E. E. PFAIFLE, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 3, 1989, pp. 104-106.

The effect of the angle of attack on the efficiency and thrust ratio of axial-flow microturbines was investigated experimentally for angles of attack varying from -16 to +13 deg using eight different rotors. It is shown that there exists an optimal range of angles of attack for each value of $Y_t = u/c_1s$. Thus, for $Y_t = 0.3$, this range is from -4 to +2 deg. An increase in the angle of attack by 2 deg (i.e., to +4 deg) leads to a 6.8-percent decrease in efficiency; a decrease by 2 deg from the optimal range (i.e., to -6 deg) leads to a 3.5-percent decrease in efficiency. As Y_t decreases, the effect of the angle of attack on efficiency becomes less pronounced and remains constant for $Y_t = 0.1$.

A90-14586 Effect of the radial clearance on the efficiency of a partial microturbine (Vliianie radial'nogo zazora na effektivnost' partial'noi mikroturbiny). B. A. KRYLOV and S. A. GUSAROV, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 3, 1989, pp. 96-98.

Results of an experimental study of the effect of the radial clearance on the efficiency of partial microturbines with a shroudless rotor are reported. With reference to results obtained for radial clearances of 0.1, 0.3, 0.5, and 1.0 mm and axial clearances of 0.1 and 1.0 mm, it is shown that the effect of the radial clearance on the turbine efficiency significantly increases with the decreasing partial admission ratio and increasing axial clearance. An analysis of the results obtained indicates that high-efficiency partial microturbines can be designed provided that the radial and axial clearances are sufficiently small.

A89-47993 Limiting the service period of gas turbine engine components on the basis of technical/economical efficiency (Ogranichenie narabotki uzlov GTD iz usloviia tekhniko-ekonomicheskoi effektivnosti ego ispol'zovaniia v ekspluatatsii). M. A. KABESHOV, M. E. SHAIKIN, and V. T. SHEPEL', *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 2, 1989, pp. 34-36.

A technical/economical approach is proposed for determining the optimal service period of gas turbine engine components before repairs. A criterion based on the cost effectiveness of engine operation is used which takes account of the profit resulting from engine operation and losses due to parametric failures. The approach proposed here is illustrated by a specific example.

A89-42422 Determination of the natural frequency spectra and modes of the fan blade rings of aviation gas turbine engines (K opredeleniiu spektrov sobstvennykh chastot i form kolebaniil ventilatornykh lopatochnykh ventsov aviatsionnykh GTD). V. V. MALYGIN, *Problemy Prochnosti* (ISSN 0556-171X), May 1989, pp. 92-95. 13 Refs.

An approach to the study of the natural frequency spectra of the fan rotors of bypass engines is proposed which is based on the use of both analytical and experimental data. The advantages of the approach, which allows the identification of all frequencies and modes of blade rings, are demonstrated. A method for the identification of the natural modes of rotors, which has been tested on various designs of bypass engines, is presented.

A89-40596 Hydraulic resistance of the inlet channels of a rotor cooling system (Gidravlicheskie soprotivleniia vkhodnykh kanalov sistemy okhlazhdeniia rotora). E. P. DYBAN, B. D. BILEKA, and V. A. MEL'NIKOVA, *Promyshlennaia Teplotekhnika* (ISSN 0204-3602), Vol. 11, No. 2, 1989, pp. 3-7. 13 Refs.

The paper is concerned with the problem of calculating the hydraulic resistance coefficient for short ($L/d = 3-5$) cylindrical and plane channels under static conditions and in the case of rotation about an axis normal to the channel axis. Calculated values of the hydraulic resistance coefficients are presented for the inlet channels of the cooling system of a static and operating gas turbine. It is shown that the hydraulic resistance of the rotating cylindrical and plane channels is higher than that of the static channels by a factor of 1.5-2.3 and 5.6-7.5, respectively.

A90-14584 Determination of the effective areas of the mixing exhaust ducts of a bypass engine from autonomous test results (Opredeleniie effektivnykh ploshchadei kanalov zatrubinnogo ustroistva TRDD po rezul'tatam avtonomnykh ispytaniil). V. I. VASIL'EV, I. V. ZEMNUKHOV, S. I. KRASHENINNIKOV, M. D. MIRSKII, and A. D. PORTNOV, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 3, 1989, pp. 93, 94.

The effective cross-sectional areas of the mixing exhaust ducts of a bypass engine are determined experimentally as a function of the exhaust configuration using small-scale (Re 10 to the 6th) and large-scale (Re 10 to the 7th) models. Dependences of the effective cross-sectional area on the exhaust geometry are obtained for lobe-type mixing exhausts. It is noted that the efficiency of bypass engine control with allowance for actual changes in the effective cross-sectional area is 20-30 lower than in the case of control based on changes in the geometrical area, which should be taken into account in the analysis of engine performance.

A90-14578 Effect of the roughness of deposits in a compressor cascade on the flow lag angle (Vliianie sherokhovatosti otlozhenii v kompressornoi reshetke na ugol otstavaniia potoka). I. U. N. MAL'TSEV and V. G. SHAKHOV, *Aviatsionnaia Tekhnika* (ISSN 0579-2975), No. 3, 1989, pp. 80-82.

The mechanism by which the surface roughness of deposits in compressor cascades affects the flow lag angle is examined with reference to the results of wind tunnel tests on plane compressor cascades with variable artificially created deposits. The flow rate and blading parameters were selected as close as possible to those of real compressors. It is found that, for a fixed angle of attack, the flow lag angle increases with the deposit roughness. The lag angle also increases with the increasing density of the cascade.

A89-37421 Dynamical calculations of engine components based on elasticity equations (O postroenii dinamicheskikh raschetov detalei dvigatelei na osnove uravnenii teorii uprugosti). N. D. KUZNETSOV, L. I. FRIDMAN, A. I. ERMAKOV, and V. N. UKHOV, *Problemy Prochnosti* (ISSN 0556-171X), March 1989, pp. 3-8. 109 Refs.

An elasticity approach to the vibration analysis of gas turbine engine components of complex configurations is proposed which makes it possible to determine the natural frequencies and modes of structures with a higher accuracy than that obtainable with methods based on kinematic hypotheses. The method consists of the approximation of geometrically complex components by canonic bodies, conjugation of these bodies, and derivation of a frequency equation for the whole system.

A89-30182 Improvement of the complex nondestructive testing of calorized turbine blades (Ratsionalizatsiia kompleksnogo nerazrushaiushchego kontroliia alitiruemykh lopatok turbin). I. U. A. GLAZKOV, *Defektoskopiia* (ISSN 0130-3082), No. 1, 1989, pp. 47-50. 6 Refs.

A study is made of the effect of the fused-slurry calorizing of turbine blades during engine rebuilding on the results of capillary (luminescent or chromatic) and eddy current testing. These methods are found to be incapable of detecting cracks up to 15 mm long in the base metal of the blades. In order to ensure the detection of these cracks, testing prior to the calorizing treatment is essential.

A89-30086 High-viscosity and bitumenous oils - Promising raw materials for the production of jet and diesel fuels (Vysokoviazkie i bitumnye nefli - Perspektivnoe syr'e dlia polucheniia reaktivnykh i dizel'nykh topliv). N. M. LIKHTEROVA, G. R. AVDZHIEV, A. F. GORENKOV, *Khimiia i Tekhnologiiia Topliv i Masel* (ISSN 0023-1169), No. 1, 1989, pp. 7-9. 7 Refs.

High-viscosity oils and natural bitumens containing more than 25 percent of resinous-asphaltene components and having a density of greater than 935 kg/cu m are investigated as possible raw materials for the production of aviation jet fuels. In particular, the composition and properties of bitumens from various deposits are briefly reviewed, and a scheme for the processing of bitumenous sandstone is presented. Jet fuels produced from bitumens are characterized with reference to their physicochemical properties.

Japanese Aerospace Literature This month: Aircraft Engines/Propulsion

A90-40633 Development of the jet-swirl high loading combustor. Y. YONEZAWA, H. TOH, S. GOTO, and M. OBATA, 26th AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, Orlando, FL, July 16-18, 1990. 8 p. (AIAA Paper 90-2451).

With the view to accelerating the mixture between fuel and air and the combustion of the resulting mixture, a new concept of high combustion loading 'jet-swirl' combustor was derived from qualitative and quantitative analysis of the pattern of flow through the combustion liner. A prototype model combustor designed to embody the features of the jet-swirl concept, was tested to verify its combustion performance. This test on the jet-swirl combustor confirms the superior combustion characteristics at high combustion loading that can be expected from this new concept of combustor.

A90-35951 Development of ceramic components for high-temperature gas turbines. Y. HAMANO, T. MAEDA, M. CHIKARASHI, and M. MATSUNAKA, *Proceedings of the 1st MRS International Meeting on Advanced Materials*, Tokyo, Japan, May 31-June 3, 1988, Vol. 5 (A90-35926 15-27). Pittsburgh, PA, Materials Research Society, 1989, pp. 229-239.

The activities of a Japanese company in the U.S. Advanced Gas Turbine Project is reviewed. Improvement of the fracture strength, stress rupture characteristics, and oxidation resistance of silicon nitride are discussed. The development of materials, process control technology, turbine rotors, and static components is examined and results from engine and rig tests are reviewed.

A91-31401 Application of numerical analysis to jet engine combustor design. HIDEKI TOH, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 30, Nov. 1990, pp. 450-455, 6 Refs.

Numerical methods are applied in practice to complement and support jet engine combustor design and development; part of the conventional 'design-trial fabrication-testing performance evaluation' cycle is replaced by iterated numerical analysis applied in a preliminary cycle of 'design-evaluation', undertaken before proceeding to actual trial fabrication testing, and final evaluation. Examples are presented of numerical methods applied to the design/development of a high temperature combustor of airblast fuel injector type, in which analysis is undertaken of flows through diffuser and through combustion liner, of temperature distributions, of flows through liner cooling slots, and of liner skin temperature distributions. In addition, results of three-dimensional flow analysis are applied to optimizing the design parameters of a jet-swirl combustor, and to calculation of the centrifugal force in a jet-swirl combustion liner.

A91-23646 Determination of cycle configuration of gas turbines and aircraft engines by an optimization procedure. Y. TSUJIKAWA and M. NAGAOKA, (ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN0022-0825), Vol. 113, Jan. 1991, pp. 100-105, 8 Refs. (ASME Paper 90-GT-115).

This paper is devoted to the analyses and optimization of simple and sophisticated cycles, particularly for various gas turbine engines and aero-engines (including the scramjet engine) to achieve maximum performance. The optimization of such criteria as thermal efficiency, specific output, and total performance for gas turbine engines, and overall efficiency, nondimensional thrust, and specific impulse for aero-engines has been performed by the optimization procedure with the multiplier method. Comparison of results with analytical solutions establishes the validity of the optimization procedure.

A90-33594 Dynamics of multi-spool gas turbines using the matrix transfer method - Applications. Y. KAZAO and E. J. GUNTER, *International Journal of Turbo and Jet-Engines* (ISSN 0334-0082), Vol. 6, No. 2, 1989, pp. 143-152.

Application of the modified matrix transfer method in which multispan rotors with multiple branches can be computed accurately and rapidly on a microcomputer is presented. The procedure is used for the dynamic analysis of turbomotors with flexible supports and flexible offset impellers and fans, turbine-generators on flexible foundations, and multispool gas turbines with flexible casings. Several rotor dynamic case studies, using simple models of a rotor coupled with a casing or foundation, are also presented. A dynamic analysis of a gas turbine with dual-span rotors (a low pressure rotor and a high pressure rotor) with flexible disks and a flexible casing is discussed. It is shown that the gas turbine system critical speeds cannot be computed using single span theory and that the interaction of flexible casing or foundation with the rotor may cause multiple or bifurcated critical speeds to occur within the operating speed range.

A90-32421 Multivariable control of jet engines. MASAHIRO KUROSAKI and SHIGEKI MURAYAMA, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 29, Nov. 1989, pp. 405-410, 6 Refs.

In order to meet higher performance requirements, aeroengines have been making increasing use of variable geometry which necessitates well coordinated multiinput controls (Multivariable Control). Any sophisticated control laws and logic can be easily implemented into Digital Electron Controls which have been recently introduced to the field of aeroengines. LQI (Linear Quadratic Integral control), output feedback, and PID controllers have been designed to investigate the Multivariable Control of Reheat Turbofan Engines. LQI controllers have shown the best performance by a comparison of the linear quadratic performance indices. Engines are at intermediate power at sea level static conditions, and the control modes, fan speed and turbine exit temperature control, and fan speed and engine exit pressure control are taken into account. Here the robust stability of LQI controllers of two control modes are studied by drawing sigma-plots, and an example of step response is also shown.

A90-12571 Cooling characteristics of a radial wafer blade. TAKAO KUMAGAI, TOYOAKI YOSHIDA, and MASAKATSU MATSUKI, *Proceedings of the 9th International Symposium on Air Breathing Engines*, Athens, Greece, Sept. 3-8, 1989, Vol. 2 (A90-12501 02-07). Washington, DC, American Institute of Aeronautics and Astronautics, 1989, pp. 680-686. Sponsorship: Research supported by the Agency of Industrial Science and Technology. 12 Refs.

A full coverage film cooled rotor blade model was developed as an advanced type for gas turbine blades. The model was made with laminated stainless wafers. Chemical etching and diffusion bonding were applied for its fabrication. The subsequent main objective was to attain high cooling effectiveness with a single passing of coolant through a stepwise cooling passage. Experimental works are composed of a water discharge test, an airflow discharge test and a high temperature cascade test. Cooling effectiveness obtained in the present study was compared with those from various air-cooled turbine vanes/blades developed in the Advanced Gas Turbine Japan national project. The blade model was successfully made in the fourth stage of trial fabrication. As a representative result, mean cooling efficiency is slightly above 0.5 with a coolant mass flow rate of 3 percent.

A91-14451 Conceptual study of space plane powered by hypersonic airbreathing propulsion system. MASATAKA MAITA, YOSHIKI OHKAMI, TATSUO YAMANAKA, and TAKASHIGE MORI, 2nd AIAA International Aerospace Planes Conference, Orlando, FL, Oct. 29-31, 1990. 10 pp. 6 Refs. (AIAA Paper 90-5225).

The paper describes the investigations of aerospace plane concept, conducted by the National Aerospace Laboratory (NAL) of Japan, with particular attention given to a concept which integrates a scram/liquid air cycle engine (LACE) hypersonic propulsion system fueling with slush hydrogen. The key requirements in achieving the space plane using scram/LACE propulsion system are described along with the mission requirements and the vehicle characteristics. Typical outputs of SSTD analysis are presented.

A91-12233 Configuration control and airworthiness management. YOSHIYUKI FUJITSUNA and KENTARO TAKE, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 30, July 1990, pp. 296-299.

Based upon V2500-A1 engine development and production experiences, the concept and policy of civil engine configuration control and airworthiness management are described together with actual process and procedure. First of all, in order to help reader's understanding, general program of civil engine development activities is explained. Then, as for development engine configuration control, the essence of the VIZ type design definition is described. On the other hand, production engine configuration control is characterized by 3-staged engineering change management system in addition to substantiation process-similarity, analysis or test. As for airworthiness management, the legal background is shown and what was done practically in V2500 certification tests is reported. Finally, future target of configuration control and airworthiness management are noted.

A90-38597 Expert diagnosis system for FJR engine troubles. KUNIASU YAMANAKA, HIDEO KOBAYASHI, TOSHIKI MORIMOTO, and HIROSHI FUJIYAMA, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 30, March 1990, pp. 100-105.

The expert diagnosis system has been developed for the FJR710/600S engine installed for the quiet STOL research aircraft 'ASUKA'. This expert system has been designed with conventional expert program on the small-sized personal computer, not only from the economical point of view but also from the viewpoint of operational convenience. The main objects of this system are to compile and integrate the knowledge of engine trouble-shooting and to verify the ability of diagnosis by small-scale expert system. This present paper describes the outline and the estimation of the system.

A90-38596 An application of expert system to jet engine diagnostic procedures. HIROSHI ISHIZAWA, KOJIRO UMENE, and TOSHIHARU WAGURI, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 30, March 1990, pp. 95-99.

Functional and performance checks (including engine control trims) are required for jet engine test runs followed by engine production or overhaul in order to verify acceptability of the engines. Diagnostic procedure resulting from engine trouble during test runs has been brought forth by experts who have many years of experience and differing backgrounds of specialized knowledge. Diagnostic procedure is the result of proper judgements based on experience and knowledge using quite a lot of data and a rapid treatment. This paper deals with an application of expert system for jet engine diagnostic procedure including knowledge acquisition, knowledge base construction, inference mechanism, applications and so forth.

A90-33595 Dynamics of multi-spool gas turbines using the matrix transfer method - Theory. Y. KAZAO and E. J. GUNTER, *International Journal of Turbo and Jet-Engines* (ISSN 0334-0082), Vol. 6, No. 2, 1989, pp. 153-161, 14 Refs.

A theoretical procedure for the dynamic analysis of multi-spool turbomotors with flexible supports and flexible branches using a modified transfer method in which multi-span rotors with multiple branches may be computed accurately and rapidly on a small engineering workstation is presented. A scaling procedure is introduced into the transfer matrices by appropriate transformations of slope, moment, and shear coefficients. The numerical difficulties caused by branches are described using a simple model and methodology to eliminate this problem is developed. A computer algorithm used to calculate undamped critical speeds of multi-span rotors with multiple branches is studied.

A90-27678 Reliability evaluation system for ceramic gas turbine components. SEIICHI HAMADA and TETSUO TERAMAE, *Japan Society of Materials Science Journal* (ISSN 0514-5163), Vol. 39, Jan. 1990, pp. 76-81, 10 Refs.

The reliability evaluation system for ceramic gas turbine components was developed. This system, termed 'GFICES', is based on the statistical strength theory using two-parameter Weibull distribution. Main functions of this system are fast fracture analysis, static fatigue analysis, dynamic fatigue analysis, and the evaluation of the effect of proof testing. In addition, several other functions such as application of bimodal Weibull theory and consideration of aging degradation of ceramic components are available. When applied to the first-stage ceramic bucket, this system has been found to be effective for the strength evaluation of ceramic structural components.

A90-12016 Mechanical rig test of FJR 710/600 engine components. HIRAO AONO, TOSHIHIRO KAWASHIMA, TETSUO CHIKATA, TATSUZO TOYODA, YASUYUKI TANAKA, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 29, March 1989, pp. 94-98.

In order to obtain type certificates of the FJR 710/600 engine, mechanical rig tests using actual engine parts were conducted in accordance with the Japan Civil Aviation Bureau (JCAB) Airworthiness Requirements. This paper presents an outline of the JCAB Airworthiness Requirements for engine structural integrity and the various mechanical rig tests which were performed by IHI. The tests are: (1) an engine casing/mount strength test to show sufficient strength capable of withstanding the flight and ground loads for an airplane, (2) overspeed test and cycle spin tests of disks to demonstrate compliance with the strength requirement, (3) bird and ice hail strike tests to evaluate fan blade strength against foreign object impact damage which causes blade failure, (4) a containment test to confirm the design propriety of the casing which contains any debris originated from blade failure, and (5) blade tests to obtain vibration characteristics and fatigue strength.

A90-25809 Computational and experimental analysis of transonic fanjet engine flow field using 3-D Euler code. NAOKI HIROSE, KEISUKE ASAI, KATUYA IKAWA, and RYUMA KAWAMURA, Technical Papers of the 3rd ISCFD Nagoya 1989 - International Symposium on Computational Fluid Dynamics, Nagoya, Japan, Aug. 28-31, 1989, (A90-25720 10-34). Nagoya, Japan, Japan Society of Computational Fluid Dynamics, 1989, pp. 635-640. 8 Refs.

A three-dimensional Euler code for fan-jet engine and Turbine Powered Simulator (TPS) wind tunnel testing were developed utilizing MacCormack's FVM scheme to confirm the validity of TPS testing method. The results were compared with the wind tunnel experimental data for an axisymmetric TPS configuration. The effects of difference between the real engine and TPS were analyzed. Three-dimensional flow analysis shows the angle of attack effects in inlet flow field and jet exhaust plume.

A90-27679 Fatigue life prediction method for gas turbine rotor disk alloy FV535. TAKESHI HORIKAWA, TOMONOBU OKADA, and TOSHIYASU TSUNENARI, *Japan Society of Materials Science, Journal* (ISSN 0514-5163), Vol. 39, Jan. 1990, pp. 82-88. 12 Refs.

The adaptability of the fatigue strength evaluation method proposed earlier by the authors for the fatigue life prediction of the piston crown of a diesel engine was applied to evaluate fatigue life of a rotor disk made of martensite stainless steel FV535. Results indicate that the fatigue crack initiation life of a notched specimen under constant stress amplitude can be well predicted using Koe's or Neuber's methods. The fatigue life prediction method proposed by the authors was found to predict well the fatigue life of a smooth specimen in the region of higher stress than the fatigue limit, by using the interaction coefficient C of 0.3. However, in the region of stress near the fatigue limit, the method predicted very conservative life, and the coefficient C was more than 5.

A90-25826 Computational simulation of arcjet thruster flow fields. KEN-ICHI TANAKA, KAZUO TSUCHIYA, KEIJI KAITA, and MICHIO NISHIDA, Technical Papers of the 3rd ISCFD Nagoya 1989 - International Symposium on Computational Fluid Dynamics, Nagoya, Japan, Aug. 28-31, 1989, (A90-25720 10-34). Nagoya, Japan, Japan Society of Computational Fluid Dynamics, 1989, pp. 773-778. 9 Refs.

The effect of nozzle geometry on the operation of the experimental dc-arcjet thruster described by Nishida et al. (1987) and Tanaka et al. (1988) is investigated by means of numerical simulations. The derivation of the governing equations and the construction of the model are outlined, and results are presented in graphs for thrusters with conical and bell-shaped nozzles and operating at mass flow rate 0.11 g/sec (with Ar as the propellant gas). The bell-shaped nozzle is shown to give superior performance because the axial velocity component observed at the outlet of the conical nozzle is eliminated. The thrust and specific impulse of the thruster are calculated as 0.42 N and 390 sec, respectively.

A90-12011 The features of FJR 710 engine. HIROKAZUMIYATAKE, HIDEO KOBAYASHI, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 29, March 1989, pp. 65-69. 10 Refs.

The flight test of the quiet STOL research aircraft ASUKA has been carried out by the National Aerospace Laboratory. The aircraft is powered by four FJR710/600S turbofan engines installed as an upper surface-blowing propulsive lift system. The FJR710/600S high bypass ratio turbofan engine, which is designed to have 4800 kgf thrust, is the latest, slightly modified version of the FJR710/600 prototype engine developed under the National Research and Development Program of the Ministry of International Trade and Industry from 1971 to 1982. The outline of the engine development program and various engine tests, such as operation under different environments, foreign object strike tests, performance and functional tests on a flying test bed, are described.

A90-23818 Current status of ceramic gas turbine R&D in Japan. KIICHIRO YAMAGISHI, YUKIO YAMADA, YOSHIHIRO ECHIZENYA, SHOJI ISHIWATA, ASME, Gas Turbine and Aeroengine Congress and Exposition, Toronto, Canada, June 4-8, 1989. 7 p. 1989. (ASME Paper 89-GT-114).

In 1988, Japan's Ministry of International Trade and Industry instituted two R&D projects for small-capacity (300 kW) ceramic-component gas turbines aimed at mobile power generation and cogeneration applications. Performance goals encompassed 42-percent higher thermal efficiency than current technology levels and turbine inlet temperatures of the order of 1350 C, in addition to reduced exhaust gas pollutant emissions. The development of a 100-kW automotive gas turbine making substantial use of ceramic components was also undertaken. A minimum ceramic component flexure strength of 400 MPa at 1500 C is required for the achievement of these performance goals.

A90-12529 Hydrogen fueled subsonic-ram-combustor model tests for an air-turbo-ram engine. T. TAMARU, K. SHIMODAIRA, T. SAITO, H. YAMADA, and S. HORIUCHI, *Proceedings of the 9th International Symposium on Air Breathing Engines*, Athens, Greece, Sept. 3-8, Vol. 1 (A90-12501 02-07). Washington, DC, American Institute of Aeronautics and Astronautics, 1989, pp. 282-290. 5 Refs.

This paper deals with a basic study to facilitate the design for the hydrogen fueled subsonic ram combustor. Three types of the flame holder scaled 1/10 of an estimated actual size were investigated to evaluate the performance for the severe inlet conditions of the hypersonic flight. Unidimensional analysis with total pressure at the exit and the static pressure on the duct wall gave the gas temperature and the Mach number of the combustion gas. Analysis of sampled gas at the exit gave radial profiles of equivalence ratio, combustion efficiency and so on. These results indicate that fuel rich zone over stoichiometry must be avoided for the fuel preparation to attain the best combustion efficiencies near stoichiometric mixture condition which is required for the engine for hypersonic flight.

A89-46853 T-4 inlet/engine compatibility flight test results. TADAYUKI HAMADA, MASAHIRO AKAGI, DAISUKE TODA, HIROSHI SHIMAZAKI, and MITSU HARU OHMOMO, 25th AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, Monterey, CA, July 10-13, 1989. 8 p. 1989. (AIAA Paper 89-2466).

Results are presented on the flight tests conducted to evaluate the engine/inlet compatibility for the F3-30 engine developed for the T-4 intermediate trainer. The test program included all the critical maneuvering conditions (including spin flight) involved in the T-4 training missions. Measurements of the pressure distortion level and the pressure recovery factor were performed by an inlet rake which had 30 pressure probes (six-leg five-ring configuration) installed at the engine face. The results of T-4/F3-30 flight tests showed no engine stalls or flame-outs beyond the design goal envelopes; the engine operation was satisfactory to 60-deg of the angle-of-attack and 40-deg sideslip at idle rating.

A90-23865 An experimental study of heat transfer and film cooling on low aspect ratio turbine nozzles. K. TAKEISHI, M. MATSUURA, S. AOKI, and T. SATO, ASME, Gas Turbine and Aeroengine Congress and Exposition, Toronto, Canada, June 4-8, 1989. 9 p. 1989 20 Refs. (ASME Paper 89-GT-187).

The effects of the three-dimensional flow field on the heat transfer and the film cooling on the endwall, suction and pressure surface of an airfoil were studied using a low speed, fully annular, low aspect $h/c = 0.5$ vane cascade. The predominant effects that the horseshoe vortex, secondary flow, and nozzle wake increases in the heat transfer and decreases in the film cooling on the suction vane surface and the endwall were clearly demonstrated. In addition, it was demonstrated that secondary flow has little effect on the pressure surface. Pertinent flow visualization of the flow passage was also carried out for better understanding of these complex phenomena. Heat transfer and film cooling on the fully annular vane passage surface is discussed.

A89-42063 3D-Euler flow analysis of fanjet engine and turbine powered simulator with experimental comparison in transonic speed. NAOKI HIROSE, KEISUKE ASAI, RYUMA KAWAMURA, and KATUYA IKAWA, 20th AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, Buffalo, NY, June 12-14, 1989. 10 pp. 29 Refs. (AIAA Paper 89-1835).

A transonic three-dimensional flow analysis code for the wind tunnel testing of a fan-jet engine and a turbine powered simulator has been developed which uses MacCormack's (1969) scheme in the finite volume form. The pressure distributions on the inlet cowl and core-jet cowl surface obtained by the code agree well with experimental observations. The results reveal the angle-of-attack effects on the inlet flow field and exhaust-jet plume, and have identified a pair of longitudinal vortices in the shear layer between the jet and the external flows.