NASA SP-7037(234)

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 234)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in December 1988 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

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INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 539 reports, journal articles and other documents originally announced in December 1988 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cummulative index will be published.

Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

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Category 11	**Chemistry and Materials** Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; propellants and fuels; and materials processing.	837

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Includes engineering (general); communications and radar; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

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Category 14 Life Sciences N.A.
Includes life sciences (general); aerospace medicine; behavioral sciences; man/system technology and life support; and space biology.

Category 15 Mathematical and Computer Sciences 857
Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

Category 16 Physics 861
Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

Category 17 Social Sciences 862
Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law, political science, and space policy; and urban technology and transportation.

Category 18 Space Sciences N.A.
Includes space sciences (general); astronomy; astrophysics; lunar and planetary exploration; solar physics; and space radiation.

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TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED

ON MICROFICHE

ACCESSION NUMBER → **N88-10026*#** National Aeronautics and Space Administration. ← CORPORATE SOURCE
Ames Research Center, Moffett Field, Calif.

TITLE → **HIMAT FLIGHT PROGRAM: TEST RESULTS AND PROGRAM ASSESSMENT OVERVIEW**

AUTHORS → DWAIN A. DEETS, V. MICHAEL DEANGELIS, and DAVID P. LUX

PUBLICATION DATE → Jun. 1986 30 p ← AVAILABILITY SOURCE

REPORT NUMBERS → (NASA-TM-86725; H-1283; NAS 1.15:86725) Avail: NTIS HC

PRICE CODE → A03/MF A01 CSCL 01C ← COSATI CODE

The Highly Manueverable Aircraft Technology (HiMAT) program consisted of design, fabrication of two subscale remotely piloted research vehicles (RPRVs), and flight test. This technical memorandum describes the vehicles and test approach. An overview of the flight test results and comparisons with the design predictions are presented. These comparisons are made on a single-discipline basis, so that aerodynamics, structures, flight controls, and propulsion controls are examined one by one. The interactions between the disciplines are then examined, with the conclusions that the integration of the various technologies contributed to total vehicle performance gains. An assessment is made of the subscale RPRV approach from the standpoint of research data quality and quantity, unmanned effects as compared with manned vehicles, complexity, and cost. It is concluded that the RPRV technique, as adopted in this program, resulted in a more complex and costly vehicle than expected but is reasonable when compared with alternate ways of obtaining comparable results. Author

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

ON MICROFICHE

ACCESSION NUMBER → **A88-10095#**

TITLE → **SYNTHESES OF REDUCED-ORDER CONTROLLERS FOR ACTIVE FLUTTER SUPPRESSION**

AUTHORS → ATSUSHI FUJIMORI and HIROBUMI OHTA Japan Society for ← JOURNAL TITLE
Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 35, no. 402, 1987, p. 353-362. In Japanese, with abstract in English. refs

Reduced-order controllers for active flutter suppression of a two-dimensional airfoil are studied using two design approaches. One is based on the generalized Hessenberg representation (GHR) in the time domain, and the other, called the Nyquist frequency approximation (NFA), is a method in the frequency domain. In the NFA method, the reduced-order controllers are designed so that the stability margin of the Nyquist plot may be increased over a specific frequency range. To illustrate and to make a comparison between the two methods, numerical simulations are carried out using a thirteenth-order controlled plant. It is to be noted that the GHR method can yield quasi-optimal controllers in the sense of minimizing quadratic performance indices. The designed controllers, however, do not have enough stability margin, and the order reduction resulting from full state controllers may not be satisfactory. On the other hand, reduced-order controllers in the NFA method can be designed with increased stability margin at the expense of the performance index. For all simulation cases, the NFA method yields second-order controllers with a better stability margin than those by the GHR method. Thus, the NFA method provides an effective method for synthesizing robust reduced-order controllers. Author

AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 234)

JANUARY 1989

01

AERONAUTICS (GENERAL)

A88-53757#
YA-7F - A TWENTY YEAR ECONOMIC LIFE EXTENSION AT COSTS WE CAN AFFORD
A. R. RUDNICKI, JR. and J. W. MAYNOR, JR. (LTV Aerospace and Defense Co., Aircraft Modernization and Support Div., Dallas, TX) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 10 p.
(AIAA PAPER 88-4460)

The USAF requirement for an interim close air support/battlefield air interdiction aircraft that will be survivable in medium/high-threat arenas of the late 1990s, using largely off-the-shelf technologies, is presently answered through a variant of the A-7D Corsair II attack aircraft. The upgrading of the A-7D proposed encompasses the addition of an afterburning engine, aerodynamic refinements, and state-of-the-art avionics. The two YA-7F prototypes planned will be equipped with F100-PW-220 afterburning turbofans, but the engine bay will be configured to accept either this or the alternative F110 engine, which possesses similar characteristics. O.C.

A88-53760*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
SOME KEY CONSIDERATIONS FOR HIGH-SPEED CIVIL TRANSPORTS
CHARLES E. K. MORRIS, JR., MATTHEW M. WINSTON, and SHELBY J. MORRIS, JR. (NASA, Langley Research Center, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 8 p. refs
(AIAA PAPER 88-4466)

Factors affecting the development of a new generation of high-speed (supersonic/hypersonic) transports are reviewed. Market projections of growth on long-range routes indicate a potential need for faster transport aircraft by the turn of the century. A review of NASA-sponsored studies shows how both market forces and technology combine to define mission performance and vehicle design constraints. The vehicle worth and price projected for a given vehicle are shown to relate to an assumed technology level. Preliminary results from an initial set of vehicle concepts lead to the conclusion that currently projected technology will need to be enhanced with increased research to meet the first market window around the year 2000. Author

A88-53761*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
TECHNOLOGY SENSITIVITY STUDIES FOR A MACH 3.0 CIVIL TRANSPORT
PETER G. COEN (NASA, Langley Research Center, Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 9 p. refs
(AIAA PAPER 88-4469)

The level of technological sophistication required for the economic viability and environmental acceptability of a Mach 3.0-cruise SST is evaluated, with a view to the development schedule and initial operating date into which the maturity of various essential technologies will translate. Attention is given to the effect of advanced aerodynamic, propulsion, structural and subsystem technologies on takeoff gross weight. A dramatic impact is noted to result from the combination of prospective technological advances in flow laminarization, advanced structures and materials, etc. O.C.

A88-53771#
SOVIET APPLICATIONS FOR HYPERSONIC VEHICLES
REUBEN F. JOHNSON (General Dynamics Corp., Fort Worth, TX) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 20 p. refs
(AIAA PAPER 88-4507)

An assessment is made of the prospective uses of a Soviet hypersonic transport (HST) aircraft, in both the near and longer term. It is suggested that the primary purpose of an HST might be to serve as a large sensor platform for naval reconnaissance that would be capable of supplementing satellite coverage in areas of momentarily exceptional interest with great flexibility and celerity. A secondary but more consequential application may be to take the form of a beam-weapons platform for the conduct of antisatellite warfare. It is postulated that initial vehicle designs will be quite rudimentary, and will be only gradually improved, in contrast to Western concern with initial production of a highly refined aircraft. O.C.

A88-53782
PREDICTING, DETERMINING, AND CONTROLLING MANUFACTURING VARIATION IN A NEW FACILITY
MARK EULERT and LUIS LUCERO (McDonnell Douglas Helicopter Co., Mesa, AZ) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 12 p.
(SAWE PAPER 1771)

The process of determining and estimating manufacturing variation for an aircraft is discussed. The problem of measuring variations and determining what part of the variation is attributable to design changes and not to manufacturing variation is examined. Tracking changes and determining the actual weight of detail parts are considered. Results from efforts to measuring manufacturing variation are presented. R.B.

A88-53800* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
AERODYNAMICS
RANDOLPH A. GRAVES, JR. (NASA, Ames Research Center, Moffett Field, CA) Exxon Air World, vol. 40, no. 2, 1988, p. 6-8.

A projection is made of likely improvements in the economics of commercial aircraft operation due to developments in aerodynamics in the next half-century. Notable among these improvements are active laminar flow control techniques' application to third-generation SSTs, in order to achieve an L/D value of about 20; this is comparable to current subsonic transports, and has the further consequence of reducing cabin noise. Wave-cancellation systems may also be used to eliminate sonic boom overpressures, and rapid-combustion systems may be able to eliminate all pollutants from jet exhausts other than CO_2. O.C.

ORIGINAL PAGE IS OF POOR QUALITY

A88-54246#
SECOND SOURCING OF A JET ENGINE
JIMMY HIX (United Technologies Corp., Pratt and Whitney, West Palm Beach, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p.
(ASME PAPER 88-GT-145)

This paper describes in detail the process of developing a 'build to print' alternate manufacturing source, which does not have access to the original design agent, for the engine of the U.S. Navy's newest jet fighter. The data used in the second sourcing process and the validation of the data are examined, and the engineering methods used in data transfer, training, and source qualification are discussed. Manufacturing source substantiation and the roles of various U.S. government agencies are addressed. The benefits accrued from second sourcing and the remaining long-term questions are considered. The trials, lessons, and triumphs associated with second sourcing are reviewed. C.D.

A88-55000
DAEDALUS - THE MAKING OF THE LEGEND
JOHN S. LANGFORD (Institute for Defense Analyses, Alexandria, VA) Technology Review (ISSN 0040-1692), vol. 91, Oct. 1988, p. 24-35.

The Daedalus flight, which was the longest human-powered flight recorded, is discussed. The process of designing the plane, the way in which the plane was transported to Greece (where the flight took place), and the conditions of the flight are examined. The flight covered 72 miles in 2 hours and 48 minutes in April, 1988. The practical applications of the technology developed for Daedalus to future aircraft, such as the construction of solar-powered aircraft are considered. R.B.

A88-55041
COST BENEFITS OF NONDESTRUCTIVE TESTING IN AIRCRAFT MAINTENANCE
DONALD J. HAGEMAIER (Douglas Aircraft Co., Long Beach, CA) Materials Evaluation (ISSN 0025-5327), vol. 46, Sept. 1988, p. 1272, 1274, 1275 (7 ff.). refs

Some specific benefits and cost savings resulting from the effective impementation of nondestructive inspection in conjunction with aircraft maintenance are identified. It is noted that specific costs associated with a given nondestructive test or inspection should be considered in relation to consequential upstream manufacturing costs associated with nondestructive evaluation (e.g., the reduced yield because of the parts that fail tests) and consequential downstream cost savings (e.g., decreased premature removal rate, reduced failure rate, and reduced liability costs). In most situations, these indirect costs are much larger than the direct costs associated with nondestructive testing. The need for developing the engineering and economic methodology to optimize tradeoffs between downstream cost savings and inspection and manufacturing costs is emphasized. V.L.

N88-28857# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
BOUNDARY LAYER SIMULATION AND CONTROL IN WIND TUNNELS
Apr. 1988 462 p
(AGARD-AR-224; ISBN-92-835-0457-7; AD-A198667) Avail: NTIS HC A20/MF A01

The results of a study performed by AGARD Working Group 09 on boundary layer simulation in wind tunnels are presented with emphasis on the transonic speed regime. This report is intended to display the current state-of-the-art in boundary layer simulation where Reynolds number is or cannot be simulated and give attention to wind tunnel effects as well as to document the physical aspects of boundary layer simulation and the research needed. Finally, a simulation methodology is proposed which can serve wind tunnel user and operator as an ordered thinking process for the design of wind tunnel tests where viscous effects are important.

N88-28879*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
EFFECTS OF INDEPENDENT VARIATION OF MACH AND REYNOLDS NUMBERS ON THE LOW-SPEED AERODYNAMIC CHARACTERISTICS OF THE NACA 0012 AIRFOIL SECTION
CHARLES L. LADSON Oct. 1988 97 p
(NASA-TM-4074; L-16472; NAS 1.15:4074) Avail: NTIS HC A05/MF A01 CSCL 01B

A comprehensive data base is given for the low speed aerodynamic characteristics of the NACA 0012 airfoil section. The Langley low-turbulence pressure tunnel is the facility used to obtain the data. Included in the report are the effects of Mach number and Reynolds number and transition fixing on the aerodynamic characteristics. Presented are also comparisons of some of the results with previously published data and with theoretical estimates. The Mach number varied from 0.05 to 0.36. The Reynolds number, based on model chord, varied from 3 x 10 to the 6th to 12 x 10 to the 6th power. Author

N88-28880*# United Technologies Research Center, East Hartford, Conn.
AN UNSTEADY HELICOPTER ROTOR: FUSELAGE INTERACTION ANALYSIS Final Report
PETER F. LORBER and T. ALAN EGOLF Washington NASA Sep. 1988 123 p
(Contract NAS1-17469)
(NASA-CR-4178; NAS 1.26:4178; R88-956977-15) Avail: NTIS HC A06/MF A01 CSCL 01B

A computational method was developed to treat unsteady aerodynamic interactions between a helicopter rotor, wake, and fuselage and between the main and tail rotors. An existing lifting line prescribed wake rotor analysis and a source panel fuselage analysis were coupled and modified to predict unsteady fuselage surface pressures and airloads. A prescribed displacement technique is used to position the rotor wake about the fuselage. Either a rigid blade or an aeroelastic blade analysis may be used to establish rotor operating conditions. Sensitivity studies were performed to determine the influence of the wake fuselage geometry on the computation. Results are presented that describe the induced velocities, pressures, and airloads on the fuselage and on the rotor. The ability to treat arbitrary geometries is demonstrated using a simulated helicopter fuselage. The computational results are compared with fuselage surface pressure measurements at several locations. No experimental data was available to validate the primary product of the analysis: the vibratory airloads on the entire fuselage. A main rotor-tail rotor interaction analysis is also described, along with some hover and forward flight. Author

N88-29717# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE FLIGHT OF FLEXIBLE AIRCRAFT IN TURBULENCE: STATE-OF-THE-ART IN THE DESCRIPTION AND MODELLING OF ATMOSPHERIC TURBULENCE
Jun. 1988 111 p Meeting held in Cesme, Turkey, 4-9 Oct. 1987
(AGARD-R-734-ADD; ISBN-92-835-0458-5) Avail: NTIS HC A06/MF A01

The large scale use of flight recorders by commercial airlines, coupled with the enhanced quality of results offered by modern computer based reduction processes makes it possible to broaden knowledge of the phenomenon of atmospheric turbulence. At the same time, new methods for predicting the response of flexible aircraft to turbulence are being proposed, and novel gust alleviation systems are being designed and tested. The presentations made at a workshop held for the discussion of these ideas are given.

N88-29725# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
THE FLIGHT OF FLEXIBLE AIRCRAFT IN TURBULENCE: STATE-OF-THE-ART IN THE DESCRIPTION AND MODELLING OF ATMOSPHERIC TURBULENCE
Dec. 1987 187 p Meeting held in Athens, Greece, 28 Sep. - 3 Oct. 1986
(AGARD-R-734; ISBN-92-835-0426-7) Avail: NTIS HC A09/MF A01

The flight of flexible aircraft in turbulence was studied. Presentations given at the first of two workshops on the subject are provided. Topics covered here are: (1) Measurements of turbulence by specially equipped aircraft, and (2) Data collection and reduction of incremental accelerations observed in commercial flights.

N88-29735# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.
ADVANCES IN FLYING QUALITIES
May 1988 194 p Lecture held in Delft, Netherlands, 26-27 May 1988, in Rome, Italy, 30-31 May 1988, and in Torrance, Calif., 15-16 Jun. 1988
(AGARD-LS-157; ISBN-92-835-0461-5) Avail: NTIS HC A09/MF A01

Judging the suitability of an aircraft to safely and effectively perform its mission without undue pilot skill and discomfort is what flying qualities is all about. Central to such judgement, and to the design of suitable aircraft plus flight control systems, is an understanding of what the pilot can do with ease and comfort or conversely what bothers him. The lectures are designed to impart such understanding to both novice and seasoned practioners in flying qualities and flight control and thereby to provide the bridge required to extend flying qualities requirements from simple classic response aircraft, to the responses attending the use of full time active control. Mathematical models of pilot control behavior are explained. The application of various model to flying qualities are discussed; and the influences, regarding the generic likes and dislikes of pilots drawn from such studies are listed.

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A88-52685#
ANALYSIS OF ROTOR TIP CLEARANCE LOSS IN AXIAL-FLOW TURBINES
SAEED FAROKHI (Kansas, University, Lawrence) Journal of Propulsion and Power (ISSN 0748-4658), vol. 4, Sept.-Oct. 1988, p. 452-457. refs

Tip clearance flow is a major contributor to the losses in axial flow turbines. Tip shrouding reduces the extent of this loss at the expense of more structural complexity and increased centrifugal blade stresses. Recent technological advance in the area of active clearance control promises to minimize the tip clearance loss without the adverse tip shrouding effects. Due to complexity of rotor tip flows, a comprehensive tip clearance loss model that accounts for the tip shape, relative wall motion, tip loading, and stage characteristics has not yet been developed. In the present paper, the rotor tip clearance flow is aerothermodynamically analyzed and a loss model is presented that includes the above-mentioned effects. Tip leakage discharge coefficient and the stage loading factor are taken as modeling parameters. Finally, earlier tip clearance loss models are reviewed and comparisons are drawn with the present work. Author

A88-52686#
WAKE-INDUCED UNSTEADY AERODYNAMIC INTERACTIONS IN A MULTISTAGE COMPRESSOR
VINCENT R. CAPECE and SANFORD FLEETER (Purdue University, West Lafayette, IN) Journal of Propulsion and Power (ISSN 0748-4658), vol. 4, Sept.-Oct. 1988, p. 458-465. USAF-supported research. Previously cited in issue 20, p. 2915, Accession no. A86-42653. refs

A88-52795
A PROJECTION-GRID SCHEME FOR CALCULATING TRANSONIC FLOW PAST A PROFILE [PROEKTSIONNO-SETOCHNAIA SKHEMA DLIA RASCHETA OBTEKANIIA PROFILIA TRANSZVUKOVYM POTOKOM]
IU. B. LIFSHITS and A. A. SHAGAEV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 28, Aug. 1988, p. 1163-1176. In Russian. refs

The boundary value problem for the full potential equation is approximated by a conservative projection-grid scheme based on the integral equality method. Additional dissipation, required for the isolation of a stable solution in the supersonic region, is introduced by modifying the density formula in accordance with artificial compressibility concepts. The resulting system of grid equations is linearized at each iteration step and solved by a multigrid algorithm. V.L.

A88-53106#
A THREE DIMENSIONAL ZONAL NAVIER-STOKES CODE FOR SUBSONIC THROUGH HYPERSONIC PROPULSION FLOWFIELDS
ROBERT H. BUSH (McDonnell Aircraft Co., Saint Louis, MO) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 12 p. refs
(AIAA PAPER 88-2830)

A three dimensional flowfield code has been written for propulsion integration studies. Geometric flexibility is provided by a flexible boundary condition implementation and a zonal grid strategy. A new Total Variation Diminishing scheme was implemented for hypersonic flows. Applications include forebody, inlet, diffuser and afterbody flows, from Mach .8 to Mach 7.4 Author

A88-53138#
A FULL NAVIER-STOKES ANALYSIS OF A THREE DIMENSIONAL HYPERSONIC MIXED COMPRESSION INLET
JEFFERY A. WHITE (Pratt and Whitney, West Palm Beach, FL) and CHAE M. RHIE (Pratt and Whitney, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 12 p. refs
(AIAA PAPER 88-3077)

Three dimensional effects in a mixed compression inlet typical of supersonic combustion ramjet engine is studied using a full Navier-Stokes analysis method. The solution procedure uses a multi-step pressure correction method with an implicit density treatment to establish the pressure and velocity fields. The stong shocks are captured using a smart numerical dissipation scheme which adapts monotonically at extrema. Numerical solutions for a mixed compression forebody/inlet are presented including performance calculations. Author

A88-53140#
STATOR/ROTOR INTERACTION IN A TRANSONIC TURBINE
MICHAEL B. GILES (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 13 p. Research supported by Rolls-Royce, PLC. refs
(AIAA PAPER 88-3093)

A numerical procedure is presently used to calculate stator/rotor interaction in the case of a highly loaded transonic first turbine stage, by solving for the inviscid unsteady Euler equations (including quasi-three-dimensional terms). Attention is given to the propagation and reflection of shocks originating at the trailing edge of the upstream stator; these produce a 40-percent variation in the lift on the rotor, leading to structural vibrations and increased losses. A simple technique is used to couple the calculations on the stator and rotor grids. O.C.

A88-53250

DEVELOPMENTS IN COMPUTATIONAL METHODS FOR HIGH-LIFT AERODYNAMICS

D. A. KING (British Aerospace, PLC, Hatfield, England) and B. R. WILLIAMS (Royal Aircraft Establishment, Farnborough, England) Aeronautical Journal (ISSN 0001-9240), vol. 92, Aug.-Sept. 1988, p. 265-288. refs

Several improvements are suggested for interaction techniques in order to improve predictions of high-lift wing configuration aerodynamics up to and beyond the stall of flow. It is noted that the direct coupling of the viscous and the inviscid flows is replaced by semiinverse and quasi-simultaneous coupling; this leads to a substantial improvement in the estimate of maximum lift. These improvements are illustrated by the novel FELMA method for viscous transonic flow prediction about high-lift airfoils. FELMA features a new type of grid generation employing incompressible streamlines and equipotentials with a transonic FEM that uses a multigrid solver. O.C.

A88-53762*# Analytical Services and Materials, Inc., Hampton, Va.

SUCTION LAMINARIZATION OF HIGHLY SWEPT SUPERSONIC LAMINAR FLOW CONTROL WINGS

W. PFENNINGER and C. S. VEMURU (Analytical Services and Materials, Inc., Hampton, VA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 11 p. refs

(Contract NAS1-18235)

(AIAA PAPER 88-4471)

An evaluation is made of a suction-based method for the laminarization of highly-swept supersonic wings at cruise Mach numbers in the 2.0-2.5 range, in the interest of the reduction of wave drag due to lift. The laminar boundary layer development, as well as Tollmien-Schlichting and crossflow instabilities, have been analyzed for the case of an X66 supercritical airfoil at 60 and 72 deg sweep, for Mach numbers of 1.56 and 2.52, respectively. Strong suction is found to be needed at the front part of the upper surface and both the upper and lower rear pressure-rise areas. O.C.

A88-53970

CONDITIONS OF THE INDUCTION-PLASMATRON MODELING OF THE CONVECTIVE NONEQUILIBRIUM HEAT TRANSFER OF BODIES IN HYPERSONIC FLOW [USLOVIIA MODELIROVANIIA KONVEKTIVNOGO NERAVNOVESNOGO TEPLOOBMENA TEL S GIPERZVUKOVYMI POTOKAMI NA INDUKTSIONNYKH PLAZMOTRONAKH]

A. F. KOLESNIKOV and M. I. IAKUSHIN (AN SSSR, Institut Problem Mekhaniki, Moscow, USSR) Teplofizika Vysokikh Temperatur (ISSN 0040-3644), vol. 26, July-Aug. 1988, p. 742-750. In Russian. refs

The possibility of the modeling of nonequilibrium heat transfer processes by using a 100-kW induction plasmatron with a 0.06-m-diameter discharge channel is investigated. Relations are established between the parameters of hypersonic flow past a smooth body and characteristics of subsonic jet flow past cylindrical models, and it is shown that these relations, when implemented in induction plasmatrons, provide full capabilities for the modeling of nonequilibrium heat transfer in a dissociated boundary layer near the critical point. V.L.

A88-53971

THREE-DIMENSIONAL HYPERSONIC VISCOUS SHOCK LAYER ON BLUNT BODIES IN FLOW AT ANGLES OF ATTACK AND SIDESLIP [GIPERZVUKOVOI PROSTRANSTVENNYI VIAZKII UDARNYI SLOI NA ZATUPLENNYKH TELAKH, OBTEKAEMYKH POD UGLAMI ATAKI I SKOL'ZHENIIA]

A. I. BORODIN and S. V. PEIGIN (Tomskii Gosudarstvennyi Universitet, Tomsk, USSR) Teplofizika Vysokikh Temperatur (ISSN 0040-3644), vol. 26, July-Aug. 1988, p. 751-758. In Russian. refs

Hypersonic flow of a viscous heat-conducting gas past a smooth blunt body at angles of attack and sideslip is examined in the context of a model of a three-dimensional viscous shock layer. A numerical method of a high order of approximation with respect to the transverse coordinate is developed for integrating equations of a three-dimensional hypersonic viscous shock layer at moderately small Reynolds numbers in the absence of plane symmetry in the flow. The effect of the Reynolds number and angles of attack and sideslip on the shock wave behavior, surface friction and heat transfer coefficients, and flow structure in the shock layer is examined. V.L.

A88-54151#

AN EXPERIMENTAL INVESTIGATION INTO THE REASONS OF REDUCING SECONDARY FLOW LOSSES BY USING LEANED BLADES IN RECTANGULAR TURBINE CASCADES WITH INCIDENCE ANGLE

ZHONGQI WANG, WENYUAN XU, WANJIN HAN, and JIE BAI (Harbin Institute of Technology, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. Research supported by National Fund of Natural Sciences. refs

(ASME PAPER 88-GT-4)

Using experiments and models, the reasons for reducing the secondary flow losses in rectangular turbine cascades by the use of leaned blades were investigated. It is shown that the dominant factor in controlling the secondary flow loss in turbine cascades is the static pressure gradient along the blade height inside the cascade channel, especially on the suction surface near the throat of cascades. The use of the straight leaned and curvilinear leaned blades was found to have a beneficial role in establishing the necessary static pressure gradient. The effectiveness of applying the positively or negatively leaned blades was increased with the increase of the incidence angle in the hub or the tip regions, respectively. I.S.

A88-54157#

AERODYNAMIC AND HEAT TRANSFER MEASUREMENTS ON A TRANSONIC NOZZLE GUIDE VANE

E. T. WEDLAKE, A. J. BROOKS, and S. P. HARASGAMA (Royal Aircraft Establishment, Farnborough, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs

(ASME PAPER 88-GT-10)

A series of tests have been carried out on an annular cascade of nozzle guide vanes designed for a high-capacity single-stage transonic turbine. Measurements of local heat transfer rates and aerodynamic data around the blade surface and on the end walls are presented, and the new test facility used in this study is briefly described. The measurements are shown to be repeatable and consistent with both predictions and previous test results from a two-dimensional cascade. The inlet turbulence level is found to be adequate to insure the suction surface boundary layer transition. V.L.

A88-54165#

AN EXPERIMENTAL INVESTIGATION INTO THE INFLUENCE OF BLADE LEANING ON THE LOSSES DOWNSTREAM OF ANNULAR CASCADES WITH A SMALL DIAMETER-HEIGHT RATIO

WANJIN HAN, ZHONGQI WANG, and WENYUAN XU (Harbin Institute of Technology, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs

(ASME PAPER 88-GT-19)

Low-speed annular cascade tunnel test results are presented for five types of cascades with different leaned blades. It is found that, for the annular cascade with a small diameter-blade height ratio and cylindrical inner and outer endwalls, the application of positively leaned blades can not only reduce the energy losses in the cascade but also improve flow behavior downstream. The decisive factor in reducing the energy losses downstream is not the reaction of the stage but the control of the amount of the low-energy gas getting into downstream, especially into the region near the hub. V.L.

A88-54173#

FLOW FIELD IN THE TIP GAP OF A PLANAR CASCADE OF TURBINE BLADES

M. YARAS, YINGKANG ZHU, and S. A. SJOLANDER (Carleton University, Ottawa, Canada) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. Research supported by Pratt and Whitney Canada. refs
(Contract NSERC-A-1671)
(ASME PAPER 88-GT-29)

Measurements are presented for the flow in the tip gap of a planar cascade of turbine blades. Three clearances of from 2.0 to 3.2 percent of the blade chord were considered. Detailed surveys of the velocity magnitude, flow direction and total pressure within the gap were supplemented by blade surface and endwall static pressure measurements. The results help to clarify the relationship between the leakage mass flow rate distribution and the driving pressure differences. It was found that even for the present relatively large clearances, fluid near the endwall experiences a pressure difference which is comparable with the blade pressure difference. It is also shown that a simple model can predict with good accuracy the mass flow rate distribution and the magnitude and direction of the velocity vectors within the gap. Author

A88-54175#

TRANSITION MODELING EFFECTS ON VISCOUS/INVISCID INTERACTION ANALYSIS OF LOW REYNOLDS NUMBER AIRFOIL FLOWS INVOLVING LAMINAR SEPARATION BUBBLES

G. J. WALKER (Tasmania, University, Hobart, Australia), P. H. SUBROTO (Indonesian Air Force, Djakarta, Indonesia), and M. F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. Navy-supported research. refs
(ASME PAPER 88-GT-32)

This paper presents a viscous/inviscid interaction analysis of flow over a NACA 65-213 airfoil at a chord Reynolds number of 240,000 using a calculative method by Cebeci et al. (1986). The computed characteristics of a midchord laminar separation bubble are compared with experimental laser-Doppler anemometer measurements by Hoheisel et al. (1984). Attention is focused on problems of modeling the laminar-turbulent transition zone within the viscous layer are addressed. The location and extent of the transition zone which best models the observed separation bubble behavior is parametrically studied. The required transition length is found to be almost an order of magnitude smaller than that predicted from conventional transition length correlations. A physical model for this greatly reduced transition length in positive pressure gradient flows is proposed. C.D.

A88-54176#

DETECTION OF SEPARATION BUBBLES BY INFRARED IMAGES IN TRANSONIC TURBINE CASCADES

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(ASME PAPER 88-GT-33)

In a test facility for straight cascades, equipped with profiles designed for a highly loaded gas turbine rotor of a high-pressure stage, experiments were conducted to clarify some effects of shock wave-boundary layer interactions. The specific aim was to determine both the position and strength of compression shocks originating from profile wake flows and the position and extent of separation bubbles. The latter are most often detected by visualization methods like surface oil flow patterns or schlieren photographs, as well as by typical properties in wall pressure distribution curves. In addition to that, the infrared image technique which has found many applications in a wide range of technical activities in the recent years, may also be used. Compared with other methods, this technique has distinct advantages in fluid mechanics applications. The whole model can be observed, without disturbing the boundary layer by tappings, measuring materials or probes. Some typical infrared images are presented and interpreted using results of pressure distribution measurements, hot-film measurements and surface oil flow visualizations. Author

A88-54183#

THE EFFECT OF THE INLET VELOCITY PROFILE IN THE THREE-DIMENSIONAL FLOW IN A REAR AXIAL COMPRESSOR STAGE

VACLAV CYRUS (Statni Vyzkumny Ustav Konstrukce Stroju, Bechovice, Czechoslovakia) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-46)

Three-dimensional flow calculations were obtained in a low-speed real axial compressor stage with an aspect ratio of 1. The working conditions of a multistage compressor stage are modelled using a specially designed screen and lengthened inlet annulus. The flow mechanism in the rotor and stator blade rows was analyzed for an inlet velocity profile with thin end-wall boundary layer thicknesses, and for a distorted inlet velocity profile with a high-turbulence intensity level. R.R.

A88-54188#

EXPERIMENTAL INVESTIGATION OF MULTISTAGE INTERACTION GUST AERODYNAMICS

VINCENT R. CAPECE and SANFORD FLEETER (Purdue University, West Lafayette, IN) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. USAF-supported research. refs
(ASME PAPER 88-GT-56)

The fundamental flow physics of multistage blade-row interactions are experimentally investigated at realistic reduced frequency values. Unique data are obtained which describe the fundamental unsteady aerodynamic interaction phenomena on the stator vanes of a three-stage axial-flow research compressor. In these experiments, the effects on vane-row unsteady aerodynamics of the following are investigated and quantified: (1) steady vane aerodynamic loading, (2) aerodynamic forcing-function waveform (including both the chordwise and transverse gust components), (3) solidity, (4) potential interactions, and (5) isolated-airfoil steady flow separation. Author

A88-54189*# Flow Application Research, Fremont, Calif.

DESIGN POINT VARIATION OF 3-D LOSS AND DEVIATION FOR AXIAL COMPRESSOR MIDDLE STAGES

WILLIAM B. ROBERTS (Flow Application Research, Fremont, CA), GEORGE K. SEROVY (Iowa State University of Science and Technology, Ames), and DONALD M. SANDERCOCK (NASA, Lewis Research Center, Cleveland, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 14 p. refs
(Contract NAG3-521)
(ASME PAPER 88-GT-57)

The available data on middle-stage research compressors operating near design point are used to derive simple empirical models for the spanwise variation of three-dimensional viscous loss coefficients for middle-stage axial compressor blading. The models make it possible to quickly estimate the total loss and deviation across the blade span when the three-dimensional distribution is superimposed on the two-dimensional variation calculated for each blade element. It is noted that extrapolated estimates should be used with caution since the correlations have been derived from a limited data base. V.L.

A88-54190#
THE USE OF FINS TO REDUCE THE PRESSURE DROP IN A ROTATING CAVITY WITH A RADIAL INFLOW
J. W. CHEW, B. STRATFORD (Rolls-Royce, PLC, Derby, England), P. R. FARTHING, and J. M. OWEN (Sussex, University, Brighton, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. Research sponsored by Rolls-Royce, PLC, Ruston Gas Turbines, PLC, and SERC. refs
(ASME PAPER 88-GT-58)

A combined theoretical and experimental study of radial inflow through a rotating cavity is reported. It is shown that radial fins attached to one of the disks are effective in reducing the pressure drop across the cavity. The mathematical model is an extension of earlier plane-disk momentum-integral methods; the fins are treated as rectangular rib elements and a rough-disk model is derived. Numerical solutions of the integral equations are given. An approximate linear solution is also derived. Experiments were conducted when both disks were plane and when one of the disks was fitted with 60 radial fins. Flow visualization revealed the flow structure in the cavity and confirmed some of the assumptions used in the theoretical model. Measurements and predictions of the pressure drop across the cavity were in reasonable agreement. Author

A88-54192#
THE USE OF BEZIER POLYNOMIAL PATCHES TO DEFINE THE GEOMETRICAL SHAPE OF THE FLOW CHANNELS OF COMPRESSORS
QINGHUAN WANG and XIAOYAN HUANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p. refs
(ASME PAPER 88-GT-60)

Casey's (1982) method is presently developed through the use of Bezier polynomial patches to define the geometrical shape of compressor flow channels. By means of this method, the geometry-defining process for the blade profile and the contour of the blade's meridional channel can be generated by the same number of patches. In addition, no restrictions are imposed on linearity in the spanwise direction in order to match the distribution of flow angles at the inlet, as well as to satisfy the requirements of various load models. The method is especially suitable for incorporation by CAD systems. O.C.

A88-54200#
THE RELATIVE MERITS OF AN INVISCID EULER 3-D AND QUASI-3-D ANALYSIS FOR THE DESIGN OF TRANSONIC ROTORS
D. P. MILLER and A. C. BRYANS (General Electric Co., Aircraft Engine Business Group, Lynn, MA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 13 p. refs
(ASME PAPER 88-GT-69)

It is the purpose of this paper to examine the flow fields in an advanced modern transonic rotor design using both axisymmetric and three dimensional techniques. Also, to determine the deviation of the axisymmetric flow from three-dimensional flow field and whether this seriously affects the results. Inviscid Euler solvers are now widely used to analyze transonic flows through turbomachines giving a reasonably accurate indication of the flow field in blade passages. Although viscous effects are important, the inviscid analysis provides significant knowledge of the flow field which is essential to transonic design. The blade-to-blade loading and work distributions are determined quite realistically by the three-dimensional and quasi-three-dimensional inviscid analyses. Through-flow and blade-to-blade inviscid solutions are presented for a highly loaded transonic rotor. Numerical solutions for various transonic rotor designs operating at peak efficiency are also compared with test data. Author

A88-54201#
DEVELOPMENT OF A 3D NAVIER STOKES SOLVER FOR APPLICATION TO ALL TYPES OF TURBOMACHINERY
W. N. DAWES (Cambridge University, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. refs
(ASME PAPER 88-GT-70)

The current stage of development of a code aimed at solving the three-dimensional Navier-Stokes equations in any type of turbomachinery geometry is described. The generality and robustness of the code are demonstrated on the basis of five different test cases, three axial and two radial configurations. A grid independence study which demonstrates near grid independent solutions for transonic compressor cascade flow is included as well. K.K.

A88-54206*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
FLUTTER OF A FAN BLADE IN SUPERSONIC AXIAL FLOW
ROBERT E. KIELB and JOHN K. RAMSEY (NASA, Lewis Research Center, Cleveland, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-78)

An application of a simple aeroelastic model to an advanced supersonic axial flow fan is presented. Lane's cascade theory is used to determine the unsteady aerodynamic loads. Parametric studies are performed to determine the effects of mode coupling, Mach number, damping, pitching axis location, solidity, stagger angle, and mistuning. The results show that supersonic axial flow fan and compressor blades are susceptible to a strong torsional mode flutter having critical reduced velocities which can be less than one. Author

A88-54207#
TURBULENCE MEASUREMENTS IN A MULTISTAGE LOW-PRESSURE TURBINE
A. BINDER, TH. SCHROEDER, and J. HOURMOUZIADIS (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. refs
(ASME PAPER 88-GT-79)

The flow in the rotor blades of a five stage low pressure turbine was investigated experimentally using hot-film probes. Time averaging, Fourier transforms and ensemble averaging are applied for data reduction. The techniques prove to be a very helpful instrument for the assessment of the flow characteristics in the relative frame. A strong interaction is identified between two successive rows of rotor blades. A physical model, developed from velocity and turbulence results, gives a comprehensive understanding of the phenomenon. The main parameter is the nonuniformity of the flow entering the downstream blade row. Separation occurs when the wake of the upstream rotor blades enters the blade passage near the leading edge, preferably on the pressure side. The interaction is quasi-steady in the relative frame and rotates with the rotor speed. It was observed only in one of three investigated blade rows. Further studies are necessary to identify the mechanism correlating the nonuniformity to the separation. Author

A88-54208#
COMPUTATION OF THREE-DIMENSIONAL TURBULENT TURBOMACHINERY FLOWS USING A COUPLED PARABOLIC-MARCHING METHOD
K. R. KIRTLEY and B. LAKSHMINARAYANA (Pennsylvania State University, University Park) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. Navy-sponsored research. refs
(ASME PAPER 88-GT-80)

A new coupled parabolic-marching method was developed to compute the three-dimensional turbulent flow in a turbine end wall cascade, a compressor cascade wake, and an axial flow compressor rotor passage. The method solves the partially parabolized incompressible Navier-Stokes equation and continuity in a coupled fashion. The continuity equation was manipulated using pseudocompressibility theory to give a convergent algorithm for complex geometries. The computed end wall boundary layers and secondary flow compared well with the experimental data for the turbine cascade as did the wake profiles for the compressor cascade using a k-epsilon turbulence model. Suction side boundary layers, pressure distributions and exit stagnation pressure losses compared reasonably well with the data for the compressor rotor. Author

A88-54210#

NUMERICAL SOLUTION TO TRANSONIC POTENTIAL EQUATIONS ON S2 STREAM SURFACE IN A TURBOMACHINE

J. Y. DU, J. Z. XU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China), Y. Q. ZHAO, and Y. GUO (Nanhua Power Research Institute, Zhuzhou, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p. refs
(ASME PAPER 88-GT-82)

A nonisentropic potential method on an S2 stream surface has been developed for the design and analysis of transonic compressors with shocks, in which the entropy increase across a shock may be directly calculated from the momentum equations in the divergence form. The numerical results show that the nonisentropic shock is weaker, placed one or two meshes further upstream compared to the classical potential calculation, and is in good agreement with the experimental data. Author

A88-54211#

QUASI-3D SOLUTIONS FOR TRANSONIC, INVISCID FLOWS BY ADAPTIVE TRIANGULATION

D. GRAHAM HOLMES, SCOTT H. LAMSON (GE Corporate Research and Development Center, Schenectady, NY), and STUART D. CONNELL (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-83)

This paper describes an algorithm for computing two-dimensional transonic, inviscid flows. The solution procedure uses an explicit Runge-Kutta time marching, finite volume scheme. The computational grid is an irregular triangulation. The algorithm can be applied to arbitrary two-dimensional geometries. When used for analyzing flows in blade rows, terms representing the effects of changes in streamsheet thickness and radius, and the effects of rotation, are included. The solution is begun on a coarse grid, and grid points are added adaptively during the solution process, using criteria such as pressure and velocity gradients. Advantages claimed for this approach are: (1) the capability of handling arbitrary geometries (e.g., multiple, dissimilar blades); (2) the ability to resolve small-scale features (e.g., flows around leading edges, shocks) with arbitrary precision; and (3) freedom from the necessity of generating 'good' grids (the algorithm generates its own grid, given an initial coarse grid). Solutions are presented for several examples that illustrate the usefulness of the algorithm. Author

A88-54213#

ON THE PREDICTION OF UNSTEADY FORCES ON GAS-TURBINE BLADES. I - TYPICAL RESULTS AND POTENTIAL-FLOW-INTERACTION EFFECTS

THEODOSIOS P. KORAKIANITIS (Washington University, Saint Louis, MO) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-89)

This paper is a contribution to the study of the generation of unsteady forces on turbine blades due to potential-flow interaction and viscous-wake interaction from upstream blade rows. A computer program is used to compute the unsteady forces on a rotor. The accuracy of the computer program is tested by comparing the results of a steady-flow calculation case and of an unsteady-flow calculation case with theory and experiment, respectively. Results are shown for typical stator-to-rotor-pitch ratios and stator outlet-flow angles. These results show that the first spatial harmonic of the unsteady force may decrease for higher stator-to-rotor-pitch ratios. This trend is explained by considering the mechanisms by which the unsteady forces are generated. In this paper the mechanism by which the potential-flow interaction affects the flow field to generate these unsteady forces is shown to vary with the stator-to-rotor-pitch ratio and with the outlet-flow angle of the stator. Author

A88-54214#

ON THE PREDICTION OF UNSTEADY FORCES ON GAS-TURBINE BLADES. II - VISCOUS-WAKE-INTERACTION AND AXIAL-GAP EFFECTS

THEODOSIOS P. KORAKIANITIS (Washington University, Saint Louis, MO) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-90)

This paper is a contribution to the study of the generation of unsteady forces on turbine blades due to viscous wake interaction and potential-flow interaction from upstream blade rows. A computer program is used to compute the unsteady forces on a rotor. Typical results for isolated viscous-wake interaction (no potential-flow interaction) are shown. These results indicate that the first spatial harmonic of the unsteady force may decrease for higher stator-to-rotor-pitch ratios. This trend is explained by considering the mechanisms by which the unsteady forces are generated. The mechanism by which the viscous wakes affect the flow field to generate these unsteady forces is shown to vary with the stator-to-rotor-pitch ratio and with the outlet-flow angle of the stator. It is also shown that by varying the axial gap between rotor and stator one can attempt to minimize the magnitude of the unsteady part of the forces generated by the combined effects of viscous-wake interaction and potential-flow interaction. Author

A88-54216#

CALCULATION OF COMPLETE THREE-DIMENSIONAL FLOW IN A CENTRIFUGAL ROTOR WITH SPLITTER BLADES

DIAN-KUI LIU and LE-JIAN JI (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-93)

The flow within a centrifugal rotor has strong characteristics of three-dimensional effect. A procedure called 'stream-surface coordinates iteration' for the calculation of complete three-dimensional flow in turbo-machinery is first described. Splitter blade techniques have been used in many rotors, especially in centrifugal compressors and pumps with high flow capacity. The difficulty of the calculation of the flow field for this type of rotor is that the mass flow ratio between the two sub-channels is unknown for the given total flow capacity. An assumption on how to determine this mass flow ratio and a procedure to calculate the complete three-dimensional flow are presented. Finally, some design criteria for the splitter blades are put forward. Experimental data from two centrifugal pump impellers equipped with different splitter blades are also given to demonstrate the efficiency of the present calculation method. Author

A88-54217#

PREDICTION OF COMPRESSOR CASCADE PERFORMANCE USING A NAVIER-STOKES TECHNIQUE

R. L. DAVIS (United Technologies Research Center, East Hartford, CT), D. E. HOBBS, and H. D. WEINGOLD (Pratt and Whitney, East Hartford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 13 p. Research supported by United Technologies Corp. refs
(ASME PAPER 88-GT-96)

An explicit, time marching, multiple-grid Navier-Stokes technique is demonstrated for the prediction of quasi-three-dimensional turbomachinery compressor cascade performance over the entire incidence range. A numerical investigation has been performed in which the present Navier-Stokes procedure was used to analyze a series of compressor cascade viscous flows for which corresponding experimental data are available. Results from these calculations show that the current viscous flow procedure is capable of predicting cascade profile loss and airfoil pressure distributions with high accuracy. The results from this numerical investigation in the form of comparisons between the predicted profile loss, exit gas angle, and pressure distributions with experimental data are presented in this paper. Results from a grid refinement study are also shown to demonstrate that the Navier-Stokes solutions are grid independent. Author

A88-54218#

THE INFLUENCE OF TURBINE CLEARANCE GAP LEAKAGE ON PASSAGE VELOCITY AND HEAT TRANSFER NEAR BLADE TIPS. I - SINK FLOW EFFECTS ON BLADE PRESSURE SIDE

D. E. METZGER and K. RUED (Arizona State University, Tempe) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-98)

A study has been conducted to investigate influences of tip leakage flow on heat transfer and flow development along the pressure side of a gas turbine blade. An analysis of the sink character of the flow situation indicates that high velocities and accelerations are generated very near the gap, and an apparatus was specifically designed to model the phenomena and to permit resolution of the expected localized near-gap heat transfer enhancement. In the experiments, leakage flow was drawn from an adjustable streamwise corner slot in a straight square test channel. A thin stainless steel ohmic-heated test surface adjacent to the slot simulated the airfoil surface. Supporting non-intrusive mean and fluctuating flowfield measurements were conducted with a laser-Doppler anemometer to aid interpretation of the heat transfer results and to provide a basis for comparison with future numerical predictions. The flowfield measurements confirm that near the gap the flow is highly accelerated, and indicate apparent relaminarization of the initially turbulent boundary layer. The heat transfer measurements show that leakage generates large increases in local heating near the gap. The presence of this undesirable enhancement helps to explain observed in-service material distress and failure of blades that appear to initiate at the pressure side tip. Author

A88-54219#

THE INFLUENCE OF TURBINE CLEARANCE GAP LEAKAGE ON PASSAGE VELOCITY AND HEAT TRANSFER NEAR BLADE TIPS. II - SOURCE FLOW EFFECTS ON BLADE SUCTION SIDES

K. RUED and D. E. METZGER (Arizona State University, Tempe) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-99)

Corner source flow experiments were carried out in a water tunnel to model the influence of tip leakage flow on heat transfer and flow development along the suction side of a gas turbine blade. The most significant effect of the leakage flow is a strong increase in local heat transfer rates immediately adjacent to the gap. The observed heat transfer effects appear to be very important from the standpoint of blade tip durability; they seem to at least partially account for the sometimes unexplained thermal distress and material failures experienced on blade tips in practice. K.K.

A88-54220#

A FAST INTERACTIVE TWO-DIMENSIONAL BLADE-TO-BLADE PROFILE DESIGN METHOD

G. D. WILLIS (NEI-APE, Ltd. W. H. Allen, Bedford, England) and A. GOULAS (Salonika, University, Greece) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-100)

To help with the design of axial flow stream turbine blading a suite of flow analysis programs has been adapted and developed. Effort has been concentrated on improving the blade-to-blade analysis and developing a two-dimensional blade-to-blade profile design method. The development and verification of the analysis program have already been reported in detail (Willis, 1987 and Willis and Goulas, 1987). This paper presents the design or inverse solution. The analysis method uses an inviscid stream function solution coupled with an integral boundary layer calculation. In the design program the required changes in the blade geometry are effected via a transpiration type model. It is therefore a 'profile refinement', rather than an 'original' design procedure, and is necessarily an iterative solution. A required velocity distribution may be specified over only part of the blade surface. Two examples are presented in this paper to illustrate the capability of the design program. Author

A88-54222#

THREE DIMENSIONAL FLOW IN RADIAL-INFLOW TURBINES

M. ZANGENEH-KAZEMI, W. N. DAWES, and W. R. HAWTHORNE (Cambridge University, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-103)

The flow through an impeller of a low speed radial-inflow turbine has been analyzed using a fully three-dimensional viscous program and good correlations with instantaneous measurements of casing static pressure and exit flow distribution have been obtained. The flow at the exit of the turbine shows a pronounced non-uniformity with a wake region of high absolute flow angle near the casing. The predictions show that the flow is fully attached inside the impeller, while secondary flows can be observed especially in the exducer moving low momentum fluid towards the casing-suction corner. The presence of these secondary flows is discussed with reference to classical secondary flow theory. However, the comparison of measurements and numerical predictions indicate that the wake flow pattern is only partly due to the secondary flow. It is shown that in fact the tip leakage flow also plays a significant role in the wake generation and correspondingly some modelling of the leakage flow is essential in any attempted numerical simulations. Author

A88-54228#

EFFECTS OF INCIDENCE ON THREE-DIMENSIONAL FLOWS IN A LINEAR TURBINE CASCADE

A. YAMAMOTO and H. NOUSE (National Aerospace Laboratory, Chofu, Japan) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 15 p. refs
(ASME PAPER 88-GT-110)

The paper discusses effects of the incidence on cascade three-dimensional flows and the associated loss generation mechanisms in a low-speed linear turbine cascade with a design turning angle of 107.1 degrees. Using a small five-hole pitot tube, the cascade flow was surveyed in great detail at fifteen or sixteen planes located axially throughout the cascade, at five different incidences from 7.2 to -53.3 degrees. Blade-to-blade flows at the cascade midspan and near the endwalls, meridional flows near the blade surfaces, and static and total pressure distributions were analyzed and many of them were presented by using tomographic representations of vectors and scalar contours and by streaklines (or particle path lines) in order to easily understand the extraordinarily complicated flows and the associated loss mechanisms. The present study gives not only new information on the incidence effects but also many solid experimental facts in a quantitative manner to our knowledge already known or speculated. Author

A88-54240#

BASE PRESSURE IN TRANSONIC SPEEDS - A COMPARISON BETWEEN THEORY AND EXPERIMENT

F. MOTALLEBI (Teheran, University, Iran) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-132)

The problem of base pressure in the absence of base bleed has been investigated for a symmetrical model with a square-cut trailing edge. The model was mounted at zero angle of attack in a transonic wind tunnel covering a range of mainstream Mach number from 0.6 to 1.3. The role of vortex shedding was found to be of great importance in the prediction of base pressure. A semi-theoretical analysis for the prediction of base pressure in subsonic and transonic speeds which includes the effect of vortex shedding is proposed. Author

A88-54242#
PERIODICITY, SUPERPOSITION, AND 3D EFFECTS IN SUPERSONIC COMPRESSOR FLUTTER AERODYNAMICS
G. A. GEROLYMOS (SNECMA, Moissy-Cramayel, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-136)

Blade-to-blade surface and three-dimensional methods based on the numerical integration of the unsteady Euler equations are presently used to study various aspects of vibrating compressor cascade unsteady aerodynamics in the supersonic flutter region. The influence of the vibrating blade in a wave-assembly vibration mode decays rapidly with pitchwise-distance from the blade; it is therefore possible to formulate the bladed disk aeroelastic problem in any assembly-modal basis. It is projected that three-dimensional methods will replace blade-to-blade surface methods when further increases in computer capacity are realized. O.C.

A88-54244#
DESIGN OF HIGH PERFORMANCE FANS USING ADVANCED AERODYNAMIC CODES
GEORGES KARADIMAS (SNECMA, Moissy-Cramayel, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-141)

In the recent past, the performance of transonic fans has been significantly improved. In addition, through the extensive use of advanced aerodynamic computation codes the development time required has been considerably reduced. Methods used range from the definition of airfoils in quasi-three-dimensional flow with boundary layer optimization to the analysis of three-dimensional inviscid flow for the stage operation at the design point and in off-design conditions. Such a set of methods was used to design the fan blade of the CFM56-5 engine to a very high performance level. This paper discusses the optimization of rotor and stator airfoils, the assessment of off-design performance, and the operational stability of this fan. A detailed comparison of full size component test data with computation results shows the validity of these methods and also identifies those areas where progress is still required. Author

A88-54251#
INVESTIGATION OF BOUNDARY LAYER TRANSITION AND SEPARATION IN AN AXIAL TURBINE CASCADE USING GLUE-ON HOT-FILM GAGES
S. B. VIJAYARAGHAVAN and P. KAVANAGH (Iowa State University of Science and Technology, Ames) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. Research supported by General Motors Corp. refs
(ASME PAPER 88-GT-151)

Experiments were conducted with glue-on hot-film gages in a large-scale axial turbine cascade to identify transition and/or separation on the suction surface of the blade. Standard strain-gage type temperature sensors were adapted and used as the gages and transition and separation were identified by examining the mean and RMS voltage output. To assist with interpreting the output of the gages, surface oil-flow visualizations were used. Results of this study showed that transition and separation could be easily identified with the hot-film gages. Depending upon the Reynolds number and free stream turbulence level, the suction surface boundary layer was found to undergo bubble-induced transition, natural transition, or a combination of both; i.e., a transition which started naturally but ended abruptly with a bubble. Author

A88-54252#
EFFECT OF FREE-STREAM TURBULENCE, REYNOLDS NUMBER, AND INCIDENCE ON AXIAL TURBINE CASCADE PERFORMANCE
S. B. VIJAYARAGHAVAN and P. KAVANAGH (Iowa State University of Science and Technology, Ames) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research supported by General Motors Corp. refs
(ASME PAPER 88-GT-152)

A large-scale, low-speed, axial turbine cascade designed for high-loading and high-turning was tested over a range of Reynolds number, turbulence level, and incidence angle. End wall suction was applied to provide two-dimensional flow over a large spanwise region of the airfoil. In all, thirty-six test conditions were examined. Overall cascade performance, including mass-averaged loss coefficents at each test flow condition, was determined from detailed five-hole pressure probe traverses in an exit plane of the cascade. In addition, using glue-on hot-film gages and surface oil-flow visualizations, transition and/or separation was identified over the suction surface of the airfoil. The measured transition start and end points were compared against predictions using existing transition models. Also, the measured losses were compared against predicted losses from boundary layer calculations based on finite difference analysis. Author

A88-54259#
NUMERICAL ANALYSIS OF AIRFOIL AND CASCADE FLOWS BY THE VISCOUS/INVISCID INTERACTIVE TECHNIQUE
C. J. HWANG, F. L. JIANG, J. M. HSIEH (National Cheng Kung University, Tainan, Republic of China), and S. B. CHANG (Chung-Shan Institute of Science and Technology, Taichung, Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-160)

Steady, incompressible/subsonic compressible, attached, and separated flows for isolated airfoils and airfoil cascades are investigated via a two-dimensional viscous-inviscid interaction calculation method. A semiinverse method couples a full-potential code with a laminar/transition/turbulent finite difference code. An algebraic eddy-viscosity formulation is employed to study the turbulent flow. Empirical data correlations are used to predict the location of the transition from laminar to turbulent flow. The FLARE approximation and inverse method are introduced to treat the separated flows. R.R.

A88-54266#
SURFACE HEAT TRANSFER FLUCTUATIONS ON A TURBINE ROTOR BLADE DUE TO UPSTREAM SHOCK WAVE PASSING
A. B. JOHNSON, M. J. RIGBY, M. L. G. OLDFIELD, R. W. AINSWORTH (Oxford University, England), and M. J. OLIVER (Rolls-Royce, PLC, Derby, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 13 p. Research supported by Rolls-Royce, PLC. refs
(Contract F33615-84-C-2475)
(ASME PAPER 88-GT-172)

A theoretical and experimental study of the observed rapid large-scale surface heat transfer rate fluctuations associated with the impingement of nozzle-guide-vane trailing edge shock waves on a transonic turbine rotor blade is presented. A simple first-order perturbation analysis of the boundary layer equations indicates that the transient adiabatic heating and cooling of the boundary layer by passing shock waves and rarefactions can produce high temperature gradients near the surface, leading to large conductive heat transfer rate fluctuations. The theory predicts fluctuating heat transfer rates which agree well with experimental values. R.R.

A88-54278#
EFFECT OF SHOCK WAVE MOVEMENT ON AERODYNAMIC INSTABILITY OF ANNULAR CASCADE OSCILLATING IN TRANSONIC FLOW
HIROSHI KOBAYASHI (National Aerospace Laboratory, Chofu, Japan) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. refs
(ASME PAPER 88-GT-187)

Effects attributable to shock wave movement on cascade flutter were examined for both turbine and compressor blade rows using a controlled oscillating annular cascade test facility and a method for accurately measuring time-variant pressures on blade surfaces. The nature of the effects and the blade surface area influenced by the shock movement were clarified in a wide range of Mach number, reduced frequency, and interblade phase angle. An unsteady aerodynamic force was generated by the shock movement, which significantly affected the occurrence of the compressor and turbine cascade flutter. For the turbine cascade, the interblade phase angle controlled the effect of the force, while in the compressor, the reduced frequency dominated it. The chordwise extent on blade surface influenced by the shock movement was suggested to be about 6 percent of the chord length. Author

A88-54285#
BEHAVIOUR OF THE LEG OF THE HORSESHOE VORTEX AROUND THE IDEALIZED BLADE WITH ZERO ATTACK ANGLE BY TRIPLE HOT-WIRE MEASUREMENTS
SHINJI HONAMI, TAKAAKI SHIZAWA (Tokyo, Science University, Japan), and MASAYUKI TAKAHAMA (Mitsubishi Heavy Industries, Ltd., Takasago, Japan) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-197)

The paper presents flow measurements within the leg protion of the horseshoe vortex. An uncambered blade of constant thickness downstream with a half-circular nose of an idealized turbine blade was installed on a flat plate. The six components of the Reynolds stresses were measured in addition to the three mean velocity components at two cross-sectional planes by a triple wire probe. The predominant vortical motion of the secondary flow occurs at the corner of the blade and the endwall. The effect of the penetrating motion of the free-stream toward the corner region induced by the vortex on the Reynolds stress is found in mean u-squared profiles near the blade, but not in mean v-squared profiles. The diffusion of the Reynolds stresses is observed in the crossflow direction. Author

A88-54286
CALIBRATION OF CFD METHODS FOR HIGH MACH NUMBER AEROENGINE FLOWFIELDS
JOHN R. CHAWNER, GREGORY S. SPRAGLE, and RICHARD J. MATUS (General Dynamics Corp., Fort Worth, TX) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-199)

The level of confidence in several CFD methods for high-Mach aeroengine flowfields was investigated by comparing the CFD flowfields, obtained using a beam-warming-based unsteady Navier-Stokes code PARC developed by Cooper (1987), a beam-warming-based parabolized Navier-Stokes (PNS) code, and a MacCormack-based PNS code, with experimental data obtained for a blunt cone at Mach 10.6, an inlet at Mach 7.4, a combustor at Mach 2.4, and an axisymmetric plug nozzle at Mach 3.2. These CFD codes showed good overall agreement with experimental data for wall pressures, integrated forces and pressure, Mach number, and chemical species profiles. In addition, the PARC code was found to be able to give a very accurate prediction of thrust for the axisymmetric nozzle. I.S.

A88-54288#
EXPERIMENTAL INVESTIGATION OF THE THREE-DIMENSIONAL FLOW IN AN ANNULAR COMPRESSOR CASCADE
H. D. SCHULZ and H. E. GALLUS (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 14 p. DFG-supported research. refs
(ASME PAPER 88-GT-201)

A detailed experimental investigation was carried out to examine the influence of blade loading on the three-dimensional flow in an annular compressor cascade. Data were acquired over a range of incidence angles. Included are airfoil and endwall flow visualization, measurement of the static pressure distribution on the flow passage surfaces, and radial-circumferential traverse measurements. The data indicate the formation of a strong vortex near the rear of the blade passage. This vortex transports low momentum fluid close to the hub toward the blade suction side and seems to be partly responsible for the occurrence of a hub corner stall. The effect of increased loading on the growth of the hub corner stall and its impact on the passage blockage is discussed. Detailed mapping of the blade boundary layer was done to determine the loci of boundary layer transition and flow separation. The data have been compared with results from an integral boundary layer method. Author

A88-54289#
TEST RESULTS AND THEORETICAL INVESTIGATIONS ON THE ARL 19 SUPERSONIC BLADE CASCADE
A. FOURMAUX, R. GAILLARD, G. LOSFELD, and G. MEAUZE (ONERA, Chatillon-sous-Bagneux, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-202)

This paper presents the ONERA contribution in a joint experimental program on the aerodynamics of supersonic airfoil cascades. The first part deals with the specific ONERA way of running cascade tests: description of the test facility, of the test model and of the instrumentation and data reduction. Then, after a brief theoretical analysis of the ARL 19 cascade, some experimental results are presented and discussed. Author

A88-54293#
INFLUENCE OF DEPOSIT ON THE FLOW IN A TURBINE CASCADE
A. BOELCS and O. SARI (Lausanne, Ecole Polytechnique Federale, Switzerland) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. Research supported by Brown Boveri et Cie. refs
(ASME PAPER 88-GT-207)

Factors affecting flow in a gas turbine cascade operating under transonic flow conditions were investigated. Special consideration was given to the effect of the deposit growing on the rotor blade on the configuration and stability of shock waves. Experiments were carried out in a linear cascade over a range of isentropic exit Mach numbers from 0.6 to 1.6 and three different inlet flow angles. The results of the flow field measurements indicate that the choked flow conditions are reached at different steady-state isentropic outlet Mach numbers for the two blade shapes that were used: the original, 'clean' blade and the blade bearing a simulated deposit. However, the 'deposit', typical for a gas turbine, did not significantly modify the boundary layer separation point. A comparison of these results with the calculations, using the time-marching method of Denton (1982) yielded good agreement only for the 'clean' blade. I.S.

A88-54296#
TIP LEAKAGE IN A CENTRIFUGAL IMPELLER
T. Z. FARGE, M. W. JOHNSON, and T. M. A. MAKSOUD (Liverpool, University, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988.

7 p. SERC-supported research. refs
(ASME PAPER 88-GT-210)

The effects of tip leakage have been studied using a 1 meter diameter shrouded impeller where a leakage gap is left between the inside of the shroud and the impeller blades. A comparison is made with results for the same impeller where the leakage gap is closed. The static pressure distribution is found to be almost unaltered by the tip leakage, but significant changes in the secondary velocities alter the size and position of the passage wake. Low momentum fluid from the suction-side boundary layer of the measurement passage and tip leakage fluid from the neighboring passage contribute to the formation of a wake in the suction-side shroud corner region. The inertia of the tip leakage flow then moves this wake to a position close to the center of the shroud at the impeller outlet. Author

A88-54297#
PERFORMANCE OF A COMPRESSOR CASCADE CONFIGURATION WITH SUPERSONIC ENTRANCE FLOW - A REVIEW AND COMPARISON OF EXPERIMENTS IN THREE INSTALLATIONS
G. K. SEROVY and T. H. OKIISHI (Iowa State University of Science and Technology, Ames) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. refs
(Contract F49620-83-K-0023)
(ASME PAPER 88-GT-211)

A compressor blade cascade whose airfoil section is representative of advanced profiles for Mach 1.4-1.8 operation has been tested with supersonic entrance flow conditions in three linear-cascade facilities, in order to ascertain the reproducibility of test conditions and measured performance, as well as to generate data sets for the validation of CFD methods for turbomechanical applications. Attention is presently given to the experimental apparatus- and method-related problems encountered. A high-confidence data set has been obtained. O.C.

A88-54302#
COMPUTATION OF THE JET-WAKE FLOW STRUCTURE IN A LOW SPEED CENTRIFUGAL IMPELLER
B. L. LAPWORTH and R. L. ELDER (Cranfield Institute of Technology, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. refs
(ASME PAPER 88-GT-217)

The low speed flow through the shrouded de-Havilland Ghost centrifugal impeller is computed using an incompressible elliptic calculation procedure. The three-dimensional viscous flow equations are solved using the SIMPLE algorithm in an arbitrary generalized coordinate system. A non-staggered grid arrangement is implemented in which pressure oscillations are eliminated using an amended pressure correction scheme. Flow computations are performed at 'nominal' low speed design and above design flow rates, and (on the coarse grids used in the calculations) good agreement is obtained with the experimentally observed jet-wake structure of the flow. Author

A88-54303#
A NEW SINGULAR INTEGRAL APPROACH FOR A VERTICAL ARRAY OF AIRFOILS
DENNIS WILSON (Texas, University, Austin) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-218)

Recently, a singular integral method was developed for solving two-dimensional compressible potential flows. The original formulation limited the applicability to single bodies in a uniform freestream. Currently, modifications are beig made so that the flowfield around multiple bodies can also be calculated. Because of the unique manner in which the integral equations are formulated, they are especially well-suited for analysis and inverse design calculations of a row of similar airfoils. A brief descripton of the formulation is given in this paper and some preliminary results are included. Author

A88-54309#
A COMPARISON BETWEEN MEASUREMENTS AND TURBULENCE MODELS IN A TURBINE CASCADE PASSAGE
PIETRO ZUNINO, MARINA UBALDI, ANTONIO SATTA, and ENRICO PEISINO (Genova, Universita, Genoa, Italy) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(Contract CNR-86,00938,59)
(ASME PAPER 88-GT-226)

Detailed measurements of mean velocity, turbulence intensity and Reynolds stresses have been performed in the passage of a cascade of turbine rotor blades. By using the experimental values of the mean velocity, the turbulence quantities are computed with three different turbulence closure models. The results are analyzed and compared with the experimental data. The capability of the closure models to describe the turbulence development associated with secondary flows in a turbine cascade is discussed. Author

A88-54314#
MEASUREMENT AND MODELLING OF THE GAS TURBINE BLADE TRANSITION PROCESS AS DISTURBED BY WAKES
J. E. LAGRAFF (Syracuse University, NY), D. A. ASHWORTH (Rolls-Royce, PLC, Derby, England), and D. L. SCHULTZ ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(Contract AF-AFOSR-85-0295)
(ASME PAPER 88-GT-232)

Heat transfer measurements were obtained on a transonic turbine blade undergoing natural transition and simulating the effect of NGV wake interactions. Wide-bandwidth heat transfer instrumentation successfully tracked trajectories of both unsteady wake passing events and transitional turbulent spots on the airfoil under the conditions of the simulated gas turbine environment. Based on low-speed theory and results of the final three-dimensional stages of boundary layer transition, the present observations are modeled by a time-marching scheme of both the inviscid wake passing interaction and the random generation and growth of turbulent spots. R.R.

A88-54315#
WAKE-BOUNDARY LAYER INTERACTIONS IN AN AXIAL FLOW TURBINE ROTOR AT OFF-DESIGN CONDITIONS
H. P. HODSON and J. S. ADDISON (Cambridge University, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. Research supported by the Central Electricity Generating Board. refs
(ASME PAPER 88-GT-233)

Rotor-blade surface flow visualization, surface-mounted hot-film anemometry, and exit pitot traverses are used to experimentally study the effects of varying the flow coefficient and Reynolds number on the performance of a single-stage low-speed turbine rotor blade at midspan. Over the Reynolds number range considered, the rotor midspan performance is found to be dominated by the suction surface transition process. The results show that the rotor midspan profile remains unchanged from the zero incidence value until pressure side stall occurs. R.R.

A88-54318#
A UNIFIED SOLUTION METHOD FOR THE FLOW CALCULATIONS ALONG S1 AND S2 STREAM SURFACES USED FOR THE COMPUTER-AIDED DESIGN OF CENTRIFUGAL COMPRESSORS
QINGHUAN WANG and HAOYU YU (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-237)

In order to facilitate the aerodynamic design for the computer-aided design of centrifugal compressor, a unified direct problem method for the flow calculations along S1 and S2 stream surfaces is presented. A single stream function equation expressed by nonorthogonal curvilinear coordinates and the unified matrix direct solution for the governing equation are used. This method greatly simplified the quasi-three-dimensional and full dimensional computing program, while improving the computing accuracy and the convergence rate. Numerical examples illustrate the advantages of the new technique for the computer-aided design of centrifugal compressors. Author

A88-54323#

TURBULENCE MEASUREMENTS AND SECONDARY FLOWS IN A TURBINE ROTOR CASCADE

D. G. GREGORY-SMITH (Durham, University, England), J. A. WALSH (Logica Space and Defence Systems, Ltd., London, England), C. P. GRAVES (Gilbert Gilkes and Gordon, Ltd., Kendal, England), and K. P. FULTON (Rolls-Royce, PLC, Derby, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. Research supported by Ministry of Defence Procurement Executive, Rolls-Royce, PLC, and SERC. refs
(ASME PAPER 88-GT-244)

This paper presents results for turbulence measurements that have been made using hot-wire anemometry in the endwall region of a high turning rotor blade cascade. It is shown that the levels of turbulence are very high in the regions of the flowfield containing the passage vortex and its associated loss core. A comparison with the total pressure loss measurements illustrates the mechanisms of loss generation within the cascade. The growth of the total pressure loss and turbulent kinetic energy were found to have similar distributions through the cascade. Author

A88-54327#

STRUCTURE OF TIP CLEARANCE FLOW IN AN ISOLATED AXIAL COMPRESSOR ROTOR

MASAHIRO INOUE and MOTOO KUROUMARU (Kyushu University, Fukuoka, Japan) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research supported by the Kurata Foundation. refs
(ASME PAPER 88-GT-251)

Ensemble-averaged and phase-locked flow patterns in various tip clearances of two axial compressor rotors were obtained by a periodic multisampling technique with a hot wire in the clearance and with a high response pressure sensor on the casing wall. A leakage flow region distinct from a through flow region exists at every clearance. In the case of a small tip clearance, the leakage jet flow interacts violently with the through flow near the leading edge, and a rolling-up leakage vortex decays downstream. As the clearance increases, a stronger leakage vortex comes into existence at a more downstream location, and a reverse flow due to the vortex grows noticeably. A scraping vortex is recognized at the pressure side near the trailing edge only for the small clearance. A horse-shoe vortex appears in the upstream half of the through flow region for every tip clearance. The solidity does not affect the flow pattern substantially except for the interaction of the leakage vortex with the adjacent blade and wake. Author

A88-54331#

NUMERICAL INTEGRATION OF THE 3D UNSTEADY EULER EQUATIONS FOR FLUTTER ANALYSIS OF AXIAL FLOW COMPRESSORS

G. A. GEROLYMOS (SNECMA, Moissy-Cramayel, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-255)

In order to analyze axial-flow compressor flutter, methods are required that compute the unsteady flow through vibrating cascades. A three-dimensional fully nonlinear method has been developed by numerically integrating the three-dimensional unsteady Euler equations, in the time-domain. The equations are discretized in a moving grid, which conforms with the vibrating blades and are integrated using the explicit MacCormack scheme, in finite-difference formulation. The method assumes a traveling-wave assembly mode of vibration. In this manner, the flow is computed in a single channel by applying the corresponding chorochronical periodicity condition at the permeable pitchwise limits. The blade vibratory mode is an input to the method obtained by a standard finite element method structural analysis code. A number of results are presented, for a transonic fan rotor, illustrating the possibilities of the method, both in started and unstarted supersonic flow conditions. Author

A88-54341#

AN EXPERIMENTAL INVESTIGATION OF A VORTEX FLOW CASCADE

YAN-PING TANG and MAO-ZHANG CHEN (Beijing Institute of Aeronautics and Astronautics, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-265)

A new type of compressor cascade, called the vortex flow cascade (shortly VFC), has been developed in the paper. The VFC is made up of the normal compressor cascade (shortly NCC) with NACA-65-0010 profile and vortex generator. Experiments are conducted for researching the effects of a large scale streamwise control vortex on the flow structure inside cascade passage. The results are encouraging. Based on the present investigation the vortical flow pattern and loss mechanism of VFC have been discussed. Author

A88-54343#

THE EFFECT OF THE REYNOLDS NUMBER ON THE THREE-DIMENSIONAL FLOW IN A STRAIGHT COMPRESSOR CASCADE

VACLAV CYRUS (Statni Vyzkumny Ustav Konstrukce Stroju, Bechovice, Czechoslovakia) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-269)

A straight compressor cascade of aspect ratio 2 was tested in a low speed tunnel within Reynolds number Re(1) = 45,000 - 150,000 and inlet flow angle alpha 1 = 35 - 48 deg. The profile of the blade was NACA 65-12-10. The purpose of the paper was to obtain data on three-dimensional flow in a straight cascade at low Reynolds numbers. Some experimental results on secondary flow have been made into simple correlation relations. Author

A88-54347#

A NEW VARIATIONAL FINITE ELEMENT COMPUTATION FOR AERODYNAMIC INVERSE PROBLEM IN TURBINES WITH LONG BLADES

REN QIN, FENMING YI, and HONGGUANG WANG (Harbin Institute of Technology, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-275)

A novel finite element computation for aerodynamic inverse problems in turbines with long blades is presented with allowance made for the effect of blade thickness, blade force, and other factors on aerodynamic parameters. A comparison is made between the computational results and those obtained using the finite difference method in noncurvilinear coordinates. It is noted that the present computer program can also be applied to the aerodynamic design of axial compressors with some modifications. K.K.

A88-54356#

NUMERICAL SIMULATION OF INVISCID TRANSONIC FLOW THROUGH NOZZLES WITH FLUCTUATING BACK PRESSURE

A. BOELCS, T. H. FRANSSON (Lausanne, Ecole Polytechnique Federale, Switzerland), and M. F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 14 p. Research sponsored by the National

Research Council. refs
(ASME PAPER 88-GT-287)
A numerical method based on the flux vector splitting approach is used to solve the problem of unsteady one-dimensional and two-dimensional inviscid transonic flow, with emphasis on the determination of the shock position through nozzles with time-varying back pressure. Both the amplitude and frequency of the imposed fluctuating exit pressure are found to be important parameters in locating the unsteady shock. It is also found that the average unsteady shock position is not necessarily identical with the steady-state position, and that an unsteady shock movement imposed by oscillating back pressure may introduce a significant lift and moment. R.R.

A88-54375*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE OF A SUPERSONIC COMPRESSOR CASCADE
T. L. TWEEDT (NASA, Lewis Research Center, Cleveland, OH), H. A. SCHREIBER, and H. STARKEN (DFVLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 13 p. refs
(ASME PAPER 88-GT-306)
Supersonic cascade wind tunnel results are presented for a linear, supersonic compressor cascade derived from the near-tip section of a high-throughflow axial flow compressor rotor over the inlet Mach number range of 1.30-1.71. Laser anemometry was used to obtain flow-velocity measurements showing the wave pattern in the entrance region. Attention is given to the unique-incidence relationship for this cascade, which relates the supersonic inlet Mach number to the inlet flow direction. An empirical correlation is obtained for the influence of the independent parameters of back pressure, axial velocity density ratio, and blade element performance. O.C.

A88-54869
NEAR-FIELD PRESSURE RADIATION AND FLOW CHARACTERISTICS IN LOW SUPERSONIC CIRCULAR AND ELLIPTIC JETS
E. GUTMARK, K. C. SCHADOW, K. J. WILSON, and C. J. BICKER (U.S. Navy, Naval Weapons Center, China Lake, CA) Physics of Fluids (ISSN 0031-9171), vol. 31, Sept. 1988, p. 2524-2532. refs
The near-field pressure fluctuations of circular and elliptic underexpanded supersonic jets were studied experimentally. Unlike the case of low subsonic jets, the pressure fluctuation characteristics at the minor axis plane of the elliptic jet were very different from those of the major axis plane. The amplitude of the pressure fluctuations at the minor axis was more than an order of magnitude higher than at the other plane. This section of the jet was also characterized by a larger spreading rate and higher amplification rate of the velocity fluctuations. The circular jet was similar to the major axis plane of the elliptic jet. The spectra of the near-field pressure fluctuations of both jets exhibited the highest peak at a frequency corresponding to the jets' preferred mode frequency. The spectral peak related to the screech tone was much stronger at the minor axis plane and had the same frequency as at the other plane. The amplitude of the dominant pressure fluctuation frequencies was mapped in the entire near field, and each one was found to be dominant in a different region. Author

A88-54907#
APPLICATION OF A HYBRID ANALYTICAL/NUMERICAL METHOD TO THE PRACTICAL COMPUTATION OF SUPERCRITICAL VISCOUS/INVISCID TRANSONIC FLOW FIELDS
G. R. INGER (Iowa State University of Science and Technology, Ames) IN: Developments in Mechanics. Volume 14(a) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 366-371.
A nonasymptotic triple deck theory of shock-turbulent boundary layer interaction has been applied to the analysis of transonic viscous/inviscid flows. The present method involves a global numerical inviscid flow region calculation based on a transonic small disturbance method coupled to a compressible turbulent boundary layer code. The local transonic shock/turbulent boundary-layer interaction is included as a local module in the shock location to produce a general hybrid inviscid boundary-layer interaction analysis code. R.R.

A88-54940#
INCOMPRESSIBLE INDICIAL RESPONSE OF INFINITE AIRFOILS IN TANDEM - SOME ANALYTICAL RESULTS
V. G. MENGLE (California, University, Los Angeles) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 857-862. refs
The aerodynamic response to arbitrary motion of infinite airfoils in tandem can be found from their indicial response. Such an indicial response is found here for the case of simultaneous step-change in the quasi-steady circulations of all the airfoils. In particular, the Laplace-transformed lift response is found in terms of Gauss hypergeometric functions and analytically studied in the complex Laplace-variable domain. The small-time asymptotic solution is shown to be derivable from that of the corresponding unstaggered cascade by simply replacing the blade gap d by jd, where j = sq rt -1. Then, 1-point Pade approximants are used to find the indicial response for small and large times, and it turns out to be oscillation-damped. The inadequacy of 1-point Pade approximants to represent the indicial response for all times is attributed to the Stokes phenomenon. Author

A88-54941# Purdue Univ., West Lafayette, Ind.
AERODYNAMICALLY FORCED RESPONSE OF AN AIRFOIL INCLUDING PROFILE AND INCIDENCE EFFECTS
HSIAO-WEI D. CHIANG and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 865-870. USAF-NASA-supported research. refs
A structural dynamics model is developed and utilized to predict the effects of airfoil profile, incidence angle, and two-dimensional gust direction on the aerodynamically forced response of an airfoil in an incompressible flow. An energy balance is performed between the unsteady aerodynamic work and the energy dissipated through the airfoil structural and aerodynamic damping, with predictions of the unsteady aerodynamics obtained from a complete first order model. It is then demonstrated that the steady aerodynamic loading and the gust direction strongly affect the amplitude of response. Also, classical thin airfoil unsteady aerodynamic models result in nonconservative predictions. Author

A88-54942#
THE AERODYNAMICS OF AN ANNULAR CASCADE OF THREE-DIMENSIONAL AIRFOILS
JOSEPH NEAL and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 871-876.
A series of experiments are described which quantify the aerodynamic performance of a three-dimensional airfoil row designed to operate over a wide range of incidence angles with low losses and no flow separation. The airfoils, designed at NASA-Lewis using an inverse, inviscid, design code with boundary layer correction, have a high thickness-to-chord ratio, spanwise varying flow turning, and a swept trailing edge to maintain constant solidity over the airfoil span. Author

A88-54943#
AERODYNAMICALLY FORCED RESPONSE OF STRUCTURALLY MISTUNED BLADED DISKS IN SUBSONIC FLOW

VINCENT R. CAPECE, GREGORY H. HENDERSON, and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 877-882.

The subsonic aerodynamically forced response of a structurally mistuned bladed disk is investigated by developing a mathematical model which includes the effects of aeroelastic coupling. A dual mode representative of the forced vibration is utilized together with a two-dimensional,inviscid, subsonic, unsteady aerodynamic airfoil cascade model. By considering a ten-bladed rotor, it is shown that the response mode and the unsteady aerodynamics determine if mistuning is beneficial. Author

A88-54944#
NONUNIFORM VANE SPACING EFFECTS ON ROTOR BLADE FORCED RESPONSE AND NOISE GENERATION
JOHN R. FAGAN, JR. and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 883-888.

A mathematical model is developed to analyze the effects on the rotor unsteady aerodynamics associated with altering the harmonic content of the rotor inlet flow field, accomplished by nonuniform circumferential spacing of the airfoils in the upstream vane row. The stator-rotor interactions are modeled by a cascade of rotor blades moving relative to a nonuniform circumferentially spaced stator vane cascade. The rotor inlet flow field is determined by tracking a typical rotor blade through the wakes of the stator row, with each velocity history decomposed into harmonic components. This model is then applied to a modern compressor configuration and the beneficial effects of nonuniform vane spacing on both forced response and noise generation demonstrated. Author

A88-54946#
PREDICTION OF TURBULENCE GENERATED RANDOM VIBRATIONAL RESPONSE OF TURBOMACHINERY BLADING
THOMAS E. BOOTH and SANFORD FLEETER (Purdue University, West Lafayette, IN) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 894-899. USAF-sponsored research.

An analysis is developed to predict the turbulence generated single-degree-of-freedom bending and torsion mode response of a blade row in a subsonic compressible flow field. The turbulence is assumed to be random in the neighborhood of the blade natural frequency of interest and to generate constant amplitude, harmonic, unsteady aerodynamic forces and moments on the blading with equally distributed frequencies. The resulting random vibrations thus occur at the blade natural frequency. The unsteady aerodynamics generated by the blade response and the effect of blade aerodynamic coupling are also considered. Author

A88-55077*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
MULTIGRID ACCELERATION OF THE FLUX-SPLIT EULER EQUATIONS
W. KYLE ANDERSON, JAMES L. THOMAS (NASA, Langley Research Center, Hampton, VA), and DAVID L. WHITFIELD (Mississippi State University, Mississippi State) AIAA Journal (ISSN 0001-1452), vol. 26, June 1988, p. 649-654. Previously cited in issue 07, p. 831, Accession no. A86-19784. refs

A88-55078#
EFFICIENT EULER SOLVER WITH MANY APPLICATIONS
GINO MORETTI (G.M.A.F., Inc., Freeport, NY) AIAA Journal (ISSN 0001-1452), vol. 26, June 1988, p. 655-660. Previously cited in issue 08, p. 1037, Accession no. A87-22576. refs

A88-55093#
QUADRATURE FORMULA FOR A DOUBLE-POLE SINGULAR INTEGRAL
RAJENDRA K. BERA (National Aeronautical Laboratory, Bangalore, India) AIAA Journal (ISSN 0001-1452), vol. 26, June 1988, p. 752-754.

Stark's (1971) quadrature formula for Cauchi integrals is presently extended in a straightforward fashion to evaluate the double-pole singular integrals typically encountered in linear lifting surface theory. The advantage of Stark's formula is that it is tailorable for integrands containing a weight function that is assumed to be positive and integrable, though not necessarily regular. O.C.

A88-55094*# North Carolina State Univ., Raleigh.
GRID EMBEDDING TECHNIQUE USING CARTESIAN GRIDS FOR EULER SOLUTIONS
R. A. MICHELTREE, H. A. HASSAN (North Carolina State University, Raleigh), and M. D. SALAS (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 26, June 1988, p. 754-756. refs
(Contract NCC1-22)

Grid-embedding techniques are presently applied to the solutions of the Euler equations on Cartesian grids for the NACA 0012 airfoil and the multielement SKF1.1 airfoil at transonic speeds. Based on comparisons with solutions on fine grids, it is shown that the present scheme, when used in conjunction with the Runge-Kutta time-stepping scheme as well as Cartesian grids, yields reduced memory requirements and a substantial reduction in computational time, without loss of accuracy. O.C.

A88-55313#
NUMERICAL SOLUTION OF THE HYPERSONIC VISCOUS SHOCK LAYER EQUATIONS WITH CHEMICAL NONEQUILIBRIUM
J. W. SHEN IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER ST-88-08)

The surface pressure distribution is measured for a blunt sphere-cone in a hypersonic wind tunnel to check the reliability of the numerical results of the implicit finite-difference scheme. The hypersonic nonequilibrium laminar flow over slender sphere-cone is calculated and the global continuity equation and normal momentum equation are solved. It is shown that schematic viscosity exists in the implicit finite-difference scheme, although the physical distortion due to the schematic viscosity is small and can be neglected in the body region. The numerical results are presented and compared with results using other methods. R.B.

N88-28860# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Civil Transport Aircraft Div.
DELTA WING CONFIGURATIONS
J. SZODRUCH *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 30-49 Apr. 1988
Avail: NTIS HC A20/MF A01

The flow field over a slender delta wing at angle of attack immersed in a supersonic stream can be divided into two characteristic regions. The windward or pressure side faces the oncoming flow and is strongly influenced by the bow shock wave; the leeward or suction side is dominated by the effects of inviscid/viscous interaction. It is mainly the leeward flow which is then affected by Reynolds number changes and especially these effects are discussed in more detail. In the past, for subsonic, transonic, and supersonic free stream Mach numbers the essential issue of design with slender wings, where vortices occur over the wing at virtually every flight condition, is to fix the location of the separation lines so that the vehicle is always controllable. This is why Reynolds number effects in these flow regimes were considered of secondary importance. On the other hand at hypersonic speeds the influence of Reynolds number on peak heating as well as on the development and size of characteristic patterns in the flow field are more important. Here hypersonic viscous interaction is dominating, especially near the wing apex, and the vortices induce high rates of heat transfer along the attachment line. The discussion is confined to free stream Mach numbers from high subsonic to supersonic. With respect to Reynolds number effects it is of major importance to define the different types of vortical flow in that velocity range and to consider the influence of wing geometry. Author

N88-28882*# Texas A&M Univ., College Station.
INVESTIGATION OF HELICOPTER ROTOR BLADE/WAKE INTERACTIVE IMPULSIVE NOISE
S. J. MILEY, G. F. HALL, and E. VONLAVANTE Jan. 1987 117 p
(Contract NCA2-OR-773-301)
(NASA-CR-177435; NAS 1.26:177435) Avail: NTIS HC A06/MF A01 CSCL 01A

An analysis of the Tip Aerodynamic/Aeroacoustic Test (TAAT) data was performed to identify possible aerodynamic sources of blade/vortex interaction (BVI) impulsive noise. The identification is based on correlation of measured blade pressure time histories with predicted blade/vortex intersections for the flight condition(s) where impulsive noise was detected. Due to the location of the recording microphones, only noise signatures associated with the advancing blade were available, and the analysis was accordingly restricted to the first and second azimuthal quadrants. The results show that the blade tip region is operating transonically in the azimuthal range where previous BVI experiments indicated the impulsive noise to be. No individual blade/vortex encounter is identifiable in the pressure data; however, there is indication of multiple intersections in the roll-up region which could be the origin of the noise. Discrete blade/vortex encounters are indicated in the second quadrant; however, if impulsive noise were produced here, the directivity pattern would be such that it was not recorded by the microphones. It is demonstrated that the TAAT data base is a valuable resource in the investigation of rotor aerodynamic/aeroacoustic behavior. Author

N88-28883# Max-Planck-Institut fuer Stroemungsforschung, Goettingen (West Germany).
NOISE GENERATION AND BOUNDARY LAYER EFFECTS IN VORTEX-AIRFOIL INTERACTION AND METHODS OF DIGITAL HOLOGRAM ANALYSIS FOR THESE FLOW FIELDS Interim Report No. 2, 28 Nov. 1987 - 28 Mar. 1988
G. E. MEIER 31 Mar. 1988 10 p
(Contract DAJA45-87-C-0051)
(AD-A194191) Avail: NTIS HC A02/MF A01 CSCL 20D

For the generation of impulsive sound waves caused by parallel interaction of a vortex and an airfoil in a plane flow field, two different mechanisms are responsible by experimental evidence. The first one originates from the area of the stagnation point of the airfoil: a temporal increase of pressure and density - in consequence of the incoming vortex - relaxes by sound wave emission, when the vortex vanishes behind the airfoils nose. This is called a compressibility wave. The second one is reasoned by a supersonic flow regime, which appears, when the stationary airfoil flow is augmented by the flow field of the vortex: at the shoulder of the airfoil we get an unsteady return to subsonics by a shock wave. This moves upstream after the vortex has passed and is named transonic wave. Evidently both mechanisms only occur, if the flow field at the airfoil is augmented by the vortex, i.e., the vortex has a special spin orientation with respect to the airfoil. GRA

N88-28884# University of Southern California, Los Angeles. Dept. of Aerospace Engineering.
UNSTEADY WATER CHANNEL Final Report, Dec. 1984 - Dec. 1987
CHIH-MING HO 29 Mar. 1988 15 p
(Contract AF-AFOSR-0064-85)
(AD-A194231; AFOSR-88-0466TR) Avail: NTIS HC A03/MF A01 CSCL 14B

When an airplane undergoes maneuvering, the motion includes many modes: pitching, plunging, translation, acceleration and deceleration. The aerodynamics of the first three types of motion are well-documented. The effects of acceleration and deceleration on the aerodynamic forces of a wing have not been explored in depth because a specially designed unsteady testing facility is necessary. The present water channel is able to provide a wide variety of free stream conditions. The test section of the water channel measures 18-in. by 18-in. and has a maximum flow rate of 3 ft/sec. In addition, a rotating gate provides programmable unsteady flow velocities. GRA

N88-28886# Florida State Univ., Tallahassee. Fluid Mechanics Research Lab.
UNSTEADY FLOW PAST AN NACA 0012 AIRFOIL AT HIGH ANGLES OF ATTACK Technical Report, Jul. 1986 - Dec. 1987
A. KROTHAPALLI, L. LOURENCO, and L. VANDOMMELEN 2 Mar. 1988 26 p
(Contract AF-AFOSR-0243-86)
(AD-A194650; FMRL-TR-2; AFOSR-88-0415TR) Avail: NTIS HC A03/MF A01 CSCL 01C

A whole field experimental technique, commonly referred to as Particle Image Velocimetry, was used for the measurement of the instantaneous two-dimensional velocity fields about an impulsively started NACA 0012 airfoil at high angles of attack. The velocity field was measured with sufficient accuracy, such that the time evolution of the vorticity field was obtained. The experiments were performed in a towing at a Reynolds number of 1400, based on the chord of the airfoil. For angles of attack greater than about 20 deg, the flow field at the upper surface of the airfoil show large scale vortical motions with the following time dependent scenario. At the initial stages of the airfoil startup, a separation bubble at the leading edge was generated and with time, it grows into an isolated primary vortex which dominated the whole flow field. Trailing behind this primary vortex were two counter rotating vortices. This multiple vortex structure grow together and move along the upper surface until it reaches the trailing edge. At this time, the primary vortex induces a trailing edge vortex. The primary and trailing edge vortices then form the wake flow field. GRA

N88-28887# Dayton Univ., Ohio. Research Inst.
AN INTEGRAL EQUATION FOR THE LINEARIZED UNSTEADY SUPERSONIC FLOW OVER A WING Final Report, May 1986 - Aug. 1987
KARL G. GUDERLEY Dec. 1987 79 p
(Contract F33615-86-C-3200)
(AD-A193773; UDR-TR-87-95; AFWAL-TR-87-3107) Avail: NTIS HC A05/MF A01 CSCL 20D

This report derives an integral equation for the linearized supersonic unsteady potential flow over a wing. Every integral equation formulation for a problem that appears originally in the form of a partial differential equation presupposes the availability of a fundamental solution. Such a fundamental solution is available for the problem at hand in the literature. It is rederived here to show its particular properties. The integral equation originally obtained requires one to carry out a limiting process in which one approaches the planform from above or below. This formulation is brought into a form in which this limiting process no longer appears and one works solely with information available at the planform. Examples which can be treated analytically bring some properties which have a bearing on a numerical approach into sharper focus. GRA

N88-28891*# Kansas Univ. Center for Research, Inc., Lawrence. Flight Research Lab.
CALCULATION OF AERODYNAMIC CHARACTERISTICS OF AIRPLANE CONFIGURATIONS AT HIGH ANGLES OF ATTACK Final Report
J. B. TSENG and C. EDWARD LAN Oct. 1988 116 p
(Contract NAG1-635)
(NASA-CR-4182; NAS 1.26:4182; CRINC-FRL-730-1) Avail: NTIS HC A06/MF A01 CSCL 01A

Calculation of longitudinal and lateral directional aerodynamic characteristics of airplanes by the VORSTAB code is examined. The numerical predictions are based on the potential flow theory with corrections of high angle of attack phenomena; namely, vortex flow and boundary layer separation effects. To account for the vortex flow effect, vortex lift, vortex action point, augmented vortex lift and vortex breakdown effect through the method of suction analogy are included. The effect of boundary layer separation is obtained by matching the nonlinear section data with the three dimensional lift characteristics iteratively. Through correlation with results for nine fighter configurations, it is concluded that reasonably accurate prediction of longitudinal and static lateral directional aerodynamics can be obtained with the VORSTAB code up to an angle of attack at which wake interference and forebody vortex effect are not important. Possible reasons for discrepancy at higher angles of attack are discussed. Author

N88-28893# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
MARION L. LASTER (Arnold Engineering Development Center, Arnold Air Force Station, Tenn.) Jul. 1988 13 p Presented at the AGARD Fluid Dynamics Panel Symposium, Naples, Italy, 28 Sep. - 1 Oct. 1987
(AGARD-AR-254; ISBN-92-835-0468-2) Avail: NTIS HC A03/MF A01

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on Aerodynamic Data Accuracy and Quality; Requirements and Capabilities in Wind Tunnel Testing, held in September 1987 in Naples, Italy. The major issues addressed were: what data acuracy is needed by users; what accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all these parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable. Author

N88-28894*# Boeing Commercial Airplane Co., Seattle, Wash.
VARIABLE SWEEP TRANSITION FLIGHT EXPERIMENT (VSTFE)-PARAMETRIC PRESSURE DISTRIBUTION BOUNDARY LAYER STABILITY STUDY AND WING GLOVE DESIGN TASK Contractor Report, Feb. 1983 - Nov. 1984
RODGER A. ROZENDAAL Washington, D.C. Jun. 1986 167 p
(Contract NAS1-15325)
(NASA-CR-3992; NAS 1.26:3992; D6-52511) Avail: NTIS HC A08/MF A01 CSCL 01A

The Variable Sweep Transition Flight Experiment (VSTFE) was initiated to establish a boundary-layer transition data base for laminar flow wing design. For this experiment, full-span upper-surface gloves will be fitted to a variable sweep F-14 aircraft. The results of two initial tasks are documented: a parametric pressure distribution/boundary-layer stability study and the design of an upper-surface glove for Mach 0.8. The first task was conducted to provide a data base from which wing-glove pressure distributions could be selected for glove designs. Boundary-layer stability analyses were conducted on a set of pressure distributions for various wing sweep angles, Mach numbers, and Reynolds number in the range of those anticipated for the flight-test program. The design procedure for the Mach 0.8 glove is described, and boundary-layer stability calculations and pressure distributions are presented both at design and off-design conditions. Also included is the analysis of the clean-up glove (smoothed basic wing) that will be flight-tested initially and the analysis of a Mach 0.7 glove designed at the NASA Langley Research Center. Author

N88-28895*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
STEADY AND UNSTEADY TRANSONIC PRESSURE MEASUREMENTS ON A CLIPPED DELTA WING FOR PITCHING AND CONTROL-SURFACE OSCILLATIONS
ROBERT W. HESS, F. W. CAZIER, JR., and ELEANOR C. WYNNE Washington, D.C. Oct. 1986 118 p MF as supplement
(NASA-TP-2594; L-16082; NAS 1.60:2594) Avail: NTIS HC A06/MF A01 CSCL 01A

Steady and unsteady pressures were measured on a clipped delta wing with a 6-percent circular-arc airfoil section and a leading-edge sweep angle of 50.40 deg. The model was oscillated in pitch and had an oscillating trailing-edge control surface. Measurements were concentrated over a Mach number range from 0.88 to 0.94; less extensive measurements were made at Mach numbers of 0.40, 0.96, and 1.12. The Reynolds number based on mean chord was approximately 10 x 10 to the 6th power. The interaction of wing or control-surface deflection with the formation of shock waves and with a leading-edge vortex generated complex pressure distributions that were sensitive to frequency and to small changes in Mach number at transonic speeds. Author

N88-29731# National Aeronautical Establishment, Ottawa (Ontario). Unsteady Aerodynamics Lab.
AIRCRAFT DYNAMICS: AERODYNAMIC ASPECTS AND WIND TUNNEL TECHNIQUES
K. J. ORLIK-RUECKEMANN *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 14 p Dec. 1987 Previously announced as N88-13320
Avail: NTIS HC A09/MF A01

The dynamic behavior of modern fighter aircraft depends more and more on unsteady aerodynamics. Until recently, the designer concentrated on classical problems such as aeroelasticity and flutter. Dynamic stability parameters were most often determined by low angle of attack calculation methods, without much recourse to experiment. The results obtained from the few dynamic experiments performed were used to confirm the absence of problems rather than as design parameters. New requirements for fighter aircraft performance include the ability to fly at high angles of attack in the presence of extensive regions of separated or vortical flows, relaxed static stability, greatly increased agility, and an interest in unorthodox geometries such as closely coupled canard or tail first configurations. The time lags and unsteady phenomena associated with flow fields resulting from rapid maneuvers and large amplitude motions significantly affect the dynamic behavior of modern fighter aircraft and become as important for aircraft design as the classical static performance criteria. A review is made of the various aerodynamic aspects affecting aircraft dynamic behavior and some experimental techniques. Author

N88-29747# Southwest Research Inst., San Antonio, Tex.
A STUDY OF THE EFFECT OF RANDOM INPUT MOTION ON LOW REYNOLDS NUMBER FLOWS Final Report, Sep. 1985 - Nov. 1987
JAMES F. UNRUH, JOEL T. PARK, and JAMES E. JOHNSON May 1988 64 p
(Contract N00014-85-C-0840)
(AD-A195559; SWRI-8814) Avail: NTIS HC A04/MF A01 CSCL 20D

The SwRI (Southwest Research Institute) large water tunnel was modified by the addition of a large test section (.71 m x .81 m x 1.8 m long) to provide low Reynolds number flows with low blockage for models in a highly separated flow condition. Flow characteristics are documented and other physical features are described. The feasibility of conducting water tunnel experiments involving unsteady aero-hydrodynamics was demonstrated by performing a series of flow visualization studies on a oscillating airfoil (NACA 0012). This experiment was carried out at a reduced frequency of 0.26 and at a Reynolds number of 50,000. For this condition, the flow was not fully separated until 17 degress angle of attack, and the downstream wash of the separated flow occurred at 22 degrees. GRA

N88-29750*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
THREE-DIMENSIONAL NAVIER-STOKES SIMULATIONS OF TURBINE ROTOR-STATOR INTERACTION
MAN MOHAN RAI Mar. 1988 6 p
(NASA-TM-100081; A-88106; NAS 1.15:100081) Avail: NTIS HC A02/MF A01 CSCL 01A

Fluid flows within turbomachinery tend to be extremely complex in nature. Understanding such flows is crucial to improving current designs of turbomachinery. The computational approach can be used to great advantage in understanding flows in turbomachinery. A finite difference, unsteady, thin layer, Navier-Stokes approach to calculating the flow within an axial turbine stage is presented. The relative motion between the stator and rotor airfoils is made possible with the use of patched grids that move relative to each other. The calculation includes endwall and tip leakage effects. An introduction to the rotor-stator problem and sample results in the form of time averaged surface pressures are presented. The numerical data are compared with experimental data and the agreement between the two is found to be good. Author

N88-29752*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
AERODYNAMICS IN GROUND EFFECT AND PREDICTED LANDING GROUND ROLL OF A FIGHTER CONFIGURATION WITH A SECONDARY-NOZZLE THRUST REVERSER
DANIEL W. BANKS Oct. 1988 131 p
(NASA-TP-2834; L-16435; NAS 1.60:2834) Avail: NTIS HC A07/MF A01 CSCL 01A

An experimental investigation of the in-ground effect aerodynamic characteristics and predicted landing-ground-roll performance of wing-canard fighter configuration with a secondary nozzle thrust reverser was completed. These tests were conducted in the Langley 14 by 22 foot Subsonic Wind Tunnel using a model equipped with a pneumatic jet for thrust simulation of nozzle pressure ratios up to 4.0. The model was tested in the landing rollout configuration at approx. wheel touchdown height for a range of decreasing dynamic pressure from 50 psf down to 10 psf. Landing-ground-roll predictions of the configuration were calculated using the wind tunnel results. Author

N88-29753*# National Aeronautics and Space Administration, Washington, D.C.
A PRELIMINARY INVESTIGATION OF DRAG REDUCTION AND MECHANISM FOR A BLUNT BODY OF REVOLUTION WITH SLANTED BASE
XUEJIAN XIA and XIAOSHEN YU Aug. 1988 17 p Transl. into ENGLISH from Acta Aerodynamica Sinica (People's Republic of China), v. 4, Mar. 1986 p 99-107 Transl. by Scientific Translation Service, Santa Barbara, Calif.
(Contract NASW-4307)
(NASA-TT-20349; NAS 1.77:20349) Avail: NTIS HC A03/MF A01 CSCL 01A

This is a preliminary study of the drag reduction effect and its mechanism of a blunt body of revolution with a 21-deg slant angle by using a series of base plates. Drag coefficients were measured to investigate the effect of base installation position and plate height. An effective drag reduction device was found. Through the measurement of base pressure and total pressure distribution and flow pattern display, flow characteristics and drag reduction mechanism in the vortex near the wake were investigated. Author

N88-29754*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
APPLICATION OF UNSTEADY AERODYNAMIC METHODS FOR TRANSONIC AEROELASTIC ANALYSIS
WOODROW WHITLOW, JR. Sep. 1988 10 p Presented at the 16th Congress of the International Council of the Aeronautical Sciences, Jerusalem, Israel, 28 Aug. - 2 Sep. 1988
(NASA-TM-100665; NAS 1.15:100665) Avail: NTIS HC A02/MF A01 CSCL 01A

Aerodynamic methods for aeroelastic analysis are applied to various flow problems. These methods include those that solve the three dimensional transonic small disturbance (TSD) potential equation, the two dimensional (2-D) full potential (FP) equation, and the 2-D thin layer Navier-Stokes equations. Flutter analysis performed using TSD aerodynamics show that such methods can be used to analyze some aeroelastic phenomena. For thicker bodies and larger amplitude motions, a nonisentropic FP method is presented. The unsteady FP equation is modified to model the entropy jumps across shock waves. The conservative form of the modified equation is solved in generalized coordinates using an implicit, approximate factorization method. Pressures calculated on the NLR 7301 and NACA 64A010A airfoils using the nonisentropic FP method are presented. It is shown that modeling shock generated entropy extends the range of validity of the FP method. A Navier-Stokes code is correlated with pressures measured on a supercritical airfoil at transonic speeds. When corrections are made for wind tunnel wall effects, the calculations correlate well with the measured data. Author

N88-29767# European Space Agency, Paris (France).
HISTORY OF AEROELASTICITY IN GERMANY FROM THE BEGINNING TO 1945
PETER BUBLITZ (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen, West Germany) Jul. 1988 466 p Transl. into ENGLISH of Geschicte der Entwicklung der Aeroelastik in Deutschland von den Anfaengen bis 1945 (Goettingen, Fed. Republic of Germany, DFVLR), Dec. 1986 319 p Original language document was announced as N88-10003
(ESA-TT-1082; DFVLR-MITT-86-25; ETN-88-93050) Avail: NTIS HC A20/MF A01; original German version available from DFVLR, VB-PL-DO, 90 60 58, 5000 Cologne, Fed. Republic of Germany 98 deutsche marks

The history of research into the aeroelasticity problems of airframes in Germany is outlined. It is shown that almost 20 yr elapsed after the beginning of powered flight before the physics of such aeroelasticity problems as static divergence and flutter were properly understood. Even then, it was not possible to avoid the aeroelastic problems which arose from the rapid progress of aviation at the time. This led to the continual introduction of new research topics. ESA

N88-29768# Army Aviation Systems Command, St. Louis, Mo.
TEST OF AN 0.8-SCALE MODEL OF THE AH-64 APACHE IN THE NASA LANGLEY FULL-SCALE WIND TUNNEL
FREDERICK A. RAITCH May 1988 49 p
(AD-A196129; USAAVSCOM-TM-87-D-5) Avail: NTIS HC A03/MF A01 CSCL 01A

This document summarizes the tests of an 0.8-scale model of the upper half of the AH-64 air vehicle in the NASA Langley full-scale tunnel, primarily to determine the large-scale blockage effects discovered during earlier tests of the same model in the NASA Langley 4- by 7-meter tunnel. As background information, and to provide continuity, the earlier program is outlined. The models were large and heavy, and therefore the balances had large capabilities. Yet, because of operational limitations with both wind tunnels involved, the only data that overlapped in flight conditions were at very low velocities. Thus, the results of these tests were inconclusive due to the time-honored difficulty of small differences in large numbers. This effect carried over into other, auxiliary tests performed during the same test series, each concerned with an attempt to detect small differences. GRA

N88-29769# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
ANGLE OF ATTACK AND SIDESLIP ESTIMATION USING AN INERTIAL REFERENCE PLATFORM M.S. Thesis
JOSEPH E. ZEIS, JR Jun. 1988 169 p
(AD-A194876; AFIT/GAE/AA/88J-2) Avail: NTIS HC A08/MF A01 CSCL 01B

Flight test concepts are developed for the estimation of angle of attack (alpha) and sideslip (beta) using an inertial reference platform. This development was further broken down into real-time, inflight estimation of alpha and post-flight estimation of alpha and beta. Following theoretical development, the concepts were tested with NASA F-15A flight data and examined real-time during a NASA Highly Integrated Digital Engine Control (HIDEC) flight test using the F-15A aircraft. Angle of attack is a critical parameter in the maneuverable, high performance aircraft of today. Yet many errors are present in the current methods of obtaining this angle. An accurate method of alpha and beta estimation could eliminate the need for such probes, and allow these quantities to be used for a broad range of applications. An inflight estimator was developed for computational speed and accuracy using inertial navigation system linear accelerations and angular rates. A second system based on linear recursive modeling was developed for post-flight estimation of alpha and beta. The data and programs specified in this research are applicable only to those aircraft mentioned, but the methods of estimation are universal. GRA

N88-29771*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
EULER ANALYSIS OF A SWIRL RECOVERY VANE DESIGN FOR USE WITH AN ADVANCED SINGLE-ROTATION PROPFAN
CHRISTOPHER J. MILLER 1988 15 p Presented at the 24th Joint Propulsion Conference, Boston, Mass., 11-13 Jul. 1988; sponsored by AIAA, ASME, SAE and ASEE
(NASA-TM-101357; E-4387; NAS 1.15:101357; AIAA-88-3152) Avail: NTIS HC A03/MF A01 CSCL 01A

Recent work has demonstrated the propulsive efficiency improvement available from single- and counter-rotation propfans as compared with current technology high bypass ratio turbofans. The concept known as swirl recovery vanes (SRV) is examined through the use of a 3-D Euler code. At high speed cruise conditions, the SRV can improve the efficiency level of a single-rotation propfan, but a concern is to have adequate hub choke margin. The SRV was designed with 2-D methods and was predicted to have hub choking at Mach 0.8 cruise. The 3-D Euler analysis properly accounts for sweep effects and 3-D relief, and predicts that at cruise the SRV will recover roughly 5 percent of the 10 percent efficiency loss due to swirl and have a good hub choke margin. Author

N88-29776*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
PRESSURE DISTRIBUTIONS FROM SUBSONIC TESTS OF AN ADVANCED LAMINAR-FLOW-CONTROL WING WITH LEADING- AND TRAILING-EDGE FLAPS
ZACHARY T. APPLIN and GARL L. GENTRY, JR. Jul. 1988 339 p
(NASA-TM-4040-PT-2; L-16405; NAS 1.15:4040-PT-2) Avail: NTIS HC A15/MF A01 CSCL 01A

An unswept, semispan wing model equipped with full-span leading- and trailing-edge flaps was tested in the Langley 14- by 22-Foot Subsonic Tunnel to determine the effect of high-lift components on the aerodynamics of an advanced laminar-flow-control (LFC) airfoil section. Chordwise pressure distributions near the midsemispan were measured for four configurations: cruise, trailing-edge flap only, and trailing-edge flap with a leading-edge Krueger flap of either 0.10 or 0.12 chord. Part 1 of this report (under separate cover) presents a representative sample of the plotted pressure distribution data for each configuration tested. Part 2 presents the entire set of plotted and tabulated pressure distribution data. The data are presented without analysis. Author

N88-29777# Rensselaer Polytechnic Inst., Troy, N.Y.
THEORETICAL AERODYNAMICS, TRANSONIC FLOW Final Report, 1 Jul. 1982 - 31 Oct. 1987
JULIAN D. COLE 12 Feb. 1988 5 p
(Contract AF-AFOSR-0155-82)
(AD-A196247; AFOSR-88-0656TR) Avail: NTIS HC A02/MF A01 CSCL 20D

A substantial body of work on transonic aerodynamics and problems using related applied mathematical techniques was carried out on this AFOSR grant. A listing of the main publications produced with the support of this grant is given. GRA

N88-29778*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
RECENT ADVANCES IN TRANSONIC COMPUTATIONAL AEROELASTICITY
JOHN T. BATINA, ROBERT M. BENNETT, DAVID A. SEIDEL, HERBERT J. CUNNINGHAM, and SAMUEL R. BLAND Sep. 1988 28 p Presented at the Symposium on Advances and Trends in Computational Structural Mechanics and Fluid Dynamics, Washington, D.C., 17-19 Oct. 1988
(NASA-TM-100663; NAS 1.15:100663) Avail: NTIS HC A03/MF A01 CSCL 01A

A transonic unsteady aerodynamic and aeroelasticity code called CAP-TSD was developed for application to realistic aircraft configurations. The code permits the calculation of steady and unsteady flows about complete aircraft configurations for aeroelastic analysis in the flutter critical transonic speed range. The CAP-TSD code uses a time accurate approximate factorization algorithm for solution of the unsteady transonic small disturbance potential equation. An overview is given of the CAP-TSD code development effort and results are presented which demonstrate various capabilities of the code. Calculations are presented for several configurations including the General Dynamics 1/9 scale F-16 aircraft model and the ONERA M6 wing. Calculations are also presented from a flutter analysis of a 45 deg sweptback wing which agrees well with the experimental data. Descriptions are presented of the CAP-TSD code and algorithm details along with results and comparisons which demonstrate these recent developments in transonic computational aeroelasticity. Author

N88-29779# Naval Ship Research and Development Center, Bethesda, Md. Aviation Dept.
ANALYSIS OF A FIXED-PITCH X-WING ROTOR EMPLOYING LOWER SURFACE BLOWING Final Report, Apr. 1985 - Sep. 1985
ALAN W. SCHWARTZ and ERNEST O. ROGERS Nov. 1987 27 p Presented at the Circulation Control Workshop, Moffett Field, Calif., 19-21 Feb. 1986 Previously announced as N88-17602 Submitted for publication
(AD-A187379; DTRC-87/045) Avail: NTIS HC A03/MF A01 CSCL 01A

Lower surface blowing (LSB) is investigated as an alternative to the variable blade pitch requirement for the X-wing Circulation Control (CC) rotor concept. Additional trailing edge blowing slots on the lower surfaces of CC airfoils provide a bidirectional lift capability that effectively doubles the control range. The operational requirements of this rotor system are detailed and compared to the projected performance attributes of LSB airfoils. Analysis shows that, aerodynamically, LSB supplies a fixed pitch rotor system with the equivalent lift efficiency and rotor control of present CC rotor designs that employ variable blade pitch. Aerodynamic demands of bidirectional lift production are predicted to be within the capabilities of current CC airfoil design methodology. Emphasis in this analysis is given to the high speed rotary wing flight regime unique to stoppable rotor aircraft. The impact of a fixed pitch restriction in hover and low speeed flight is briefly discussed. Author

N88-29781# National Aeronautical Establishment, Ottawa (Ontario).
THE USE OF HOT-FILM TECHNIQUE FOR BOUNDARY LAYER STUDIES ON A 21 PERCENT THICK AIRFOIL
M. KHALID May 1987 54 p
(NAE-AN-45; NRC-27892) Avail: NTIS HC A04/MF A01

A heat transfer method of studying boundary layer flows over airfoils at transonic test conditions was investigated. The method employs very thin DISA hot-film gauges housing Constant

Temperature Anemometer probes. Provided that the thickness dimension of the films remains less than the critical disturbances height for inducing transition of the laminar boundary layer, the heat transfer response from the films, positioned carefully on the model surface, can be studied to determine the boundary layer characteristics. Results from an application study on a 21 percent thick laminar flow airfoil model are presented and dissussed.
Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A88-53540
CARING FOR THE HIGH-TIME JET
J. M. RAMSDEN and JOHN MARSDEN Flight International (ISSN 0015-3710), vol. 134, Sept. 3, 1988, p. 153-156.

An investigative account is given of the factors that led to the catastrophic fuselage pressurized structure failure of Aloha N73711, a B737-200 airliner with 89,000 flights completed over its long career. Structural failure may have been initiated by a tear along the lap joint at either one of two different stringers; the explosive decompression may then have bent the right window panel outwards, ripping the rest of the section around the butt-joints, and tearing it raggedly off below floor level on the left side of the aircraft. Attention is presently given to the characteristics of a typical fuselage lap joint. O.C.

A88-54400
ICING TECHNOLOGY BIBLIOGRAPHY
SAE Aerospace Information Report SAE AIR 4015, Nov. 1987, 149 p. refs
(SAE AIR 4015)

A compendium of references from the open literature on icing technology is presented, including both national and foreign sources. The general topics addressed include: meteorology of icing clouds, meteorological instruments, propeller icing, induction system icing, gas turbine engine and inlet icing studies, wing icing, windshield icing, ice adhesion and mechanical properties, heat transfer, helicopter climatic tests and icing, and helicopter rotor blade icing. Other general subjects considered are: engine snow ingestion and snow measurements, droplet trajectories and impingement, ice accretion modeling, icing test facilities and icing simulation, aircraft ice formation, runway icing, microwave sensing and ice protection systems, iced airfoil performance, land and sea ice studies, fluid and two-phase flow dyanmics, liquid evaporation and ice crystal formation studies, electrical modeling, and radome icing. C.D.

A88-55288
A PROFILE OF US AIR FORCE AIRCRAFT MISHAP INVESTIGATION
JOSEPH F. TILSON (USAF, Directorate of Aerospace Safety, Norton AFB, CA) IN: ISTFA 1987 - International Symposium for Testing and Failure Analysis: Advanced materials; Proceedings of the Symposium, Los Angeles, CA, Nov. 9-13, 1987. Metals Park, OH, ASM International, 1987, p. 159-162.

An account is given of the administrative organization and roles of the USAF Safety Investigation Board (SIB), whose primary function is to ascertain the causes of mishaps. Attention is given to the SIB president's management of a given investigation and the function of engineers and laboratory analysts. It is noted that technological advancements are significantly affecting SIB analyses of mishaps, in the form of crash-survivable flight data recorders, failure analyses of composite materials, fly-by-wire/fly-by-light flight control systems, and advanced maneuvering flight profiles. O.C.

A88-55290
HELICOPTER CREW SEAT FAILURE ANALYSIS
JOHN G. COWIE (U.S. Army, Materials Technology Laboratory, Watertown, MA) IN: ISTFA 1987 - International Symposium for Testing and Failure Analysis: Advanced materials; Proceedings of the Symposium, Los Angeles, CA, Nov. 9-13, 1987. Metals Park, OH, ASM International, 1987, p. 171-178.

A failure analysis was conducted on a helicopter crew seat which failed during an FAA simulated crash survivability test. This seat is an advanced composite of ultrahigh strength steel and Kevlar. The failure which resulted in the steel fracturing into several pieces was due to a small crack emanating from one of the shock-absorber mounting holes. Stresses generated during the crash test achieved high enough levels to propagate the small crack. The exact initiation site was the tensile (aft) side of the shock-absorber mounting hole. In addition to the small crack, the inside surface of the hole exhibited many deep 'score-marks' as a result of poor machining practice. The small crack originated from one of these score-marks. Mechanical property tests conducted on the steel proved the material to be within specification. However, the relatively low fracture toughness and Charpy energy enabled the small crack to easily propagate at the design stress. Author

N88-28896*# Nevada Univ., Reno. Engineering Research and Development Center.
AERODYNAMICS OF SEEING ON LARGE TRANSPORT AIRCRAFT Final Technical Report, 1 Dec. 1985 - 30 Nov. 1986
WILLIAM C. ROSE 15 Aug. 1988 4 p
(Contract NCC2-382)
(NASA-CR-183122; NAS 1.26:183122) Avail: NTIS HC A02/MF A01 CSCL 01C

Efforts were undertaken to obtain a set of data that examined the level of turbulence and the scale sizes in the shear layer existing over the fence quieted cavity on the NASA-Ames Kuiper Airborne Observatory (KAO). These data were to be taken during the present study and compared with data taken from previous wind tunnel experiments, for which both aerodynamic and direct optical measurements were made. The data obtained during the present study were presented and discussed in light of their impact on the quality of optical images, that is, seeing through the shear layer. In addition, scaling relationships were presented that allow optical data obtained in one aerodynamic environment to be estimated for another one at perhaps different Mach numbers, scale sizes, or aircraft configurations. Author

N88-28898 Civil Aviation Authority, London (England).
SMOKE HOODS: NET SAFETY BENEFIT ANALYSIS
Nov. 1987 25 p
(CAA-PAPER-87017; ISBN-0-86-039330-5; ETN-88-92653) Avail: Civil Aviation Authority, Greville House, 37 Gratton Road, Cheltenham, United Kingdom 7 pounds

The benefits to airline passengers of smoke hoods were assessed by studying past accidents. It is concluded that the provision of effective passenger smoke hoods in public transport aircraft of more than 30 seats would result in a modest saving of life. The analysis shows that the saving expected is of the order of 9 fire related deaths per year world-wide if the accident/fire history of the past 20 yr is broadly repeated. This total would be massively reduced if credit is taken for lavatory fire precautions in the VARIG B707 near Orly (France) in 1973. The analysis also shows that even if the wearing of smoke hoods results in a delayed or slower evacuation, the net benefit remains positive, but reduced. ESA

N88-28899# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Stuttgart (West Germany). Inst. fuer Bauweisen und Konstruktionsforschung.
CRASH SIMULATION CALCULATIONS AND COMPONENT IDEALIZATION FOR AN AIRFRAME. COMPUTER CODE KRASH 79 [CRASHSIMULATIONSRECHNUNGEN UND BAUTEILIDEALISIERUNG FUER EINEN FLUGZEUGUNTERBODEN. RECHENCODE KRASH 79]

WOLFGANG G. HIENSTORFER 28 Jan. 1987 164 p In GERMAN
(ETN-88-92971) Avail: NTIS HC A08/MF A01

A metal airframe of an aircraft of the weight class 3T was investigated in crash cases with a mainly vertical impact component using the simulation program KRASH 79. The results of the simulation calculations are shown in the form of acceleration/time evolutions of the discretized masses of the idealized structure and of structural displacements in the frame. The deformation behavior of a given seat structure was determined, and the dynamic-response index allows one to predict back injuries. Configuration-typical force/displacement characteristics under axial pressure loading were obtained in dimensionless form, allowing the determination of the dynamic response of the airframe. ESA

N88-28900*# National Aeronautics and Space Administration, Washington, D.C.
CONTRIBUTIONS TO THE MODELING OF WIND SHEAR FOR DANGER STUDIES
MANFRED SWOLINSKY Sep. 1988 190 p Transl. into ENGLISH of Beitraege zur Modellierung von Scherwind fuer Gefaehrdungsuntersuchungen (Brunswick, Fed. Republic of Germany, Technischen Univ. Carolo-Wilhelmina), Apr. 1986 200 p Original language document was announced as N88-10463 Transl. by Scientific Translation Service, Santa Barbara, Calif.
(Contract NASW-4307)
(NASA-TT-20293; NAS 1.77:20293) Avail: NTIS HC A09/MF A01 CSCL 01C

Wind models for flight simulation and the study of the danger during landing due to wind shear were developed. It is demonstrated that the typical wind conditions in weather phenomena such as thunderstorm downdrafts and surface boundary layer wind shear can be approximated by simple engineeringf models, whereby known solutions and flow forms from flow mechanics were adapted. The good agreement between models and airborne measurements is demonstrated. Based on the developed models the degree of danger during landing under different wind shear conditions was estimated. Author

N88-29783# Loughborough Univ. of Technology (England). Dept. of Transport Technology.
AN ANALYSIS OF TIME AND SPACE REQUIREMENTS FOR AIRCRAFT TURNROUNDS
ROBERT E. CAVES Aug. 1987 41 p
(TT-8705) Avail: NTIS HC A03/MF A01

By their very nature, airport aprons occupy the space between the runway system and the terminal buildings. Most attempts to increase runway capacity, by the use of parallel taxiways or larger aircraft, reduce the available apron space. Similarly, the growth of piers and satellites to provide extra gates also restricts the apron. The situation is worsened further when more space is required for passenger processing, due to the rate of increase of processing efficiency not keeping pace with traffic growth, yet there is no room for landsite expansion. Discussed is the influence of aircraft technology on apron capacity Author

N88-29785# Army Aviation Engineering Flight Activity, Edwards AFB, Calif.
JUH-1H REDESIGNED PNEUMATIC BOOT DEICING SYSTEM FLIGHT TEST EVALUATION Final Report, 15 Nov. 1983 - 7 Mar. 1986
MATTHEW S. GRAHAM, LORAN A. HAWORTH, and JACK L. KIMBERLY Aug. 1987 144 p
(AD-A194918; USAAEFA-83-13) Avail: NTIS HC A07/MF A01 CSCL 08L

The U.S. Army Aviation Engineering Flight Activity conducted an evaluation of the Pneumatic Boot Deicing System (PBDS) with two pneumatic deicer boot designs, referred to as second and third generation. The objective of the test was to conduct feasibility testing of the pneumatic system concept for deicing helicopter rotor blades in forward flight, and to assess any changes to aircraft performance and handling qualities. Phase 1 consisted of a ground and inflight structural loads survey which established an operational envelope. Phase 2 consisted of forward flight testing in artificial and natural icing conditions of the second generation design only. Phase 3 consisted of limited artificial rain erosion tests of the second generation design. Phase 4 consisted of performance and handling qualities evaluation of the second generation design. Hover and level flight performance were greatly improved over the first generation, but a significant performance penalty still exists. Handling qualities were essentially unchanged from the standard UH-1H. Two unsatisfactory and six undesirable reliability and maintainability characteristics were identified. GRA

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

A88-52952
MICROPROCESSOR FUNCTIONAL-ADAPTIVE PROCESSING OF SIGNALS OF RADIO-NAVIGATION SYSTEMS IN AN ONBOARD SUBSYSTEM [MIKROPROTSESSORNAIA FUNKTSIONAL'NO-ADAPTIVNAIA OBRABOTKA SIGNALOV SISTEM RADIONAVIGATSII V BORTOVOI PODSISTEME]
A. K. BERNIUKOV *Radiotekhnika (ISSN 0033-8486)*, July 1988, p. 78-83. In Russian. refs

The paper presents an analysis of the feasibility of digital functional-adaptive processing in the case of a microprocessor implementation of an onboard receiver of the angle-measurement channel of a pulse-time aircraft navigation and landing system of MLS type and of a shoran system. An algorithm for eliminating the effect of multipath noise on the navigation/landing system is examined. B.J.

A88-53628#
PROCESSING PSEUDO SYNTHETIC APERTURE RADAR IMAGES FROM VISUAL TERRAIN DATA
M. E. STURGELL (USAF, Avionics Laboratory, Wright-Patterson AFB, OH) and J. R. LEWONSKI (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 10-16.
(AIAA PAPER 88-4576)

The paper discusses a solution in the area of simulating synthetic aperture radar (SAR) high resolution map imagery from terrain board visual data to aid a pilot in determining safe landing vectors on bomb-damaged runways. The visual data were obtained from a terrain board system using a method that considered image centers, rotations, and fields-of-view. The image processing software was developed to convert the collected still images into pseudo-SAR images. A program was written to process and store the large number of pseudo-SAR images onto a videodisc as an ordered library. This library was randomly accessed and displayed in a real-time flight simulation through a videodisc based system. After the pilot designated a reasonable touchdown point on the SAR cockpit display the simulation host passed the appropriate coordinates to the Inertial Navigation Systems which computed the proper approach vector for display. Author

N88-28906# Royal Signals and Radar Establishment, Malvern (England).
FINE RESOLUTION ERRORS IN SECONDARY SURVEILLANCE RADAR ALTITUDE REPORTING
D. B. JENKINS, B. A. WYNDHAM, and P. BANKS Jan. 1988 45 p Sponsored by the Civil Aviation Authority, London, United Kingdom
(RSRE-87019; BR106199; ETN-88-93137) Avail: NTIS HC A03/MF A01

Faults in the three C bits used to encode the fine resolution part of the secondary surveillance radar (SSR) pressure altitude message, for use in airborne collision avoidance systems, were investigated for aircraft using UK airspace and transmitting SSR Mode A Identification Codes other than the Conspicuity Codes 4321 and 4322. Of 132,773 aircraft trajectories investigated, 581 trajectories, involving at least 68 aircraft, exhibit a C bit fault, a frequency of occurrence of 0.44 percent. On the basis of SSR Mode A Identification Code, aircraft in a sample of 44,191 trajectories were identified and examined separately involving those undertaking international flights under civil air traffic control (ATC), those undertaking domestic flights under civil ATC, those receiving a service from military ATC, and those transmitting codes issued by airport approach ATC. The frequency of C bit faults varies significantly according to the type of flight, and is particularly high among aircraft transmitting approach codes, suggesting that the overall frequency found in any given volume of airspace depends on the types of flight undertaken in that airspace, and might be high in the vicinity of airport approaches. ESA

N88-28907 Civil Aviation Authority, London (England).
UK AIRMISSES INVOLVING COMMERCIAL AIR TRANSPORT
Apr. 1988 66 p
(CAA-1/88; ISSN-0951-6301; ETN-88-93146) Avail: Civil Aviation Authority, Greville House, 37 Gratton Road, Cheltenham, United Kingdom

Airmiss statistics from 1977 to Aug. 1987 for United Kingdom airspace are presented. Reports of incidents are summarized. ESA

N88-29788 Eurocontrol Experimental Centre, Bretigny (France).
OBSERVED TRACK-KEEPING PERFORMANCE OF DC10 AIRCRAFT EQUIPPED WITH THE COLLINS AINS-70 AREA NAVIGATION SYSTEM: KARLSRUHE AND MASSTRICHT UACS (UPPER AREA CONTROL CENTRES) Report, Mar. 1982 - Oct. 1984
L. CLARKE, H. DAVID, and W. OENEMA Feb. 1987 92 p
(EEC-202) Avail: NTIS HC E05/MF E05; copy not available from STI Facility CSCL 17G

The results are described which were obtained from data on 964 flights by DC10 aircraft equipped with the Collins AINS-70 Area Navigation System which is based on automatic double DME updating of inertial sensors. Author

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A88-52375
JUMP STRUT MEANS SHORTER TAKEOFF ROLLS
JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 8, Sept. 1988, p. 17-19.

A 'jump strut'-equipped nose landing gear can cut fighter aircraft takeoff roll lengths in half; alternatively, that capability can be translated into a 25-percent payload increase when enough runway distance is available for a normal ground roll. It is presently noted that the jump strut system can be retrofitted to existing aircraft landing gears, with only a modest increase in weight. Whereas a typical tactical aircraft may require 1000 feet of runway for a takeoff speed of 140 knots, the same aircraft could be airborne at 500 feet, with only a 100-knot takeoff speed. NASA-Ames has investigated the application of the jump strut principle to the Quiet STOL Research Aircraft. O.C.

A88-52651
NEW MATERIALS AND FATIGUE RESISTANT AIRCRAFT DESIGN; PROCEEDINGS OF THE FOURTEENTH ICAF SYMPOSIUM, OTTAWA, CANADA, JUNE 8-12, 1987
DAVID L. SIMPSON, ED. (National Aeronautical Establishment Ottawa, Canada) Symposium sponsored by the International Committee on Aeronautical Fatigue. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, 641 p. For individual items see A88-52652 to A88-52673.

The present conference discusses damage tolerance in pressurized fuselages, the fatigue of mechanically-alloyed Al, the fatigue behavior of adhesively-bonded aircraft structures, the modeling and analysis of the effect of 'cold-working' on fatigue life, the damage tolerance of an Arall lower wing skin panel, and the concise description and reconstruction of spectrum loading. Also discussed are the use of composite materials to repair metallic structures, the effect of thickness on crack growth rate, the transition to novel structural technologies for new aircraft, the impact and damage-tolerance properties of CFRP, and the damage tolerance of impact-damaged CFRP wing skin laminates. O.C.

A88-52652
DAMAGE TOLERANCE IN PRESSURIZED FUSELAGES
T. SWIFT (Douglas Aircraft Co., Long Beach, CA) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 1-77. refs

The fatigue and damage tolerance capability of pressurized fuselage structure is extremely sensitive to stress level, geometrical design, and material choice. Considerable improvements have been made in designing fuselage structure to sustain large, obviously detectable damage. The historical evolution of these improvements is discussed. Consideration is given to the difficulties and current concerns associated with in-service, noninspectable, multisite damage within a damage tolerance philosophy that depends upon inspection. Recommendations are given related to operating stress level, design detail, and material choice required for long service life and large damage capability of minimum-gage pressurized structure. Author

A88-52653
FATIGUE CRACK GROWTH CHARACTERIZATION OF JET TRANSPORT STRUCTURES
M. MILLER, V. K. LUTHRA, and U. G. GORANSON (Boeing Commercial Airplane Co., Seattle, WA) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 79-125. refs

Structural airworthiness requirements for new and maturing jet transports include demonstration of damage tolerance and an assurance that damage will be detected before safety is affected. This paper describes aspects of the development of structural inspections on Boeing models 757 and 767 and the implications in terms of fatigue crack growth analysis techniques used to support damage detection assessments. A simple analytical crack growth model is described and correlated with an extensive test data base, including the key variables of spectrum type, thickness, material, and load sequence effects. This model is shown to predict crack growth to an accuracy suitable for engineering assessment by large teams of analysts. Author

A88-52654
EVALUATION OF NEW MATERIALS IN THE DESIGN OF AIRCRAFT STRUCTURES
M. IOANNOU, L. J. KOK, T. M. FIELDING, and N. J. MCNEILL (de Havilland Aircraft Company of Canada, Ltd., Downsview) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 127-149.

Experimental and analytical evaluations of Al-Li alloys and Arall have been performed to determine their suitability as candidate materials in the design of aircraft structures. A description of the analytical approach and the experimental results are presented.

The cost effectiveness of their application is also addressed. Author

A88-52659
ASPECTS OF THE FATIGUE BEHAVIOUR OF TYPICAL ADHESIVELY BONDED AIRCRAFT STRUCTURES
A. GALASSO, A. DEL CORE (Aeritalia S.p.A., Gruppo Velivoli da Trasporto, Naples, Italy), A. LANCIOTTI, and L. LAZZERI (Pisa, Universita, Italy) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 227-262. refs

An evaluation has been made of the prospects for the extension of structural adhesive bonding techniques to primary aircraft structures, especially for the construction of selected fuselage panels of the ATR 72 aircraft. Attention is given to the results of an evaluation of the fatigue behavior typical of fighter aircraft structures. The adhesive presently employed, AF-163, is easy to use in production runs, and has been found to yield performance levels that render this technology safe from the viewpoint of fatigue. O.C.

A88-52660
USE OF COMPOSITE MATERIALS TO REPAIR METAL STRUCTURES
C. A. ELKINS (Central Servicing and Development Establishment, Norfolk, England) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 263-282.

The background to the use of composite materials to repair metal structure is described with a summary of the types of material used. The patch design and repair procedure are given in detail, together with the limitations on the use of this method of repair. Six applications are briefly described with photographs of the individual repairs and reinforcements. A summary of the current applications is given before future applications are discussed. Author

A88-52662
FATIGUE CRACK PROPAGATION TEST PROGRAMME FOR THE A320 WING
I. G. GRAY (British Aerospace, PLC, Civil Aircraft Div., Bristol, England) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 297-335. Research supported by British Aerospace, PLC. refs

This paper presents the results from an A320 crack propagation coupon test program. It shows the effect of gust truncation, active gust load alleviation, low level gust omission and ground load spectra truncation on the crack propagation lives for three different aluminum alloys, L97 (2024-T351), 7010-T7651 and 7150-T651. Author

A88-52665
ACCOUNTING FOR SERVICE ENVIRONMENT IN THE FATIGUE EVALUATION OF COMPOSITE AIRFRAME STRUCTURE
JOHANN J. GERHARZ, MATTHIAS BERG (Fraunhofer-Institut fuer Betriebsfestigkeit, Darmstadt, Federal Republic of Germany), and OGUZ GOEKGOEL (Messerschmitt-Boelkow-Blohm GmbH, Hamburg, Federal Republic of Germany) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 403-424. Research supported by Messerschmitt-Boelkow-Blohm GmbH; Bundesministerium der Verteidigung. refs
(Contract BMVG-RUEFO-4)

In fatigue proof testing of large composite structures only incomplete simulation of expected environment is economically feasible. To account for missing environmental effects application of the compensation factor concept is proposed. The compensation factors were derived from coupon specimen testing with the simplistic loading for large composite structures and with quasi-realistic environmental fatigue loading. Details of test results, their application to design and proof of the composite structure, and the testing procedure are given. Author

A88-52666
ENSTAFF - A STANDARD TEST SEQUENCE FOR COMPOSITE COMPONENTS COMBINING LOAD AND ENVIRONMENT
DIETER SCHUETZ and JOHANN J. GERHARZ (Fraunhofer-Institut fuer Betriebsfestigkeit, Darmstadt, Federal Republic of Germany) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 425-444. refs

The development of a loading standard for tests with composites combining mechanical loads with temperature cycles in a flight-by-flight program is described. Special attention is also paid to the moisture preconditioning of specimen and the moisture management during the test. Author

A88-52668
DAMAGE TOLERANCE ASPECTS OF AN EXPERIMENTAL ARALL F-27 LOWER WING SKIN PANEL
L. H. VAN VEGGEL, A. A. JONGEBREUR (Fokker Aircraft, Amsterdam, Netherlands), and J. W. GUNNINK (Delft, Technische Hogeschool, Netherlands) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 465-502. refs

This paper deals with the damage tolerance aspects of structures built from ARALL. After a brief introduction of the design of the ARALL F27 panel, the damage tolerance aspects of the panel itself and detail components are discussed. Attention is given to ARALL coupon properties and results of fatigue tests on structural parts. A comparison is then made with the results of the all metal wing panel configuration. The structural performance of ARALL laminates is excellent in tension-loaded-fatigue prone areas due to the good damage tolerance properties of this material. Author

A88-52670
DAMAGE TOLERANCE OF IMPACT DAMAGED CARBON FIBRE COMPOSITE WING SKIN LAMINATES
T. J. VAN BLARICUM, D. S. SAUNDERS, G. CLARK, and T. E. PREUSS (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 537-556. refs

This paper describes the work ARL has carried out in developing static and fatigue compression test procedures for large gage area specimens, as well as work currently underway in the development of NDI techniques for assessment of the defects in composites. Also described briefly are the results of a number of experimental programs which have been completed or are currently in progress. Author

A88-52671
IMPACT AND DAMAGE TOLERANCE PROPERTIES OF CFRP SANDWICH PANELS - AN EXPERIMENTAL PARAMETER STUDY FOR THE FOKKER 100 CA-EP FLAP
L. H. VAN VEGGEL (Fokker Aircraft, Amsterdam, Netherlands) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 557-583.

As a part of the development work on the Fokker F100 flap, a parameter study was performed to investigate the effect of different impact parameters, fatigue parameters and material parameters on the impact and damage tolerance properties of sandwich panels. The objective of the program was to determine how to treat impact damage during the certification program of the Fokker F100 CFRP-flap, to identify the most important parameters and to determine the allowable strain level. Author

A88-52672
CERTIFICATION OF PRIMARY COMPOSITE AIRCRAFT STRUCTURES
R. S. WHITEHEAD (Northrop Corp., Aircraft Div., Hawthorne, CA) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 585-617. refs

An evaluation is made of lessons learned in the course of two major USAF composite primary structures R&D programs, in order to formulate a series of recommended certification procedures. Attention is given to static strength, fatigue/durability, and damage tolerance. It is noted that (1) composite structures are uniquely sensitive to out-of-plane loads; (2) a multiplicity of potential failure modes exists; and (3) the failure modes of full-scale structures are difficult to predict; however, (4) static strength testing is able to identify structural 'hot spots'. O.C.

A88-52673
STRUCTURAL TECHNOLOGY TRANSITION TO NEW AIRCRAFT
JOHN W. LINCOLN (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 619-629.

The method presented has been developed in order to ensure that a given structural technology can be successfully transferred from the laboratory to the full-scale development of an aircraft. Five factors are noted to be common to past successful transfers of novel technologies: (1) stabilized processing methods for the materials in question; (2) producibility; (3) well-characterized materials properties; (4) the predictability of structural performance; and (5) supportability. The aircraft development schedule must be taken into account when the data base for each of these factors is established. O.C.

A88-52692#
TECHNOLOGY OF FLIGHT SIMULATION
V. SRINIVAS (Aeronautical Development Establishment, Bangalore, India) (Seminar on Pilot Training through Flight Simulators, Bangalore, India, Apr. 3, 4, 1987) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 39, Nov. 1987, p. 143-152. refs

The design and performance of flight simulators used for the training of Indian military and commercial pilots are reviewed. Topics discussed include the requirements for environmental and equipment cues; the generation of motion, visual, control-feel, instrument, aural, navigation and communication, and flight cues; the simulation computer system; real-time interfaces; and the instructor station. A flow chart and photographs of the military simulator are provided, and the effectiveness and cost-efficiency of simulator training are demonstrated on the basis of statistical data. T.K.

A88-52697#
POSSIBLE FUTURE DEVELOPMENTS OF MOTORGLIDERS AND LIGHT AIRCRAFT
PIERO MORELLI (Torino, Politecnico, Turin, Italy) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 39, Nov. 1987, p. 179-188.

After a brief review of the development of light aircraft and sailplanes in the past 50 years, the basic innovations in sailplane technology are outlined. The recent development of motor gliders is then illustrated. In order to stimulate the development of light aircraft with low operational costs, a new type of competition is suggested where speed and fuel consumption are both taken into accout. Finally, the possible development of a self-sustaining motor glider is considered. Author

A88-53149#
PROPULSION SYSTEM INTEGRATION FOR MACH 4 TO 6 VEHICLES
VICTOR SALEMANN (Boeing Co., Seattle, WA) and MARK ANDREWS (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 19 p. (AIAA PAPER 88-3239A)

A comparative evaluation is conducted of alternative powerplants and their integration with vehicle inlet and exhaust geometries for the Mach 4-6 flight regime. The powerplant cycles in question are the turbojet, turbofan, variable-cycle turbofan, ejector turbofan, and air turboramjet; their prospective performance is considered in view of the various inlet, ducting, and exhaust system design requirements. Three basic integrations of twin engine installations with Mach 6 vehicle fuselage/wing configurations are formulated and compared with respect to takeoff gross weight for a given mission. O.C.

A88-53161#
COOL GAS GENERATOR SYSTEMS
ROBERT D. PEHA and J. SCOTT NEISH (Rocket Research Co., Redmond, WA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 5 p. (AIAA PAPER 88-3363)

The paper describes the operation and application of three cool gas generator systems used for emergency/recovery purposes in the CH-46 helicopter emergency flotation system, 747 emergency escape slide, and Torpedo MK 50 buoyancy. All of these inflation systems utilize a solid propellant gas generator to initially pressurize a working fluid before expulsion from the inflator. Consistent operation over a wide storage temperature range and tailorable gas temperature are among the advantages of these systems. K.K.

A88-53249
THE MINIMISATION OF HELICOPTER VIBRATION THROUGH BLADE DESIGN AND ACTIVE CONTROL
S. P. KING (Westland Helicopters, Ltd., Yeovil, England) Aeronautical Journal (ISSN 0001-9240), vol. 92, Aug.-Sept. 1988, p. 247-263.

A treatment is presented of the problem of helicopter vibration at main rotor blade passing frequency product bR, where b is the number of blades and R the rotor speed. The magnitude of the rotor vibration can be minimized through careful rotor design and placement of the fuselage natural vibration frequencies relative to bR, as presently illustrated by the case of the Westland 30-300 aircraft. Attention is also given to active vibration control methods employing self-adaptive systems for higher-harmonic blade pitch control and active airframe structural response control at key locations. O.C.

A88-53539
THE TURBOPROP CHALLENGE
ALAN POSTLETHWAITE Flight International (ISSN 0015-3710), vol. 134, Sept. 3, 1988, p. 101, 102, 104-107.

While the 74-seat ATR72 twin-turboprop commuter airliner has been designed for use by regional airlines, it appears to possess a degree of operational performance and economy that may directly challenge turbofan airliners on short-range routes. It is accordingly projected that as many as 350 of these aircraft may be sold, not only in the deregulated U.S. market, but in the European Economic Community market when it undergoes liberalization after 1992. Attention is presently given to the design features and manufacturing methods employed in ATR72 production. O.C.

A88-53634#
REAL-TIME SIMULATION OF HELICOPTERS USING THE BLADE ELEMENT METHOD
KOOS ZWAANENBURG (Applied Dynamics International, Ann Arbor, MI) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC,

American Institute of Aeronautics and Astronautics, 1988, p. 49-53.
(AIAA PAPER 88-4582)

This paper discusses the experience gained in applying the AD 100 computer to the real-time simulation of helicopters using the blade element method. The use of a single computer, together with the ADSIM simulation language, eliminates many of the problems associated with the application of multiple general-purpose computers, programmed in FORTRAN, to such a large and complex real-time simulation. In particular, this paper shows that the implementation of the blade element rotor equations for the UH-60A Black Hawk helicopter is a straightforward task on the AD 100. Author

A88-53649#
VSRA IN-FLIGHT SIMULATOR - ITS EVALUATION AND APPLICATIONS
MASAKI KOMODA (Tokyo Metropolitan Institute of Technology, Japan), NAGAKATSU KAWAHATA (Nihon University, Chiba, Japan), YUKICHI TSUKANO, and TAKATSUGU ONO (National Aerospace Laboratory, Tokyo, Japan) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 171-181. refs
(AIAA PAPER 88-4605)

The paper describes an in-flight simulator named VSRA (variable stability and response airplane), in some detail. The VSRA system is designed based upon an explicit model following theory. Only linearized dynamics are assumed. Discussed are technical difficulties which are pertinent to the VSRA systems and have been overcome to achieve good model following capabilities. Two examples of VSRA's application to studying problems concerning man-machine dynamic systems are included to show that the VSRA is a mandatory device to some classes of flight mechanical problem. Author

A88-53650*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, Tex.
NASA SHUTTLE TRAINING AIRCRAFT FLIGHT SIMULATION OVERVIEW
CHARLES R. JUSTIZ and SURESH M. PATEL (NASA, Johnson Space Center, Houston, TX) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 182-190.
(AIAA PAPER 88-4608)

The Shuttle Training Aircraft (STA) is a variable stability, variable control law flying simulator used by NASA/JSC to train astronauts in the final landing phase of a Space Shuttle Orbiter. A general outline is given for the STA flight simulation system. An overview is given of the software generation and verification process through the Advanced Validation System (AVAS). The flight test techniques for software verification will be reviewed and the process for releasing the software for flight training will be covered. The astronaut STA training syllabus is examined. Parameter matching with the Orbiter in the final approach phase of de-orbit and landing is briefly examined. Simulation performance will be assessed against flight data, performance measurement, and cue synchronization. Author

A88-53651#
GROUND SIMULATOR REQUIREMENTS BASED ON IN-FLIGHT SIMULATION
LOUIS H. KNOTTS and RANDALL E. BAILEY (Calspan Advanced Technology Center, Buffalo, NY) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 191-197. refs
(Contract F33615-83-C-3603)
(AIAA PAPER 88-4609)

The results of three research programs initiated to evaluate issues relevant to the simulation fidelity of the NT-33A in-flight simulator aircraft are discussed. In the course of two of these studies, a comparison was made of the handling qualities for several aircraft configurations when flown in the NT-33A compared to the same configurations flown in a ground Vertical Motion Simulator; allowable time delays were determined for several different aircraft types during up-and-away tracking tasks. The third NT-33A program was designed to investigate the effect of feel-system dynamics on the aircraft handling qualities. It was shown that an aircraft configuration with known poor handling qualities was not necessarily evaluated as such in a ground simulator. It is emphasized that calibration and documentation is an essential step in the set-up of a simulation of the aircraft dynamics, as well as of the time-delay and the control-stick characteristics. I.S.

A88-53652#
VISTA/F16 - THE NEXT HIGH-PERFORMANCE IN-FLIGHT SIMULATOR
GARY K. HELLMANN, DAVID E. FREARSON, and JACK BARRY, JR. (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 198-205.
(AIAA PAPER 88-4610)

A new, high-performance in-flight simulator aircraft is required by the Air Force to support aeronautical research and development over the next twenty-five to thirty years. The Variable Stability In-Flight Simulator Test Aircraft (VISTA) is a USAF Advanced Development Program to design, build, test, and field an improved high perfomance in-flight simulator using an F-16D as the host aircraft. The primary mission of VISTA will be in-flight simulation of the flight characteristics and pilot interfaces of new flight vehicles and advanced weapon systems. Author

A88-53752*# *National Aeronautics and Space Administration.* Ames Research Center, Moffett Field, Calif.
THE APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY TO AERONAUTICAL SYSTEM DESIGN
E. E. BOUCHARD (Lockheed Aeronautical Systems Co., Burbank, CA), G. H. KIDWELL (NASA, Ames Research Center, Moffett Field, CA), and J. E. ROGAN (Georgia Institute of Technology, Atlanta) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 21 p. refs
(AIAA PAPER 88-4426)

This paper describes the automation of one class of aeronautical design activity using artificial intelligence and advanced software techniques. Its purpose is to suggest concepts, terminology, and approaches that may be useful in enhancing design automation. By understanding the basic concepts and tasks in design, and the technologies that are available, it will be possible to produce, in the future, systems whose capabilities far exceed those of today's methods. Some of the tasks that will be discussed have already been automated and are in production use, resulting in significant productivity benefits. The concepts and techniques discussed are applicable to all design activity, though aeronautical applications are specifically presented. Author

A88-53753#
A QUASI-PROCEDURAL, KNOWLEDGE-BASED SYSTEM FOR AIRCRAFT DESIGN
ILAN KROO (Stanford University, CA) and MASAMI TAKAI AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 11 p. refs
(AIAA PAPER 88-4428)

An aircraft-design program has been developed that combines a rule-based advice and warning system with an extensible set of analysis routines in an unconventional architecture; its procedural modules for aircraft aerodynamics, structures, propulsion, and operating costs calculations allow results to be obtained upon execution in the requisite order. These modules are procedural, allowing programmers a degree of flexibility for the inclusion of either brief definitions or complex local procedures. This structure is encapsulated in an executive routine with a highly interactive, event-driven, graphical interface and expert system. O.C.

A88-53754*# Georgia Inst. of Tech., Atlanta.
DEVELOPMENT OF A MICRO-COMPUTER BASED INTEGRATED DESIGN SYSTEM FOR HIGH ALTITUDE LONG ENDURANCE AIRCRAFT
DAVID W. HALL (David Hall Consulting, Sunnyvale, CA) and J. EDWARD ROGAN (Georgia Institute of Technology, Atlanta) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 23 p. NASA-sponsored research. refs
(AIAA PAPER 88-4429)

A microcomputer-based integration of aircraft design disciplines has been applied theoretically to sailplane, microwave-powered aircraft, and High Altitude Long-Endurance (HALE) aircraft configurational definition efforts. Attention is presently given to the further development of such integrated-disciplines approaches through the incorporation of AI techniques; these are then applied to the aforementioned case of the HALE. The 'windFrame' language used, which is based on HyperTalk, will allow designers to write programs using a highly graphical, user interface-oriented environment. O.C.

A88-53758#
CANARD CERTIFICATION LOADS - PROGRESS TOWARD ALLEVIATING FAA CONCERNS
TERENCE J. BARNES and EDWARD A. GABRIEL (FAA, Washington, DC) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 14 p.
(AIAA PAPER 88-4462)

An evaluation is made of FAA concerns with permitted structural loads on general aviation aircraft with canard configurations; such aircraft include the Beech Starship, OMAC Laser 3000, AVTEK 400, Piaggio P-180, and Gyroflug Speed Canard. A canard aircraft's forward airfoil is the first to penetrate gusts, causing pitch-up and main wing lift/loading increases. In addition, the influence of the forward lifting surface on the main wing varies with both its location and the given flight conditions. A lifting-surface or full-configuration aerodynamic model is recommended for the evaluation of forward airfoil effects. O.C.

A88-53759#
A COMPARISON OF CFD AND FULL SCALE VARIEZE WIND TUNNEL RESULTS
MARK E. BEYER (OMAC, Inc., Albany, GA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 11 p. refs
(AIAA PAPER 88-4463)

Computational fluid dynamic analysis, CFD, is compared the full scale wind tunnel results. The configuration modeled is the Rutan VariEze with leading edge droops and a low canard. Comparisons incorporate results from wind tunnel tests conducted by NASA in the Langley 30 by 60 Foot Tunnel. Computational modeling makes use of VariEze kit plans, scale drawings, and cordax data taken directly from the wind tunnel model. Analysis was performed using computer codes VSAERO and MCARF revised for use on the Compaq 386. Author

A88-53763#
THE IMPACT OF VTOL ON THE CONCEPTUAL DESIGN PROCESS
DANIEL P. RAYMER (Lockheed Aeronautical Systems Co., Burbank, CA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 16 p. refs
(AIAA PAPER 88-4479)

The factors influencing the conceptual design of jet VTOL aircraft are discussed. The paper is intended to introduce the CTOL-experienced aircraft conceptual designer to some of the unique requirements and pitfalls which must be considered when performing configuration layout and vehicle sizing on a VTOL aircraft concept. Author

A88-53764#
HIGH SPEED TRANSPACIFIC PASSENGER FLIGHT
G. M. GREGOREK, R. R. BOYD, and P. S. WEISSMAN (Ohio State University, Columbus) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 13 p.
(AIAA PAPER 88-4484)

Of four eight-student design teams, two undertook the design of a Mach 5-cruise HST and the remaining two of a Mach 3-cruise SST; each of the aircraft would carry 250 passengers over 6500 n. mi., and would be able to operate from 15,000-ft runways. Four design concepts were conceived and evaluated; the SSTs were a variable-sweep oblique wing and a cranked arrow wing, both using conventional turbojets and liquid hydrocarbon fuels, while the HSTs respectively employ fixed-sweep and variable-sweep wings, and are powered by variable-cycle turbojet/ramjet propulsion systems fueled by methane. Development and operating cost considerations favor the SSTs over the HSTs. O.C.

A88-53765#
PRELIMINARY DESIGN OF TWO TRANSPACIFIC HIGH SPEED CIVIL TRANSPORTS
LOUIS J. HENDRICH (Kansas, University, Lawrence) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 8 p. Research supported by Universities Space Research Association. refs
(AIAA PAPER 88-4485B)

Two high speed civil transport design concepts are presented. Both transports are designed for a 5500 n.m. range with 300 passengers. The first design concept is a Mach 2.5 joined-wing single fuselage transport. The second design concept is a Mach 4.0, twin fuselage, variable sweep wing transport. The use of conventional hydrocarbon fuels is emphasized to reduce the amount of change required in current airport facilities. Advanced aluminum alloys are used in the designs when possible to reduce material and production costs over more 'exotic' materials. Methods to reduce the airport noise, community noise, and fly-over noise are incorporated into the designs. In addition, requirements set forth by the FARs have been addressed. Author

A88-53767#
PLANFORM EFFECTS ON HIGH SPEED CIVIL TRANSPORT DESIGN
S. H. CASS and C. M. BALL (California State Polytechnic University, Pomona) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 13 p. refs
(AIAA PAPER 88-4487)

A Universities Space Research Association (USRA) sponsored (undergraduate) study is presented on planform effects on high speed civil transport design in the Mach 3 to 6 range. A request for proposal and mission profile was common to four aircraft designs. These air-craft were designed to the same mission in order to draw conclusions regarding the performance of the aircraft. The four configurations considered were the blended-wing-body concept, joined wing concept, oblique wing concept and the caret (waverider) concept. This paper presents the overall trends common to the four configurations during high speed flight. Conclusions on the best planform are left to the reader due to the fact that the designs all have positive and negative aspects. However, the paper points out these positive and negative aspects for each area of the design. Author

A88-53768#
DESIGN CONCEPTS FOR AN ADVANCED CARGO ROTORCRAFT
D. P. SCHRAGE (Georgia Institute of Technology, Atlanta), M. F. COSTELLO, and D. N. MITTLEIDER AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 11 p. refs
(AIAA PAPER 88-4496)

The Advanced Cargo Rotorcraft (ACR) heavy-lift helicopter's configurational possibilities are presently evaluated for a case of no speed requirement greater than 200 kts. Single-main rotor, tanden-rotor, and 'warm-cycle' ACR helicopter configurations are considered; of these, the technologies entailed by the former two configurations are most ready for implementation, and therefore render them the lowest-risk and minimum-cost solutions. If payload requirements rise far enough to drive vehicle gross weight above 100,000 lbs, the warm cycle ACR alternative becomes the most attractive. O.C.

A88-53769#
INTEGRATED THRUST VECTORING ON THE X-29A
J. F. KLAFIN (Grumman Corp., Aircraft Systems Div., Bethpage, NY) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 17 p. refs
(AIAA PAPER 88-4499)

The X-29A forward swept wing planform offers special advantages at high angle-of-attack for thrust vectoring evaluation. The goal of this investigation was to evaluate the controllability of the X-29A with multiaxis thrust vectoring for angles-of-attack up to +90 deg. Analytical design techniques were applied to integrate two-axis thrust vectoring with the X-29A aerodynamic flight control laws. Lateral-directional control law cross-coupling provided roll control about the velocity vector. Piloted simulations were used for handling quality evaluation with the aircraft trimmed outside the X-29A flight envelope at 0.2 Mach, 15,000 feet and 33 deg angle-of-attack. Longitudinal control achieved a Level 1 handling quality rating for angles-of-attack up to +90 deg. Lateral-directional control achieved a Level 2 handling quality rating up to +75 deg angle-of-attack. Better lateral-directional ratings appeared achievable with control law improvements. Aircraft controllability at very low speeds and high angles-of-attack can open superagility vistas for tactical applications. The capability can be provided; the tactics require development. Author

A88-53770#
ASSESSMENT OF A SOVIET HYPERSONIC TRANSPORT
RICHARD D. WARD, MARK A. LEAGUE, and EDDIE MOORE (General Dynamics Corp., Fort Worth, TX) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 14 p.
(AIAA PAPER 88-4506)

An evaluation has been made of existing indications of Soviet interest in, and progress towards, an operational hypersonic transport (HST) applicable in both the civilian and the military spheres. The first hard data on a Soviet HST was obtained at the 1987 Paris Air Show, which indicated that research had been conducted by the Tupolev design bureau on a Mach 5-6 cruise vehicle of 100 m length; its first flight was projected to be in 1999, and would be large enough to carry 300 passengers over 4500 miles. Methane is the probable fuel employed. An account is given of the organization of the present analysis effort. O.C.

A88-53776
THE CRITICALITY OF WEIGHT AND BALANCE ON COMPETITION AIRCRAFT
BRUCE J. BOLAND (Lockheed-California Co., Burbank) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 19 p.
(SAWE PAPER 1756)

The sensitivity of a high-performance short-coupled aircraft to weight change and center of gravity movement is demonstrated. A 'hands-on' application of weight and balance principles is provided. The aircraft considered, the Tsunami, is an all metal low-wing monoplane designed for the purpose of racing, record setting, and research. K.K.

A88-53781
ADVANCED COMPOSITE AIRFRAME PROGRAM (ACAP) - AN UPDATE AND FINAL ASSESSMENT OF WEIGHT SAVING POTENTIAL
WILLIAM H. MARR (U.S. Army, Aeronautical Systems Div., Fort Eustis, VA) and JOHN G. SUTTON (United Technologies Corp., Sikorsky Aircraft, Stratford, CT) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 26 p. refs
(SAWE PAPER 1770)

The U.S. Army's Advanced Composite Airframe Program (ACAP) is charged with the development of helicopter primary structures for the 1990s that will yield significant weight and cost savings over current structural and materials techniques. Attention is presently given to a utility helicopter fuselage developed under ACAP auspices which meets U.S. Army survivability requirements, while exceeding 17-percent cost and 22-percent weight reduction requirements with a figure of 23 percent in each category. O.C.

A88-53783
LOCKHEED HTTB - STOL PERFORMANCE FEATURES
GUY W. PACKARD (Lockheed-Georgia Co., Marietta) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 18 p.
(SAWE PAPER 1772)

An account is given of the lift-enhancement and low speed stability and control-improving design changes made to the C-130-based High Technology Test Bed (HTTB) aircraft in order to achieve the 1500-foot runway length requirement anticipated for next-generation tactical cargo aircraft. Configurational modifications of the airframe encompassed longer-chord flaps and leading edges, spoilers, extended-chord control surfaces, empennage leading edge extensions, and a high sink-rate landing gear. A more powerful engine was incorporated. All HTTB primary flight controls were changed from 'boost' type to full-power operation. O.C.

A88-53784
ULTIMATE FACTOR FOR STRUCTURAL DESIGN OF MODERN FIGHTERS
O. SENSBURG, O. BARTSCH, and H. BERGMANN (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 33 p. refs
(SAWE PAPER 1775)

An examination and reevaluation is conducted of the classic fighter aircraft structural design stipulation of a 1.5 ultimate stress factor, in light of the application of highly redundant flight control systems (FCSs) to highly unstable aircraft, such as those with canard configurations. This total dependence of aircraft stability on FCSs, and the dependence of applied loads on the FCS in turn, means that design loads cannot be exceeded; it is therefore judged possible to reduce the ultimate load factor to 1.4 or less. O.C.

A88-53786
A DIFFERENT APPROACH TO THE INTERRELATED SUBJECTS OF WEIGHT, PERFORMANCE, AND PRICE AS APPLIED TO COMMERCIAL TRANSPORT AIRCRAFT
EDMOND J. GAUTHIER (Boeing Commercial Airplane Co., Seattle, WA) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 27 p.
(SAWE PAPER 1779)

Commercial airplane sizing is a complex process in which experts in the diverse disciplines of mass properties, aerodynamics, propulsion, and finance perform studies and iterate these studies until a satisfactory design is evolved. Because each discipline has its own set of fine-tuned detailed parametric relationships often buried deep within elaborate computer programs, it is not easy to understand the big picture - how the individual parameters influence the size (weight) of the resultant design. This paper employs many simplifications in all disciplines in order to develop a method for an easy understanding of airplane sizing. It begins with a different approach to weight categories, followed by an overall performance parameter derivation, and introduces a ballpark evaluation of airplane price. The resulting simplified method is then applied to the value of a pound and to fuel efficiency comparisons. Author

A88-53789
OVERVIEW OF LOCKHEED C-130 HIGH TECHNOLOGY TEST BED PROGRAM
CLARENCE M. CAMPBELL (Lockheed-Georgia Co., Marietta) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 29 p. refs
(SAWE PAPER 1786)

The High Technology Test Bed (HTTB) flight test aircraft is a highly instrumented platform based on the four-engine C-130 tactical airlifter for the study of prospective benefits from the integration of such generic technologies as HUDs, mission computers, GPS, FLIR, metal-matrix composites, weather-mapping radars, etc. STOL is a major goal of the HTTB effort, and is reflected in the incorporation of more powerful engines, empennage leading-edge extensions, a high sink-rate landing gear, and an extended-chord aileron. A roll-, pitch-, and yaw-augmenting digital flight control system is also incorporated. O.C.

A88-53790
ESTIMATING FUSELAGE WEIGHT PENALTY REQUIRED TO SUPPRESS NOISE FROM PROPFANS
PHILIP L. BREUER (Boeing Military Airplane Co., Wichita, KS) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 7 p.
(SAWE PAPER 1787)

With advances in counter-rotating, unducted propfan propulsion technology, an accurate and rapid method of estimating the fuselage weight penalty due to suppression of external noise generated by propfans is needed to support initial aircraft design. Such a method for use in the preliminary/conceptual design phase is presented in this paper. This method predicts the fuselage weight penalty based upon specific air vehicle configuration data, acoustic phenomena, and mission requirements. The noise level is analytically determined at discrete fuselage panel locations over the entire fuselage, and the total weight penalty is the sum of the delta weights calculated for these individual panels. Use and application of input parameters are discussed and examples showing the sound pressure level patterns on the fuselage surface for different longitudinal engine locations are shown. Author

A88-53791
CRASHWORTHINESS VS. AIRWORTHINESS
PHILIP F. KAUFMAN (U.S. Navy, Naval Air Development Center, Warminster, PA) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 17 p. refs
(SAWE PAPER 1788)

This paper discusses the relevance of the standards set for the airworthiness of an aircraft and the safety of flight to the requirements of crashworthiness of the aircraft and aircraft installations in case of an accident. It is emphasized that the crashworthiness is an important aspect of the aircraft design process and that crashworthiness can be achieved by an effective mix of many crashworthiness factors. These factors include providing a protective shell, adequate tie downs, energy attenuation (seats, landing gear, fuselage, and cargo), eliminating environmental debris, and minimizing post-crash hazards, such as egress, fire, and toxic fumes. The solution that takes in consideration all these elements has to be examined within the framework of a total systems approach to crashworthy design. I.S.

A88-53797
WEIGHT GROWTH IN AIRLINE SERVICE
J. H. WOOD (British Airways, PLC, Hounslow, England) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 11 p.
(SAWE PAPER 1796)

An analysis is conducted into the reasons for weight growth in several different aircraft fleets during the last 12-18 months. A major refurbishment program has been conducted for the One-Eleven airliners, in conjunction with mandatory modifications; these encompass turbofan engine noise-suppression device retrofits, the fireblocking of passenger and crew seats, and the installation of toilet smoke detection systems and floor-proximity escape path lighting. Other fleet aircraft studied are the B747, B737, B757, Tristar, and Concorde. O.C.

A88-53798
ECONOMICAL TECHNOLOGY APPLICATION IN COMMERCIAL TRANSPORT DESIGN
MICHAEL L. DRAKE (Boeing Commercial Airplane Co., Seattle, WA) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 16 p.
(SAWE PAPER 1798)

An evaluation is made of the development status and applicability to state-of-the-art medium-range transport aircraft of technologies that may improve airline operating cost. The aircraft in question are of B757 class. Attention is given to factors figuring in direct operating costs, the cost effects of Al-Li alloy and advanced composite structures' introduction, the operational advantages of such systems as electronic engine controls and fly-by-wire control for relaxed static stability flight characteristics, and the effect on operating economics of airport delays that may be precluded through improved technologies' application. O.C.

A88-54310#
HELICOPTER HEALTH MONITORING FROM ENGINE TO ROTOR
J. F. MARRIOTT and J. F. M. KAYE (Hawker Siddeley Dynamics Engineering, Ltd., Welwyn Garden City, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-227)

The practical aspects of helicopter health and usage monitoring systems are discussed with emphasis on the implications of on-board vibration monitoring. The discussion includes a brief review of monitoring system evolution, monitoring requirements and functions, integrated monitoring system design concepts, and operating requirements, limits, and standards. A general diagram of an integrated health and usage monitoring system is shown. V.L.

A88-54954#
DYNAMICS OF HELICOPTER ROTORS
J. K. SURESH and V. RAMAMURTI (Indian Institute of Technology, Madras) IN: Developments in Mechanics. Volume 14(c) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 1042-1047. refs

The large-deformation dynamic behavior of bearingless helicopter rotors is investigated analytically. The geometrical configuration of the problem is illustrated with drawings; fundamental equations of motion are derived (taking nonlinear and composite characteristics into account); and a formulation for the equilibrium condition is obtained. T.K.

A88-55317#
PILOTAGE SYSTEM FOR THE PRONAOS GONDOLA
G. BRONDINO (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p
(IAF PAPER 88-008)

In the framework of Pronaos, a French program for submillimetric astronomy, a balloon-gondola vehicle carrying a 2-m submillimetric telescope is being developed. The scientific requirements for the observations demand a precision of + or - 15 arcsecs, and a stability of 5 arcsecs rms on the pointing accuracy during the flight. The gondola weighs 2200 kg at take off, has dimensions of 4 X 4 m at the base and is 7.5 m high. The flight has a typical altitude of 36 km and the estimated volume of the balloon is 800,000 cu m. A detailed description of the system and simulation results are presented. R.B.

N88-28867# Aircraft Research Association Ltd., Bedford (England).
TRANSPORT-TYPE CONFIGURATIONS
A. B. HAINES and A. ELSENAAR (National Aerospace Lab., Amsterdam, Netherlands) *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 139-163 Apr. 1988
Avail: NTIS HC A20/MF A01

Various reasons can be advanced for treating transports as a separate, distinct class of aircraft for the purpose of defining a detailed viscous simulation methodology. The detailed methodology as described was based on past experience and an appreciation of how the advances in computational fluid dynamics can be exploited to place the methodology on a more scientific basis. It is recommended that, to gain experience, the proposed methodology should be applied for a significant period in parallel with whatever is the established practice. Any large differences in the extrapolated results should be assessed to find whether the reasons justify departure from existing practice: in other words, the methodology that was set forth should be better, being on a sound scientific basis, but it will still have to prove itself in the future. Author

N88-28868# Aircraft Research Association Ltd., Bedford (England).
COMBAT AIRCRAFT
A. B. HAINES *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 164-190 Apr. 1988
Avail: NTIS HC A20/MF A01

Devising a viscous simulation methodology for model tests of a combat aircraft design is more difficult than for a subsonic transport. The geometry is more complicated and hence, more difficult to model for a computational fluid dynamics (CFD) calculation; the flow patterns are more complex and can contain various interacting features; there is more interest in the development of the flow beyond the buffet-onset boundary; the ability to manipulate the boundary layer in the model tests is more limited. The emphasis in the methodology rests on the in-depth study of the flow patterns and, in particular, the identification of the scale-sensitive viscous effects in the flow patterns over the model under test. The description of these flow patterns and of how, in principle, to construct a methodology to meet the various possible situations, is based on past experience and on an awareness of the advances in CFD methods. Author

N88-28908# Conrad Technologies, Inc., King of Prussia, Pa.
STRUCTURAL DYNAMICS OF MANEUVERING AIRCRAFT Final Report, Jul. 1986 - Sep. 1987
M. M. REDDI Sep. 1987 90 p
(Contract N62269-86-C-0278)
(AD-A192376; CTI-8601; NADC-88014-60) Avail: NTIS HC A05/MF A01 CSCL 20K

The technical objectives of the research are to establish the minimum level of modeling necessary for predicting the dynamic stresses in fighter aircraft during maneuvers and transitions between maneuvers, to identify the physical phenomena which are significant, to identify potential shortfalls in current aircraft design technology and to identify areas for further research. A symmetric wing, modeled as a beam with quasi-steady aerodynamic loads introduced through the vortex lattice method, is used for the dynamic evaluation. The dynamical equations of motion are solved in the time domain by the Runge-Kutta method specialized to second order equations. The maneuver dynamic analysis program, MANDYN, written in FORTRAN 77, uses the parameters of real variable-geometry airplane. An extensive investigation of dynamic loads resulting from a simple maneuver for various severity levels revealed that the lowest natural frequency and load application time are significant factors in determining the validity of the load factor approach. Recommendations based on the study results are made. GRA

N88-28911# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Abteilung Mathematische Verfahren und Datentechnik.
ESTIMATION OF AIRCRAFT PARAMETERS USING FILTER ERROR METHODS AND EXTENDED KALMAN FILTER
RAVINDRA JATEGAONKAR (Technische Univ., Brunswick, West Germany) and ERMIN PLAETSCHKE Mar. 1988 59 p
(DFVLR-FB-88-15; ISSN-0171-1342; ETN-88-92933) Avail: NTIS HC A04/MF A01; DFVLR, VB-PL-DO, 90 60 58, 5000 Cologne, Fed. Republic of Germany, 23 Deutsche marks

Four algorithms for parameter estimation in linear and nonlinear systems accounting for process and measurement noise using two different approaches, namely direct approach and filtering approach, are compared. In the direct approach the iterative Gauss-Newton method incorporating a suitable state estimator is used to estimate the unknown parameters by optimization of the likelihood function. For the state estimation both time-varying and steady-state filters are used. In the filtering approach the unknown parameters are estimated as augmented states using the extended Kalman filter. The estimation results from three model postulates, one linear and two nonlinear, to extract aircraft derivatives from simulated and flight test data are used for comparison. Aspects such as convergence, computational time, parameter estimates and their accuracies are evaluated for each of the four estimation algorithms. ESA

N88-28912# Technische Univ., Brunswick (West Germany). Fakultaet fuer Maschinenbau und Elektrotechnik.
A CONTRIBUTION TO THE QUANTITATIVE ANALYSIS OF THE INFLUENCE OF DESIGN PARAMETERS ON THE OPTIMAL DESIGN OF PASSENGER AIRCRAFT Ph.D. Thesis [EIN BEITRAG ZUR QUANTITATIVEN ANALYSE DES EINFLUSSES VON AUSLEGUNGSPARAMETERN AUF DEN OPTIMALEN ENTWURF VON VERKEHRSELUGZEUGEN]
HANS-WILHELM POHL 1987 160 p In GERMAN
(ETN-88-92979) Avail: NTIS HC A08/MF A01

The dependencies of passenger aircraft design parameters on several factors were analyzed, with emphasis on the effects of fuel price increases. With a view to optimization calculations a two-phase program system for the aircraft was developed; it is represented in the form of timing charts. The first part of the program pre-optimizes a large number of design parameters, performs sensitivity studies, and indentifies side-minima. The results are used as initial values in the second part of the program to determine the optimized design with substantially better precision. The optimization programs determine the effects of external boundary conditions on the design. The effects of fuel costs and capital costs on the optimum design are presented. ESA

N88-28913# European Space Agency, Paris (France).
ADDITIONAL INVESTIGATIONS INTO THE AIRCRAFT LANDING PROCESS: TEST DISTRIBUTIONS
HANNS-JUERGEN PETERS (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne, West Germany) Jun. 1988 74 p Transl. into ENGLISH of Erganzende Untersuchungen zum Landeprozess von Flugzeugen - Testverteilungen, Cologne, Federal Rep. of West Germany (DFVLR) Original language document was announced as N88-16686
(ESA-TT-1099; DFVLR-MITT-87-13; ETN-88-93055) Avail: NTIS HC A04/MF A01; original German version available from DFVLR, VB-PL-DO, 90 60 58, 5000 Cologne, Fed. Republic of Germany 25.50 deutsche marks

The landing times for the 10 German civil airports, without waiting times due to aircraft allocations to holding areas, were investigated using a simulation model for the landing process. Test distributions were developed. Results are synthetic landing time distributions with waiting times, the adaptation of which to the empirical landing time distribution was evaluated using the Chi-square test. Further improvements of the adaptation of the simulated distribution to the empirical one can be obtained by structural changes of the test distribution, e.g., by limitation of the maximum landing time. ESA

N88-28914* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
HIGH PERFORMANCE FORWARD SWEPT WING AIRCRAFT Patent
DAVID G. KOENIG, inventor (to NASA), KIYOSHI AOYAGI, inventor (to NASA), MICHAEL R. DUDLEY, inventor (to NASA), and SUSAN B. SCHMIDT, inventor (to NASA) 30 Aug. 1988 14 p Filed 24 Nov. 1986 Supersedes N87-18561 (25 - 11, p 1439)
(NASA-CASE-ARC-11636-1; US-PATENT-4,767,083; US-PATENT-APPL-SN-933963; US-PATENT-CLASS-244-12.3; US-PATENT-CLASS-244-12.4; US-PATENT-CLASS-244-207; US-PATENT-CLASS-244-45-A; US-PATENT-CLASS-244-55)
Avail: US Patent and Trademark Office CSCL 01C

A high performance aircraft capable of subsonic, transonic and

supersonic speeds employs a forward swept wing planform and at least one first and second solution ejector located on the inboard section of the wing. A high degree of flow control on the inboard sections of the wing is achieved along with improved maneuverability and control of pitch, roll and yaw. Lift loss is delayed to higher angles of attack than in conventional aircraft. In one embodiment the ejectors may be advantageously positioned spanwise on the wing while the ductwork is kept to a minimum.
Official Gazette of the U.S. Patent and Trademark Office

N88-28915*# Douglas Aircraft Co., Inc., Long Beach, Calif.
CRITICAL JOINTS IN LARGE COMPOSITE PRIMARY AIRCRAFT STRUCTURES. VOLUME 2: TECHNOLOGY DEMONSTRATION TEST REPORT
BRUCE L. BUNIN Jun. 1985 209 p
(Contract NAS1-16857)
(NASA-CR-172587; NAS 1.26:172587; ACEE-26-TR-3478-VOL-2)
Avail: NTIS HC A10/MF A01 CSCL 01C

A program was conducted to develop the technology for critical structural joints in composite wing structure that meets all the design requirements of a 1990 commercial transport aircraft. The results of four large composite multirow bolted joint tests are presented. The tests were conducted to demonstrate the technology for critical joints in highly loaded composite structure and to verify the analytical methods that were developed throughout the program. The test consisted of a wing skin-stringer transition specimen representing a stringer runout and skin splice on the wing lower surface at the side of the fuselage attachment. All tests were static tension tests. The composite material was Toray T-300 fiber with Ciba-Geigy 914 resin in 10 mil tape form. The splice members were metallic, using combinations of aluminum and titanium. Discussions are given of the test article, instrumentation, test setup, test procedures, and test results for each of the four specimens. Some of the analytical predictions are also included. Author

N88-28916*# Douglas Aircraft Co., Inc., Long Beach, Calif.
CRITICAL JOINTS IN LARGE COMPOSITE PRIMARY AIRCRAFT STRUCTURES. VOLUME 3: ANCILLARY TEST RESULTS
BRUCE L. BUNIN and R. L. SAGUI Washington, D.C. Jun. 1985 338 p
(Contract NAS1-16857)
(NASA-CR-172588; NAS 1.26:172588; ACEE-26-TR-3958A-VOL-3) Avail: NTIS HC A15/MF A01 CSCL 01C

A program was conducted to develop the technology for critical structural joints for composite wing structure that meets all the design requirements of a 1990 commercial transport aircraft. The results of a comprehensive ancillary test program are summarized, consisting of single-bolt composite joint specimens tested in a variety of configurations. These tests were conducted to characterize the strength and load deflection properties that are required for multirow joint analysis. The composite material was Toray 300 fiber and Ciba-Geigy 914 resin, in the form of 0.005 and 0.01 inch thick unidirectional tape. Tests were conducted in single and double shear for loaded and unloaded hole configurations under both tensile and compressive loading. Two different layup patterns were examined. All tests were conducted at room temperature. In addition, the results of NASA Standard Toughness Test (NASA RP 1092) are reported, which were conducted for several material systems. Author

N88-28917*# Boeing Military Airplane Development, Wichita, Kans.
MULTIPLE-PURPOSE SUBSONIC NAVAL AIRCRAFT (MPSNA): MULTIPLE APPLICATION PROPFAN STUDY (MAPS) Final Report
R. M. ENGELBECK, C. T. HAVEY, A. KLAMKA, C. L. MCNEIL, and M. A. PAIGE Sep. 1986 219 p
(Contract NAS3-24529)
(NASA-CR-175104; NAS 1.26:175104; D500-11313-1) Avail: NTIS HC A10/MF A01 CSCL 01C

Study requirements, assumptions and guidelines were identified regarding carrier suitability, aircraft missions, technology availability, and propulsion considerations. Conceptual designs were executed for two missions, a full multimission aircraft and a minimum mission aircraft using three different propulsion systems, the UnDucted Fan (UDF), the Propfan and an advanced Turbofan. Detailed aircraft optimization was completed on those configurations yielding gross weight performance and carrier spot factors. Propfan STOVL conceptual designs were exercised also to show the effects of STOVL on gross weight, spot factor and cost. An advanced technology research plan was generated to identify additional investigation opportunities from an airframe contractors standpoint. Life cycle cost analysis was accomplished yielding a comparison of the UDF and propfan configurations against each other as well as against a turbofan with equivalent state of the art turbo-machinery. Author

N88-28918*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
TEST RESULTS AT TRANSONIC SPEEDS ON A CONTOURED OVER-THE-WING PROPFAN MODEL
ALAN D. LEVIN, DONALD B. SMELTZER, and RONALD C. SMITH Jul. 1986 98 p
(NASA-TM-88206; A-86082; NAS 1.15:88206) Avail: NTIS HC A05/MF A01 CSCL 01C

A semispan wing/body model with a powered highly loaded propeller has been tested to provide data on the propulsion installation drag of advanced propfan-powered aircraft. The model had a supercritical wing with a contoured over-the-wing nacelle. It was tested in the Ames Research Center's (ARC) 14-foot Transonic Wind Tunnel at a total pressure of 1 atm. The test was conducted at angles of attack from -0.5 to 4 deg at Mach numbers ranging from 0.6 to 0.8. The test objectives were to determine propeller performance, exhaust jet effects, propeller slipstream interference drag, and total powerplant installation drag. Test results indicated a total powerplant installation drag of 82 counts (0.0082) at a Mach number of 0.8 and a lift coefficient of 0.5, which is approximately 29 percent of a typical airplane cruise drag.
Author

N88-29721# Lockheed Aeronautical Systems Co., Burbank, Calif. Dynamic Loads Div.
A SUMMARY OF METHODS FOR ESTABLISHING AIRFRAME DESIGN LOADS FROM CONTINUOUS GUST DESIGN CRITERIA
RICHARD N. MOON *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 40 p Jun. 1988
Avail: NTIS HC A06/MF A01

Continuous gust design criteria for airframe design are specified in FAR 25, JAR 25 and various U.S. military specs. Two forms of criterion, the design envelope approach and the mission analysis, are usually referenced as an acceptable means of compliance. However, these criteria do not provide methods of applying the statistical results of the airframe manufacturer, subject to approval of the certifying agency. Some of the methods that are currently used by U.S. airframe manufacturers are summarized. Continuous gust design requirements from various certifying agencies are reviewed. A brief discussion is also provided on the methods employed to include the effect of the L-1011 Tristar active controls wing load alleviation system on the loads due to corrective roll control in turbulence. Author

N88-29722# Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (West Germany). Civil and Transport Aircraft Div.
COMPARISON OF THE INFLUENCE OF DIFFERENT GUST MODELS ON STRUCTURAL DESIGN
MANFRED MOLZOW *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 17 p Jun. 1988
Avail: NTIS HC A06/MF A01

Depending on the country of certification, different gust models and means of compliance of the airworthiness requirements have to be covered in structural design of civil transport aircraft. The influence on aircraft design from gust models, aircraft modeling, and control systems and laws is demonstrated on example of a short to medium range transport aircraft. Recommendations for future harmonized approaches in gust methods and modeling are given. Author

N88-29738# National Aerospace Lab., Amsterdam (Netherlands).

LOW-SPEED LONGITUDINAL FLYING QUALITIES OF MODERN TRANSPORT AIRCRAFT

H. A. MOOIJ *In* AGARD, Advances in Flying Qualities 16 p May 1988

Avail: NTIS HC A09/MF A01

The suitability of an aircraft with respect to human control is determined by its handling qualities. In modern transport aircraft the handling qualities are determined to a high degree by the flight control system. An introduction to the following aspects of closed loop flight control systems for modern transport aircraft is given: stabilization and maneuvering functions, candidate implementation forms, manipulators for flight control, and mathematical representations of the airframe/flight control system combination required for prediction and evaluation purposes. Regarding criteria for good handling qualities of transport aircraft, the terminal flight phase (takeoff, initial climb, final approach and landing) are of prime interest. A treatise on a number of promising quantitative criteria for transport aircraft equipped with advanced flight control systems is given. Two groups of criteria are distinguished: criteria based on the dynamic characteristics of the aircraft alone and criteria based on the dynamic characteristics of the pilot/aircraft closed loop system. In the latter case, a quasi-linear describing function for the human controller behavior is used. Author

N88-29739# Systems Technology, Inc., Hawthorne, Calif.

ADVANCES IN FLYING QUALITIES: CONCEPTS AND CRITERIA FOR A MISSION ORIENTED FLYING QUALITIES SPECIFICATION

ROGER H. HOH *In* AGARD, Advances in Flying Qualities 28 p May 1988

Avail: NTIS HC A09/MF A01

There has been considerable activity over the past 8 years to upgrade the military flying qualities specifications for conventional aircraft, as well as for V/STOLs and helicopters. The primary objectives of these upgrades has been to account for the use of high gain, high authority augmentation, and to more directly reflect the requirements of the intended missions into the specifications. The methodologies developed to accomplish the latter objective are summarized. A brief overview of the Lower Order Equivalent Systems and Bandwidth criteria follows. Problems with the specification of control sensitivity, and potential solutions are then discussed, followed by a brief presentation of the use of time vs frequency domain criteria. An empirical method to combine the Cooper-Harper Handling Qualities Ratings (HQRs) from each axis of control into an overall rating is then presented. Finally, a proposed specification for precision flare and landing is given, followed by an example application of the method. Author

N88-29740# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.

A SECOND LOOK AT MIL PRIME FLYING QUALITIES REQUIREMENTS

ROBERT J. WOODCOCK *In* AGARD, Advances in Flying Qualities 15 p May 1988

Avail: NTIS HC A09/MF A01

Current and projected applications of flying qualities criteria are addressed. The current state of the art, its deficiencies, and needs for further work are addressed. The rationale for the new U.S. Military Standard and Handbook on flying qualities is briefly discussed. With advanced vehicles, the scope of flying qualities is expanding, opening new areas to investigate and creating new problems. With relaxed static stability now commonly used, control margin is a prime safety consideration: control must be available for stabilization, maneuvering and recovery from any possible attitude, as well as for trim. Flying qualities aspects of agility include the need for nonlinear flying qualities metrics, and control systems that provide both rapid maneuvering and good damping for tight tracking. For all aspect engagement, the pilot needs to be thoroughly integrated with displays, automatic flight control modes and other systems. For dynamic longitudinal flying qualities, MIL-STD 1797 presents the Control Anticipation Parameter of an equivalent classical system as a primary criterion, but gives several alternatives in recognition of other problems. Author

N88-29789*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

COMPRESSION PYLON Patent Application

JAMES C. PATTERSON, JR., inventor (to NASA) 23 Jun. 1988 14 p

(NASA-CASE-LAR-13777-1; NAS 1.71:LAR-13777-1; US-PATENT-APPL-SN-210480) Avail: NTIS HC A03/MF A01 CSCL 01C

A compression pylon for an aircraft with a wing-mounted engine, that does not cause supersonic airflow to occur within the fuselage-wing-pylon-nacelle channel is presented. The chord length of the pylon is greater than the local chord length of the wing to which it is attached. The maximum thickness of the pylon occurs at a point corresponding to the local trailing edge of the wing. As a result, the airflow through the channel never reaches supersonic velocities. NASA

N88-29790*# Draper (Charles Stark) Lab., Inc., Cambridge, Mass.

INTELLIGENT FAULT DIAGNOSIS AND FAILURE MANAGEMENT OF FLIGHT CONTROL ACTUATION SYSTEMS Final Report, May 1986 - Mar. 1988

WILLIAM F. BONNICE and WALTER BAKER May 1988 90 p (Contract NAS2-12404)

(NASA-CR-177481; NAS 1.26:177481; CSDL-R-2055) Avail: NTIS HC A05/MF A01 CSCL 01C

The real-time fault diagnosis and failure management (FDFM) of current operational and experimental dual tandem aircraft flight control system actuators was investigated. Dual tandem actuators were studied because of the active FDFM capability required to manage the redundancy of these actuators. The FDFM methods used on current dual tandem actuators were determined by examining six specific actuators. The FDFM capability on these six actuators was also evaluated. One approach for improving the FDFM capability on dual tandem actuators may be through the application of artificial intelligence (AI) technology. Existing AI approaches and applications of FDFM were examined and evaluated. Based on the general survey of AI FDFM approaches, the potential role of AI technology for real-time actuator FDFM was determined. Finally, FDFM and maintainability improvements for dual tandem actuators were recommended. Author

N88-29792# Anamet Labs., Inc., Hayward, Calif.

COMPUTER PROGRAMS FOR GENERATION OF NASTRAN AND VIBRA-6 AIRCRAFT MODELS Final Report, Dec. 1985 - Dec. 1986

STEVEN G. HARRISON Apr. 1988 94 p

(Contract F33615-84-C-3216)

(AD-A195467; REPT-1286-1A; AFWL-TR-87-21) Avail: NTIS HC A05/MF A01 CSCL 12E

This report describes a series of computer programs designed to aid the analyst in preparing input data for aircraft models to be analyzed using NASTRAN and/or VIBRA-6. The programs permit creation of either beam or plate-type models of aircraft, subsequent postprocessing of NASTRAN OUTPUT2 files, and creation of VIBRA-6 AERO, IMOD and LOAD fixed data decks. In addition, the analyst may specify use of either the Ritz procedure or standard NASTRAN eigensolvers to derive normal modes of the aircraft for use in the VIBRA-6 vulnerability assessment. A command procedure is provided to orchestrate the execution of the various programs, to keep track of file assignments and to maintain a history of program use. GRA

N88-29795# RAND Corp., Santa Monica, Calif.
AIRCRAFT AIRFRAME COST ESTIMATING RELATIONSHIPS: STUDY APPROACH AND CONCLUSIONS
R. W. HESS and H. P. ROMANOFF Dec. 1987 107 p
(Contract F49620-86-C-0008)
(R-3255-AF; LC-87-28382; ISBN-0-8330-0810-2) Avail: NTIS HC A06/MF A01

Generalized equations are presented for estimating the development and production costs of aircraft airframes. Provided are separate cost estimating relationships (CERs) for engineering, tooling, manufacturing labor, and quality-control hours; manufacturing material, development support, and flight-test cost; and total program cost. The CERs, expressed in the form of exponential equations, were derived by multiple least-squares regression analysis. They were derived from a data base consisting of 34 military aircraft with first flight dates ranging from 1948 to 1978. Most of the aircraft technical data were obtained from either original engineering documents such as manufacturers' performance substantiation reports, or from official Air Force and Navy documents. The cost data were obtained from the airframe manufacturers, either directly from their records or indirectly through standard DoD reports such as Contractor Cost Data Reporting system. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A88-53156#
NAVY APPLICATION OF A STANDARD FATIGUE AND ENGINE MONITORING SYSTEM
ARIF DHANIDINA (Northrop Corp., Electronics Div., Hawthorne, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 13 p. refs
(AIAA PAPER 88-3315)

A fatigue and engine monitoring system (FEMS) specified by the Navy for implementation on the F-14A+, F-14D, and A-6F weapon systems is described. The FEMS consists of an airborne data acquisition system (ADAS) and a data storage set. The way in which the ADAS functions in these weapon systems is discussed. K.K.

A88-53772#
DEVELOPMENT, ANALYSIS, AND FLIGHT TEST OF THE LOCKHEED AERONAUTICAL SYSTEM COMPANY HTTB HUD
M. E. HOLBROOK (Lockheed Aeronautical Systems Co., Marietta, GA) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 5 p.
(AIAA PAPER 88-4511)

A HUD suitable for a tactical airlifter with autonomous STOL capability, such as the High Technology Test Bed (HTTB) C-130 research aircraft, has been developed and tested aboard the HTTB. This process involved the selection of a baseline system, its analysis, the iterative definition of display design requirements, the simulation of sections of the proposed flight station in an engineering simulator, engineering pilot analysis, the correction of problems, and interfacing with actual hardware. O.C.

A88-53826#
PRELIMINARY DEFINITION OF PRESSURE SENSING REQUIREMENTS FOR HYPERSONIC VEHICLES
R. JOHN HANSMAN, JR. and BRYAN H. KANG (MIT, Cambridge, MA) AIAA, NASA, and AFWAL, Conference on Sensors and Measurement Techniques for Aeronautical Applications, Atlanta, GA, Sept. 7-9, 1988. 10 p. Research supported by the Charles Stark Draper Laboratory, Inc. refs
(AIAA PAPER 88-4652)

The air data and engine inlet control measurement requirements for advanced hypersonic vehicles such as NASP were estimated based on anticipated trajectories and vehicle configurations. Surface pressure based measurements systems such as the Shuttle Entry Air Data System (SEADS) appear to be the most promising candidates for advanced hypersonic vehicles. A SEADS-like forebody pressure distribution system for air data measurement combined with an inlet surface pressure array for active inlet control is considered to be the most viable air data measurement configuration. Due to the stringent requirements on the air data and inlet control parameters, as well as the need to locate the surface pressure sensors in regions of extreme thermal load resulted in rigorous pressure transducer requirements (0.1 percent accuracy at 3000 F orifice temperature). Existing-technology high precision pressure transducers were found to require active or passive cooling in a hypersonic air data system. Author

A88-53827#
DIGITAL EMULATION OF THE AH-64A CONTRAST TRACKER
CHRIS CASTO (McDonnell Douglas Helicopter Co., Mesa, AZ) AIAA, NASA, and AFWAL, Conference on Sensors and Measurement Techniques for Aeronautical Applications, Atlanta, GA, Sept. 7-9, 1988. 5 p.
(AIAA PAPER 88-4652B)

A low-cost system for simulating the contrast tracker of the AH-64A helicopter target acquisition designation system is proposed. Two VME-based circuit boards, a single-board computer (SBC) and a video frame grabber, function as a digital image processor which accepts video input from the simulation system's image generator or IR effects processor. An Ada program running on the SBC is designed to track potential targets which are stored in the digital image. R.R.

A88-53830*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, Calif.
AN AIRBORNE SYSTEM FOR VORTEX FLOW VISUALIZATION ON THE F-18 HIGH-ALPHA RESEARCH VEHICLE
ROBERT E. CURRY (NASA, Flight Research Center, Edwards, CA) and DAVID M. RICHWINE (PRC Systems Services, Edwards, CA) AIAA, NASA, and AFWAL, Conference on Sensors and Measurement Techniques for Aeronautical Applications, Atlanta, GA, Sept. 7-9, 1988. 13 p. refs
(AIAA PAPER 88-4671)

A flow visualization system for the F-18 high-alpha research vehicle is described which allows direct observation of the separated vortex flows over a wide range of flight conditions. The system consists of a smoke generator system, on-board photographic and video systems, and instrumentation. In the present concept, smoke is entrained into the low-pressure vortex core, and vortice breakdown is indicated by a rapid diffusion of the smoke. The resulting pattern is observed using photographic and video images and is correlated with measured flight conditions. R.R.

A88-54725
DEVELOPMENT OF A MHZ RF LEAK DETECTOR TECHNIQUE FOR AIRCRAFT HARDNESS SURVEILLANCE
LOTHAR O. HOEFT, TOM M. SALAS, JOSEPH S. HOFSTRA (BDM Corp., Albuquerque, NM), and WILLIAM D. PRATHER (USAF, Weapons Laboratory, Kirtland AFB, NM) IN: IEEE 1988 International Symposium on Electromagnetic Compatibility, Seattle, WA, Aug. 2-4, 1988, Record. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 210-217. refs

A technique for electromagnetically exciting aircraft that produces surface magnetic- and electric-field distributions similar to those resulting from exposure to plane waves is presented. Surface magnetic fields in the range of 1 to 10 mA/m are easily produced for frequencies between 1 and 10 MHz. Measurement of the magnetic field at a prescribed distance from the outside and inside surfaces of hardened apertures, such as window screens and gasketed doors, using a small loop sensor and a battery-operated field-strength meter allows the shielding effectiveness of these hardening elements to be determined. When a current probe is substituted for the loop, this technique can also be used to characterized conductive penetrations. This technique has great potential as an aircraft hardness surveillance tool because it is simple to implement, quantitative and capable of not only characterizing each hardening element, but also finding the electromagnetic hot spots. I.E.

N88-28919*# CK Consultants, Inc., Mariposa, Calif.
AVIONICS SYSTEM DESIGN FOR HIGH ENERGY FIELDS: A GUIDE FOR THE DESIGNER AND AIRWORTHINESS SPECIALIST Final Report
ROGER A. MCCONNELL Jun. 1987 235 p
(Contract NAS2-12448)
(NASA-CR-181590; NAS 1.26:181590; DOT/FAA/CT-87/19)
Avail: NTIS HC A11/MF A01 CSCL 01D

Because of the significant differences in transient susceptibility, the use of digital electronics in flight critical systems, and the reduced shielding effects of composite materials, there is a definite need to define pracitices which will minimize electromagnetic susceptibility, to investigate the operational environment, and to develop appropriate testing methods for flight critical systems. The design practices which will lead to reduced electromagnetic susceptibility of avionics systems in high energy fields is described. The levels of emission that can be anticipated from generic digital devices. It is assumed that as data processing equipment becomes an ever larger part of the avionics package, the construction methods of the data processing industry will increasingly carry over into aircraft. In Appendix 1 tentative revisions to RTCA DO-160B, Environmental Conditions and Test Procedures for Airborne Equipment, are presented. These revisions are intended to safeguard flight critical systems from the effects of high energy electromagnetic fields. A very extensive and useful bibliography on both electromagnetic compatibility and avionics issues is included. Author

N88-28921# Crew Systems Consultants, Yellow Springs, Ohio.
IMPROVEMENT OF HEAD-UP DISPLAY STANDARDS. VOLUME 2: EVALUATION OF HEAD-UP DISPLAYS TO ENHANCE UNUSUAL ATTITUDE RECOVERY Final Report, 1 Oct. 1984 - 15 Jun. 1987
RICHARD L. NEWMAN Sep. 1987 61 p
(Contract F33615-85-C-3602)
(AD-A194601; TR-87-14; AFWAL-TR-87-3055-VOL-2) Avail: NTIS HC A04/MF A01 CSCL 25C

Several variations of head-up display symbologies were evaluated in a fixed base simulator to study their effect on unusual attitude recovery using head-up display data alone. The results indicate that pitch scale compression, additional bank information, and slanted pitch ladder lines enhance recoveries from unusual attitudes. Automatic deletion of the velocity vector symbol at high angles-of-attack also enhances recovery. Recommendations for future head-up display symbologies are made. GRA

N88-28922# Crew Systems Consultants, Yellow Springs, Ohio.
IMPROVEMENT OF HEAD-UP DISPLAY STANDARDS. VOLUME 5: HEAD UP DISPLAY ILS (INSTRUMENT LANDING SYSTEM) ACCURACY FLIGHT TESTS Final Report, 1 Oct. 1984 - 15 Jun. 1987
RICHARD L. NEWMAN and RANDALL E. BAILEY Sep. 1987 45 p
(Contract F33615-85-C-3602; F33615-83-C-3603)
(AD-A194602; TR-87-13; AFWAL-TR-87-3055-VOL-5) Avail: NTIS HC A03/MF A01 CSCL 01D

An in-flight investigation of the effect of head-up display symbol accuracy has been conducted using a variable stability T-33 aircraft. The results indicate that 100 to 200 ft lateral errors and 500 to 1500 ft longitudinal errors in locating a contact analog synthetic runway did not cause difficulties for the evaluation pilots. There was no apparent tendency for the subjects to follow HUD cues and ignore real world cues. GRA

N88-28923# Management Consulting and Research, Inc., Falls Church, Va.
AIRCRAFT AVIONICS AND MISSILE SYSTEM INSTALLATION COST STUDY. VOLUME 1: TECHNICAL REPORT AND APPENDICES A THROUGH E Final Report, Apr. 1987 - Feb. 1988
KIRSTEN M. PEHRSSON and GEORGE R. KREISEL 12 Feb. 1988 233 p
(Contract N00600-84-D-4171)
(AD-A194605; MCR-TR-8711/12-1) Avail: NTIS HC A11/MF A01 CSCL 05C

This report documents a parametric cost model for aircraft avionics installations and modifications. Cost and technical data collected during a previous avionics installation cost study, as well as data collected from data sources identified during this effort were used to analyze costs of individual avionics black-box modifications or installations into aircraft. The report details the methodology used to construct the data base and to develop cost-estimating relationships (CERs). Details of CERs developed for non-recurring costs, recurring installation/modification kit costs, labor costs, and manhours are provided, as well as the supporting data used in the analyses. The report is only available to authorized U.S. Government personnel. GRA

N88-29365*# Arizona State Univ., Tempe. Dept. of Computer Science.
AVIONIC EXPERT SYSTEMS
FOROUZAN GOLSHANI *In* NASA, Marshall Space Flight Center, Second Conference on Artificial Intelligence for Space Applications p 123-129 Aug. 1988 Sponsored in part by Sperry Research Trust Foundation
Avail: NTIS HC A99/MF E03 CSCL 01D

At the heart of any intelligent flight control system, there is a knowledge based expert system. The efficiency of these knowledge bases is one of the major factors in the success of aviation and space control systems. In the future, the speed and the capabilities of the expert system and their underlying data base(s) will be the limiting factors in the ability to build more accurate real time space controllers. A methodology is proposed for design and construction of such expert systems. It is noted that existing expert systems are inefficient (slow) in dealing with nontrivial real world situations that involve a vast collection of data. However, current data bases, which are fast in handling large amounts of data, cannot carry out intelligent tasks normally expected from an expert system. The system presented provides the power of deduction (reasoning) along with the efficient mechanisms for management of large data bases. In the system, both straight forward evaluation procedures and sophisticated inference mechanisms coexist. The design methodology is based on mathematics and logic, which ensures the correctness of the final product. Author

N88-29719# Technische Univ., Brunswick (West Germany). Inst. for Guidance and Control.
FLIGHT TEST EQUIPMENT FOR THE ON-BOARD MEASUREMENT OF WIND TURBULENCE
G. SCHAENZER, M. SWOLINSKY, and P. VOERSMANN (Aerodata Flugmesstechnik G.m.b.H., Brunswick, West Germany) *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 11 p Jun. 1988
Avail: NTIS HC A06/MF A01

The knowledge of the actual wind and turbulence situation along the flight path of an aircraft is an important factor in the area of meteorological and aeronautical research. Different flight test programs for the onboard implementation of offline and online wind and turbulence measuring systems are presented. The theoretical principle of the determination of all three components of the wind vector is stated. A summary of the installed sensors, the data acquisition systems and computer equipment is presented and the essential effects of sensor errors on the accuracy of wind determination are discussed. Author

N88-29730# National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.
THE NAE ATMOSPHERIC RESEARCH AIRCRAFT
J. I. MACPHERSON and S. W. BAILLIE *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 19 p Dec. 1987
Avail: NTIS HC A09/MF A01

The Flight Research Laboratory of the NAE of Canada operates a T-33 and a Twin Otter aircraft instrumented for atmospheric research studies. The instrumentation in the aircraft is described with emphasis on the strapped down inertial Doppler system used to derive the mean and turbulent components of the atmospheric motion. Example data from several research projects are presented to demonstrate the measurement and analysis capabilities of the aircraft and their data playback facilities. Author

N88-29797# Essex Corp., Alexandria, Va.
USE OF COLOR CRTS (CATHODE RAY TUBES) IN AIRCRAFT COCKPIT: A LITERATURE SEARCH, REVISION B Final Report
STEVEN L. HALE and HANNS J. BILLMAYER Apr. 1988 24 p
(Contract DAAA15-88-C-0005; DA PROJ. 1L1-62716-A-700)
(AD-A195062; EFR-014-REV-B; HEL-TN-3-88-REV-B) Avail: NTIS HC A02/MF A01 CSCL 09E

A literature search was conducted to assess the utility and feasibility of incorporating color cathode ray tubes (CRTs) in military aircraft cockpits and is presented in annotated bibliography format. The advantages and disadvantages of color CRTs are reviewed. It is concluded that the incorporation of color on aircraft CRTs will prove beneficial and that potential problems associated with the use of color displays can be eliminated with proper display design and the advancement of technology. GRA

N88-29800# Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio.
A MULTIPROCESSOR AVIONICS SYSTEM FOR AN UNMANNED RESEARCH VEHICLE Final Report, 1 Jan. - 15 Dec. 1987
DANIEL B. THOMPSON Mar. 1988 197 p
(AD-A194806; AFWAL-TR-88-3003) Avail: NTIS HC A09/MF A01 CSCL 12F

AFWAL/FIGL is developing a new Unmanned Research Vehicle (URV) testbed system for low cost flight testing of advanced flight control concepts. This new system will incorporate a modular/reconfigurable airframe, will possess greater aerodynamic capabilities, and will utilize an advanced avionics/control system to allow embedded computation of flight test applications. AFWAL/FIGL has utilized its in-house experience in multiprocessor systems technologies to develop a first phase prototype system comprised of multiple microprocessors and a parallel backplane bus. A multiprocessor software operating system and interprocessor communications protocol have been developed and tested. To demonstrate the capabilities of the system and the development of parallel software, an applications set of parallel software tasks have been developed and demonstrated. The hardware and software architecture, approach taken in the development, and results achieved are described in this report. GRA

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AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A88-52676#
COMBUSTION-GENERATED TURBULENCE IN PRACTICAL COMBUSTORS
D. R. BALLAL (Dayton, University, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 4, Sept.-Oct. 1988, p. 385-390. Previously cited in issue 20, p. 3154, Accession no. A87-45161. refs
(Contract F33615-82-C-2255)

A88-52684*# Purdue Univ., West Lafayette, Ind.
CONTROL OF ROTOR AERODYNAMICALLY FORCED VIBRATIONS BY SPLITTERS
SANFORD FLEETER, DAVID A. TOPP (Purdue University, West Lafayette, IN), and DANIEL HOYNIAK (NASA, Lewis Research Center, Cleveland, OH) (Structures, Structural Dynamics and Materials Conference, 27th, San Antonio, TX, May 19-21, 1986, Technical Papers. Part 2, p. 77-88) Journal of Propulsion and Power (ISSN 0748-4658), vol. 4, Sept.-Oct. 1988, p. 445-451. Previously cited in issue 18, p. 2612, Accession no. A86-38892. refs

A88-52698#
VIABILITY RATING BY FUEL INDEXING METHOD
P. P. S. SARMA, S. N. ACHARYA, B. K. SINHA (Indian Airlines, Hyderabad, India), and U. P. SINGH (Indian Airlines, Madras, India) Aeronautical Society of India, Journal (ISSN 0001-9267), vol. 39, Nov. 1987, p. 189-196.

This article suggests and demonstrates a method of quantifying the net response of an aircraft/engine to a cumulated complexity of operational variables. This method makes use of the most sensitive operational input, the fuel, as the indexing medium. An aircraft/engine is rated as per fuel index for the purpose of assessment of comparative performance viabilities within a type or group. These ratings are categorized into (1) operational viability ratings and (2) overhaul viability ratings for the purpose of reviewing and rectification action, which includes tracking down, prevention, and correction of defective procedures, systems, and/or components. Author

A88-53102#
ADVANCED TECHNOLOGY ENGINE SUPPORTABILITY - PRELIMINARY DESIGNER'S CHALLENGE
JOHN J. CIOKAJLO and JAMES E. HARTSEL (General Electric Co., Evendale, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 7 p.
(AIAA PAPER 88-2796)

The U.S. military services have undertaken a cooperative program with private industry aimed at the integration of radically advanced engineering disciplines, including supportability, into future fighter aircraft propulsion systems having three times the thrust/weight values typical of state-of-the-art engines. This effort, which is scheduled to proceed over a period of 15 years, will grapple with the possibilities for supportability of novel materials used in engine structural components. O.C.

A88-53103#
TESTING OF THE 578-DX PROPFAN PROPULSION SYSTEM
D. C. CHAPMAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), J. GODSTON (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT), and D. E. SMITH (United Technologies, Corp., Hamilton Standard Div., Windsor Locks, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 11 p.
(AIAA PAPER 88-2804)

In preparation for a flight test program, the 578-DX Propfan Demonstrator Propulsion System has undergone comprehensive testing of such major components as the gearbox, the turbine power section, and the propulsion system mounts. Additional evaluations have been undertaken of the engine and propfan control systems, the lubrication and heat-rejection system, and interactions among major system components. Attention is given to the results obtained with both aluminum propeller blades and composite, spar-and-shell propfan blades. O.C.

A88-53104#
UDF ENGINE/MD80 FLIGHT TEST PROGRAM
HERBERT E. NICHOLS (General Electric Co., Cincinnati, OH)

AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 14 p.
(AIAA PAPER 88-2805)

The fuel efficiency improvements demonstrated by the Unducted Fan (UDF) engine during its flight trials as one of the two engines of an MD80 airliner are comparable to preflight predictions; cruise SFC levels of the order of 20-40 percent better than current low-to-moderate bypass turbofans were obtained. UDF demonstrator engine acoustics also met important noise emission goals, including an 82-dBA worst-seat cabin internal noise limit. When employing a 10-blade front rotor/8-blade rear rotor, the UDF met FAR 36 Part III community noise limits. O.C.

A88-53111#
DIRECT LIFT ENGINE FOR ADVANCED V/STOL TRANSPORT
ROBERT F. TAPE (Rolls-Royce, Inc., Atlanta, GA) and RAYMOND BULL (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 9 p. Research supported by USAF and Rolls-Royce, Inc.
(AIAA PAPER 88-2890A)

A 'direct-lift' 40,000-lb thrust class engine concept has been formulated for application in future advanced V/STOL military transport aircraft of approximately C-130 scaling. The turbomechanical configurations considered achieve thrust:weight values of the order of 33:1 through the use of both advanced, low-density materials and innovative design features. A swiveling of the entire engine is judged best for thrust-vectoring with engines of this type, and large-radius bellmouth intakes with longitudinal doors are the chosen installation design for three or more engines mounted in tandem. O.C.

A88-53119#
TOWARDS THE OPTIMUM DUCTED UHBR ENGINE
J. A. BORRADAILE (Rolls-Royce, PLC, London, England) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 7 p.
(AIAA PAPER 88-2954)

Next-generation ultrahigh bypass ratio (UHBR) ducted turbofans with variable-pitch blading and downgeared fan rotors offer specific fuel consumption improvements of the order of 10 percent over comparable-output conventional turbofans, with a 50-percent increase in fan rotor diameter but only small changes in weight and maintenance cost; high cruise speed and installation position advantages are also noted. Attention is given to an alternative configuration with the same bypass ratio, where the engine-front UHBR fan rotor is replaced by a contrarotating low pressure turbine/ducted two-stage fan at the engine's aft end. O.C.

A88-53121#
FUTURE SUPERSONIC TRANSPORT NOISE - LESSONS FROM THE PAST
M. J. T. SMITH, B. W. LOWRIE, J. R. BROOKS (Rolls-Royce, PLC, London, England), and K. W. BUSHELL (Rolls-Royce, Inc., Atlanta, GA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 16 p. refs
(AIAA PAPER 88-2989)

While the small, carefully operated Concorde SST fleet has come to be accepted at important airports, next-generation SSTs will be larger than Concorde and must therefore enlist advanced techniques to comply with FAR Part 36, Stage 3. This entails the use of an engine cycle which, during takeoff, is equivalent to a high bypass ratio turbofan with a mean exhaust velocity no greater than 400 m/sec. Such variable-cycle engines, whether for Mach 2 or 3 cruise, are technically possible but difficult to develop. Variable engine cycle is further entailed by overland flight requirements, which require subsonic flight to prevent sonic boom overpressures. O.C.

A88-53122#
A USEFUL SIMILARITY PRINCIPLE FOR JET ENGINE EXHAUST SYSTEM PERFORMANCE
W. M. PRESZ, JR. (Western New England College, Springfield, MA) and E. M. GREITZER (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 11 p. refs
(AIAA PAPER 88-3001)

A similarity principle that facilitates the inference of exhaust systems' performance on the basis of model tests conducted with uniform stagnation temperatures is presented and verified in light of calculations and comparisons with existing data. Potential applications encompass single-flow nozzles, forced mixers, exhaust jets, and ejector nozzles. It is shown that appropriately chosen performance parameters will be similar for both hot flow and cold flow model tests, as long as the initial Mach numbers and total pressures of the flowfield are simulated. O.C.

A88-53136#
ATR PROPULSION SYSTEM DESIGN AND VEHICLE INTEGRATION
J. A. BOSSARD, K. L. CHRISTENSEN, and G. E. POTH (Aerojet TechSystems Co., Sacramento, CA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 10 p.
(AIAA PAPER 88-3071)

The air turboramjet (ATR) propulsion cycle and its prospective design features are presently discussed with a view to ATR advantages in advanced missile powerplant applications, by comparison to conventional turbojets and rocket/ramjets. The advantages encompass enhanced survivability through higher-than-turbojet speeds, coupled with the possibility of lower-than-ramjet-speed initial operation, to obviate the ramjet's requisite booster rocket. The strong interactions between the ATR engine and airframe flight characteristics render the complete vehicle's design optimization iteration process critical. O.C.

A88-53137*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
A PRELIMINARY DESIGN STUDY OF SUPERSONIC THROUGH-FLOW FAN INLETS
PAUL J. BARNHART (NASA, Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Middleburg Heights, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 11 p. refs
(Contract NAS3-24105)
(AIAA PAPER 88-3075)

From Mach 3.20 cruise propulsion systems, preliminary design studies for two supersonic through-flow fan primary inlets and a single core inlet were undertaken. Method of characteristics and one-dimensional performance techniques were applied to assess the potential improvements supersonic through-flow fan technology has over more conventional systems. A fixed geometry supersonic through-flow fan primary inlet was found to have better performance than a conventional inlet design on the basis of total pressure recovery, air flow, aerodynamic drag and size and weight.
Author

A88-53151*# Vigyan Research Associates, Inc., Hampton, Va.
CFD PREDICTION OF THE REACTING FLOW FIELD INSIDE A SUBSCALE SCRAMJET COMBUSTOR
T. CHITSOMBOON (Vigyan Research Associates, Inc., Hampton, VA), G. B. NORTHAM, R. C. ROGERS, and G. S. DISKIN (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 7 p.
(Contract NAS1-17919)
(AIAA PAPER 88-3259)

A three-dimensional, Reynolds-averaged Navier-Stokes CFD code has been used to calculate the reacting flowfield inside a hydrogen-fueled, subscale scramjet combustor. Pilot fuel was injected transversely upstream of the combustor and the primary fuel was injected transversely downstream of a backward facing step. A finite rate combustion model with two-step kinetics was used. The CFD code used the explicit MacCormack algorithm with point-implicit treatment of the chemistry source terms. Turbulent mixing of the jets with the airstream was simulated by a simple mixing length scheme, whereas near wall turbulence was accounted for by the Baldwin-Lomax model. Computed results were compared with experimental wall pressure measurements. Author

A88-53167#
DIMENSIONING OF TURBINE BLADES FOR FATIGUE AND CREEP
B. DAMBRINE and J. P. MASCARELL (SNECMA, Moissy-Cramayel, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 1, 1988, p. 35-45. refs

Improving the performance of aircraft engines entails raising the gas temperature at the turbine intake. This has led SNECMA to improve cooling techniques, mechanical computation methods, lifetime prediction methods and the materials themselves. This article presents the dimensioning problems, and in particular the use of the ONERA method for determining the lifetime of turbine blades. Author

A88-53774#
THE RTM322 ENGINE IN THE S-70C HELICOPTER
PAUL E. SCEARS and PETER SEWELL (Rolls-Royce, PLC, Leavesden, England) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 9 p.
(AIAA PAPER 88-4576)

An account is given of the design features and S-70C helicopter-based developmental flight testing status of the 2000-hp class RTM322 turboshaft engine, which is a candidate for future incorporation into not only production S-70s but also H-60, EH101, and NH90 helicopters; a power growth potential of the order of 3000 hp is projected for the engine. Attention is given to installation, control, and engine/airframe dynamic characteristics, as well as ground and flight test results. The digital control system used will significantly ease the engine's integration into series production aircraft. O.C.

A88-54137* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
TOWARD IMPROVED DURABILITY IN ADVANCED AIRCRAFT ENGINE HOT SECTIONS; PROCEEDINGS OF THE THIRTY-THIRD ASME INTERNATIONAL GAS TURBINE AND AEROENGINE CONGRESS AND EXPOSITION, AMSTERDAM, NETHERLANDS, JUNE 5-9, 1988
DANIEL E. SOKOLOWSKI, ED. (NASA, Lewis Research Center, Cleveland, OH) Congress and Exposition sponsored by ASME. New York, American Society of Mechanical Engineers, 1988, 128 p. For individual items see A88-54138 to A88-54146.

The present conference on durability improvement methods for advanced aircraft gas turbine hot-section components discusses NASA's 'HOST' project, advanced high-temperature instrumentation for hot-section research, the development and application of combustor aerothermal models, and the evaluation of a data base and numerical model for turbine heat transfer. Also discussed are structural analysis methods for gas turbine hot section components, fatigue life-prediction modeling for turbine hot section materials, and the service life modeling of thermal barrier coatings for aircraft gas turbine engines. O.C.

A88-54138*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
NASA HOST PROJECT OVERVIEW
D. E. SOKOLOWSKI (NASA, Lewis Research Center, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 1-4. refs

NASA's Hot Section Technology, or 'HOST', program has developed improved analytical models for the aerothermal environment, thermomechanical loading, material behavior, structural response, and service life of aircraft gas turbine engines' hot section components. These models, in conjunction with sophisticated computer codes, can be used in design analyses of critical combustor and turbine elements. Toward these ends, efforts were undertaken in instrumentation, combustion, turbine heat transfer, structural analysis, fatigue/fracture, and surface protection. Attention is presently given to the organization of HOST activities and their specific subject matter. O.C.

A88-54140*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
ASSESSMENT, DEVELOPMENT, AND APPLICATION OF COMBUSTOR AEROTHERMAL MODELS
J. D. HOLDEMAN (NASA, Lewis Research Center, Cleveland, OH), H. C. MONGIA (General Motors Corp., Indianapolis, IN), and E. J. MULARZ (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 23-37. Previously announced in STAR as N88-19469. refs

The gas turbine combustion system design and development effort is an engineering exercise to obtain an acceptable solution to the conflicting design trade-offs between combustion efficiency, gaseous emissions, smoke, ignition, restart, lean blowout, burner exit temperature quality, structural durability, and life cycle cost. For many years, these combustor design trade-offs have been carried out with the help of fundamental reasoning and extensive component and bench testing, backed by empirical and experience correlations. Recent advances in the capability of computational fluid dynamcis codes have led to their application to complex 3-D flows such as those in the gas turbine combustor. A number of U.S. Government and industry sponsored programs have made significant contributions to the formulation, development, and verification of an analytical combustor design methodology which will better define the aerothermal loads in a combustor, and be a valuable tool for design of future combustion systems. The contributions made by NASA Hot Section Technology (HOST) sponsored Aerothermal Modeling and supporting programs are described. Author

A88-54141*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
REVIEW AND ASSESSMENT OF THE DATABASE AND NUMERICAL MODELING FOR TURBINE HEAT TRANSFER
H. J. GLADDEN and R. J. SIMONEAU (NASA, Lewis Research Center, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 39-55. refs

The objectives of the HOST Turbine Heat Transfer subproject were to obtain a better understanding of the physics of the aerothermodynamic phenomena and to assess and improve the analytical methods used to predict the flow and heat transfer in high-temperature gas turbines. At the time the HOST project was initiated, an across-the-board improvement in turbine design technology was needed. A building-block approach was utilized and the research ranged from the study of fundamental phenomena and modeling to experiments in simulated real engine environments. Experimental research accounted for approximately 75 percent of the funding while the analytical efforts were approximately 25 percent. A healthy government/industry/university partnership, with industry providing almost half of the research, was created to advance the turbine heat transfer design technology base.
Author

A88-54143#
STRUCTURAL ANALYSIS APPLICATIONS
R. L. MCKNIGHT (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 83-95. refs

An account is given of the application of computer codes for the efficient conduct of three-dimensional inelastic analyses to aircraft gas turbine combustor, turbine blade, and turbine stator vane components. The synergetic consequences of the program's activities are illustrated by an evaluation of the computer analyses of thermal barrier coatings and of the Space Shuttle Main Engine's High Pressure Fuel Turbopump turbine blading. This software, in conjunction with state-of-the-art supercomputers, can significantly reduce design-task burdens. O.C.

A88-54146*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
VIEWS ON THE IMPACT OF HOST
J. B. ESGAR (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) and D. E. SOKOLOWSKI (NASA, Lewis Research Center, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 117-123.

The Hot Section Technology (HOST) Project, which was initiated by NASA Lewis Research Center in 1980 and concluded in 1987, was aimed at improving advanced aircraft engine hot section durability through better technical understanding and more accurate design analysis capability. The project was a multidisciplinary, multiorganizational, focused research effort that involved 21 organizations and 70 research and technology activities and generated approximately 250 research reports. No major hardware was developed. To evaluate whether HOST had a significant impact on the overall aircraft engine industry in the development of new engines, interviews were conducted with 41 participants in the project to obtain their views. The summarized results of these interviews are presented. Author

A88-54153#
MULTIVARIABLE TURBOFAN ENGINE CONTROL FOR FULL FLIGHT ENVELOPE OPERATION
JOHN A. POLLEY, SHRIDER ADIBHATLA, and PAUL J. HOFFMAN (General Electric Co., Cincinnati, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-6)

The design of a full flight envelope nonlinear multivariable controller is described for a single-bypass variable-cycle jet engine. The nonlinear controller is obtained by using appropriate engine corrected parameters to schedule multivariable linear compensator gains designed at selected operating points of the flight envelope. The KQ (K-matrix compensator, Q-desired response) multivariable control design technique is used to design the compensators using linear state-space models obtained from a detailed nonlinear aerothermo model. The controller is implemented in the detailed nonlinear aerothermo model. The paper decribes an example KQ compensator design, the corrected-parameter gain scheduling approach and controller performance validation by nonlinear simulation. Computer simulations for sea-level static, and supersonic operating points are included to show the closed-loop transient performance in the presence of an acceleration fuel schedule. Author

A88-54168#
REAL TIME SIMULATORS FOR USE IN DESIGN OF INTEGRATED FLIGHT AND PROPULSION CONTROL SYSTEMS
WILLIAM J. DAVIES, CHARLIE L. JONES, and ROBERT A. NOONAN (United Technologies Corp., Pratt and Whitney, West Palm Beach, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p.
(ASME PAPER 88-GT-24)

New testing requirements necessitated by the integration of Full Authority Digital Electronic Controls (FADEC) with the flight control are examined with emphasis on the need for the use of real time integrated flight and propulsion control test benches. The propulsion system simulation described here includes the following major components: the digital models and data monitor, an electronic verifier unit, a control data acquisition system, and the actual FADEC, which can be either a breadboard or an engine mounted unit. It is noted that integrated flight and propulsion control simulators will have an increasing impact on the design process, support of early concept evaluations, system integration tests, flight clearance, and flight test support. V.L.

A88-54170#
A DETAILED CHARACTERIZATION OF THE VELOCITY AND THERMAL FIELDS IN A MODEL CAN COMBUSTOR WITH WALL JET INJECTION
C. D. CAMERON, J. BROUWER, C. P. WOOD, and G. S. SAMUELSEN (California, University, Irvine) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(Contract F08635-83-C-0052; N00140-83-C-9151)
(ASME PAPER 88-GT-26)

This work represents a first step in the establishment of a data base to study the interaction and influence of liquid fuel injection, wall jet interaction, and dome geometry on the fuel air mixing process in a flowfield representative of a practical combustor. In particular, the aerodynamic and thermal fields of a model gas turbine combustor are characterized via detailed spatial maps of velocity and temperature. Measurements are performed at an overall equivalence ratio of 0.3 with a petroleum JP-4 fuel. The results reveal that the flowfield characteristics are significantly altered in the presence of reaction. Strong on-axis backmixing in the dome region, present in the isothermal flow, is dissipated in the case of reaction. The thermal field exhibits the primary, secondary and dilution zone progression of temperatures characteristic of practical gas turbine combustors. A parametric variation on atomizing air reveals a substantial sensitivity of the mixing in this flow to nozzle performance and spray symmetry. Author

A88-54224#
DESIGN OPTIMIZATION OF GAS TURBINE BLADES WITH GEOMETRY AND NATURAL FREQUENCY CONSTRAINTS
TSU-CHIEN CHEU (Textron, Inc., Avco Lycoming Textron Div., Stratford, CT), BO PING WANG (Texas, University, Arlington), and TING-YU CHEN (National Chunghsing University, Taichung, Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-105)

In this paper an automated procedure is presented to obtain the minimum weight design of gas turbine blades with geometry and multiple natural frequency constraints. The objective is achieved using a combined finite element-sequential linear programming, FEM-SLP technique. Thickness of selected finite elements are used as design variables. Geometric constraints are imposed on the thickness variations such that the optimal design has smooth aerodynamic shape. Based on the natural frequencies and mode shapes obtained from finite element analysis an assumed mode reanalysis technique is used to provide the approximate derivatives of weight and constraints with respect to design variables for sequential linear programming. The results from SLP provide the initial design for the next FEM-SLP process. An example is presented to illustrate the interactive system developed for the optimization procedure. Author

A88-54239#
AN EMISSIONS DATABASE FOR U.S. NAVY AND AIR FORCE AIRCRAFT ENGINES
HENRY B. FAULKNER, MELVIN PLATT (Northern Research and Engineering Corp., Woburn, MA), ANTHONY F. KLARMAN (U.S. Naval Air Propulsion Test Center, Trenton, NJ), and MARK D. SMITH (USAF, Engineering and Services Center, Tyndall AFB, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-129)

This paper presents a data base on the pollutant emission by the U.S. Navy and Air Force aircraft engines collected over the last twenty years. The resulting data base contains all of the available emission data as well as background information on each engine model tested for emission and the conditions for each test. In addition, all of the unclassified operational engine models of the U.S. Navy and Air Force are listed, whether or not emission data are available, and, for models for which emission data are not available, a similar engine model whose data can be reasonably substituted is identified. I.S.

A88-54247#
DESIGN AND TEST OF NON-ROTATING CERAMIC GAS TURBINE COMPONENTS
ANDRE L. NEUBURGER and GILLES CARRIER (Pratt and Whitney Canada, Longueuil) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-146)

This paper deals with elements of an on-going ceramics research and development program at a major manufacturer of turbine engines for general aviation and commuter aircraft. The program comprises design and test of non-rotating, ceramic components for two widely used turboprop engines. The design, analysis and test of three components are discussed: a simple ceramic turbine shroud, a metal and ceramic turbine shroud, and an all-ceramic nozzle vane assembly. Fabrication and assembly of these components are described. A discussion of non-destructive evaluation and component prooftesting includes a prooftest strategy that seeks to retain the stronger half of a sample of specimens. Candidate ceramics, silicon carbide and silicon nitride, are assessed and chosen as the shroud and vane materials. The paper also includes assessment of improvements in fuel efficiency, specific power and operating cost, some based on test results and some on analysis. Author

A88-54249#
A UK PERSPECTIVE ON ENGINE HEALTH MONITORING (EHM) SYSTEMS FOR FUTURE TECHNOLOGY MILITARY ENGINES
N. A. BAIRSTO (RAF, London, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p.
(ASME PAPER 88-GT-148)

The first part of the paper deals with the background to the UK experience in EHM. The programs that have led to the UK's experience are given and some lessons learned are outlined which will be applied to Engine Health Monitoring (EHM) in future engines. The UK policy for the fleetwide fit of EHM equipment is stated. In the second part, the application of EHM to advanced technology engines is examined from a personal viewpoint. Future engines will include materials and aerothermal cycles that are in the research and development field. The impact of a structured approach to durability, the anticipated reduction of engine spares holdings and the requirement to improve flight safety and enhance engine availability are advanced as arguments in support of the development of EHM techniques alongside the development of future engines. Author

A88-54295#
FAULT DIAGNOSIS OF GAS TURBINE ENGINES FROM TRANSIENT DATA
G. L. MERRINGTON (Department of Defence, Aeronautical Research Laboratories, Melbourne, Australia) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(ASME PAPER 88-GT-209)

The desirability of being able to extract relevant fault diagnostic information from transient gas turbine data records is discussed. A method is outlined for estimating the effects of unmeasured fault parameters from input/output measurements. The resultant sensitivity of the technique depends on the sampling rate and the measurement noise. Author

A88-54301#
ANALYSIS OF EFFICIENCY SENSITIVITY ASSOCIATED WITH TIP CLEARANCE IN AXIAL FLOW COMPRESSORS
IAN N. MOYLE (U.S. Naval Postgraduate School, Monterey, CA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. Navy-supported research. refs
(ASME PAPER 88-GT-216)

The effects of tip clearance changes on efficiency in axial compressors are typically established experimentally. The ratio of change of efficiency with change of clearance gap varies significantly for different compressors in the published data. An analysis of this sensitivity range in terms of the blade and stage design parameters was initiated. The analysis revealed that the sensitivity range largely resulted from a derivation at constant flow of the efficiency decrement. It was also found that a generalized loss method of generating the sensitivities produced a much improved correlation of the change in efficiency with change in clearance over a variety of machines, configurations and speeds. Author

A88-54304#
FLOW MEASUREMENTS IN ROTATING STALL IN A GAS TURBINE ENGINE COMPRESSOR
R. C. BEST, J. G. C. LAFLAMME, and W. C. MOFFATT (Royal Military College of Canada, Kingston) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. DND-supported research. refs
(ASME PAPER 88-GT-219)

Hot sensor anemometry has been used to make detailed flow measurements on the first four stages of a 10-stage compressor operating as part of a turbojet engine mounted on a test stand. Results for a number of axial and tangential locations show clear evidence of rotating stall in the front stages during the part-speed operation of the engine. The stall cell configuration and rotating speed as well as details of flow speed and angle at hub, mid and tip radii are discussed. It is concluded that, although rotating stall has its origins in flow instability, it is a highly reproducible phenomenon. V.L.

A88-54306#
TRANSIENT PERFORMANCE TRENDING FOR A TURBOFAN ENGINE
J. R. HENRY and W. C. MOFFATT (Royal Military College of Canada, Kingston) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 11 p. DND-supported research. refs
(ASME PAPER 88-GT-222)

The feasibility of using engine data acquired during takeoff to trend the performance of a modern turbofan engine (GE-F404) is investigated. Representative engine data from operational aircraft are used to estimate various trending parameters, with a data capture window used to minimize the scatter of nominal engine performance. The factors influencing the repeatability of takeoff data, such as throttle rate, variable geometry, and instrumentation effects, are discussed in detail. The trending of transient performance data is shown to be a viable means of detecting certain engine faults, and recommendations concerning the implementation of such a program for the F404 engine are made. V.L.

A88-54312#
PRECISION ERROR IN A TURBOFAN ENGINE MONITORING SYSTEM
J. R. HENRY and W. C. MOFFATT (Royal Military College of Canada, Kingston) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. DND-supported research. refs
(ASME PAPER 88-GT-229)

Precision error in the turbofan engine monitoring system of a modern fighter, based on steady state and transient data records, is examined. The general design and operation of the engine monitoring system are described, and a method is presented for estimating the overall system precision. It is found that precision errors in sensing are much lower than those in the conditioning and processing of engine data. It is further shown that possible improvements in the monitoring system are constrained by data sampling rates and digital word formats. V.L.

A88-54317#

A METHANOL/OXYGEN BURNING COMBUSTOR FOR AN AIRCRAFT AUXILIARY EMERGENCY POWER UNIT

E. CARR and H. TODD (Lucas Aerospace, Ltd., Burnley, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 4 p.
(ASME PAPER 88-GT-236)

High altitude facility performance test results are presented for a 300-kW output oxygen-oxidant combustor, applicable to emergency aircraft electrical or hydraulic power turbine use, that is cooled by the methanol it employs as fuel. It is found that the combustor lights reliably at 20 km simulated altitude with -40 C oxygen temperature, and possesses a mechanical service life that is in excess of prospective aircraft applications requirements. O.C.

A88-54319#

LINEAR STATE VARIABLE DYNAMIC MODEL AND ESTIMATOR DESIGN FOR ALLISON T406 GAS TURBINE ENGINE

S. VITTAL RAO, D. MOELLENHOFF (Missouri-Rolla, University, Rolla), and J. A. JAEGER (General Motors Corp., Allison Gas Turbines Div., Indianapolis, IN) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. Research supported by General Motors Corp.
(ASME PAPER 88-GT-239)

This paper describes a procedure for developing a State Variable Model for the Allison T406 gas turbine engine. This linear model is useful for designing controllers using modern control techniques. The engine and V-22 rotor system is modeled around an operating point by using four state variables and one input variable. For a given power setting, it is observed that two linear models are sufficient to represent the engine dynamics over the entire flight envelope. A relationship between surge margin and the state variables is also developed. It is demonstrated that these linear models are useful in designing an estimator for accommodating hard sensor failures. Author

A88-54321#

NUMERICAL CORRELATION OF GAS TURBINE COMBUSTOR IGNITION

F. P. LEE, T. KOBLISH (Textron, Inc., Textron-Turbo Components, Walled Lake, MI), and N. MARCHIONNA (Textron, Inc., Stratford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-242)

In single can combustor ignition tests, different results were obtained for pressure atomizing and airblast atomizing fuel injectors as well as for various ignition locations. In order to understand the effect of fuel spray characteristics and ignition locations on gas turbine combustion ignition characteristics, a computer simulation of fuel droplet ignition at engine starting flow conditions has been conducted. An ignition model for evaporating fuel droplets was incorporated with the numerical droplet tracking scheme in the computational flow field, which included a simulated ignition point source. A large number of various size droplets were computed for their trajectories and ignition reactions. A statistical data base was established to calculate the ignition probability of droplets in terms of number and mass fraction. A correlation between predicted ignition probability trends and experimental ignition data for two different injector/ignitor configurations was demonstrated. Author

A88-54322#

AGT101/ATTAP CERAMIC TECHNOLOGY DEVELOPMENT

G. L. BOYD and D. M. KREINER (Allied-Signal Aerospace Co., Garrett Auxiliary Power Div., Phoenix, AZ) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p.
(ASME PAPER 88-GT-243)

The Advanced Gas Turbine development program designated 'AGT101' exposed ceramic gas turbine components to over 250 hours of operation, including 85 hours of engine hot section tests at over 2200 F, before its completion in June 1987. The ceramic gas turbine component development effort then proceeded in August 1987 with the 5-year Advanced Turbine Technology Applications Project, which will improve ceramic component fabrication processes as well as analysis, testing, and verification procedures. Ceramic component reliability and durability will also be tested in engine operating environments. O.C.

A88-54326#

FLOW COMPUTATION AND BLADE CASCADE DESIGN IN TURBOPUMP TURBINES

GILLES BILLONNET (ONERA, Chatillon-sous-Bagneux, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-248)

The aerodynamic blade cascade design of a two stage axial supersonic turbine is investigated by using an inviscid flow computation method. The flow inside such kind of turbine is characterized by high inlet Mach numbers and large deflection angles as well as supersonic flow matching between stator and rotor. Most of the computed flow configurations give strong shock waves in the blade-to-blade channels, so that boundary-layer separation phenomena are anticipated. The inverse mode calculation is applied in order to avoid adverse pressure gradients on the walls. The semiinverse method allows to get the geometry of a blade profile corresponding to a given pressure distribution on the suction side and the pressure side, the solidity being fixed. A new design of the turbine blade cascade is then considered in order to achieve the desired velocity diagram. Author

A88-54333#

RECENT ADVANCES IN ENGINE HEALTH MANAGEMENT

KENNETH PIPE and CELIA FISHER (Stewart Hughes, Ltd., Southampton, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. Research supported by the Ministry of Defence Procurement Executive.
(ASME PAPER 88-GT-257)

New measurement capabilities developed in the last five years have greatly enhanced the ability of monitoring systems to produce acceptable engine distress and maintenance information to pilots. The more recent advances are particularly useful for military and helicopter engines. This paper describes three new techniques, with descriptions of their application. These include direct aerodynamic thrust measurement, gas path distress analysis and analysis of the dynamic behavior of gas turbines. The paper concludes by suggesting the impact of these techniques on systems design for future engines. Author

A88-54335#

A COMPARISON OF ENGINE DESIGN LIFE OPTIMIZATION RESULTS USING DETERMINISTIC AND PROBABILISTIC LIFE PREDICTION TECHNIQUES

EDWARD J. REED (Pratt and Whitney, West Palm Beach, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p.
(ASME PAPER 88-GT-259)

This paper documents a study conducted to determine the optimum design life of a turbine disk. The study traded weight against maintenance with the optimum being determined through a life cycle cost analysis. Both deterministic and probabilistic life prediction techniques were employed to establish maintenance frequency and cost. Comparing probabilistic with deterministic life optimization results was a major objective of this study. Both life prediction techniques resulted in the same optimum life conclusion with the probabilistic analysis giving additional insight into the decision drivers. Author

A88-54337#
STRUCTURAL DESIGN AND ITS IMPROVEMENTS THROUGH THE DEVELOPMENT OF THE XF3-30 ENGINE
HIDEKATSU KIKUCHI (Japan Defence Agency, Tokyo) and KIYOSHI ISHII (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-261)
The XF3-30 engine has been successfully completed its Qualification Test at March 1986 and the production has started as the powerplant for Japan Self Defence Force's intermediate trainer T-4. The first flight of the T-4 powered by two XF3-30 engine was made on July 29, 1985. More than 500 test flights have been made in these two years and engine flight time has accumulated to over 1500 hours. Strict structural integrity requirements have been imposed on this XF3-30 engine to meet the MIL-E-5007D specification. This paper describes the structural features of this engine and some structural problems encountered through the development. The improvements for these development problems are covered. Author

A88-54346#
RESPONSE OF LARGE TURBOFAN AND TURBOJET ENGINES TO A SHORT-DURATION OVERPRESSURE
M. G. DUNN (Calspan Advanced Technology Center, Buffalo, NY), R. M. ADAMS, and V. S. OXFORD (DNA, Washington, DC) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(Contract DNA001-83-C-0182)
(ASME PAPER 88-GT-273)
A high-thrust, low bypass ratio turbofan and a high-thrust turbojet were subjected to ground tests to ascertain the influence of thrust settling and overpressure level on operating characteristics. The results obtained indicate that, while overpressure has little influence on either high-pressure compressor speed or exhaust gas total pressure, the magnitude of the overpressure has a pronounced influence on turbine exhaust total pressure and on the inlet casing and diffuser casing radial displacements. The turbojet's turbine casing was significantly affected by the overpressure, while the turbofan's casing was relatively insensitive. O.C.

A88-54363#
CAUSES FOR TURBOMACHINERY PERFORMANCE DETERIORATION
W. TABAKOFF (Cincinnati, University, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(Contract DAAG29-82-K-0029)
(ASME PAPER 88-GT-294)
Experiments have been carried out on a two-stage gas turbine with blunt leading edge blades and on a single-stage axial flow compressor to investigate the effect of particulates and erosion on performance deterioration. It is found that particle concentrations change the pressure distribution along the turbine blades and decrease the performance of the turbine. The degree of performance deterioration increases with particle concentration and diameter. The compressor rig experiments indicate a significant reduction in engine efficiency due to erosion damage. The performance deterioration is mainly due to changes in the blade leading and trailing edges, tip leakage, surface roughness, and changes in pressure distribution. V.L.

A88-54366#
DEVELOPMENT OF THE T406-AD-400 OIL SCAVENGE SYSTEM FOR THE V-22 AIRCRAFT
JOHN R. ARVIN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p.
(ASME PAPER 88-GT-297)
The T406-AD-400 is a front drive, free power turbine engine rated at 6150 shp which is being developed to power the multiservice V-22 Osprey tilt rotor aircraft. The V-22 is a vertical takeoff and landing (VTOL) aircraft. To achieve VTOL the engine nacelles, located at the tip of each wing, are tilted upward placing the axis of rotation of the prop-rotor and engine in a vertical orientation. Once airborne, the nacelles are tilted forward such that the axis of rotation is horizontal for the 'airplane' mode. The requirement to operate both horizontally and vertically places additional requirements on the engine lubrication system. The sumps must be scavenged over this wide range of orientations. A unique approach, patented by General Motors, was used to scavenge the oil from each of the three sumps. This scavenge system is lighter and lower in cost than conventional approaches. The test facilities and development are discussed in this paper. Author

A88-54369#
XG40 - ADVANCED COMBAT ENGINE TECHNOLOGY DEMONSTRATOR PROGRAMME
A. F. JARVIS (Rolls-Royce, PLC, Bristol, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. Research supported by Ministry of Defence Procurement Executive.
(ASME PAPER 88-GT-300)
The XG40 R&D program was instituted in 1982 in order to produce gas turbine engine technologies that would be applicable to 1990s fighter aircraft, while lending themselves to broader application in civilian engine programs. The performance goals of the XG40 encompassed the achievement of a 10:1 thrust:weight ratio with good dry thrust SFC, as well as stringent operating cost, reliability, and durability requirements. Direct fighter aircraft applications of this engine are the European Fighter Aircraft and future, reengined Tornados. Attention is given to the design features of the fan, high-pressure compressor, combustion chamber, high- and low-pressure turbines, and engine control systems. O.C.

A88-54370#
DESIGN ASPECTS OF RECENT DEVELOPMENTS IN ROLLS-ROYCE RB211-524 POWERPLANTS
R. J. PARKES (Rolls-Royce, PLC, Derby, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p.
(ASME PAPER 88-GT-301)
This paper describes recent design changes in the RB211-524 powerplant. In response to the market requirement for a wide bodied aircraft to make journeys of increased range, the specific fuel consumption of the latest -524 engine has been improved by 14 percent, compared with initial versions. The potential of the three shaft concept has been coupled with the latest aerodynamic technology to produce over 25 percent more thrust at essentially the same engine size. This increased thrust has been achieved while meeting the latest noise and gaseous emissions regulations, and while achieving continuing improvements in engine reliability. Electronic engine control has been introduced to provide improved aircraft operation and maintenance. A.

A88-54371#
DEVELOPING THE ROLLS-ROYCE TAY
N. J. WILSON (Rolls-Royce, PLC, East Kilbride, Scotland) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 13 p.
(ASME PAPER 88-GT-302)
The evolution of the Tay engine, launched in response to the requirement for an engine suitable for powering a noise compliant aircraft in the 70-100 seat range, is reviewed. The engine is derived from the Spey Mk 555 installed in the Fokker F28 aircraft and incorporates several latest technology features, modularity and maintenability being the key areas addressed in the design. The general design, main components, and the principal performance characteristics of the Tay 650 engine are described. V.L.

A88-54372#
ENERGY MANEUVERABILITY AND ENGINE PERFORMANCE REQUIREMENTS
MICHAEL J. CADDY and WILLIAM K. ARNOLD (U.S. Navy, Naval Air Development Center, Warminster, PA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p.
(ASME PAPER 88-GT-303)

The 'energy maneuverability' concept is presently defined in simplistic terms as an introduction to a method for the comparative evaluation of fighter aircraft. A tradeoff sensitivity analysis is then developed for a generic future-generation fighter that illustrates the relationship between engine performance requirements and fighter maneuverability. It is found that, while thrust vectoring yields no significant energy maneuverability-related improvement, it can furnish enhanced stability and control characteristics at high-alpha conditions, as well as improve aircraft agility. O.C.

A88-54374#
DEVELOPMENT OF THE F404/RM12 FOR THE JAS 39 GRIPEN
L. LARSSON (Volvo Flygmotor AB, Trollhattan, Sweden), L. B. VENO, and W. J. DAUB (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-305)

The F404/RM12 engine is a derivative of the F404-GE-400 used by the F-18 for the propulsion system requirements of the Swedish JAS 39 fighter aircraft. A new three-stage fan module is incorporated which yields a 10-percent airflow increase and superior birdstrike resistance. An increase in the compressor discharge pressure limit furnishes improved thrust in specific regions of the flight envelope, and a higher turbine inlet temperature yields a sea level static thrust of 18,105 lbs, by comparison to the F404-GE-400's 16,000 lbs. Hot section materials have been improved to allow service life requirements to be met under the enhanced temperature and pressure conditions. O.C.

A88-54379#
STRATIFIED CHARGE ROTARY ENGINES FOR AIRCRAFT
ROBERT E. MOUNT and GASTON GUARDA (John Deere Technologies International, Inc., Rotary Engine Div., Wood-Ridge, NJ) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-311)

Substantial progress has been made over the past two years in the technological status and production aspects of Stratified Charge Rotary Engines, a new propulsion technology for aircraft of the 1990s. A 400 HP aircraft engine, designed in cooperation with Avco-Lycoming (during late 1986) is currently undergoing testing at John Deere's Rotary Engine Division. Current status and design features are reported in this paper and related to overall research and technology enablement efforts toward several families of advanced liquid cooled, turbocharged and intercooled engines over a wide power range for commercial general aviation. Capabilities for high altitude, long endurance, military unmanned aircraft missions are examined. Application to fixed and rotary wing aircraft are planned. Author

A88-54380#
F100-PW-229 - HIGHER THRUST IN SAME FRAME SIZE
BERNARD L. KOFF (Pratt and Whitney, West Palm Beach, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p.
(ASME PAPER 88-GT-312)

The F100-PW-229 fighter aircraft engine is a higher-thrust derivative of the F100-PW-220 and in the same frame size. The increased thrust was achieved by increasing the flow and pressure ratio of the two-spool compression system, accompanied by an increase in turbine temperature. The increased-length compression system was offset by an innovative design intermediate case and a reduced length combustor to maintain overall engine axial length. The -229 engine has a thrust-to-weight ratio of 8.0, with a 20-30 percent performance increase over the -220 model across the flight map. Significant improvements in maintainability have been incorporated while retaining the proven durability and operability features of the -220 engine. Author

A88-54383#
A TURBINE WHEEL DESIGN STORY
WILSON R. TAYLOR, KEITH WHELESS, and LEE G. GRAY (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p.
(ASME PAPER 88-GT-316)

The features of the jet fuel starter (JFS), which is used to start the F100 main propulsion engines for the F-15 fighter aircraft, are discussed. In an attempt to prolong the lifespan of the JFS, the USAF conducted an analysis of the disk to determine if it was reasonable to eliminate the fragmentation holes and slots. In addition, a NASTRAN finite element stress analysis was performed. The power turbine wheel redesign considered meets the requirements of containment; it can be manufactured at a lower cost and yield an improved life. K.K.

A88-54386#
EVALUATION OF POTENTIAL ENGINE CONCEPTS FOR A HIGH ALTITUDE LONG ENDURANCE VEHICLE
EDWARD J. KOWALSKI (Boeing Co., Seattle, WA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-321)

The potential of several propulsion system candidates for a high-altitude long-endurance (HALE) aircraft is evaluated. The engines examined include the classical turbofan engine with bypass ratios up to 8, the ultrahigh bypass ratio turbofan with bypass ratios up to 20, the unducted fan engine, and the turboprop in a pusher and tractor configuration with single and counter rotation propfans. The impact of high altitude (up to 60,000 feet) surveillance mission requirements on aircraft design characteristics, engine cycle characteristics, and propulsion system concepts is discussed. V.L.

A88-54507
TOWARDS SIMULTANEOUS PERFORMANCE - APPLICATION OF SIMULTANEOUS STABILIZATION TECHNIQUES TO HELICOPTER ENGINE CONTROL
K. DEAN MINTO (GE Corporate Research and Development Center, Schenectady, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 852-859. refs

Ongoing research aimed at refining a design algorithm, namely simultaneous stabilization, is reported. Through application of the simultaneous stabilization design technique to a realistic aerospace control problem, an attempt is made to demonstrate the practical utility of the method, and identify the technical issues that remain to be resolved. The focus of this study is the GE T700 turboshaft engine, when coupled to the Apache and Blackhawk helicopter airframes. Experiences are described with an indirect design technique to obtain an LT1 compensator that simultaneously satisfies two loop-shaping type performance criteria, one for each engine-airframe combination. I.E.

A88-54619
FIBER OPTICS FOR AIRCRAFT ENGINE CONTROLS
MARK A. OVERSTREET and ROBERT F. HOSKIN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1819-1824.

An examination is made of the fundamental physical characteristics of fiber-optic sensor technology, including EMI (electromagnetic interference) immunity, light weight and small size, high temperature and radiation tolerance, flexibility, stability, and durability. Principles of operation for fiber-optic sensors and systems are discussed, including basic design principles, extrinsic vs. intrinsic sensing, and typical fiber-optic links. A discussion of the state of the art and applications provides the status of development and outlook for various fiber sensor types (pressure, temperature, etc.) for the applications defined. I.E.

A88-54620

VERY HIGH SPEED INTEGRATED CIRCUITS/GALLIUM ARSENIDE ELECTRONICS FOR AIRCRAFT ENGINE CONTROLS

MARK A. OVERSTREET (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1825-1830.

VHSIC/GaAs technology has been studied to define how it can be developed and applied to improve control system performance for aircraft engines. The results of this study are presented. Discussed are related programs and the common areas of VHSIC and GaAs technology with emphasis on the unique optoelectronic and adverse environment characteristics of GaAs. Attributes of materials, devices, circuits, systems, and other topics are addressed, along with future application requirements for engine control application. The state of the art in VHSIC/GaAs components and their possible applications are discussed. A summary is presented of the environmental and performance payoffs offered, and some conclusions are provided about the current state of the art as it applies to engine control applications, future applications potential, risk, and the degree of further development required. I.E.

A88-54621

THE CHARACTERIZATION OF HIGH TEMPERATURE ELECTRONICS FOR FUTURE AIRCRAFT ENGINE DIGITAL ELECTRONIC CONTROL SYSTEMS

J. D. WILEY (Wisconsin, University, Madison) and D. C. DENING (General Electric Co., Syracuse, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1831-1836.
(Contract F33615-86-C-2666)

A characterization of high-temperature electronics is presented including high-temperature effects, semiconductors, and barrier metallizations. Design solutions and material selections for mitigation of high-temperature effects are indicated. The following semiconductor materials are considered for future high-temperature applications: silicon, gallium arsenide, gallium phosphide, silicon carbide, and diamondlike carbon. I.E.

A88-54622

DATA FLOW ANALYSIS OF CONCURRENCY IN A TURBOJET ENGINE CONTROL PROGRAM

PHILLIP L. SHAFFER and TIMOTHY L. JOHNSON (GE Corporate Research and Development Center, Schenectady, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1837-1845. refs

The amount of concurrency which is inherent in an engine control algorithm and a methodology for computing this measure based on existing programs are presented. The control is partitioned into functional blocks, followed by analyses of data dependencies and of execution time. Concurrency is increased by modification and decomposition of bottleneck functions. For the control program analyzed, exploitation of concurrency at the function level allows a reduction of execution time to 15 percent of the sequential execution time. I.E.

A88-54623

HIGH TEMPERATURE, LIGHTWEIGHT, SWITCHED RELUCTANCE MOTORS AND GENERATORS FOR FUTURE AIRCRAFT ENGINE APPLICATIONS

EIKE RICHTER (General Electric Co., Aircraft Engine Business Group, Cincinnati, OH) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1846-1851.
(Contract F33615-86-C-2666)

The potential of electrical power systems for engine actuation, fuel delivery and power generation have been investigated, projecting technology developments in magnetic materials, insulation systems, and advanced power electronics for the year 2000. The results of the projections are described, and the key technological developments required to achieve those designs are identified. Comparisons to similar systems based on technologies used today are made to demonstrate the advantages of the future electrical control and accessory systems for the advanced aircraft engines. The particular applications discussed are motor-driven actuator system, motor-driven fuel delivery system, three alternate generating systems, fan-driven cantilevered generator, gas-generator-compressor-driven starter/generator, and separate turbine-driven generator. I.E.

A88-54624

POTENTIAL APPLICATION OF COMPOSITE MATERIALS TO FUTURE GAS TURBINE ENGINES

JAMES C. BIRDSALL, WILLIAM J. DAVIES (Pratt and Whitney, East Hartford, CT), RICHARD DIXON (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), MATTHEW J. IVARY (Parker Hannifin Corp., Parker Bertea Aerospace Group, Irvine, CA), GARY A. WIGELL (Sundstrand Corp., Rockford, IL) et al. IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1852-1856.

Several firms have evaluated the viability of composite materials and control component design to reduce engine control system weight. Each of the component suppliers has used engine-manufacturer requirements to evaluate the benefits and shortfalls of composite materials when used in the gas turbine control environment. Study results indicate a significant weight reduction, up to 30 percent, when composites are used for electronic control housings, actuators, and fuel pumps. This projected benefit is tempered with requirements for electromagnetic compatibility, fluid tolerance, and ability to withstand high environmental temperatures and vibration levels. I.E.

A88-54658

SCHEDULING TURBOFAN ENGINE CONTROL SET POINTS BY SEMI-INFINITE OPTIMIZATION

D. M. STIMLER (GE Control Systems Laboratory, Schenectady, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2256-2263. refs

It is shown that modern semiinfinite optimization methods provide a powerful method for determining the operating schedules of control set points for advanced turbofan engines, giving the engineer considerable design freedom. The use of these methods to develop engine schedules which optimize complex performance objectives and explicitly satisfy performance requirements on engine variables is shown. This approach is also shown to provide insights as to the limits of engine performance and the control requirements of the engine. The methods are illustrated by determining portions of the steady-state and transient operating schedules of a state-of-the-art single-bypass turbofan engine. I.E.

A88-54938#

A STUDY OF AERODYNAMIC NOISE FROM A CONTRA-ROTATING AXIAL COMPRESSOR STAGE

P. B. SHARMA and D. S. PUNDHIR (Indian Institute of Technology, New Delhi, India) IN: Developments in Mechanics. Volume 14(b) - Midwestern Mechanics Conference, 20th, West Lafayette, IN, Aug. 31-Sept. 2, 1987, Proceedings. West Lafayette, IN, Purdue University, 1987, p. 801-806. Research supported by the Aerospace Research and Development Board of India. refs

The paper reports an investigation of aerodynamic noise from a contra-rotating axial compressor stage of 0.66 hub-tip ratio. Measurements of noise at three axial locations from intake to the exit of the compressor stage are reported for different speed ratios. Spectrum analysis of noise signals is also presented. The axial spacing between the rotors is shown to have a marked influence on the noise generation from contra-rotating rotors. Author

N88-28925# Naval Air Development Center, Warminster, Pa. Air Vehicle and Crew Systems Technology Directorate.
AGARD (ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT) ENGINE DISC MATERIAL COOPERATIVE TEST (SUPPLEMENTARY PROGRAM)
EUN U. LEE 12 Aug. 1987 47 p
(AD-A193678; NADC-87169-60) Avail: NTIS HC A03/MF A01 CSCL 11F

From a gas turbine engine compressor spool of Ti-17 alloy, cylindrical unnotched specimens and flat double edge notched specimens were machined and fatigue-tested. The flat double edge notched specimens were also subjected to electrical potential drop measurements. The microstructure and fracture surface morphology of the representative specimens were examined. The variation of fatigue life, N, with applied stress range, delta sigma, was described by an equation of the form log N = a + b (delta sigma). The variation of normalized crack voltage, (V/V sub o)/(V sub R/V sub Ro), with normalized crack length, (a/w), was given by an equation of the form (V/V sub o)/(V sub R/V sub Ro) = A + A sub 1 (a/w) + A sub 2 (a/w)sq + A sub 3 (a/w) cu. GRA

N88-28926# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France).
AGARD ENGINE DISC COOPERATIVE TEST PROGRAMME
A. J. A. MOM and M. D. RAIZENNE (National Aeronautical Establishment, Ottawa, Ontario) Aug. 1988 87 p
(AGARD-R-766; ISBN-92-835-0475-5) Avail: NTIS HC A05/MF A01

The initial results of an AGARD test program on fatigue behavior of engine disc materials are described. The first phase of the program, the Core Program, was aimed at test procedure and specimen standardization and calibration of the various laboratories. A detailed working document is included which describes the testing fundamentals and procedures and includes the analysis procedures used for handling the test data. Fatigue crack initiation and propagation testing was performed on Ti-6Al-4V material under room temperature and constant amplitude loading conditions using four different specimen designs. All results were statistically analyzed for possible significant differences in material behavior due to disc processing variables, specimen location in the disc or testing laboratory. Author

N88-28927*# Hamilton Standard, Windsor Locks, Conn.
EXPERIMENTAL AND ANALYTICAL EVALUATION OF THE EFFECTS OF SIMULATED ENGINE INLETS ON THE BLADE VIBRATORY STRESSES OF THE SR-3 MODEL PROP-FAN Final Report
PREM N. BANSAL Sep. 1985 118 p
(Contract NAS3-24222)
(NASA-CR-174959; NAS 1.26:174959) Avail: NTIS HC A06/MF A01 CSCL 21E

A cooperative wind tunnel test program, referred to as GUN-3, had been conducted previously to assess the effect of inlet configuration and location on the inlet face pressure recovery and inlet drag in the presence of a high-speed advanced turboprop. These tests were conducted with the inlets located just downstream of the SR-3 model Prop-Fan, a moderately swept, eight-bladed 62.2 cm (24.5 inch) diameter advanced, high-speed turboprop model fabricated from titanium. During these tests, two blades of the SR-3 model Prop-Fan were strain gaged to measure the vibratory blade stresses occurring during the inlet aerodynamic test program. The purpose of the effort reported herein was to reduce and analyze the test results related to the vibratory strain gage measurements obtained. Three inlet configurations had been tested. These were: (1) single scoop, (2) twin scoop, and (3) annular. Each of the three inlets was tested at a position just behind the rotor. The single scoop inlet was also tested at a position further aft. Tests were also done without an inlet. These results emphasize the importance of avoiding critical speeds in the continuous operating range. B.W.

N88-28928*# Hamilton Standard, Windsor Locks, Conn.
SR-7A AEROELASTIC MODEL DESIGN REPORT
D. NAGLE, S. AUYEUNG, and J. TURNBERG Washington, D.C. Oct. 1986 118 p
(Contract NAS3-23051)
(NASA-CR-174791; NAS 1.26:174791; HSER-9251) Avail: NTIS HC A06/MF A01 CSCL 21E

A scale model was designed to simulate the aeroelastic characteristics and performance of the 2.74 meter (9 ft.) diameter SR-7L blade. The procedures used in this model blade design are discussed. Included in this synopsis is background information concerning scaling parameters and an explanation of manufacturing limitations. A description of the final composite model blade, made of titanium, fiberglass, and graphite, is provided. Analytical methods for determining the blade stresses, natural frequencies and mode shapes, and stability are discussed at length. Author

N88-28929*# General Electric Co., Cincinnati, Ohio. Aircraft Engine Business Group.
E3 10C COMPRESSOR TEST ANALYSIS OF HIGH-SPEED POST-STALL DATA
S. D. DVORAK, W. M. HOSNY, and W. G. STEENKEN Oct. 1986 109 p
(Contract NAS3-24211)
(NASA-CR-179521; NAS 1.26:179521; R86AEB564) Avail: NTIS HC A06/MF A01 CSCL 21E

In-stall characteristics from high-speed post-stall transients are determined. The transient, surge-cycle nature of high-speed post-stall operation precludes the possibility of obtaining in-stall characteristics in a steady-state manner, as is possible during low-speed post-stall operation, which is characterized by quasi-steady rotating-stall behavior. Maximum likelihood parameter estimation techniques were used to obtain the quasi-steady high-speed characteristics from transient data. The necessary data was first obtained from a specially instrumented compressor that was tested well beyond its limits of normal operation. The unsteady, post-stall data thus obtained was then digitized and processed through a simplified analytical model to construct the input-output relationship necessary for estimation. In-stall characteristics were determined using this estimation procedure at two different high-speed conditions, 90 and 98.5 percent corrected speed. The estimated characteristics were found to be robust in the presence of measurement noise and unmodelled system dynamics, but the compressor response-time constants, also estimated, were more sensitive to these same disturbances. The experimentally determined low-speed in-stall characteristics and the estimated high-speed in-stall characteristics were then incorporated into a one-dimensional compressor simulation model developed as a parallel effort to the compressor testing and data reduction effort, which yielded predictable results. Author

N88-28930*# United Technologies Corp., East Hartford, Conn.
THE EFFECTS OF INLET TURBULENCE AND ROTOR/STATOR INTERACTIONS ON THE AERODYNAMICS AND HEAT TRANSFER OF A LARGE-SCALE ROTATING TURBINE MODEL. VOLUME 3: HEAT TRANSFER DATA TABULATION 65 PERCENT AXIAL SPACING Final Report
R. P. DRING, M. F. BLAIR, and H. D. JOSLYN Washington, D.C. May 1986 235 p
(Contract NAS3-23717)
(NASA-CR-179468; NAS 1.26:179468; UTRC/R86-956480-VOL-3) Avail: NTIS HC A11/MF A01 CSCL 21E

This is Volume 3 - Heat Transfer Data Tabulation (65% Axial Spacing) of a combined experimental and analytical program which was conducted to examine the effects of inlet turbulence on airfoil heat transfer. The experimental portion of the study was conducted in a large-scale (approximately 5X engine), ambient temperature, rotating turbine model configured in both single stage and stage-and-a-half arrangements. Heat transfer measurements were obtained using low-conductivity airfoils with miniature thermocouples welded to a thin, electrically heated surface skin. Heat transfer data were acquired for various combinations of low or high inlet turbulence intensity, flow coefficient, first-stator/rotor axial spacing, Reynolds number and relative circumferential position of the first and second stators. Author

N88-29803# Rolls-Royce Ltd., Derby (England).
V2500 ENGINE COLLABORATION
G. E. KIRK and M. ITOH 26 Oct. 1987 6 p Presented at the 1987 Tokyo International Gas Turbine Conference, Tokyo, Japan, 26-30 Oct. 1987
(PNR90423; ETN-88-92668) Avail: NTIS HC A02/MF A01
International collaboration in developing the V2500 gas turbine engine is described. The engine configuration and parts are outlined. Engineering management and communication are discussed. ESA

N88-29804*# United Technologies Corp., East Hartford, Conn.
THE EFFECTS OF INLET TURBULENCE AND ROTOR/STATOR INTERACTIONS ON THE AERODYNAMICS AND HEAT TRANSFER OF A LARGE-SCALE ROTATING TURBINE MODEL. VOLUME 2: HEAT TRANSFER DATA TABULATION. 15 PERCENT AXIAL SPACING Final Report
R. P. DRING, M. F. BLAIR, and H. D. JOSLYN Washington, D.C. May 1986 242 p
(Contract NAS3-23717)
(NASA-CR-179467; NAS 1.26:179467; UTRC-R86-956480-VOL-2) Avail: NTIS HC A11/MF A01 CSCL 21E
A combined experimental and analytical program was conducted to examine the effects of inlet turbulence on airfoil heat transfer. The experimental portion of the study was conducted in a large-scale (approx 5X engine), ambient temperature, rotating turbine model configured in both single stage and stage-and-a-half arrangements. Heat transfer measurements were obtained using low-conductivity airfoils with miniature thermcouples welded to a thin, electrically heated surface skin. Heat transfer data were acquired for various combinations of low or high inlet turbulence intensity, flow coefficient, first-stator/rotor axial spacing, Reynolds number and relative circumferential position of the first and second stators. Aerodynamic measurements obtained as part of the program include distributions of the mean and fluctuating velocities at the turbine inlet and, for each airfoil row, midspan airfoil surface pressures and circumferential distributions of the downstream steady state pressures and fluctuating velocities. Analytical results include airfoil heat transfer predictions produced using existing 2-D boundary layer computation schemes and an examination of solutions of the unsteady boundary layer equations. The results are reported in four separate volumes, of which this is Volume 2: Heat Transfer Data Tabulation; 15 Percent Axial Spacing. Author

N88-29805# Minnesota Univ., Minneapolis. Dept. of Mechanical Engineering.
STUDIES OF GAS TURBINE HEAT TRANSFER AIRFOIL SURFACE AND END-WALL COOLING EFFECTS Annual Report, Mar. 1987 - Mar. 1988
E. R. ECKERT, R. J. GOLDSTEIN, S. V. PATANKAR, and T. W. SIMON Mar. 1988 58 p
(Contract F49620-85-C-0049)
(AD-A195165; A4-TR-88-0546) Avail: NTIS HC A04/MF A01 CSCL 20M
Research results on curved surface heat transfer, airfoil heat transfer, film cooling and end-wall heat transfer are presented. These studies focus on the recovery process of a turbulent boundary layer from curvature, heat transfer measurements and numerical prediction techniques of film-cooling on an adiabatic flat plate by injection through a single row of holes. GRA

N88-29807*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
AEROELASTIC RESPONSE OF METALLIC AND COMPOSITE PROPFAN MODELS IN YAWED FLOW
KRISHNA RAO V. KAZA, MARC H. WILLIAMS, ORAL MEHMED, and G. V. NERAYANAN (Sverdrup Technology, Inc., Cleveland, Ohio.) 1988 26 p Presented at the 24th Joint Propulsion Conference, Boston, Mass., 11-13 Jul. 1988; sponsored in part by AIAA, ASEE, ASME and SAE
(NASA-TM-100964; E-4229; NAS 1.15:100964; AIAA-88-3154) Avail: NTIS HC A03/MF A01 CSCL 21E
An analytical investigation of aeroelastic response of metallic and composite propfan models in yawed flow was performed. The analytical model is based on the normal modes of a rotating blade and the three dimensional unsteady lifting surface aerodynamic theory including blade mistuning. The calculated blade stresses or strains are compared with published wind tunnel data on two metallic and three composite propfan wind tunnel models. The comparison shows a good agreement between theory and experiment. Additional parametric results indicate that blade response is very sensitive to the blade stiffness and also to blade frequency and mode shape mistuning. From these findings, it is concluded that both frequency and mode shape mistuning should be included in aeroelastic response analysis. Furthermore, both calculated and measured strains show that combined blade frequency and mode shape mistuning has beneficial effects on response due to yawed flow. Author

N88-29808# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
FAILURE ANALYSIS FOR GAS TURBINES
A. J. A. MOM 18 Apr. 1987 36 p In DUTCH; ENGLISH summary Presented at the Symposium van de Bond voor Materialenkennis Schade in Constructies voor Gebruik bij Hoge Temperature, Wageningen, The Netherlands, 16 Oct. 1986
(NLR-MP-87037-U; B8803805; ETN-88-92612) Avail: NTIS HC A03/MF A01
A number of failures in gas turbines are discussed, including methods of preventing similar failures, in order to illustrate the diversity of failure analysis. The significance of failure analysis is explained, and the potential benefits of failure analysis for gas turbine users are mentioned. The background, reasons, and materials investigation of the F-16 crash in Lauwersmeer (Netherlands) are described. For the fracture of first-stage turbine blades of a jet motor, the damage analysis and the lifetime analysis are outlined. Damage due to crack formation in compressor drive shafts is treated. ESA

N88-29809# Rolls-Royce Ltd., Derby (England).
DEVELOPING THE ROLLS-ROYCE TAY
N .J. WILSON 30 Jun. 1988 14 p Presented at the 33rd ASME Gas Turbine Conference, Amsterdam, The Netherlands, Jun. 1988
(PNR90447; ETN-88-92680) Avail: NTIS HC A03/MF A01
The evolution of the Tay engine, launched in response to the requirement for an engine suitable for powering a FAR Part 36 Stage 3 noise compliant aircraft in the 70 to 100 seat range is reviewed. The engine, which is derived from the Spey (RB183) Mk 555 installed in the Fokker F28 aircraft, incorporates latest technology features which are already in service in large turbofan engines. Modularity and maintainability in the design of the engine are discussed in regard to operation in service. ESA

N88-29810# General Electric Co., Cincinnati, Ohio. Advanced Technology Operation.
EMPIRICAL FLUTTER PREDICTION METHOD Final Report, Sep. 1984 - Sep. 1987
J. K. CASEY 5 Mar. 1988 358 p
(Contract F33615-84-C-2457)
(AD-A195699; R87AEG; AFWAL-TR-87-2087) Avail: NTIS HC A16/MF A01 CSCL 20D
Design of advanced technology engines is often limited by compressor blade instability or flutter. Test points from the annular cascade data base were analyzed, to predict from aeromechanical data which of 14 types of stability or instability would result. The basic approach was to identify for each pair of stability regions, linear combinations (hyperplanes) of the aeromechanical variables,

whose numerical value would be above a critical level for all test points in one stability region and would be below the critical level for test points in the other stability region. It was found that 76 pct of the pairs of stability regions allowed a hyperplane to discriminate between the two regions, but for 24 pct a curved surface or nonlinear combination variables would be needed. Review of 85 pct of the 891 test points used to construct the hyperplanes revealed that the hyperplanes correctly identify the stability condition of 59 pct of the points in a literal sense, but are correct in a broader practical sense for 79 pct of the points. When the hyperplanes were applied to 51 validation test points taken from several actual engine/rig test data, they gave virtually no correct results, which was not immediately explainable. GRA

N88-29811*# Southwest Research Inst., San Antonio, Tex. Dept. of Materials Sciences.
CONSTITUTIVE MODELING FOR ISOTROPIC MATERIALS Final Report
K. S. CHAN, U. S. LINDHOLM, and S. R. BODNER Jun. 1988 155 p
(Contract NAS3-23925; SWRI PROJ. 06-7576)
(NASA-CR-182132; NAS 1.26:182132) Avail: NTIS HC A08/MF A01 CSCL 21E

The third and fourth years of a 4-year research program, part of the NASA HOST Program, are described. The program goals were: (1) to develop and validate unified constitutive models for isotropic materials, and (2) to demonstrate their usefulness for structural analysis of hot section components of gas turbine engines. The unified models selected for development and evaluation were those of Bodner-Partom and of Walker. The unified approach for elastic-viscoplastic constitutive equations is a viable method for representing and predicting material response characteristics in the range where strain rate and temperature dependent inelastic deformations are experienced. This conclusion is reached by extensive comparison of model calculations against the experimental results of a test program of two high temperature Ni-base alloys, B1900+Hf and Mar-M247, over a wide temperature range for a variety of deformation and thermal histories including uniaxial, multiaxial, and thermomechanical loading paths. The applicability of the Bodner-Partom and the Walker models for structural applications has been demonstrated by implementing these models into the MARC finite element code and by performing a number of analyses including thermomechanical histories on components of hot sections of gas turbine engines and benchmark notch tensile specimens. The results of the 4-year program have been published in four annual reports. The results of the base program are summarized in this report. The tasks covered include: (1) development of material test procedures, (2) thermal history effects, and (3) verification of the constitutive model for an alternative material. Author

N88-29813# Research Inst. of National Defence, Stockholm (Sweden).
REVIEW OF RESEARCH CONCERNING SOLID FUEL RAMJET (SOFRAM) AT THE RESEARCH INSTITUTE OF NATIONAL DEFENCE (FOA) 2
RALF ELIASSON May 1988 21 p In SWEDISH; ENGLISH summary
(FOA-C-20714-2.1; ISSN-0347-3694; ETN-88-93058) Avail: NTIS HC A03/MF A01

An airbreathing engine for velocities over Mach 1.8 is described. A tube-formed propellant of an outer diameter 72 mm was studied. Results show that to reach the optimum length of the motor it is necessary to use a propellant with a higher burning rate than HTPB. Ten different compositions of HTPB propellants were tested: 10 percent ammonium perchlorate increases combustion velocity by 40 percent, but a higher amount can lead to pressure vibrations in the combustion area; the addition of 5 percent lampblack reduces the velocity by 20 percent. Computed figures are given for artillery ammunition of 155 mm driven by SOFRAM. A secondary air intake (a by-pass) was also investigated. Stable combustion is achieved with 42 percent of the air by-passed, the mechanical output being 7 or 8 percent higher, but the combustion chamber must be modified to avoid vibrations. ESA

N88-29911# Pratt and Whitney Aircraft, West Palm Beach, Fla. Engineering Div.
FUEL PROPERTY EFFECTS ON THE US NAVY'S TF30 ENGINE
S. A. MOSIER and P. A. KARPOVICH (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 15 p Jun. 1988
Avail: NTIS HC A22/MF A01

The TF30 engine was introduced into Navy service in 1972 and is scheduled to continue to power the carrier based F14 for some time. Although the engine was designed and developed to operate on specification grade JP-5 fuel, it is conceivable that during its lifetime, the TF30 might have to operate on out-of-spec or broadened-spec fuels. This contingency could arise should the availability of high grade petroleum crude oil used for aircraft fuel production be decreased. Therefore, a program of experimentation and analysis was conducted to evaluate the effects of broadened-spec petroleum fuels on the performance, durability and operability of the TF30-P-414A engine. As fuel quality deteriorated, some reductions in engine performance characteristics were observed. However, based upon limited time testing, the TF30-P-414A engine was shown to be capable of operating on liquid petroleum fuels having a wide range of properties. Author

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

A88-53148#
VEHICLE MANAGEMENT SYSTEMS - THE LOGICAL EVOLUTION OF INTEGRATION
STEVE W. JACOBS (McDonnell Aircraft Co., Saint Louis, MO) and CHARLES A. SKIRA (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 9 p.
(AIAA PAPER 88-3175)

Vehicle management is the integrated control of the flight, propulsion, and aircraft utility systems. The implementation of this concept into a control architecture forms a Vehicle Management System (VMS). A practical VMS design can provide significant performance and supportability benefits to military aircraft. Performance enhancements are achieved by integrated control to optimize previously independent systems. Supportability is increased through the comprehensive diagnostics, component commonality, and reduced complexity provided by integrated digital systems. This paper reviews the concept of a VMS and addresses the issues of functional and physical integration. A generic approach to VMS design is outlined and illustrated. Key elements for future VMS bench and flight demonstration are also identified. Author

A88-53251
MODELLING OF AIRCRAFT PROGRAM MOTION WITH APPLICATION TO CIRCULAR LOOP SIMULATION
W. BLAJER (Radom, Wyzsza Szkola Inzynierska, Poland) Aeronautical Journal (ISSN 0001-9240), vol. 92, Aug.-Sept. 1988, p. 289-296. refs

The objective of this paper is to present the principles of a mathematical model of aircraft prescribed motion. Requirements imposed on the aircraft motion are treated as program constraints on the system and both the transient dynamic solution of motion equations and the control ensuring the exact realization of the prescribed motion are obtained as a result. The approach used is equivalent to the Lagrange multiplier method, generalized for the purpose of this paper. It consists of the solution of the set of differential/algebraic equations of index exceeding three. The presented mathematical model has been applied to the simulation of aircraft prescribed motion in a loop. The flight along an ideal circle and the flight with additionally demanded constant velocity are described. Some results of numerical calculations are demonstrated. Author

A88-53755#
A KNOWLEDGE BASED SYSTEM OF SUPERMANEUVER SELECTION FOR PILOT AIDING
HUBERT H. CHIN (Grumman Corp., Aircraft Systems Div., Bethpage, NY) AIAA, AHS, and ASEE, Aircraft Design, Systems and Operations Meeting, Atlanta, GA, Sept. 7-9, 1988. 9 p. refs
(AIAA PAPER 88-4442)

The Maneuver Selection Aiding System, 'MASAS', employs fuzzy logic, tactical planning, and knowledge-base techniques to select supermaneuver strategies, such as controlled-sideslip and high-alpha tactics, that will aid pilots during defined missions. MASAS encompasses a supermaneuverable selector, a tactical planner, and an executive planner; each of these interfaces with both a knowledge base and an exceptions-handler. The selector uses the Max-Min operator on the fuzzy relations matrix to select suitable strategies; regional planning qualifies regional threat effects and identifies potentially safe supermaneuvers among threats and within geometry constraints. O.C.

A88-53796
INFLIGHT CG-CONTROL - SYSTEM ASPECTS
H. DRACHENBERG (Messerschmitt-Boelkow-Blohm GmbH, Bremen, Federal Republic of Germany) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 25 p. refs
(SAWE PAPER 1795)

The Inflight Center-of-Gravity (CG) Control System that entered airline operation in 1985 aboard the A-310-300 airliner determines and controls CG position through the manipulation of fuel volumes located within the aircraft's horizontal tailplane (the 'trim tank'), as well as in its fuselage and wings. Attention is presently given to the electrical/electronics systems considerations that entered into the definition, design, testing, certification, and operation of this system, as well as to the form taken by the cockpit displays responsible for the monitoring of the system. O.C.

A88-53799
IMMP - A COMPUTER SIMULATION OF FUEL CG VERSUS VEHICLE ATTITUDE
GERALD JON MOLCZYK (General Dynamics Corp., Convair Div., San Diego, CA) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 23 p.
(SAWE PAPER 1801)

The Interactive Maneuvering Model Program, IMMP, simulates the center-of-gravity (CG) displacement behavior of a fuel mass in a semidepleted fuel tank during aircraft maneuvering by means of a FEM analysis of the tank's cross-sectional area. This allows the evaluation of iterative vertical and lateral CG drift, followed by complete CG determination on the basis of the coordinated 'stacking' of cross-sectional mass-properties elements. IMMP furnishes accurate, cost-effective mass properties inputs for flight simulations concerned with operational and technical evaluations of aircraft performance. O.C.

A88-54424* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
APPLICATION OF AI METHODS TO AIRCRAFT GUIDANCE AND CONTROL
RICHARD M. HUESCHEN and JOHN W. MCMANUS (NASA, Langley Research Center, Hampton, VA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1988, p. 195-201. refs

A research program for integrating artificial intelligence (AI) techniques with tools and methods used for aircraft flight control system design, development, and implementation is discussed. The application of the AI methods for the development and implementation of the logic software which operates with the control mode panel (CMP) of an aircraft is presented. The CMP is the pilot control panel for the automatic flight control system of a commercial-type research aircraft of Langley Research Center's Advanced Transport Operating Systems (ATOPS) program. A mouse-driven color-display emulation of the CMP, which was developed with AI methods and used to test the AI software logic implementation, is discussed. The operation of the CMP was enhanced with the addition of a display which was quickly developed with AI methods. The display advises the pilot of conditions not satisfied when a mode does not arm or engage. The implementation of the CMP software logic has shown that the time required to develop, implement, and modify software systems can be significantly reduced with the use of the AI methods. I.E.

A88-54474
A WORKSTATION FOR THE INTEGRATED DESIGN AND SIMULATION OF FLIGHT CONTROL SYSTEMS
RICHARD DEAN COLGREN (Lockheed Aeronautical Systems Co., Burbank, CA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1988, p. 608-613. refs

The development of a workstation which integrates design, analysis, and simulation methods used for flight-control-system synthesis is described. Aerodynamic, propulsion, and structural models can be directly interfaced for analysis and synthesis work, and the results transferred to a flight simulator and to the dynamic structural model. The workstation is implemented with an executive which handles most input/output operations internally so that data management by the user is minimized. Also planned is an expert-aided approach, by which predicted flying qualities are used to evaluate the performance of the closed-loop system. If the desired flying qualities are not attained, a rule base would advise the user on how to modify the flight control system. A modular approach allows novel techniques to be implemented easily as executives or as additional modules. I.E.

A88-54526* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
CONSIDERATIONS FOR AUTOMATED NAP-OF-THE-EARTH ROTORCRAFT FLIGHT
VICTOR H. L. CHENG and BANAVAR SRIDHAR (NASA, Ames Research Center, Moffett Field, CA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 967-976. refs

The authors consider nap-of-the-earth (NOE) rotorcraft flight as one of the applications in which obstacle avoidance plays a key role, and investigate the prospects of automating the guidance functions of NOE flight. Based on a proposed structure for the guidance functions, obstacle detection and obstacle avoidance are identified as the two critical components requiring substantial advancement before an automating guidance system can be realized. The major sources of difficulties in developing these two components are discussed, including sensor requirements for which a systematic analysis is provided. I.E.

A88-54528
PERIODIC NEIGHBORING OPTIMUM REGULATOR APPLIED TO A HYPERSONIC SCRAMJET CRUISER
C.-H. CHUANG, Q. WANG, and J. L. SPEYER (Texas, University, Austin) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 983-989. refs

For a reasonable model of a hypersonic scramjet cruiser, optimum fuel cruise trajectories are determined. Two local minimums are obtained which give nearly the same fuel consumption. One local minimum is periodic which has amplitude variations of about 25,000 feet and a mean of about 100,000 feet. The other local minimum is a static path where the maximum thrust is just equal to the aerodynamic drag. This static path seems to be unobtainable except possibly asymptotically. However, for the periodic path which is realizable, a periodic neighboring optimum regulator is derived. This regulator includes variations in the control variables of lift coefficient and thrust switch times. The mass change of the vehicle, which is tacitly assumed negligible in producing the nominal path, is included explicitly in this regulator. The performance of this regulator presented. I.E.

A88-54549* City Coll. of the City Univ. of New York.
EIGENSTRUCTURE ASSIGNMENT FOR THE CONTROL OF HIGHLY AUGMENTED AIRCRAFT
KENNETH M. SOBEL (City College, New York) and FREDERICK J. LALLMAN (NASA, Langley Research Center, Hampton, VA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1267-1276. refs

Eigenstructure assignment is utilized to design flight control laws for aircraft with many control effectors. It is shown that a previous eigenstructure design for the flight propulsion control coupling (FPCC) aircraft lateral dynamics with three control surfaces exhibits a lack of stability robustness because the control distribution matrix is nearly rank-deficient. A method is mapped back, reducing the control space to two dimensions by using the singular value decomposition. After the design is complete, the controller is mapped back to the original three-dimensional control space. This design approach yields a controller with both smaller gains and improved multivariable stability margins at the aircraft inputs. An interesting characteristics of the control mapping, as applied to the given example, is that the most effective inputs have the larger gains while the less effective inputs have smaller gains. I.E.

A88-54570* Rice Univ., Houston, Tex.
OPTIMIZATION AND GUIDANCE OF PENETRATION LANDING TRAJECTORIES IN A WINDSHEAR
A. MIELE, T. WANG (Rice University, Houston, TX), and W. W. MELVIN (Delta Airlines, Inc., Atlanta, GA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1428-1439. Research supported by Boeing Commercial Airplane Co. and Air Line Pilots Association. refs
(Contract NAG1-516)

The optimization and guidance of penetration landing trajectories in a windshear are considered. It is assumed that the aircraft is controlled by the angle of attack and the power setting. For the optimal trajectory, the performance index being minimized measures the deviation of the flight trajectory from the nominal trajectory. In turn, the nominal trajectory includes two parts: the approach part (nominal glide slope constant) and the flare part (nominal glide slope varying linearly with the horizontal distance). Numerical results show that the optimal trajectory deviates somewhat from the nominal trajectory in the shear region. A guidance scheme is developed to approximate the optimal trajectory. The angle of attack is determined by the windshear intensity, the absolute path inclination, and the glide slope angle, while the power setting is determined by the windshear intensity and the velocity. Numerical results indicate that the guidance trajectory is close to the optimal trajectory. I.E.

A88-54571* Georgia Inst. of Tech., Atlanta.
HELICOPTER TRAJECTORY PLANNING USING OPTIMAL CONTROL THEORY
P. K. A. MENON (Georgia Institute of Technology, Atlanta), V. H. L. CHENG (NASA, Ames Research Center, Moffett Field, CA), and E. KIM IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1440-1447. refs
(Contract NAG2-463)

A methodology for optimal trajectory planning, useful in the nap-of-the-earth guidance of helicopters, is presented. This approach uses an adjoint-control transformation along with a one-dimensional search scheme for generating the optimal trajectories. In addition to being useful for helicopter nap-of-the-earth guidance, the trajectory planning solution is of interest in several other contexts, such as robotic vehicle guidance and terrain-following guidance for cruise missiles and aircraft. A distinguishing feature of the present research is that the terrain constraint and the threat envelopes are incorporated in the equations of motion. Second-order necessary conditions are examined. I.E.

A88-54598
H(INFINITY)-OPTIMAL DESIGN FOR HELICOPTER CONTROL
ANDREW YUE and IAN POSTLETHWAITE (Oxford University, England) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1679-1684. Research supported by the Royal Aircraft Establishment. refs

Results of a study into the use of H(infinity)-optimization for the design of robust feedback control laws for improving the handling qualities of a battlefield helicopter are reported. Control laws are designed for precise control of pitch and roll attitude, yaw rate, and heave velocity in the hover fight condition. I.E.

A88-54650
DETECTION, IDENTIFICATION AND ESTIMATION OF SURFACE DAMAGE/ACTUATOR FAILURE FOR HIGH PERFORMANCE AIRCRAFT
A. K. CAGLAYAN, K. RAHNAMAI, and S. M. ALLEN (Charles River Analytics, Inc., Cambridge, MA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2206-2212. refs
(Contract F33615-84-C-3608)

A hierarchical failure detection, identification, and estimation (FDIE) algorithm for use in a self-repairing flight-control system in a high-performance aircraft is described. This hierarchical FDIE system consists of two subsystems: (1) an actuator-failure detection (AFD) system that detects stuck, runaway, and floating actuator failures based on local information and (2) a surface-damage detection and isolation (SDDI) system which detects partial surface loss failures and provides an estimate for the surface control effectiveness parameters after the impairment based on global information. Preliminary FDIE results are presented from a 6-DOF nonlinear simulation of a combat reconfigurable-control aircraft under typical flight conditions, pilot inputs, and gust levels. I.E.

A88-54652
A HYPERSTABLE MODEL-FOLLOWING FLIGHT CONTROL SYSTEM USED FOR RECONFIGURATION FOLLOWING AIRCRAFT IMPAIRMENT
C. J. DITTMAR (General Electric Co., Aircraft Control Systems Dept., Binghamton, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2219-2224. refs

Techniques have been developed for remixing the commands issued by flight control laws that assume unimpaired operation. This approach allows impairments to be accommodated that previously were not. This increase in fault tolerance does not decrease reliability because no additional hardware is installed on the aircraft. Instead, previously existing redundant control surfaces are used to greater advantage. A recent effort has focused on an implicit approach, as opposed to a previously mechanized explicit approach. The implicit approach, which is termed hyperstable model-following flight control (HMFC), is estimated to be an order of magnitude smaller in size than the explicit approach, which is termed the control reconfiguration feature (CRF). This reduction in size is accomplished without a loss in performance. In fact, performance can increase because the reduced complexity allows a higher iteration rate, and hence reduced reconfiguration time. HMFC will successfully reconfigure under conditions for which the CRF will not, while possessing robustness with respect to disturbances and unmodeled states. I.E.

A88-54653
AUTOMATED DESIGN OF CONTINUOUSLY-ADAPTIVE CONTROL - THE 'SUPER-CONTROLLER' STRATEGY FOR RECONFIGURABLE SYSTEMS
JOHN F. ELDER, IV and ROGER L. BARRON (Barron Associates, Inc., Stanardsville, VA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2225-2231. Research supported by Century Computing, Inc. and Universal Energy Systems, Inc. refs

Modern military aircraft undergo rapid and often unpredictable changes in dynamics during flight. This requires a method for developing simple, robust, high-performance control systems that vary in real time with operating and fault-condition changes in the system being controlled; that is, that reconfigure rapidly to face rapidly changing conditions. A supercontroller strategy is outlined that shows promise of meeting this need. The authors describe the supercontroller design technique and preliminary simulation results that are based on single-effector and simultaneous multiple-effector impairments of a control-reconfigurable combat aircraft. I.E.

A88-54654
APPLICATION OF SUPERCONTROLLER TO FIGHTER AIRCRAFT RECONFIGURATION
HARRY N. GROSS (U.S. Air Force Academy, Colorado Springs, CO) and BARRY S. MIGYANKO (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2232-2237. refs

A discussion is presented of a fighter aircraft control system design using the supercontroller methodology. A polynomial network is developed for each control surface to enable the aircraft to perform a range of maneuvers at a single flight condition subject to locked control surfaces. Performance is compared to that of the baseline aircraft and of a reconfigurable aircraft with explicit failure detection and isolation. I.E.

A88-54656
ROBUST CONTROL STRATEGY FOR TAKE-OFF PERFORMANCE IN A WINDSHEAR
Y. H. CHEN and S. PANDEY (Syracuse University, NY) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2244-2249. refs

A robust control strategy has been studied for an aircraft during takeoff. The effects of different wind-shear intensities have been analyzed for different models. As the complexity of the model increases and as a more complete model is taken into account, the survivability of the aircraft degrades. However, the robust control strategy yields results which are comparable to the best known results. The robust control is designed via a deterministic approach. The only information it utilizes is the upper bound of the allowable control magnitude. The resulting system behavior (namely, the stability) is described in a deterministic way. I.E.

A88-54659
MULTIPLE-MODEL PARAMETER-ADAPTIVE CONTROL FOR IN-FLIGHT SIMULATION
THOMAS J. BERENS and DANIEL J. BIEZAD (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2264, 2265. refs

The authors incorporate a priori information into a multiple-model estimation algorithm which assigns a probability weighting to each estimator within a bank of estimators. Final parameter estimates used in adaptive control are formed as a probabilistic weighted sum of individual estimates. Simulations of the system show excellent tracking performance throughout the flight envelope. I.E.

A88-54660
APPROXIMATION SCHEMES FOR AN AEROELASTIC-CONTROL SYSTEM
J. TURI and S. M. RANKIN, III (Worcester Polytechnic Institute, MA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2266, 2267. refs

The problem of designing active control schemes for flutter suppression in flexible aircraft is discussed. Based on a well-posed state-space formulation, the authors present an abstract framework to study approximation techniques for the active flutter control of an airfoil with flap in two-dimensional unsteady flow of an inviscid incompressible fluid. Conditions on the abstract approximation scheme are formulated which guarantee the uniform convergence of the approximate solutions in bounded time intervals, and it is shown how the conditions can be applied to the averaging-projections approximation scheme. I.E.

A88-54661
A MINIMAL REALIZATION ALGORITHM FOR FLIGHT CONTROL SYSTEMS
CHUN SHUNG HSU, D. HOU (Washington State University, Pullman), and GREGORY ROBEL (Boeing Commercial Airplane Co., Seattle, WA) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, 1988, p. 2268-2270. refs

A computationally simple procedure to obtain a minimal realization from a given transfer-function matrix is presented. The simplicity of the method is a consequence of taking advantage of the fact that many models of flight-control systems have distinct and/or pairs of complex-valued eigenvalues. Two illustrative flight-control examples (X-29 and Airbus A300) are provided to demonstrate the applicability of the method. I.E.

A88-55064#
PILOT/VEHICLE ANALYSIS OF A TWIN-LIFT HELICOPTER CONFIGURATION IN HOVER
R. A. HESS (California, University, Davis) and P. M. TRAN (General Dynamics Corp., Pomona, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Sept.-Oct. 1988, p. 465-472. Previously cited in issue 08, p. 1052, Accession no. A87-22571. refs

A88-55275#
CONTROL SURFACE SELECTION BASED ON ADVANCED MODES PERFORMANCE
MARIO INNOCENTI (Auburn University, AL) and ALDO TONON (Aeritalia S.p.A., Turin, Italy) AIAA, Atmospheric Flight Mechanics Conference, Minneapolis, MN, Aug. 15-17, 1988. 10 p. refs
(AIAA PAPER 88-4356)

The problem of control surface configuration selection is presently considered for the implementation of an advanced fighter flight control system's fuselage-aiming mode. Both canard/flap and elevator/flap combinations are considered for control in the longitudinal plane, while rudder-and-vertical fin and axisymmetric brakes are evaluated in the lateral plane. The figure-of-merit defined for these configurational alternatives is based exclusively on closed-loop dynamics behavior and flight control system requirements. O.C.

N88-28931# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
TIME PERIODIC CONTROL OF A MULTI-BLADE HELICOPTER Ph.D. Thesis
STEPHEN G. WEBB May 1988 218 p
(AD-A194435; AFIT/DS/AA/88-2) Avail: NTIS HC A10/MF A01 CSCL 01C

The flap-lag equations of motion of an isolated rotor blade and those for a rigid helicopter containing four blades free to flap and lag are derived. Control techniques are developed which stabilize both systems for a variety of flight conditions. Floquet theory is used to investigate the stability of a rotor blade's flap-lag motion. A modal control technique, based on Floquet theory, is used to eliminate the blade's instabilities using collective and cyclic pitch control mechanisms. The technique shifts the unstable roots to desired locations while leaving the other roots unaltered. The control, developed for a single design point, is shown to significantly reduce or eliminate regions of flap-lag instabilities for a variety of off-design conditions. Both scalar and vector control are successfully used to stabilize the blade's motion. Coupling the flap-lag equations of motion of four rotor blades to a rigid airframe alters the flap lag, and airframes roots. The airframe roots are stabilized using a combination of the body's pitch attitude and pitch rate feedback to the main rotor's longitudinal cyclic pitch. The modal control technique is used to eliminate multiple blade instabilities by first controlling a pair of unstable roots at a specific design point. The resulting closed loop system is a new linear system with periodic coefficients. Another modal controller is designed for this new system to shift a second pair of unstable roots to desired locations. GRA

N88-28932# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (West Germany). Unternehmensbereich Transport- und Verkehrsflugzeuge.

VARIABLE WING CAMBER CONTROL SYSTEMS FOR THE FUTURE AIRBUS PROGRAM Final Report, Jun. 1987

JUERGEN RENKEN Bonn, Fed. Republic of Germany Bundesministerium fuer Forschung und Technologie Feb. 1988 132 p In GERMAN; ENGLISH summary
(Contract BMFT-LFL-83618)
(MBB-UT-104/88; ETN-88-92965) Avail: NTIS HC A07/MF A01

The physics background of camber variation is overviewed. The principles of the mechanical realization of chordwise and spanwise camber variation, including the effects of elastic deformation, the actuation and control concepts, camber laws and performance maximization including the effects on the operational flight and the implementation of the variable camber function in an A-320 aircraft are described. The potential fuel saving benefits of camber variation and the technical investment are related to the other high cost, high risk technological efforts aiming at further fuel saving performed in the entire aircraft scenario. It is concluded that with the presented camber variation a technology is available which offers a considerable fuel saving potential at low cost, low risk, and with a negligible weight increase. ESA

N88-29718# Federal Aviation Administration, Seattle, Wash.

CURRENT AND PROPOSED GUST CRITERIA AND ANALYSIS METHODS: AN FAA OVERVIEW

TERENCE J. BARNES *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 12 p Jun. 1988
Avail: NTIS HC A06/MF A01

An FAA overview is presented of the gust criteria and analysis methods used in the various types of flight vehicle certified under the FAR's. The current criteria for small airplanes, transports, and rotorcraft are presented, and the status of proposed criteria for the tilt rotor and aerospace plane are discussed. The amount of discussion on each class of vehicle depends on the significance of gust loads as design loads, and the importance of vehicle flexibility. Transport airplane gust criteria development, usage and problems are discussed in some detail. Analysis methods used by U.S. industry are covered in a separate paper. Author

N88-29723# Office National d'Etudes et de Recherches Aeronautiques, Paris (France).

MEASURED AND PREDICTED RESPONSES OF THE NORD 260 AIRCRAFT TO THE LOW ALTITUDE ATMOSPHERIC TURBULENCE

J. L. MEURZEC and F. POIRION *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 9 p Jun. 1988
Avail: NTIS HC A06/MF A01

A program of in situ measures using the Nord 260 plane equipped with accelerometers has allowed the comparison of the predicted and the measured responses of the flexible aircraft to turbulence. It shows a good agreement between the two sets of results and it emphasizes the better modeling of the turbulence using the isotropic model rather than the cylindrical one. Author

N88-29724# Civil Aviation Authority, Redhill (England). Airworthiness Div.

A REVIEW OF MEASURED GUST RESPONSES IN THE LIGHT OF MODERN ANALYSIS METHODS

V. CARD *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 14 p Jun. 1988
Avail: NTIS HC A06/MF A01

In the past simplified models of aircraft used to assess operational gust statistics have led to conservative estimates of derived gust exceedances. Modern refinements in aircraft modeling techniques have gradually introduced conservatism in the process of calculating gust loads. Gust statistics reviewed in the light of these modern analytical methods support the CAA view that gust velocities developed for use with simple rigid aircraft models are too severe for use with a modern dynamic analysis. Even in the light of improved safety targets, a 10 per cent reduction in design gust velocity can be readily justified. Further reductions may be justified on the basis of mission analysis considerations, or by investigation of more recent acceleration statistics collected by the current generation of transport aircraft. In the latter case, it will be essential to account for all relevant features of the subject aircraft in the derivation of gust velocities so as to obtain a true picture of the gust statistics. Author

N88-29726*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

STATUS REVIEW OF ATMOSPHERE TURBULENCE AND AIRCRAFT RESPONSE

J. C. HOUBOLT *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling at Atmospheric Turbulence 11 p Dec. 1987
Avail: NTIS HC A09/MF A01 CSCL 01C

A brief review is made of the understanding of aircraft encounter of atmospheric turbulence, both from the point of view of describing or modeling the turbulence and with respect to the ability to calculate resulting airplane loads. Some of the more recent studies of gust measurements and of reducing airline gust response data are discussed. Special attention is given to gust analysis requirements as involved in airplane certification and whether there is a need for additional or different requirements. A review is made of a recent study in which amazingly simple and universal gust response equations were discovered; the possible impact of these new findings on future work is indicated. Author

N88-29729# Taylor (J.), Camberley (England).

AN INTERIM COMPARISON OF OPERATIONAL CG RECORDS IN TURBULENCE ON SMALL AND LARGE CIVIL AIRCRAFT

J. TAYLOR *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 31 p Dec. 1987
Avail: NTIS HC A09/MF A01

Operational records have been made on British Airways aircraft for the period May 1980 to April 1985 and analyzed for about 650,000 flying hours on a number of different aircraft. Records were obtained for about 2 to 5 minutes of Normal Acceleration, Pitch Angle, Roll Angle, Height and Speed for nearly all those events which had an increment of 1 g or more, i.e., 29 events; similar records were also obtained for nearly all those events with an increment of 0.5 g or more with flaps down from May 1983 to April 1985, i.e., 33 events. An interim examination of the 29 events with 1 excess g or more, with special emphasis on 15 of them is made and includes an estimate of the interaction of maneuvers and turbulence, an estimate of the frequency of occurrence of high level intensity gusts and of the equiprobability relationships of gust levels and gust gradients. It was found that gusts that are important for a particular response are strongly dependent on the rate per sub 5 km at which zero crossings occur in that response. Using the Kaynes formula for gust intensity and zero crossings, it was found that the equiprobability relationships of gust levels and gust gradients can be represented on a single diagram for all sizes of aircraft at all heights. Author

N88-29732# British Aerospace Aircraft Group, Weybridge (England). Military Aircraft Div.
RE-ASSESSMENT OF GUST STATISTICS USING CAADRP DATA
B. W. PAYNE, A. E. DUDMAN, and K. C. GRIFFITHS *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 22 p Dec. 1987
Avail: NTIS HC A09/MF A01

The measured incremental c.g. accelerations of the BAC 1-11 operating on scheduled flights are compared with the equivalent theoretical predictions in a gust environment. Some of the results of the study are: (1) An analysis of the measured Civil Airworthiness Authority Data Recording Program data, based upon a significant 58,733 flying hours, gave an incremental vertical c.g. acceleration of 1.25 g at the datum probability value of 2 x .00005 exceedances per hour; (2) The theoretical predictions from all the flight segments in the Mission Analysis gave an incremental c.g. acceleration of .238 g at the datum exceedance value; and (3) Therefore in the comparison between the measured and predicted analyses for a similar mission considerable differences were found with measured frequencies of exceedance of about one half those predicted using current airworthiness requirements. Author

N88-29814# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
AN ANALYSIS OF LATERAL-DIRECTIONAL HANDLING QUALITIES AND EIGENSTRUCTURE OF HIGH PERFORMANCE AIRCRAFT M.S. Thesis
MICHAEL J. COSTIGAN Jun. 1988 218 p
(AD-A194874; AFIT/GAE/AA/88J-1) Avail: NTIS HC A10/MF A01 CSCL 01A

The relationship between an aircraft's lateral-directional handling qualities and its corresponding eigenstructure is examined. Intuition and simple methematical models were used to develop desirable eigenvectors. For conventional aircraft, the dutch roll eigenvector was shown to a function of the roll to sideslip (phi/beta) ratio. Flight control laws to produce the desired eigenstructures were derived using eigenstructure assignment with output feedback. The control laws were based on a twelfth order linear model of the lateral-directional dynamics of the YA-7D DIGITAC, and varied the dutch roll phi/beta ratio. The handling qualities of the YA-7D were examined. The flight testing consisted of both open loop tasks, and closed loop tasks in which Cooper-Harper ratings were assigned. GRA

N88-29815*# Lockheed-Georgia Co., Marietta.
N-VERSION SOFTWARE DEMONSTRATION FOR DIGITAL FLIGHT CONTROLS Final Report
DENNIS B. MULCARE and LYNN A. BARTON Apr. 1987 152 p
(Contract NAS2-11853)
(NASA-CR-181483; NAS 1.26:181483; AD-A189864; DOT/FAA/CT-86/33) Avail: NTIS HC A08/MF A01 CSCL 01D

This report illustrates how four independently developed versions of digital flight controls applications software might be used in quadruplex system architecture. This approach to software fault tolerance is called N-version software. Here each computer channel has distinct versions of Ada programming units performing the same functions concurrently. Since intermediate software results are voted to detect and isolate discrepant computations, cross-channel synchronization occurs at each voting plane. The demonstration of this system was based on a high-level software design, English language specifications, and associated Ada program unit specifications parts. The demonstration was performed in non-realtime on a single VAX 8600 computer using an Ada multitasking test harness to effect voting plane synchronization and test case application and analyses. GRA

N88-29816*# Odetics, Inc., Anaheim, Calif.
THREAT EXPERT SYSTEM TECHNOLOGY ADVISOR
E. R. KURRASCH and L. R. TRIPP Aug. 1987 101 p
(Contract NAS2-12558)
(NASA-CR-177479; NAS 1.26:177479) Avail: NTIS HC A06/MF A01 CSCL 01C

A prototype expert system was developed to determine the feasibility of using expert system technology to enhance the performance and survivability of helicopter pilots in a combat threat environment while flying NOE (Nap of the Earth) missions. The basis for the concept is the potential of using an Expert System Advisor to reduce the extreme overloading of the pilot who flies NOE mission below treetop level at approximately 40 knots while performing several other functions. The ultimate goal is to develop a Threat Expert System Advisor which provides threat information and advice that are better than even a highly experienced copilot. The results clearly show that the NOE pilot needs all the help in decision aiding and threat situation awareness that he can get. It clearly shows that heuristics are important and that an expert system for combat NOE helicopter missions can be of great help to the pilot in complex threat situations and in making decisions. Author

N88-29817*# Draper (Charles Stark) Lab., Inc., Cambridge, Mass.
DEVELOPMENT AND DEMONSTRATION OF AN ON-BOARD MISSION PLANNER FOR HELICOPTERS
OWEN L. DEUTSCH and MUKUND DESAI May 1988 126 p
(Contract NAS2-12419)
(NASA-CR-177482; NAS 1.26:177482; CSDL-R-2056) Avail: NTIS HC A07/MF A01 CSCL 01C

Mission management tasks can be distributed within a planning hierarchy, where each level of the hierarchy addresses a scope of action, and associated time scale or planning horizon, and requirements for plan generation response time. The current work is focused on the far-field planning subproblem, with a scope and planning horizon encompassing the entire mission and with a response time required to be about two minutes. The far-feld planning problem is posed as a constrained optimization problem and algorithms and structural organizations are proposed for the solution. Algorithms are implemented in a developmental environment, and performance is assessed with respect to optimality and feasibility for the intended application and in comparison with alternative algorithms. This is done for the three major components of far-field planning: goal planning, waypoint path planning, and timeline management. It appears feasible to meet performance requirements on a 10 Mips flyable processor (dedicated to far-field planning) using a heuristically-guided simulated annealing technique for the goal planner, a modified A* search for the waypoint path planner, and a speed scheduling technique developed for this project. Author

N88-29818# Texas A&I Univ., Kingsville.
A FIBER OPTIC COLLECTIVE FLIGHT CONTROL SYSTEM FOR HELICOPTERS M.S. Thesis
ELLIS WAYNE GOLSON May 1988 62 p
(AD-A195406) Avail: NTIS HC A04/MF A01 CSCL 20F

The objective of this thesis is to design a fiber optic transmission system to replace the present collective flight control system for helicopters. A discussion of the present collective control system is presented as well as fiber optic system components necessary to provide positive collective control of the aircraft. Computer simulation has been utilized where possible to verify modulation and receiver circuitry. The fiber optic system provides advantages in weight, survivability, and cockpit organization. GRA

N88-29819*# Manudyne Systems, Inc., Los Altos, Calif.
MINIMUM-COMPLEXITY HELICOPTER SIMULATION MATH MODEL Final Contractor Report, Jul. 1985 - Jul. 1987
ROBERT K. HEFFLEY and MARC A. MNICH Apr. 1988 102 p
Prepared for Army Research and Technology Labs., Moffett Field, Calif.

(Contract NAS2-11665)
(NASA-CR-177476; NAS 1.26:177476; USAAVSCOM-TR-87-A-7)
Avail: NTIS HC A06/MF A01 CSCL 01C

An example of a minimal complexity simulation helicopter math model is presented. Motivating factors are the computational delays, cost, and inflexibility of the very sophisticated math models now in common use. A helicopter model form is given which addresses each of these factors and provides better engineering understanding of the specific handling qualities features which are apparent to the simulator pilot. The technical approach begins with specification of features which are to be modeled, followed by a build up of individual vehicle components and definition of equations. Model matching and estimation procedures are given which enable the modeling of specific helicopters from basic data sources such as flight manuals. Checkout procedures are given which provide for total model validation. A number of possible model extensions and refinement are discussed. Math model computer programs are defined and listed. Author

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RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A88-53135*# Virginia Univ., Charlottesville.
UNIQUE, CLEAN-AIR, CONTINUOUS-FLOW, HIGH-STAGNATION-TEMPERATURE FACILITY FOR SUPERSONIC COMBUSTION RESEARCH
R. H. KRAUSS, J. C. MCDANIEL, JR., J. E. SCOTT, JR., R. B. WHITEHURST, III, C. SEGAL (Virginia, University, Charlottesville) et al. AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 27 p. NASA-supported research. refs
(AIAA PAPER 88-3059A)

Accurate, spatially-resolved measurements can be conducted of a model supersonic combustor in a clean air/continuous flow supersonic combustion facility whose long run times will allow not only the point-by-point mapping of flow field variables with laser diagnostics but facilitate the simulation of steady-state combustor conditions. The facility will provide a Mach 2 freestream with static pressures in the 1 to 1/6 atm range, and stagnation temperatures of up to 2000 K. O.C.

A88-53626
AIAA, FLIGHT SIMULATION TECHNOLOGIES CONFERENCE, ATLANTA, GA, SEPT. 7-9, 1988, TECHNICAL PAPERS
Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 367 p. For individual items see A88-53627 to A88-53671.

The conference presents papers on wide-field-of-view helmet mounted display systems for helicopter simulation, processing pseudosynthetic aperture radar images from visual terrain data, image extrapolation from flight simulator visual systems, multiple frame rate integration, real-time simulation of helicopters using the blade element method, present and future developments of the NLR moving base research flight simulator, and mission-oriented simulator development. Other topics include a computer systems upgrade for the Shuttle mission training facility, tactical air combat in a real-time multiple engagement simulation, simulation tools for crew system assessment, a methodology for simulation validation using optimal time history matching, and human performance data in simulation design. Consideration is also given to visual-vestibular interaction of pilot's perception of aircraft or simulator motion, time delay compensation using supplementary cues in aircraft simulator systems, and software tools for building dedicated real-time applications. K.K.

A88-53629#
IMAGE EXTRAPOLATION FOR FLIGHT SIMULATOR VISUAL SYSTEMS
KEITH BLANTON (Ivex Corp., Norcross, GA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 17-22.
(AIAA PAPER 88-4577)

Flight simulator visual systems which can render detailed terrain databases with realistic texturing are typically very expensive. However, constraining the terrain to be an absolutely flat plane can offer tremendous advantages in many important simulation scenarios over conventional systems. This paper outlines the fundamental principles behind a new approach based on this assumption and describes some of the implementation issues which must be considered. The result is a visual system which can generate images with high quality texturing and detail and maintain a guaranteed frame rate. These techniques are the basis around which the IVEX Corporation VDS-1000 flight simulator visual system was designed. Author

A88-53630#
DYNAMIC TEXTURE IN VISUAL SYSTEM
MASARU FUJINO and MASATO OGATA (Mitsubishi Precision Co., Ltd., Kamakura, Japan) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 23-25.
(AIAA PAPER 88-4578)

In the current CGI visual system, texture mapping is used to enhance the detail of image. The state of the ocean waves and stirring of grass on the ground surface, however, are not sufficiently simulated. To improve the image, it is developed a system which computes linear combinations of some basic patterns, and using the computation results, a multistage color mixing is performed. Parameters specifying texture patterns are controlled to generate various dynanmic textures. The image of dynamic ocean surface will produce effective training of ASW mission by helicopter. Author

A88-53635#
PRESENT AND FUTURE DEVELOPMENTS OF THE NLR MOVING BASE RESEARCH FLIGHT SIMULATOR
C. J. JANSEN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 54-61.
(AIAA PAPER 88-4584)

The paper presents an overview of the upgrading program of the NLR Flight Simulator. The avionics system consists of: an ARINC bus interface system to couple o.a. EFIS displays, a general-purpose graphics station, and a programmable EFIS. The new fully hydrostatic 6-degrees-of-freedom motion system with high bandwidth (only 45 deg phase lag at 4 Hz for acceleration commands from the simulator computer) is described in more detail. Finally, the digital motion interface and the proposed bus interface system are described. Author

A88-53642*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE LANGLEY ADVANCED REAL-TIME SIMULATION (ARTS) SYSTEM
DANIEL J. CRAWFORD, JEFF I. CLEVELAND, II, and RICHARD O. STAIB (NASA, Langley Research Center, Hampton, VA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 109-121.
(AIAA PAPER 88-4595)

This paper is intended as a status report on the ARTS system. It briefly describes the architecture and principal subsystems including: the CAMAC network system (hardware and software), the clocking system, the signal converters, the control consoles, and the minicomputer and microcomputer interfaces. The performance and reliability of the system exceeds expectations and component failure data over an 11-month period are presented. Planned enhancements, including the replacement of the mainframe computers, are discussed. Author

A88-53653*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

SIMULATOR EVALUATION OF TAKEOFF PERFORMANCE MONITORING SYSTEM DISPLAYS

DAVID B. MIDDLETON, LEE H. PERSON, JR. (NASA, Langley Research Center, Hampton, VA), and RAGHAVACHARI SRIVATSAN (Vigyan Research Associates, Inc., Hampton, VA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 206-214. refs
(AIAA PAPER 88-4611)

The development of head-up and head-down cockpit displays to convey symbolic status and advisory information to the pilot to aid him in his decision to continue or abort takeoff is described. It also describes a pilot-in-the-loop evaluation of the displays using the NASA Langley transport systems research vehicle fixed-base simulator. It was found that the head-up display was monitored with little effort and did not obstruct or distract from the runway scene. K.K.

A88-53657#

REAL-TIME SIMULATION - A TOOL FOR DEVELOPMENT AND VERIFICATION

DAVID R. BLOEM and ROBERT NAIGUS (SLI Avionics System Corp., Grand Rapids, MI) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 244-249.
(AIAA PAPER 88-4618)

A baseline real-time laboratory simulation tool for the development and verification of avionics systems ranging from a flight management system to a navigation attack system is described. This tool is used for all aspects of product development including system/software development, full system verification and validation, on-site flight test support, and field customer training support. The laboratory design methodology and its associated configuration are discussed as well as specific design features of the real-time simulation. K.K.

A88-53658#

SIMULATOR TRANSPORT DELAY MEASUREMENT USING STEADY-STATE TECHNIQUES

WILLIAM V. JOHNSON and MATTHEW S. MIDDENDORF (Systems Research Laboratories, Inc., Dayton, OH) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 250-254.
(AIAA PAPER 88-4619)

This paper describes a flight simulator transport delay measurement technique along with detailed apparatus descriptions and application considerations. The frequency domain method described was used to measure the delay in a flight simulator used for research investigating temporal fidelity effects on human performance. The transport delay is differentiated from the total delay in the system. Further, time delay contributions from each part of the simulation are described. Author

A88-53659#

DETERMINATION OF HELICOPTER SIMULATOR TIME DELAY AND ITS EFFECTS ON AIR VEHICLE DEVELOPMENT

JOHN WOLTKAMP, S. RAMACHANDRAN, and ROGER BRANSON (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 255-263. refs
(AIAA PAPER 88-4620)

The system architecture, techniques of measuring throughput delays, and results of a study to determine simulator hardware time delay are discussed. An average total system delay of about 87 milliseconds is found. An analysis of pilot performance did not reveal any significant changes due to increased simulator delays, but did show that the pilot control activity increased in the low-speed high-gain tasks. Although with increased time delay the Cooper-Harper rating increased (indicating degradation in perceived handling qualities), for the type of helicopter simulated, there was no definite time delay at which the ratings changed abruptly. R.R.

A88-53667*# Army Aviation Research and Development Command, Moffett Field, Calif.

THE EFFECT OF PERSPECTIVE DISPLAYS ON ALTITUDE AND STABILITY CONTROL IN SIMULATED ROTARY WING FLIGHT

K. A. O'DONNELL (U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA), W. W. JOHNSON, and C. T. BENNETT (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 325-331. refs
(AIAA PAPER 88-4634)

The effect of perspective displays on flight performance is investigated using two simulation experiments. In the first, a perspective grid display was superimposed on computer-generated terrain and subjects attempted to maintain their initial attitude in a simulated hover using terrain and/or one of four grid patterns. Horizontal lines produced the best attitude control performance. In the second experiment, a square grid was studied in combination with various visual display configurations and grid attachment conditions. It was found that performance with the panel-mounted display was significantly worse than with the out-the-window or helmet-mounted displays. The results suggested that the partial grid attachment condition improved hovering performance with the panel-mounted display. K.K.

A88-53847* National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.

THE APPLICATION OF CRYOGENICS TO HIGH REYNOLDS NUMBER TESTING IN WIND TUNNELS. II - DEVELOPMENT AND APPLICATION OF THE CRYOGENIC WIND TUNNEL CONCEPT

R. A. KILGORE and D. A. DRESS (NASA, Langley Research Center, Hampton, VA) Cryogenics (ISSN 0011-2275), Sept. 1984, p. 484-493. refs

The development and application of the cryogenic wind tunnel concept at the Langley Research Center are described. Particular attention is given to the low-speed cryogenic tunnel and the pilot transonic cryogenic tunnel. The major conclusions with respect to the operation and performance of the pilot transonic cryogenic tunnel after almost 4000 h of operation at cryogenic temperatures are that: (1) purging, cooldown, and warm-up times are acceptable and can be predicted with good accuracy, and that (2) the quantity of liquid nitrogen required for cooldown and running can be predicted with good accuracy. The U.S. National Transonic Facility is described in detail. K.K.

A88-54280#

ACQUISITION OF UNSTEADY PRESSURE MEASUREMENTS FROM A HIGH SPEED MULTI-STAGE COMPRESSOR

WILLIAM W. COPENHAVER and CHRISTOPHER J. WORLAND (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-189)

Two methods for acquiring transient pressure measurements from a high speed multi-stage compressor are presented. Data were obtained from upstream, inter-stage and downstream measurement locations on the compressor during unsteady operation. The two methods of data acquisition were real time digital conversion of close coupled pressures and frequency modulated (FM) analog recording of high response measurements.

The close coupled measurements provide for a nominal frequency response of 70 Hz while the high response measurements provided 200 Hz nominal response. A description of both acquisition systems is provided with discussion of the limitations involved in both methods. Examples and comparisons of data obtained by both methods are presented. Author

A88-54357#
A NEW METHOD OF MODELING UNDEREXPANDED EXHAUST PLUMES FOR WIND TUNNEL AERODYNAMIC TESTING
V. SALEMANN and J. M. WILLIAMS (Boeing Co., Seattle, WA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(Contract F33615-84-C-0518)
(ASME PAPER 88-GT-288)

A method for modeling hot underexpanded exhaust plumes with cold model scale plumes has been developed to support a wind tunnel test of a rocket powered crew ejection seat. The method involves scaling the model and nozzle external geometry (including the nozzle exit area), matching the model dynamic pressure ratio to the full-scale dynamic pressure ratio, and matching the model thrust coefficient to the full-scale thrust coefficient. A generalized method-of-characteristics computer code was used to determine the plume shapes of both a hot half-scale nozzle of area ratio 3.2 and a cold model scale nozzle of area ratio 1.3. R.R.

A88-54384#
NAVY V/STOL ENGINE EXPERIENCE IN ALTITUDE TEST FACILITY
WILLIAM H. CUNNINGHAM and JOSEPH F. BOYTOS (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p.
(ASME PAPER 88-GT-317)

The Pegasus V/STOL Engine used in the AV-8B/GR MK5 Harrier II Aircraft presents several unique installation requirements for testing in an Altitude Test Facility. These requirements are dictated by the fact that the Pegasus engine has four separate exhaust nozzles, and the short, highly-curved Harrier inlet creates unusual inlet distortion conditions.The Naval Air Propulsion Center has designed and fabricated equipment which has been used to test the Pegasus engine under simulated altitude conditions. During engine testing, problems were encountered with the rear nozzle exhaust collectors and the proposed solutions are presently being implemented. This paper describes the development of the Navy capability to test the Pegasus engine in an uninstalled performance configuration, and with total pressure distortion screens; with aircraft accessories loaded; and with a mock-up of the AV-8B aircraft inlet to determine the effects of combined total and static pressure distortion on engine performance and surge margin. Author

N88-28859*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
HIGH-ASPECT-RATIO WINGS
JOHN B. PETERSON, JR. *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 21-29 Apr. 1988
Avail: NTIS HC A20/MF A01 CSCL 14B

High-aspect-ratio aircraft include most transport aircraft such as commercial and military transports, business aircraft, and cargo aircraft. Generally, these types of aircraft are designed to cruise over a narrow range of lift coefficients and Mach numbers in the performance of their mission. Emphasis is therefore placed on the cruise performance of transport aircraft and every effort is made to obtain accurate wind-tunnel data to use as a basis for prediction of full-scale cruise performance. However, off-cruise performance is also important and methods were developed for extrapolating wind-tunnel data on buffet and flutter at transonic speed. Transport-type aircraft were tested extensively in various wind tunnels around the world and many different test techniques were developed to simulate higher Reynolds numbers. Methods developed for one tunnel may not be applicable to another tunnel because of differences in size, Reynolds number capability, running time, and test objectives. Many of the methods of boundary-layer control developed in two-dimensional airfoil testing can be applied in tests of transport configurations, but sometimes the three-dimensional flow fields that develop on tranpsort aircraft can make application of the two-dimensional methods difficult or impossible. The discussion is intended to be a representative, but not exhaustive, survey of the various methods of high Reynolds number simulation in the testing of high-aspect-ratio aircraft. Author

N88-28861# British Aerospace Public Ltd. Co., Weybridge (England). Aircraft Group.
COMPLEX CONFIGURATIONS
A. G. T. CROSS *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 50-67 Apr. 1988
Avail: NTIS HC A20/MF A01

The practice of simulating high flight Reynolds number behavior in a low Reynolds number facility is well known. However the problems now encountered at transonic speeds are considerable and vary for different model designs such that it is difficult to predict with real confidence the actual flight conditions. In two dimensions these scale effects become more apparent as the degree of supercritical flow is increased and in particular with rearward movement of shocks. In three dimensions the problems are more severe particularly when wing sweep is high due to vortex and turbulent attachment line flows, both of which are Reynolds number dependent and when complex configurations are considered the potential for scale sensitive effects is considerable owing to the many regions where flow separation can occur. The designer will often seek to avoid scale sensitive flow separations in model tests and this amounts to designing for low Reynolds number with a reduction in the potential gains to be had for design for full scale. By furthering the understanding of scale effects more realiable use can be made of Reynolds number simulation techniques, so enabling design for conditions closer to full scale with significant gains in flight performance. The current practice with regard to high Reynolds number simulation in transonic wind tunnels for industrial standards of testing relating to complex aircraft configurations is reviewed. Author

N88-28865# National Research Council of Canada, Ottawa (Ontario).
COMPUTATIONAL TOOLS FOR SIMULATION METHODOLOGIES
Y. Y. CHAN *In* AGARD, Boundary Layer Simulation and Control in Wind Tunnels p 115-131 Apr. 1988
Avail: NTIS HC A20/MF A01

In the brief review of the computational capabilities for viscous flows, it was shown that the methods of solution of the governing equations were well developed. Turbulence modeling is adequate for simple flows, though further verification and developments are still needed for complex flows. Interactions of viscous and inviscid flows, which are basic characteristics of transonic flows are propertly formulated and analyzed. Attached flows can be predicted accurately for a wide range of Reynolds numbers. Flows with moderate separations near the leading or trailing edges and the shock wave-boundary layer interactions can be treated by the interactive methods. Methods for two-dimensional flows are better developed while three-dimensional and unsteady flow methods are showing rapid progress. In general, computations can be applied to simple configurations or components of a complex configuration. The interaction of computational simulations with wind tunnel test programs has effectively augmented the capabilities of these tests. The information provided by computations is now essential for design and checking of the test and for interpretation and extrapolation of the results. Due to strict requirement of accuracy in aerodynamic tests, applications of computation are limited, at present, to stimulation of attached flows. For complex flow simulations, especially with flow separation, further development is needed in better understanding the physical nature of the flow and its modeling. Author

N88-28933*# Applied Cryogenics and Materials Consultants, Inc., Hampton, Va.
TECHNOLOGY FOR PRESSURE-INSTRUMENTED THIN AIRFOIL MODELS Final Report
DAVID A. WIGLEY Washington Sep. 1988 42 p
(Contract NAS1-18066)
(NASA-CR-4173; NAS 1.26:4173) Avail: NTIS HC A03/MF A01 CSCL 14B

A novel method of airfoil model construction was developed. This Laminated Sheet technique uses 0.8 mm thick sheets of A286 containing a network of pre-formed channels which are vacuum brazed together to form the airfoil. A 6.25 percent model of the X29A canard, which has a 5 percent thick section, was built using this technique. The model contained a total of 96 pressure orifices, 56 in three chordwise rows on the upper surface and 37 in three similar rows on the lower surface. It was tested in the NASA Langley 0.3 m Transonic Cryogenic Tunnel. Unique aerodynamic data was obtained over the full range of temperature and pressure. Part of the data was at transonic Mach numbers and flight Reynolds number. A larger two dimensional model of the NACA 64a-105 airfoil section was also fabricated. Scale up presented some problems, but a testable airfoil was fabricated. Author

N88-28934# Massachusetts Inst. of Tech., Lexington.
AIRPORT SURFACE TRAFFIC AUTOMATION STUDY
WALTER M. HOLLISTER 9 May 1988 80 p
(Contract F19628-85-C-0002)
(AD-A194553; ATC-156; DOT/FAA/PS-87/1) Avail: NTIS HC A05/MF A01 CSCL 17G

This report documents a study of requirements for an Airport Surface Traffic Automation (ASTA) system. The objective was to determine the necessary functions, establish the cost and benefits, and outline a modular system design. The highest priority function identified was an improved surface surveillance and communication system. The greatest potential for safety benefits is provided by automatic conflict alert and collision warning for pilots and controllers to prevent runway incursion accidents. Strategic and tactical planning assistance to maximize runway utilization can improve controller productivity while keeping them responsible for final decisions. The report contains a modular design for ASTA and includes specifications for a man-in-the loop simulation of the system. GRA

N88-28935# Naval Postgraduate School, Monterey, Calif.
FLOW VISUALIZATION ON A SMALL SCALE M.S. Thesis
ROY L. HIXSON, III Mar. 1988 42 p
(AD-A194728) Avail: NTIS HC A03/MF A01 CSCL 14B

A quarter scale model of the planned renovated form of an existing flow visualization tunnel was designed and constructed to test the quality of flow and for small scale research and flow visualization demonstrations. Three flow visualization techniques were developed, including fog injection, helium bubbles, and smoke wire. In addition to velocity calibration and test section mapping of the tunnel, the latter two of these methods were used for visualizing flows around three different shaped bodies as demonstration that the tunnel's design objectives were realized. Both techniques produced excellent photographic results of flows around a block of rectangular cross section, a circular cylinder and an airfoil. GRA

N88-28936# Naval Postgraduate School, Monterey, Calif.
HOT-WIRE MEASUREMENTS OF COMPRESSOR BLADE WAKES IN A CASCADE WIND TUNNEL M.S. Thesis
ADEM BAYDAR Mar. 1988 58 p
(AD-A194737) Avail: NTIS HC A04/MF A01 CSCL 14B

A hot-wire system, with software designed for calibrating and taking data with single, double and triple hot-wire sensors separately, or three probes at once, was verified and used to make wake measurements downstream of a compressor stator blade in a cascade wind tunnel. Using a single hot-wire probe, velocity and turbulence data were obtained in the wake of the controlled-diffusion blade in order to verify laser Doppler velocimeter (LDV) data taken in earlier studies. The tests were conducted at three inlet angles from near design incidence towards the expected stall condition at a Mach number of 0.25 and Reynolds number of about 700,000. Wake profiles were obtained from 0.08 to 0.2 chord lengths downstream of the blade. Good agreement was found with LDV measurements. Measurements at the highest incidence angle showed that the wake constituted one third of the flow and yet no separation occurred before the trailing edge on the suction side of the blade. GRA

N88-29742# British Aerospace Public Ltd. Co., Preston (England).
THE ROLE OF SIMULATION IN FLYING QUALITIES AND FLIGHT CONTROL SYSTEM RELATED DEVELOPMENT
A. G. BARNES *In* AGARD, Advances in Flying Qualities 21 p May 1988
Avail: NTIS HC A09/MF A01

Flight simulation makes a vital contribution to the understanding of flying quality requirements and to the clearance of modern aircraft flight controls. The background to the use of simulators, both airborne and ground based is presented, and the experimental techniques, including validation and hardware requirements are discussed. The limitations which equipments can impose are presented, and examples are given of the use of flight simulation in flying qualities research. Finally, the techniques required for the clearance of current designs are highlighted, and a direction for future research is indicated. Author

N88-29820*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
COMPUTER PROGRAMS FOR CALCULATION OF STING PITCH AND ROLL ANGLES REQUIRED TO OBTAIN ANGLES OF ATTACK AND SIDESLIP ON WIND TUNNEL MODELS
JOHN B. PETERSON, JR. Jul. 1988 47 p
(NASA-TM-100659; NAS 1.15:100659) Avail: NTIS HC A03/MF A01 CSCL 14B

Two programs have been developed to calculate the pitch and roll angles of a wind-tunnel sting drive system that will position a model at the desired angle of attack and and angle of sideslip in the wind tunnel. These programs account for the effects of sting offset angles, sting bending angles and wind-tunnel stream flow angles. In addition, the second program incorporates inputs from on-board accelerometers that measure model pitch and roll with respect to gravity. The programs are presented in the report and a description of the numerical operation of the programs with a definition of the variables used in the programs is given. Author

N88-29821*# Stanford Univ., Calif. Dept. of Aeronautics and Astronautics.
AN EXPERIMENTAL STUDY OF AN ADAPTIVE-WALL WIND TUNNEL
ZEKI CELIK and LEONARD ROBERTS Aug. 1988 155 p
(Contract NCC2-77)
(NASA-CR-183152; NAS 1.26:183152; JIAA-TR-87) Avail: NTIS HC A08/MF A01 CSCL 14B

A series of adaptive wall ventilated wind tunnel experiments was carried out to demonstrate the feasibility of using the side wall pressure distribution as the flow variable for the assessment of compatibility with free air conditions. Iterative and one step convergence methods were applied using the streamwise velocity component, the side wall pressure distribution and the normal velocity component in order to investigate their relative merits. The advantage of using the side wall pressure as the flow variable is to reduce the data taking time which is one the major contributors to the total testing time. In ventilated adaptive wall wind tunnel testing, side wall pressure measurements require simple instrumentation as opposed to the Laser Doppler Velocimetry used to measure the velocity components. In ventilated adaptive wall tunnel testing, influence coefficients are required to determine the pressure corrections in the plenum compartment. Experiments were carried out to evaluate the influence coefficients from side wall pressure distributions, and from streamwise and normal velocity

distributions at two control levels. Velocity measurements were made using a two component Laser Doppler Velocimeter system.
Author

N88-29822# AeroVironment, Inc., Monrovia, Calif.
DEVELOPMENT AND DESIGN OF WINDTUNNEL AND TEST FACILITY FOR RPV (REMOTE PILOTED VEHICLE) ENHANCEMENT DEVICES Final Report, 15 Sep. 1987 - 15 Apr. 1988
BART D. HIBBS, HERMAN M. DREES, and PETER B. LISSAMAN 15 Apr. 1988 59 p
(Contract DAAH01-87-C-1049; ARPA ORDER 5916)
(AD-A194842; AV-FR-88/807) Avail: NTIS HC A04/MF A01 CSCL 14B

Viscous drag represent a significant power demand on flight vehicles. Reductions of this requirement could result in higher speeds and altitudes, longer endurance and heavier payloads. General streamlining by shape control is highly developed so that the viscous drag of most vehicles consists mainly of turbulent skin friction. Recent work in surface (riblets, etc.) and near-surface (vortex generator, etc.) devices has indicated that even this drag level can be further reduced by modifying the turbulent process near the surface. Drag reductions of about seven percent have been claimed for riblets and have been generally supported by various experiments. Engineering applications of these devices shows great potential, but to date have not been extensively pursued because of lack of definitive data. Remote Piloted Vehicles (RPV's) would benefit from these devices, but operate over a Reynolds number range such that much standard aeronautical research is inapplicable. A new facility is required to test and develop new devices appropriate for RPV's. This facility should be capable of testing, with and without pressure gradients, over the necessary range of scales and speeds with sufficient accuracy that engineering design decisions can be made about existing devices and improved, advanced units to be developed. A special purpose closed-return wind tunnel has been designed with a 26 foot long, 4 foot by 4 foot working cross-section driven by a 40 HP motor and operating at speeds up to 120 ft/sec. GRA

N88-29823# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio.
CONTROLLED DEGRADATION OF RESOLUTION OF HIGH-QUALITY FLIGHT SIMULATOR IMAGES FOR TRAINING EFFECTIVENESS EVALUATION M.S. Thesis
DENNIS D. KAIP 1988 66 p
(AD-A196189; AFIT/CI/NR-88-46) Avail: NTIS HC A04/MF A01 CSCL 05I

A flight simulator is a device used to train pilots and air crews without the use of an actual aircraft. The use of flight simulators for training is widespread in both the military and civilian sector. The use of flight simulators has significant advantages over the operation of the actual aircraft. In addition, pilots and air crews can practice complex and/or dangerous maneuvers in a flight simulator without risking loss of life or aircraft. As described by Schachter 6, sophisticated flight simulators recreate most of the aspects of flying: aircraft instruments, motion of the aircraft, gravitational forces, radar, and out-the-window views. Most modern flight simulators use computer generated imagery (CGI) to produce the out-the-window views in real-time in response to inputs from flight controls. The imagery can be displayed in a variety of ways: on large CRTs, projected onto the inside of a dome, or through helmet-mounted displays. Different training tasks are presumed to have different requirements with respect to brightness, contrast, and resolution. The goal for visual display flight training simulators in general, is not realism, but training effectiveness. Therefore, the design requirements for flight simulators should take into consideration the desired training task. GRA

N88-29824# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany).
SUPERSONIC WALL ADAPTATION IN THE RUBBER TUBE TEST SECTION OF THE DFVLR GOETTINGEN
A. HENDERGOTT, E. STANEWSKY, and E. WEDEMEYER Apr. 1987 15 p
(IB-222-87-A-08) Avail: NTIS HC A03/MF A01

Wind tunnel tests in the rubber tube test section have been performed in order to investigate the possibility of reducing supersonic wall interferences by adaptation of the rubber walls. Although the spacing of the jack positions is not sufficiently close for the supersonic wall adaptation, encouraging results were obtained for a cone-cylinder model. Author

N88-29825*# Southwest Research Inst., San Antonio, Tex.
SPRAY AUTOMATED BALANCING OF ROTORS: METHODS AND MATERIALS Final Report
ANTHONY J. SMALLEY, RICHARD M. BALDWIN, and WILBUR R. SCHICK Aug. 1988 122 p
(Contract NAS3-25069; DA PROJ. 1L1-62209-AH-76)
(NASA-CR-182151; NAS 1.26:182151; AVSCOM-TR-88-C-018)
Avail: NTIS HC A06/MF A01 CSCL 14B

The work described consists of two parts. In the first part, a survey is performed to assess the state of the art in rotor balancing technology as it applies to Army gas turbine engines and associated power transmission hardware. The second part evaluates thermal spray processes for balancing weight addition in an automated balancing procedure. The industry survey reveals that: (1) computerized balancing equipment is valuable to reduce errors, improve balance quality, and provide documentation; (2) slow-speed balancing is used exclusively, with no forseeable need for production high-speed balancing; (3) automated procedures are desired; and (4) thermal spray balancing is viewed with cautious optimism whereas laser balancing is viewed with concern for flight propulsion hardware. The FARE method (Fuel/Air Repetitive Explosion) was selected for experimental evaluation of bond strength and fatigue strength. Material combinations tested were tungsten carbide on stainless steel (17-4), Inconel 718 on Inconel 718, and Triballoy 800 on Inconel 718. Bond strengths were entirely adequate for use in balancing. Material combinations have been identified for use in hot and cold sections of an engine, with fatigue strengths equivalent to those for hand-ground materials.
Author

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ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A88-53105#
COMBINED ENGINES FOR FUTURE LAUNCHERS
MARCEL F. POULIQUEN (Societe Europeenne de Propulsion, Suresnes, France), MICHEL DOUBLIER (SNECMA, Corbeil, France), and DOMINIQUE SCHERRER (ONERA, Chatillon-sous-Bagneux, France) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 6 p.
(AIAA PAPER 88-2823)

In 1986, studies were initiated in France under CNES (Centre National d'Etudes Spatiales) contract to evaluate new propulsion concepts for Advanced Space Transportation Systems. A number of combined engine cycles using airbreathing and rocket propulsion were listed and a systematic analysis of the most promising concepts was initiated. At the moment, the airturborocket, the airturborocket-ram-rocket, the airturboexpander-ram-rocket have been evaluated. The paper gives the main results and describes the arrangement of the concepts. Author

A88-54567* Georgia Inst. of Tech., Atlanta.
TRAJECTORY OPTIMIZATION AND GUIDANCE LAW DEVELOPMENT FOR NATIONAL AEROSPACE PLANE APPLICATIONS
A. J. CALISE, J. E. CORBAN, and G. A. FLANDRO (Georgia Institute of Technology, Atlanta) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1406-1411. refs
(Contract NAG1-784)

The problem of onboard trajectory optimization for an airbreathing, single-stage-to-orbit vehicle is examined. A simple model representative of the aerospace plane concept, including a dual-mode propulsion system composed of scramjet and rocket engines, is presented. Consideration is restricted to hypersonic flight within the atmosphere. An energy state approximation is used in a four-state model for flight of a point mass in a vertical plane. Trajectory constraints, including those of dynamic pressure and aerodynamic heating, are initially ignored. Singular perturbation methods are applied in solving the optimal control problem of minimum fuel climb. The resulting reduced solution for the energy state dynamics provides an optimal altitude profile dependent on energy level and control for rocket thrust. A boundary-layer analysis produces an approximate lift control solution in feedback form and accounts for altitude and flight path angle dynamics. The reduced solution optimal climb path is presented for the unconstrained case and the case for which a maximum dynamic pressure constraint is enforced. I.E.

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A88-52655
FATIGUE OF ELEVATED TEMPERATURE POWDER METALLURGY ALUMINUM ALLOY MECHANICALLY FASTENED JOINTS
J. C. EKVALL and L. BAKOW (Lockheed-California Co., Burbank) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 151-175.
(Contract F33615-83-C-3200)

Results are presented for constant amplitude fatique tests conducted at room temperature and 260 C on lap joint specimens fabricated from 7075-T6 (room temperature only), CZ42 (Al-7.1Fe-6.OCe) and CU78 (Al-8.3Fe-4.OCe) sheet materials. Specimens were fabricated with NAS1200 and LS15905 A-286 flush head rivets, and A-286 and Ti-6Al-4V Hi-Loks. Variables evaluated with LS15905 rivets included A-286 aging treatment and rivet head countersink angle. The NAS1200 rivets provided joints with the best fatigue performance at both room and elevated temperature. Author

A88-52657
MICROSCOPIC INNER DAMAGE CORRELATED WITH MECHANICAL PROPERTY DEGRADATION DUE TO SIMULATED FATIGUE LOADING IN METAL MATRIX COMPOSITES
AKIRA KOBAYASHI and NOBUO OHTANI (Tokyo, University, Japan) IN: New materials and fatigue resistant aircraft design; Proceedings of the Fourteenth ICAF Symposium, Ottawa, Canada, June 8-12, 1987. Warley, England, Engineering Materials Advisory Services, Ltd., 1987, p. 195-214.

SiC/Aluminum composites are subjected to two-stage fatigue loading to investigate the inner material damage in correlation with mechanical properties from the microscopic point of view. It was found that the fatigue life is governed by the internal microcrack or void formation, hence the fatigue life in the case of cumulative loading can be estimated by the inspection of inner microcracks. Final fracture at higher stress amplitude is initiated from the specimen interior like composites and not like metals. Author

A88-53164#
FLAME STABILIZATION IN SUPERSONIC COMBUSTION
M. BARRERE and A. MESTRE (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 1, 1988, p. 1-13. refs

The nature of procedures thus far identified for the stabilization of flames in supersonic flow is discussed, and their applications in various supersonic combustor-stabilization systems are analyzed. These considerations are of prominent importance in the design optimization of scramjet engines, whether fueled by such conventional hydrocarbon fuels as kerosene or by hydrogen. Both the step technique, which establishes stagnant areas in the recirculation kernels and low velocity areas in the boundary layers, and the creation of pockets or vortices in the flow, are considered to be useful methods for combustion stabilization. O.C.

A88-53542
C/C COMPOSITE MATERIALS FOR AIRCRAFT BRAKES
SHRIKANT AWASTHI and JERRY L. WOOD (Allied-Signal Aerospace Co., Bendix Wheels and Brakes Div., South Bend, IN) Advanced Ceramic Materials (ISSN 0883-5551), vol. 3, Sept. 1988, p. 449-451.

C/C composites can simultaneously function as aircraft landing gear brakes' friction materials, heat sinks, and structural components. The important C/C composite brake performance parameters of peak torque, oxidation characteristics, and stability, among others, are controlled through engineering of the composition and processing of the material. The heat capacity of C/C brakes is 2.5 times that of steel, while its strength at elevated temperatures is 2 times that of steel; 40-percent weight savings over conventional steel brakes are thereby obtainable. O.C.

A88-53556
NICRAL/BENTONITE THERMAL SPRAY POWDER FOR HIGH TEMPERATURE ABRADABLE SEALS
M. A. CLEGG and M. H. MEHTA (Sherritt Gordon Mines, Ltd., Fort Saskatchewan, Canada) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando, FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 41-45. Research supported by the National Research Council of Canada. refs

The function and basic requirements of turbine engine clearance control abradable seals are reviewed. For the specific case of an abradable seal operating in the temperature range 650-850 C, the use of a thermal sprayed deposit of an alloy composite powder consisting of a bentonite core particle coated with an alloy layer of NiCrAl is described. A series of tests were carried out to arrive at an optimum combination of abradability, erosion resistance, and oxidation resistance in the thermal sprayed deposit. The selected composite powder consists of a closely sized bentonite core in the range 75-150 microns, coated with an alloy consisting of Ni5 pct Cr3 pct Al, such that the alloy coating to core ratio is 80:20 by weight. When flame sprayed by standard practice this powder was found to produce an abradable seal with the optimum combination of desired properties. Author

A88-53566
EXPERIMENTAL AND THEORETICAL ASPECTS OF THICK THERMAL BARRIER COATINGS FOR TURBINE APPLICATIONS
G. JOHNER, V. WILMS (Leybold AG, Hanau, Federal Republic of Germany), K. K. SCHWEITZER, and P. ADAM (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando,

FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 155-166. refs

Thick (2 mm) plasma-sprayed yttria-stabilized-zirconia coatings are shown to effectively insulate the turbine casings of small gas turbines. It is shown that the most ideal structure, one containing tetragonal and cubic phases and no monoclinic phases, can be achieved if the powder is fully melted. A thermal barrier coating that is dense and exhibits a fine network of segmentation cracks can be achieved by 'hot spraying' (which assures the complete melting of the powder and microwelding of the individual platelets). R.R.

A88-53838
MEETING THE HIGH TEMPERATURE CHALLENGE - THE NON-METALLIC AERO ENGINE
R. H. JEAL (Rolls-Royce, PLC, Derby, England) Metals and Materials (ISSN 0266-7185), vol. 4, Sept. 1988, p. 539-542.

Substantial increases in gas turbine engine performance are obtainable through the introduction of advanced, highly refractory/low-density materials such as metal-matrix and ceramic-matrix composites, whose design methodologies and manufacturing technologies are currently under intensive development. It is speculated that future aircraft engines, perhaps becoming operational in the first decade of the next century, will have a glass- or metal-matrix compressor and a ceramic turbine; design methodologies for turbine components will involve the design of an appropriate material as well as the component's structure. O.C.

A88-53955
EFFECT OF LOADING ASYMMETRY ON THE LOW-CYCLE FATIGUE OF ZHS6F ALLOY UNDER CYCLIC TEMPERATURE CHANGES [VLIIANIE ASIMMETRII NAGRUZHENIIA NA MALOTSIKLOVUIU USTALOST' SPLAVA ZHS6F PRI TSIKLICHESKOM IZMENENII TEMPERATURY]
A. N. VETROV and V. I. MOLODKIN (Kievskii Institut Inzhenerov Grazhdanskoi Aviatsii, Kiev, Ukrainian SSR) Problemy Prochnosti (ISSN 0556-171X), Aug. 1988, p. 46-50. In Russian.

The low-cycle fatigue behavior of ZhS6F blade alloy under asymmetric nonisothermal loading is investigated experimentally, and statistical estimates of lognormal thermal-cycling life distribution of the specimens are obtained by the maximum likelihood method. A mathematical life model is proposed which is based on the approximation of maximum stress amplitude diagrams under axisymmetric low-cycle loading by a shifted-ellipse equation. A comparison is made between model predictions and experimental data. V.L.

A88-53996
CORROSION AND PROTECTION OF GAS TURBINE BLADES [KORROZIIA I ZASHCHITA LOPATOK GAZOVYKH TURBIN]
VALENTIN IL'ICH NIKITIN Leningrad, Izdatel'stvo Mashinostroenie, 1987, 272 p. In Russian. refs

The characteristics of the damage of gas turbine blades resulting from sulfide-oxide corrosion, the mechanisms of this type of corrosion, and its various forms are reviewed. Different types of anticorrosion coatings and methods for depositing such coating on the blades of gas turbines are then discussed. In particular, attention is given to the possibility of extending the life of gas turbine plants by using corrosion-resistant alloys, fuel additives, and surface and bulk alloying of the blades. V.L.

A88-54001
PRINCIPLES OF THE USE OF FUELS AND LUBRICANTS IN CIVIL AVIATION [OSNOVY PRIMENENIIA GORIUCHE-SMAZOCHNYKH MATERIALOV V GRAZHDANSKOI AVIATSII]
ALEKSEI ALEKSEEVICH LITVINOV Moscow, Izdatel'stvo Transport, 1987, 312 p. In Russian. refs

Various jet, diesel, gasoline, and gaseous fuels used in civil aviation are examined, as are lubricants and various special fluids used in engines, systems, and mechanisms. In particular, attention is given to the general characterization of fuels, lubricants, and special fluids; dependence of the reliability of engines on fuel properties; characteristics of friction systems and the use of oils and lubricants in various mechanisms; and the use and properties of fluids for hydraulic power systems, deicing liquids, and detergents. The discussion also covers the environmental aspects of the use of fuels and lubricants and safety engineering in handling flammable materials. V.L.

A88-54145*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
LIFE MODELING OF THERMAL BARRIER COATINGS FOR AIRCRAFT GAS TURBINE ENGINES
R. A. MILLER (NASA, Lewis Research Center, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 109-115. Previously announced in STAR as N88-15060. refs

Thermal barrier coating life models developed under the NASA Lewis Research Center's Hot Section Technology (HOST) Program are summarized. An initial laboratory model and three design-capable models are discussed. Current understanding of coating failure mechanisms are also summarized. Author

A88-54166#
FLAME SPEEDS IN FUEL SPRAYS WITH HYDROGEN ADDITION
P. E. SOJKA, A. H. LEFEBVRE (Purdue University, West Lafayette, IN), and G. A. RICHARDS ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-20)

The influence of hydrogen addition on the burning rates of kerosine sprays in air is studied experimentally. Flame speeds are measured as a function of fuel drop size, equivalence ratio, and hydrogen concentration. The results obtained show that evaporation rates have a controlling effect on flame speeds over wide ranges of mean drop size. They also demonstrate that the burning rates of liquid kerosine-air mixtures are augmented appreciably by the addition of small quantities of hydrogen to the air flowing into the combustion zone. Author

A88-54167#
EFFECT OF MOLECULAR STRUCTURE ON SOOT FORMATION CHARACTERISTICS OF AVIATION TURBINE FUELS
OMER L. GULDER, BORIS GLAVINCEVSKI (National Research Council of Canada, Div. of Mechanical Engineering, Ottawa), and SUDHAKAR DAS (Indian Institute of Petroleum, Dehradun, India) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-21)

The smoke point has been shown to be quantitatively related to the molecular structure of hydrocarbon fuels. Here, a fast technique for determining molecular composition of commercial and experimental fuels, in terms of carbon type structure by using a proton NMR spectrometry is described. By measuring the smoke-point soot yields of a laminar diffusion flame with a group of fuels (all having a constant H/C ratio) it is shown that neither the smoke point nor H/C ratio alone can describe the sooting propensity of turbine fuels. The results indicate that smoke point and H/C are complementary to each other in describing the sooting propensities of turbine fuels. Author

A88-54225#
THE BLOWOUT OF TURBULENT JET FLAMES IN CO-FLOWING STREAMS OF FUEL-AIR MIXTURES
M. G. KIBRYA, G. A. KARIM, and I. WIERZBA (Calgary, University, Canada) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. NSERC-supported research. refs
(ASME PAPER 88-GT-106)

The blowout limit of a turbulent jet diffusion flame in co-flowing streams of lean fuel air mixtures is examined. The blowout limit of the flame, and thereby the maximum thermal output of a burner can be extended significantly, without any modification to the burner, through the presence of a small amount of fuel homogeneously mixed with the surrounding air. The extent of this extension is related to the observed limit of fuel concentration in the surrounding stream that brings about flame flashback conditions. The flame blowout limits involving different gaseous hydrocarbon fuels have been established at atmospheric pressure and the data were correlated in terms of the surrounding fuel concentrations relative to their corresponding flashback limits. Author

A88-54226#
EVAPORATION OF FUEL DROPLETS IN TURBULENT COMBUSTOR FLOW
S. WITTIG, W. KLAUSMANN, B. NOLL, and J. HIMMELSBACH (Karlsruhe, Universitaet, Federal Republic of Germany) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(Contract DFG-SFB-167)
(ASME PAPER 88-GT-107)

Detailed measurements of a recirculating, droplet charged air flow within a model combustor are compared with predictions based on three different evaporation models. Similar results are obtained with the simplified d-squared law, the uniform temperature model, and thin skin model for relatively short droplet-heatup phases. Discrepancies, however, are observed under conditions where the droplet heating phase is relatively long, i.e., at low temperature conditions. Extended evaporation models, therefore, are necessary when the ignition performance is to be analyzed. Author

A88-54257#
FLOW IN LINER HOLES FOR COUNTER-CURRENT COMBUSTION SYSTEMS
N. ABUAF (General Electric Co., Schenectady, NY), N. S. RASMUSSEN, and L. C. SZEMA (General Electric Co., Aircraft Engine Business Group, Evendale, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-158)

Heavy duty gas turbine combustion systems have a 'reverse flow' combustion-cooling air network. High-temperature gradients have been observed in some combustion liners around the plain holes, or around the cylindrical inserts welded into the mixing holes. Flow visualization tests were performed in a countercurrent flow facility. Measurements of pressure and velocity distributions in and around the mixing hole jet were taken, and mass flow rates and discharge coefficients were calculated in order to characterize and compare the two geometries. The results with a plain hole (square-edged orifice) and the cylindrical insert show the presence of a sharp separation region at the trailing edge (combustion side) of the liner hole, which may cause the high-temperature gradients observed under operating conditions. The measured discharge coefficients show a dependence on the insert geometry, the flow parameter (K), and the bottom section (combustion side) counter-current flow velocity. Author

A88-54262#
NOTES ON THE OCCURRENCE AND DETERMINATION OF CARBON WITHIN GAS TURBINE COMBUSTORS
J. ODGERS and E. R. MAGNAN (Universite Laval, Quebec, Canada) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. NSERC-supported research. refs
(ASME PAPER 88-GT-164)

Details are presented of two series of experiments to investigate carbon determination in gas turbine combustion chambers. The first series employed a gravimetric technique to examine carbon distribution within the various zones of a combustor with the aim of identifying zones of formation and oxidation. In the second series a fairly comprehensive investigation of the technique of measuring Smoke Number was made with the objective of obtaining details relevant to its accuracy and applicability. Mixtures of iso-octane and benzene were used as fuel, thereby permitting the effects of hydrogen content to be established. The results are correlated with others obtained previously. Author

A88-54269#
FIBER METAL ACOUSTIC MATERIALS FOR GAS TURBINE EXHAUST ENVIRONMENTS
MICHAEL S. BEATON (Brunswick Corp., Technetics Div., De Land, FL) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-175)

Feltmetal fiber metal acoustic materials function as broad band acoustic absorbers. Their acoustic energy absorbance occurs through viscous flow losses as sound waves pass through the tortuous pore structure of the material. A new Feltmetal fiber metal acoustic material has been designed for use in gas turbine auxiliary power unit exhaust environments without supplemental colling. The physical and acoustic properties of FM 827 are discussed. Exposure tests were conducted under conditions which simulated auxiliary power unit operation. Weight gain and tensile strength data as a function of time of exposure at 650 C are reported. Fabrication of components with fiber metal acoustic materials is easily accomplished using standard roll forming and gas tungsten arc welding practices. Author

A88-54277#
NEW EROSION RESISTANT COMPRESSOR COATINGS
H. J. KOLKMAN (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. Research supported by the Royal Netherlands Air Force. refs
(ASME PAPER 88-GT-186)

The erosion resistance of a conventional improved aluminum-based compressor coating (Sermetel 5380 DP) and of several new coatings, including TiN, Ti2B, and tungsten carbide (WC 100 and WC 111) coatings, was investigated. The test specimens were 2-mm thick AISI 410 steel coupons austenitized and tempered to a hardness of R(C) = 26. The coated and uncoated specimens were tested in a compressor rig of Kolkman (1982, 1983), in which specimens could be tested under simulated service conditions (150 C temperature, 130 m/s air velocity, and quartz erodent with mean particle velocity of 55 m/s), and the erosion rate was measured as a function of the angle of attack (alpha = 10, 20, 40, 60, and 90 deg). It was found that new compressor coatings exhibited lower erosion rates than the conventional coating, with the Ti2B coating showing the highest erosion resistance. I.S.

A88-54282#
WHISKER ORIENTATION MEASUREMENTS IN INJECTION MOLDED SI3N4-SIC COMPOSITES
J. T. NEIL and D. A. NORRIS (GTE Laboratories, Inc., Waltham, MA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p.
(Contract DE-AC05-84OR-21400)
(ASME PAPER 88-GT-193)

Hot pressed composites of Si3N4 containing 30 percent SiC whiskers have shown substantial improvements in strength and fracture toughness relative to monolithic silicon nitride. Injection molded samples made of this composite material distorted in a systematic manner during densification by hot isostatic pressing. Whisker orientation and aspect ratio measurements based on digitized SEM micrographs were used to evaluate microstructure with respect to injection molding direction. Results show definite orientation of whiskers during injection molding which can be related to the observed densification distortion. Author

A88-54283#
THE PERFORMANCE OF A SURROGATE BLEND IN SIMULATING THE SOOTING BEHAVIOR OF A PRACTICAL, DISTILLATE JP-4
C. P. WOOD and G. S. SAMUELSEN (California, University, Irvine) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(Contract F08635-86-C-0309; N00140-83-C-9151)
(ASME PAPER 88-GT-194)

A surrogate fuel has been developed to simulate the atomization and combustion performance of a practical petroleum distillate JP-4. The surrogate is comprised of fourteen pure hydrocarbons and formulated to reproduce the distillation curve and compound class composition of the parent petroleum distillate fuel. The present study addresses the sooting performance of the two fuels, as well as that of two reference fuels (isooctane and a high aromatic petroleum JP-5) of purposefully disparate properties. The sooting performance of the petroleum and surrogate JP-4 are nearly identical and distinctly different from that of either the isooctane or the JP-5. The surrogate represents, as a result, an attractive fuel blend for the study of fuel compositional effects on the combustion performance of practical fuels in spray-fired combustor. Author

A88-54351#
THERMAL BARRIER COATINGS FOR JET ENGINES
F. C. TORIZ, A. B. THAKKER, and S. K. GUPTA (Rolls-Royce, Inc., Atlanta, GA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-279)

Recent research aimed at the development of thermal barrier coatings (TBC) for vane airfoils and rotating turbine blades is reviewed. Particular attention is given to the work done on the prevention of coating failure to the thermal cycling, oxidation of the bond coat, erosion due to gas stream solid particles, deposition of gas stream molten debris, and acid leaching of coating phase stabilizers. Attention is also given to the objectives of minimizing the performance losses due to rough coatings and insuring the consistently high quality of the coatings. The TBC systems discussed include chromia silica titania, ceria yttria stabilized zirconia, magnesia stabilized zirconia, yttria stabilized zirconia, and zirconia titania yttria. V.L.

A88-54364#
TURBOMACHINERY ALLOYS AFFECTED BY SOLID PARTICLES
W. TABAKOFF (Cincinnati, University, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. DOE-supported research. refs
(ASME PAPER 88-GT-295)

In operating gas turbine engines in dusty environments, severe erosion of compressor and turbine components results. This erosion adversely affects engine performance. Predicting erosion in the rotating machine of gas turbine is a complex problem. This paper presents test data from the high temperature material erosion facility at the University of Cincinnati. Data were obtained between a target temperature of ambient and 649 C (1200 F) for AM355, Rene 41 and L605 cobalt. In addition, particle velocity and impingement angle were varied. Author

A88-54857#
COMPOSITES BREAK THE ICE
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 26, Sept. 1988, p. 46, 47.

A88-55286
SERVICE FAILURE OF A 7049 T73 ALUMINUM AIRCRAFT FORGING
M. L. MCCARTHY (U.S. Navy, Naval Aviation Depot, Norfolk, VA) IN: ISTFA 1987 - International Symposium for Testing and Failure Analysis: Advanced materials; Proceedings of the Symposium, Los Angeles, CA, Nov. 9-13, 1987. Metals Park, OH, ASM International, 1987, p. 109-114. refs

A Naval aircraft main landing gear fitting failed upon landing after five years of service. Examination of the aluminum 7049 T73 die forging revealed an unusual brittle fracture zone located at the forging parting plane. The intergranular fracture surface had the appearance of a stress corrosion crack in a material thought to be resistant to such attack. The results of extensive examination and testing are evaluated. Residual tensile stress and less than optimum heat treatment appear to have contributed to the parting plane failure. Theories, including stress corrosion cracking, corrosion fatigue and hydrogen assisted cracking, are offered to explain the unexpected morphology of the initial fracture surface. Author

N88-28979# Dornier-Werke G.m.b.H., Oberpfaffenhofen (West Germany). Claudius Dornier Seastar.
DEVELOPMENT OF A GLASS FIBER WING FOLLOWING THE CONSTRUCTION REGULATION FAR PART 23 [ENTWICKLUNG EINES GLASFASERTRAGFLUEGELS NACH FAR PART 23]
H. LUCAS 1986 31 p In GERMAN Presented at the 4th BMFT Statusseminars, Munich, Fed. Republic of Germany, 28-30 Apr. 1986
(Contract BMFT-LFK-8531)
(ETN-88-92966) Avail: NTIS HC A03/MF A01

A wing was developed for the amphibious aircraft Seastar using low pressure processing (LPP) of fiber reinforced plastics. The fundamentals and the development of the LPP technique are outlined. The technical and economic advantages of the LPP technique are explained. The application of the LPP construction method to aircraft following the regulation FAR Part 23 is outlined. It is shown that the LPP technique fulfils regulation requirements and is suited for any type of high quality vehicle cell. ESA

N88-28983*# Douglas Aircraft Co., Inc., Long Beach, Calif.
CRITICAL JOINTS IN LARGE COMPOSITE PRIMARY AIRCRAFT STRUCTURES. VOLUME 1: TECHNICAL SUMMARY Final Report
BRUCE L. BUNIN Sep. 1985 64 p
(Contract NAS1-16857)
(NASA-CR-3914; NAS 1.26:3914; ACEE-26-FR-3504) Avail: NTIS HC A04/MF A01 CSCL 11D

A program was conducted at Douglas Aircraft Company to develop the technology for critical joints in composite wing structure that meets all the design requirements of a 1990 commercial transport aircraft. In fulfilling this objective, analytical procedures for joint design and analysis were developed during Phase 1 of the program. Tests were conducted at the element level to supply the empirical data required for methods development. Large composite multirow joints were tested to verify the selected design concepts and for correlation with analysis predictions. The Phase 2 program included additional tests to provide joint design and analysis data, and culminated with several technology demonstration tests of a major joint area representative of a commercial transport wing. The technology demonstration program of Phase 2 is discussed. The analysis methodology development, structural test program, and correlation between test results and analytical strength predictions are reviewed. Author

N88-29004# Aptech Engineering Services, Inc., Sunnyvale, Calif.
STRESS INTENSITY FACTORS FOR CRACKED METALLIC STRUCTURES UNDER RAPID THERMAL LOADING Final Report, Aug. 1986 - May 1987
RUSSELL C. CIPOLLA and KIMBLE J. CLARK Oct. 1987 75 p
(Contract F33615-86-C-3217)
(AD-A191219; AES-8609709F-1; AFWAL-TR-87-3059) Avail: NTIS HC A04/MF A01 CSCL 20K

High intensity heating of aircraft structures can challenge the structural integrity of critical aircraft components, especially when they may contain flaws. The evaluation of flawed components requires the application of fracture mechanics wherein crack tip stress intensity factors are used to provide a quantitative means of assessing structural integrity. The primary objectives of this project were to develop an analysis method for computing stress intensity factors for severe thermal loadings of interest to the Air Force and to demonstrate the applicability of the method to small microcomputers. GRA

N88-29042# Southwest Research Inst., San Antonio, Tex. Oelvoir Fuels and Lubricants Research Facility.
DEVELOPMENT OF A TEST METHOD TO DETERMINE POTENTIAL PEROXIDE CONTENT IN TURBINE FUELS. PART 2 Interim Report, Sep. 1985 - May 1987
G. E. FODOR, D. W. NAEGELI, K. B. KOHL, and J. P. CUELLAR, JR. Jun. 1987 32 p
(Contract N00014-85-C02520; DAAK70-85-C-0007; DAAK70-87-C-0043)
(AD-A192244; BFLRF-243-PT-2) Avail: NTIS HC A03/MF A01 CSCL 21D

Through the generally accepted 43 C and 65 C bottle storage method of accelerated aging, the relative ratings of six selected fuels' oxidative tendencies were established. In the 43 C test, storage for about 12 weeks produces results that are comparable to a full year's storage under ambient conditions. To develop a practical test method for the prediction of peroxide potential of fuels, experimental conditions were sought so that the oxidative tendencies of fuels could be assessed within a reasonable time. Accordingly, a matrix of experiments was designed to allow selection of reaction conditionally, the results of experiments should allow the development of global reaction kinetics to aid the determination of fuel peroxidation potential and to shed light on the reaction mechanism. The oxidations were carried out in a stirred pressurized reactor at 60, 80, 100, and 120 C, under oxygen pressures of 240, 790, or 1140 kPa (abs) for periods of up to 70 hours. GRA

N88-29877# Technische Univ., Berlin (West Germany). Inst. fuer Luft- und Raumfahrt.
INVESTIGATIONS ON THE MODIFICATION OF STRUCTURAL RELIABILITY BY SUBSTITUTION OF ALUMINUM BY CARBON FIBER REINFORCED PLASTICS IN AIRCRAFT CONSTRUCTION [UNTERSUCHUNGEN ZUR VERAENDERUNG DER STRUKTURZUVERLAESSIGKEIT BEI SUBSTITUTION VON ALUMINIUM DURCH KOHLEFASERKUNSTSTOFF IN FLUGZEUGKONSTRUKTIONEN]
BERND ZIEGLER 1988 188 p In GERMAN
(ILR-MITT-195; ETN-88-93115) Avail: NTIS HC A09/MF A01

Reliability theory for elementary components is outlined in the case of serial and parallel connected systems and the obtained redundancy is analyzed. Investigations for the determination of material strength distribution and reliability properties of aluminum alloy and carbon reinforced plastics are described. Tensile strength and elongation are measured for AlCuMg alloy components in serial and parallel systems and their reliability is evaluated. For carbon reinforced plastics variation of fiber angles effects is studied on tensile strength and reliability of aircraft components. ESA

N88-29885# Southwest Research Inst., San Antonio, Tex.
EVALUATION OF BOND TESTING EQUIPMENT FOR INSPECTION OF ARMY ADVANCED COMPOSITE AIRFRAME STRUCTURES Final Report, 1 Jul. 1987 - 12 Feb. 1988
HEGEON KWUN and DAVID G. ALCAZAR 12 Feb. 1988 45 p
(Contract DLA900-84-C-0910)
(AD-A195795) Avail: NTIS HC A03/MF A01 CSCL 01C

Forty-one ultrasonic bond testing instruments for nondestructive inspection of composite airframe structures were evaluated based on information available in the literature. In addition, three of these instruments, the Fokker Bondtester Model 80-L, the BondaScope 2100, and the Sonatest UFD-S, were evaluated in the laboratory using ten specimens of composite airframe structures supplied by the Army. All the specimens had unknown flaw conditions. Both the Fokker Bondtester and the BondaScope required only a few hours of operator training in calibration and operation. Both instruments require a liquid couplant and are used for spot checking. The UFD-S instrument was difficult to set up and calibrate without reference samples of known characteristics. Also, extensive operator training is required to calibrate and operate the UFD-S instrument. The UFD-S uses a wheel probe which does not require a liquid couplant and allows continuous scanning of the specimen. The inspection speed of the UFD-S was therefore much greater than that of the other two instruments. Surface roughness, surface curvature, and variations in paint thickness were observed to limit the applicability of the instruments. GRA

N88-29889# Dayton Univ., Ohio.
FATIGUE CRACK GROWTH CHARACTERISTICS OF ARALL (TRADEMARK)-1 Interim Report, Aug. 1987 - Jan. 1988
JOHN J. RUSCHAU May 1988 34 p
(Contract F33615-84-C-5130)
(AD-A196185; UDR-TR-88-21; AFWAL-TR-88-4075) Avail: NTIS HC A03/MF A01 CSCL 11D

Constant amplitude and spectrum fatigue crack growth rate properties were evaluated for ARALL-1 aluminum laminate. Testing was performed on M(T) specimens under both lab air and high humidity conditions. Crack length monitoring was performed on each aluminum ply utilizing electrical-potential drop techniques to gain a better insight into the fatigue cracking process. Results indicate an outstanding superiority of ARALL-1 in terms of fatigue crack growth resistance over conventionally produced 7000 series aluminum. Fatigue cracking in each of the aluminum plies was fairly uniform, with no large discrepancies in total crack length or growth rates observed between the various plies. For samples tested under a fighter-type load history, the effect of high humidity was actually beneficial, with fatigue crack growth rates typically one-half of those developed under lab air conditions. Explanations based on increased delamination regions are offered to explain this behavior. GRA

N88-29890# Rensselaer Polytechnic Inst., Troy, N.Y.
PROCESSING TECHNOLOGY RESEARCH IN COMPOSITES Final Report, 1 Oct. 1986 - 30 Sep. 1987
RUSSELL J. DIEFENDORF 31 Dec. 1987 6 p
(Contract AF-AFOSR-0053-87)
(AD-A195693; AFOSR-88-0669TR) Avail: NTIS HC A02/MF A01 CSCL 11D

Chemical vapor deposition has been used for over fifteen years for depositing carbon matrices in carbon/carbon composites used for reentry nose-tips, rocket nozzle throat inserts, and aircraft brakes. The same technology is appropriate for depositing silicon carbide or other matrices in ceramic-ceramic composites, or ceramic/carbon composites. Furthermore, chemical vapor deposition is a powerful technique for applying the graded oxidation resistant coatings required for carbon/carbon composites in long time oxidizing environments. Modern instrumentation allows many variations in properties to be made which had been impossible in the past. It is for these reasons that we proposed the acquisition of a state-of-the-art Low Pressure Chemical Vapor Deposition Apparatus. GRA

N88-29910# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Propulsion and Energetics Panel.
COMBUSTION AND FUELS IN GAS TURBINE ENGINES
Jun. 1988 515 p In ENGLISH and FRENCH Symposium held in Chania, Greece, 19-23 Oct. 1987
(AGARD-CP-422; ISBN-92-835-0465-8) Avail: NTIS HC A22/MF A01

The attention of combustor designers and researchers has focused upon two main factors: the identification of the significance of fuel degradation upon combustion design and performance, and the potential prizes to be gained by the development of better design techniques. The aim of the conference was to review progress made in these areas under four main subject headings: namely, alternative fuels and fuel injection, combustor development, soot and radiation, and the development of mathematical models for the design of gas turbine combustors.

N88-29913# Purdue Univ., West Lafayette, Ind. School of Mechanical Engineering.
ATOMIZATION OF ALTERNATIVE FUELS
ARTHUR H. LEFEBVRE *In* AGARD, Combustion and Fuels in Gas Turbine Engines 14 p Jun. 1988
Avail: NTIS HC A22/MF A01

The influence of atomization quality on several key aspects of combustion performance is reviewed. The performance parameters considered include combustion efficiency, lean blowout, and lean lightup, and also the pollutant emissions of carbon monoxide, unburned hydrocarbons, oxides of nitrogen, and smoke. The fuel properties of importance are described and equations are presented for estimating the effects of changes in fuel properties on spray characteristics for the main types of fuel nozzle employed in aero gas turbines, namely plain orifice, pressure swirl, and airblast atomizers. The anticipated effects on atomization of changes from conventional to alternative fuels is discussed. Author

N88-29915# Karlsruhe Univ. (West Germany). Lehrstuhl und Inst. fuer Thermische Stroemungsmaschinen.
TURBULENCE EFFECTS ON THE DROPLET DISTRIBUTION BEHIND AIRBLAST ATOMIZERS
S. WITTIG, W. KLAUSMANN, and B. NOLL *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p Jun. 1988 Sponsored in part by the Forschunbsvereinigung Verbrennungskraftmaschinen, e.V., and German National Science Foundation, Fed. Republic of Germany
Avail: NTIS HC A22/MF A01

Turbulent fluctuations of the airflow in gas turbine combustion chambers have decisive influence on the mixing of fuel droplets and air both in premixing regions and primary zones. Detailed measurements in a recirculating, droplet charged airflow in a combustor model are conducted with an optical diffraction type particle sizer. These investigations yield information about the local fuel concentrations as well as the local concentration weighted diameter distributions under cold and hot airflow conditions. The spray is produced by a prefilming airblast nozzle, which is built into the combustor model. The calculation of the above mentioned quantities using a new computational model shows that in considering turbulence fluctuations significant improvement of the results is obtained and excellent agreement between predicted and measured values is achieved. Therefore, the results indicate that turbulence can be one of the major influencing parameters on droplet distribution. Author

N88-29916# United Technologies Research Center, East Hartford, Conn.
NOZZLE AIRFLOW INFLUENCES ON FUEL PATTERNATION
T. J. ROSFJORD and W. A. ECKERLE (Clarkson Univ., Potsdam, N.Y.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 12 p Jun. 1988 Previously announced in IAA as A88-44765
(Contract F33615-85-C-2515)
Avail: NTIS HC A22/MF A01

The velocity and turbulence levels downstream of eight variations of a model gas turbine, aerating, fuel nozzle were measured. The nozzle configurations were assemblies which purposefully altered the airflow in a swirler or contouring swirl vane trailing edges. Data were acquired by a traversing, two component laser velocimeter in planes 0.060 in. or 2.50 in. downstream from the nozzle exit. Analyses of these data indicated that very symmetric flow fields can be produced. Such control was easier to achieve for the airflow than the fuel, supporting the position that nozzle patternation quality was more dependent on the fuel distribution in the nozzle. The presence of swirler wakes could always be discerned at the nozzle exit; the extreme variations imposed by coarse swirlers could dominate the flow. Such airflow influences were not apparent in the velocity profiles at downstream locations. However, their influence in convecting a higher fuel mass flux persisted from the nozzle exit and produced extreme variations in the spray pattern. Author

N88-29918# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (West Germany). Inst. fuer Antriebstechnik.
INFLUENCE OF OPERATING CONDITIONS ON THE ATOMIZATION AND DISTRIBUTION OF FUEL BY AIR BLAST ATOMIZERS
M. CAO, H. EICKHOFF, F. JOOS, and B. SIMON (Technische Univ., Munich, West Germany) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 8 p Jun. 1988 Sponsored by the Federal German Ministry of Research and Technology, Berlin
Avail: NTIS HC A22/MF A01

The performance of a gas turbine combustion chamber depends essentially on the distribution of the fuel in the primary zone. Ignition, stability of combustion, wall temperatures, and smoke and pollutant emission are all affected. Maintaining a fixed geometry, the droplet size and spray angle under variation of the air pressure drop at constant temperature were measured using two test liquids in an air blast atomizer system. Correlation equations were provided for both variables. Known correlations were confirmed for the droplet size. The spray angle is pressure related, increasing very rapidly with increasing pressure. Author

N88-29919# Cranfield Inst. of Tech., Bedford (England). School of Mechanical Engineering.
SPRAY PERFORMANCE OF A VAPORIZING FUEL INJECTOR
A. K. JASUJA and H. C. LOW (Rolls-Royce Ltd., Bristol, England) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 13 p Jun. 1988
Avail: NTIS HC A22/MF A01

The spray performance of a vaporizer fuel injector of a type that has accumulated extensive service experience in sub- and super-sonic commercial and military aircraft applications is examined. Spray performance data covers a wide range of operating conditions including the effects of fuel quality as well as the atomizing air temperature. The objective is to further not only the current level of understanding regarding the fundamental functional aspects of vaporizer technology but also the data base for future designs. Author

N88-29920# Laval Univ. (Quebec). Dept. du Genie Mecanique.
THE CHARACTERIZATION OF COMBUSTION BY FUEL COMPOSITION: MEASUREMENTS IN A SMALL CONVENTIONAL COMBUSTOR
D. KRETSCHMER and J. ODGERS *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p Jun. 1988 Sponsored by National Defence Canada
Avail: NTIS HC A22/MF A01

In a continuing program on the effects of fuel properties on combustion, some 20 pure hydrocarbons and synthesized fuels were tested at atmospheric conditions in a one third scale version of an aircraft type combustor. This combustor used a Simplex type pressure jet atomizer. Each fuel was burned over a range of air-fuel ratios, and at each condition, a full exhaust gas analysis was done, exhaust temperature distribution was measured, as also weak extinction. The results and their implications are discussed. Author

N88-29922# Rolls-Royce Ltd., Bristol (England).
HIGH PERFORMANCE TURBOFAN AFTERBURNER SYSTEMS
A. SOTHERAN *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p Jun. 1988
Avail: NTIS HC A22/MF A01

The modern turbofan afterburner is characterized by its high boost and efficiency and by its compact geometry which is achieved by locating the flameholding baffles immediately downstream of the turbine exhaust plane of the engine core and bypass gas stream. At the confluence, the stream divider may be a simple cylinder or it may be of lobed configuration to encourage mixing between the two gas streams in the downstream jet pipe in order to improve the unboosted thrust of the engine. The geometry of the afterburner hardware must be adapted to suit the choice of mixed or unmixed configurations. In flight, selection of the afterburner must be fast and reliable under all flight conditions with times to full thrust of the order of only a second or two. Both the light up and the subsequent acceleration to full thrust are expected to be smooth with no excessive initial thrust jump. Synchronization and matching of the afterburner fuel with the variable final nozzle must be accurate at all times to maintain the engine turbomachinery on its required running lines. The afterburner must always be free of combustion driven pressure oscillations which can occur either in cross stream modes or in longitudinal modes, both of which can be mechanically damaging and, in some cases, cause fan surge and other intolerable effects in the engine. The afterburner must incorporate appropriate measures to avoid various potential thermal problems including fuel boiling and gumming in the supply manifolds and excessive heat transfer to the jet pipe and aircraft engine bay. Author

N88-29925# Southwest Research Inst., San Antonio, Tex.
FUEL EFFECTS ON FLAME RADIATION AND HOT-SECTION DURABILITY
C. A. MOSES and P. A. KARPOVICH (Naval Air Propulsion Test Center, Trenton, N.J.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 16 p Jun. 1988
Avail: NTIS HC A22/MF A01

The results of combustor experiments relating to fuel effects on combustor durability are summarized and analyzed with respect to Navy aircraft operations and maintenance. By combining life ratio models with data on mission profiles, models were developed that predict the impact of flying an aircraft on a fuel of reduced hydrogen content in terms of the combustor life lost in flying a typical mission. To determine the effect of decreasing hydrogen content on maintenance requirements, the life ratio models were combined with data obtained from maintenance depots on combustor life along with information on the importance of combustor life in determining engine overhaul schedules. From this, it was possible to identify which engines or aircraft would be most affected by decreases in hydrogen content, and at what point increases in maintenance requirements are likety to be realized. Author

N88-29926# California Univ., Irvine. Combustion Lab.
THE PERFORMANCE OF A SURROGATE BLEND IN SIMULATING JP-4 IN A SPRAY-FUELED COMBUSTOR
G. S. SAMUELSEN and C. P. WOOD *In* AGARD, Combustion and Fuels in Gas Turbine Engines 6 p Jun. 1988 Sponsored in part by the Naval Air Propulsion Center
(Contract F08635-86-C-0309)
Avail: NTIS HC A22/MF A01

A surrogate fuel was developed to simulate the atomization and combustor performance of a practical distillate JP-4. The surrogate is comprised of 14 pure hydrocarbons and formulated based on the distillation curve and compound of the distillate parent. In previous work, the atomization performance (evaluated in terms of the atomization quality in an isothermal chamber), and the combustor performance (evaluated in terms of the velocity and thermal fields in a spray fueled combustor) were found to be equivalent for the parent and surrogate JP-4. The sooting performance of the two fuels is addressed, as well as two reference fuels (a JP-5 and isooctane) of purposefully disparate properties. The sooting performance of the parent and surrogate JP-4 are nearly identical, and distinctly different from that of either the JP-5 or the isooctane. The surrogate represents, as a result, an attractive fuel blend for the study of fuel compositional effects on the sooting performance of petroleum fuels in spray fueled combustor. Author

N88-29929# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of mechanical Engineering.
RADIATION TRANSFER IN GAS TURBINE COMBUSTORS
M. G. CARVALHO and P. J. M. COELHO *In* AGARD, Combustion and Fuels in Gas Turbine Engines 22 p Jun. 1988 Sponsored by Instituto Nacional de Investigacao Cientifica, Lisbon, Portugal
Avail: NTIS HC A22/MF A01

The prediction of the local flow, heat transfer and combustion processes inside a three-dimensional can combustor chamber of a gas turbine is presented. A 3-D numerical solution technique is used to solve the governing time averaged partial differential equations and the physical modeling for the turbulence, combustion and thermal radiation. The heat transfer modeling is emphasized. A method to calculate the distribution of temperature, radiative heat flux and total heat flux of the liner is described. The implications of neglecting radiative heat transfer in gas turbine combustion chamber calculations are discussed. The influence of working pressure on the radiative heat transfer is investigated comparing the radiative heat flux and the temperature distribution of the liner for three different working pressures: 5, 15 and 25 bar. Author

N88-29930# Royal Aircraft Establishment, Farnborough (England). Propulsion Dept.
GAS TURBINE SMOKE MEASUREMENT: A SMOKE GENERATOR FOR THE ASSESSMENT OF CURRENT AND FUTURE TECHNIQUES
S. P. GIRLING *In* AGARD, Combustion and Fuels in Gas Turbine Engines 10 p Jun. 1988
Avail: NTIS HC A22/MF A01

Smoke measurement from gas turbine engines is one instrumentation technique that remains, literally, a black art. Current methods are inaccurate, slow, insensitive and unable to detect transients. A smoke generator was developed capable of generating by pyrolysis of aviation kerosene, stable levels of smoke for prolonged periods, representative of that from engines. Particle size measurements have enabled the comparison of smokes from different sources and provided a greater understanding of the problems of representative sampling using currently approved methods. Several alternative measurement techniques were evaluated using the smoke generator, precluding the need for expensive engine testing. This has promoted research into instrumentation that will give a truer indication of particulate criteria of interest to the engine designer and customer, for example truer visibility and erosiveness. Author

N88-29935# General Electric Co., Cincinnati, Ohio. Aircraft Engines.
NUMERICAL MODELS FOR ANALYTICAL PREDICTIONS OF COMBUSTOR AEROTHERMAL PERFORMANCE CHARACTERISTICS
D. L. BURRUS, W. SHYY, and M. E. BRAATEN (General Electric Co., Schenectady, N.Y.) *In* AGARD, Combustion and Fuels in Gas Turbine Engines 25 p Jun. 1988
Avail: NTIS HC A22/MF A01

An overview of the work performed at GE Aircraft Engines under an ongoing program to develop and improve the sophisticated analytical models for the design and analysis of aircraft turbine engine combustors is presented. This effort has focused on the full three-dimensional (3-D) elliptic combustor internal flow model. The objectives of the program are reviewed. The progress made in the past five years is discussed starting with the initial application and assessment of first generation 3-D combustor models based on cartesian grids, progressing to the development and recent application of an improved second generation 3-D combustor model based on a body fitted generalized curvilinear grid. Finally, a brief review of planned future modeling activities to be conducted under this program will be discussed. Author

N88-29962# Aptech Engineering Services, Inc., Sunnyvale, Calif.
STRESS INTENSITY FACTORS FOR CRACKED METALLIC STRUCTURES UNDER RAPID THERMAL LOADING Final Report, Aug. 1986 - May 1987
RUSSELL C. CIPOLLA and KIMBLE J. CLARK Oct. 1987 74 p
(Contract F33615-86-C-3217; AF PROJ. 3005)
(AES-8609709F-1; AFWAL-TR-87-3059) Avail: NTIS HC A04/MF A01 CSCL 11F

High intensity heating of aircraft structures can challenge the structural integrity of critical aircraft components, especially when they may contain flaws. The evaluation of flawed components requires the application of fracture mechanics wherein crack tip stress intensity factors are used to provide a quantitative means of assessing structural integrity. The primary objectives were to develop an analysis method for computing stress intensity factors for severe thermal loadings of interest to the Air Force and to demonstrate the applicability of the method to microcomputers. A methodology was developed based on influence functions to determine stress intensity factors for structures exposed to intense thermal heating. A demonstration of the method is given and results detailed. Author

N88-29991# Coordinating Research Council, Inc., Atlanta, Ga. Hydroperoxide Potential of Jet Fuels Panel.
DETERMINATION OF THE HYDROPEROXIDE POTENTIAL OF JET FUELS
Apr. 1988 111 p
(AD-A195975; CRC-559) Avail: NTIS HC A06/MF A01 CSCL 21D

In 1963 and in 1976, peroxide attack on certain engine rubber parts was found with the use of some Far Eastern fuels. The problem was corrected by requiring oxidation inhibitor be added to fuels meeting Specifications DERD 2494 and MIL-T-5624. Because the majority of commercial aviation turbine fuel had not shown significant peroxide formation, CRC was requested to develop a technique which would identify the hydroperoxide-forming tendencies of jet fuels. Heating the fuel at 65 C for four weeks and measuring the peroxide number is concluded to be an adequate Go/No Go test. GRA

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A88-52733
FIBRE OPTIC FLOW SENSORS BASED ON THE 2 FOCUS PRINCIPLE
H. SELBACH and A. LEWIN (Polytec GmbH, Waldbronn, Federal Republic of Germany) IN: Laser anemometry - Advances and applications; Proceedings of the Second International Conference, Glasgow, Scotland, Sept. 21-23, 1987. Berlin and New York, Springer-Verlag, 1988, p. 195-206. refs

Flow sensors are widely used in air-breathing engines to provide the engineers with sufficient information concerning the flow losses. The laser 2 focus velocimeter has become a very powerful tool for detailed internal flow studies in turbomachinery and other situations where a harsh environment and the size of the particles required make measurements difficult. So far, laser focus velocimeters which incorporate optical fibers have not been available. This paper discusses new optical designs based on optical fibers for two-dimensional and three-dimensional time of flight velocimeters. Author

A88-53123#
DESIGN CODE VERIFICATION OF EXTERNAL HEAT TRANSFER COEFFICIENTS
F. O. SOECHTING and O. P. SHARMA (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 6 p.
(AIAA PAPER 88-3011)

A comparative study is conducted for measured and predicted heat-transfer coefficients of air-cooled turbine blade airfoils. A modified version of the STAN-5 boundary layer code was used to obtain analytical predictions of the heat transfer levels for the cascade test conditions. A two-dimensional cascade test was conducted at engine-level Mach number and Reynolds number distributions in order to obtain baseline data that can be used with engine data in order to quantify the effects of environmental conditions on heat transfer levels and distributions. O.C.

A88-53128#
GAS TEMPERATURE MEASUREMENTS IN SHORT DURATION TURBOMACHINERY TEST FACILITIES
L. N. CATTAFESTA and A. H. EPSTEIN (MIT, Cambridge, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 8 p. Research supported by Rolls-Royce, Inc. and USAF. refs
(AIAA PAPER 88-3039)

Thermocouple rakes for use in short-duration turbomachinery test facilities have been developed using very fine thermocouples. Geometry variations were parametrically tested and showed that bare quartz junction supports (76 microns in diameter) yielded superior performance, and were rugged enough to survive considerable impact damage. Using very low cost signal conditioning electronics, temperature accuracies of 0.3 percent were realized yielding turbine efficiency measurements at the 1-percent level. Ongoing work to improve this accuracy is described. Author

A88-53142#
NAVIER-STOKES SOLUTIONS FOR ROTATING 3-D DUCT FLOWS
B. N. SRIVASTAVA (Avco Research Laboratory, Inc., Everett, MA) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 11 p. refs
(AIAA PAPER 88-3098)

This paper deals with the computation of three-dimensional viscous turbulent flow in a rotating rectangular duct of low aspect ratio using thin-layer Navier-Stokes equations. Scalar form of an approximate factorization implicit scheme along with a modified q-omega turbulence model has been utilized for mean flow predictions. The predicted mean flow behavior has been favorably compared with the experimental data for mean axial velocity, channel pressure and cross-flow velocities at a flow Mach number of 0.05 and a rotational speed of 300 rpm. Author

A88-53145#
ADVANCED STRUCTURAL INSTRUMENTATION - AN OVERVIEW
ANTHONY J. DENNIS (United Technologies Research Center, East Hartford, CT) AIAA, ASME, SAE, and ASEE, Joint Propulsion Conference, 24th, Boston, MA, July 11-13, 1988. 3 p.
(AIAA PAPER 88-3144)

An attempt was made to demonstrate the accuracy and durability of advanced strain and temperature sensors in an environment typical of advanced gas turbine engines. A first-stage turbine disk which operates at a maximum temperature of 1250 F at a speed of 13,200 rpm was the test component selected for this demonstration. The strain sensors were new alloy wire and advanced thin film static gages as well as the twin core fiber-optic strain sensor. The survivability of a heat flux sensor and a special strain gage overcoat layer was also revealed. K.K.

A88-53166#
NEW VERSION ANTISTATIC COATING TESTER
A. BRUERE (ONERA, Chatillon-sous-Bagneux, France) La Recherche Aerospatiale (English Edition) (ISSN 0379-380X), no. 1, 1988, p. 29-34.

For new antistatic coatings applied to the composite materials used in aeronautical construction, the performance of the CORAS antistatic-coating resistivity meter had to be improved. The performance of the new version is increased by a factor of 100, for measurements of surface resistances of 100 kohm/unit area or less, with an accuracy and resolution of the order of 10 kohm/unit area. Author

A88-53563
HYPERVELOCITY APPLICATION OF TRIBOLOGICAL COATINGS
ED COVE (General Electric Co., Lynn, MA) and R. COLE (Plasma Technology, Inc., South Windsor, CT) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando, FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 123-130.

Application of the sliding wear tribological coating 'Tribaloy' T-800 to various jet engine components using a hypervelocity oxyfuel thermal spray system has been successfully demonstrated. Qualitative coating-properties evaluations were performed which characterized external surface hardness, microstructure, bond tensile strength, and component wear. Engine tests indicate that component life can be more than tripled using the present system. R.R.

A88-53571
HIGH TEMPERATURE TESTING OF PLASMA SPRAYED THERMAL BARRIER COATINGS
J. NERZ, G. BANCKE, H. HERMAN (New York, State University, Stony Brook), and D. S. ENGLEBY (Engleby and Others Co., Inc., Morehead City, NC) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando, FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 253-257.
(Contract N00014-86-C-0016)

Mar-M200 superalloy tubes have been coating using state-of-the-art plasma spray techniques and tested at high temperatures in a study of the failure mechanisms of thermal barrier coatings. The high temperature behavior was evaluated using a natural gas flame rig and static furnace oxidation tests. Cycled nd uncycled samples were evaluated using optical and electron metallography and electron microprobe analysis. The results indicate that for thermal barrier coatings with vacuum plasma sprayed bond coats, failure results from bond-coat-oxidation-induced stresses developed near the bond coat/thermal barrier interface. Thermal barrier coatings with air plasma spray bond coats degrade more rapidly due to the decreased oxidation resistance of the bond coat. Failure, in this case, occurs at the bond coat/substrate interface. Author

A88-53579
PLASMA SPRAYED TUNGSTEN CARBIDE-COBALT COATINGS
B. DULIN (Plasma-Technics, Inc., Hollywood, FL) and A. R. NICOLL (Plasma-Technik AG, Wohlen, Switzerland) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando, FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 345-351. refs

The use of the plasma spray process in fabricating WC-Co layers of 12 and 17 percent Co, respectively, to various aircraft engine specifications is described. Consideration is also given to the development of the plasma spraying of various WC-Co powders to meet general industrial requirements. It is noted that the plasma spray parameters are correlated with bond strength, microhardness, phase content, and microstructure of the coatings. Semiautomatic metallographic preparation is also discussed. K.K.

A88-53581* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
COMPOSITE MONOLAYER FABRICATION BY AN ARC-SPRAY PROCESS
LEONARD J. WESTFALL (NASA, Lewis Research Center, Cleveland, OH) IN: Thermal spray: Advances in coatings technology; Proceedings of the National Thermal Spray Conference, Orlando, FL, Sept. 14-17, 1987. Metals Park, OH, ASM International, 1988, p. 417-426. refs

A single layer (monotape) technique for fabricating complex high-temperature tungsten-fiber-reinforced superalloy composites is proposed. The fabrication of sheets of arc-sprayed monotape 38 cm wide and 122 cm long has been demonstrated. Composites fabricated using the method are shown to have equal tensile strength and a cleaner matrix than composites fabricated from powder metal cloth monotapes, and the present technique is less expensive than the powder metal fabrication techniques. R.R.

A88-53795
INDUSTRIAL PRODUCTION OF CFRP-COMPONENTS IN AIRBUS CONSTRUCTION
JUERGEN MASKOW (Airbus Industrie, Toulouse, France) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 9 p.
(SAWE PAPER 1794)

An account is given of the application of CFRP construction to the vertical stabilizer of the A340 airliner. The results obtained include a 20-percent weight saving over the aluminum alloy alternative structure, together with a parts-count reduction of from 2072 metallic parts to 96 and a reduction of the number of fasteners from 50,000 to 5800. The CFRP structure takes the form of integrally-stiffened laminate stabilizer skins that are mounted on a stiffening framework. A robotic prepreg tape-laying apparatus is employed. O.C.

A88-53829#
INSTRUMENTATION AND TECHNIQUES FOR STRUCTURAL DYNAMICS AND ACOUSTICS MEASUREMENTS
RICHARD TALMADGE, GENE MADDUX, and DOUGLAS HENDERSON (USAF, Aeronautical Systems Div., Wright-Patterson AFB, OH) AIAA, NASA, and AFWAL, Conference on Sensors and Measurement Techniques for Aeronautical Applications, Atlanta, GA, Sept. 7-9, 1988. 13 p. refs
(AIAA PAPER 88-4667)

This paper summarizes the instrumentation and techniques used by the Structural Dynamics Branch of the Air Force Wright Aeronautical Laboratories in dynamic testing of aircraft, spacecraft, and missiles. Modal testing of aircraft is discussed, including accelerometers, automatic gain ranging amplifiers, and signal multiplexers. Laser techniques of structural motion measurement are discussed, including a description of video holography (electronic speckle pattern interferometry) and its application to modal testing of aircraft and missile components. Acoustic testing of structures at elevated temperatures is discussed, including techniques for achieving higher sound-pressure levels and the development of high-temperature accelerometers and microphones. Author

A88-53840
SURFACE ENGINEERING FOR HIGH TEMPERATURE ENVIRONMENTS
A. E. WEATHERILL and B. J. GILL (Union Carbide UK, Ltd., Coatings Service Div., Swindon, England) Metals and Materials (ISSN 0266-7185), vol. 4, Sept. 1988, p. 551-555. refs

An account is given of the techniques applicable to the design and fabrication of carefully formulated surface coatings capable of furnishing mechanical, chemical, and thermal resistance in gas turbine engine hot-section environments. Both detonation-gun and plasma-spraying methodologies are discussed; the former is used to deposit W-, Cr-, and Co-based compositions that impart rubbing or fretting wear resistance, while the latter confer thermal insulation and oxidation and thermal shock resistance, especially in the case of combustion chamber components. O.C.

A88-53954
DEFORMATION AND DAMAGE OF THE MATERIAL OF GAS TURBINE ENGINE BLADES DURING THERMAL CYCLING IN GAS FLOW [DEFORMIROVANIE I POVREZHDENIE MATERIALA LOPATOK GTD PRI TEPLOSMENAKH V GAZOVOM POTOKE]
G. N. TRET'IACHENKO and V. G. BARILO (AN USSR, Institut Problem Prochnosti, Kiev, Ukrainian SSR) Problemy Prochnosti (ISSN 0556-171X), Aug. 1988, p. 39-42. In Russian. refs

The thermodynamic processes of energy dissipation in the material of wedge-shaped zones of gas turbine blades are investigated analytically. A procedure for determining that part of energy dissipated in the blade material which corresponds to damage accumulation is proposed. It is shown that, by using the entropy increment resulting from irreversible material deformation as a fatigue life criterion, it is possible to predict the service life of gas turbine blades. V.L.

A88-53961

CALCULATION OF STRESS RELAXATION IN THE SURFACE-HARDENED LAYER NEAR A HOLE IN THE DISK OF A GAS-TURBINE ENGINE [RASCHET RELAKSATSII NAPRIAZHENII V POVERKHNOSTNO UPROCHNENNOM SLOE U OTVERSTIIA DISKA TURBINY GTD]

IU. P. SAMARIN, E. V. GRINEVICH, L. A. MURATOVA, and V. P. RADCHENKO (Kuibyshevskii Politekhnicheskii Institut, Kuibyshev, USSR) Problemy Prochnosti (ISSN 0556-171X), Aug. 1988, p. 87-92. In Russian. refs

The relaxation of residual compressive stresses generated in the surface layer of a workpiece during plastic surface working is examined. A method is proposed for calculating residual stress relaxation in the surface-hardened layer near a hole in a gas turbine disk under conditions of general creep in the plane stressed state. The method is based on the conjugation of solutions to two problems: the creep problem for a disk with stress raisers in the form of circular holes and the problem of stress relaxation in the surface-hardened layer near a hole in a disk with allowance for the evolution of the stress-strain state of the disk. The procedure, which has been implemented in software, is demonstrated by performing a stress relaxation analysis for a turbine disk of EI698 alloy at 700 C. V.L.

A88-53998

MECHANIZATION OF JOINT PRODUCTION DURING THE ASSEMBLY OF AIRCRAFT STRUCTURES [MEKHANIZATSIIA OBRAZOVANIIA SOEDINENII PRI SBORKE AVIATSIONNYKH KONSTRUKTSII]

GENNADII MIKHAILOVIC SHCHETININ, MIKHAIL IVANOVICH LYSOV, and VALENTIN MIKHAILOVIC BUROV Moscow, Izdatel'stvo Mashinostroenie, 1987, 256 p. In Russian. refs

The fundamentals of the design of various positioning devices and special mechanization aids for producing joints during the assembly of aircraft structures are presented. In particular, attention is given to the conditions of assembly and characterization of assembly systems; typical assembly processes and advanced equipment for producing riveted joints; mechanization of hole machining during the bench assembly of components and units; and mechanization of the production of riveted and bolted joints during field assembly. The discussion also covers the general structure of a flexible assembly system, the principal stages of assembly line design, and prediction of assembly mechanization requirements. V.L.

A88-54139*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

ADVANCED HIGH TEMPERATURE INSTRUMENTATION FOR HOT SECTION RESEARCH APPLICATIONS

D. R. ENGLUND and R. G. SEASHOLTZ (NASA, Lewis Research Center, Cleveland, OH) IN: Toward improved durability in advanced aircraft engine hot sections; Proceedings of the Thirty-third ASME International Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 5-9, 1988. New York, American Society of Mechanical Engineers, 1988, p. 5-21. refs

Programs to develop research instrumentation for use in turbine engine hot sections are described. These programs were initiated to provide improved measurements capability as support for a multidisciplinary effort to establish technology leading to improved hot section durability. Specific measurement systems described here include heat flux sensors, a dynamic gas temperature measuring system, laser anemometry for hot section applications, an optical system for viewing the interior of a combustor during operation, thin film sensors for surface temperature and strain measurements, and high temperature strain measuring systems. The paper will describe the state of development of these sensors and measuring systems and, in some cases, will show examples of measurements made with this instrumentation. The paper covers work done at the NASA Lewis Research Center and at various contract and grant facilities. Author

A88-54152*# United Technologies Research Center, East Hartford, Conn.

THE EFFECTS OF TURBULENCE AND STATOR/ROTOR INTERACTIONS ON TURBINE HEAT TRANSFER. II - EFFECTS OF REYNOLDS NUMBER AND INCIDENCE

M. F. BLAIR, R. P. DRING, and H. D. JOSLYN (United Technologies Research Center, East Hartford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs

(Contract NAS3-23717)

(ASME PAPER 88-GT-5)

Part I of this paper presents airfoil heat transfer data obtained in a rotating turbine model at its design rotor incidence. This portion of the paper presents heat transfer data obtained in the same model for various combinations of Reynolds number and inlet turbulence and for a very wide range of rotor incidence. On the suction surfaces of the first stage airfoils the locations and lengths of transition were influenced by both the inlet turbulence level and the Reynolds number. In addition it was demonstrated that on the first stage pressure surfaces combinations of high Reynolds number and high turbulence can produce heat transfer rates well in excess of two-dimensional turbulent flow. Rotor heat transfer distributions indicate that for relatively small deviations from the design incidence, local changes to the heat transfer distributions were produced on both pressure and suction sides near the stagnation region. For extremely large negative incidence the flow was completely separated from the rotor pressure surface producing very high local heat transfer. Author

A88-54164*# Sverdrup Technology, Inc., Cleveland, Ohio.

DEVELOPMENT OF A THERMAL AND STRUCTURAL ANALYSIS PROCEDURE FOR COOLED RADIAL TURBINES

GANESH N. KUMAR (Sverdrup Technology, Inc., Cleveland, OH) and RUSSELL G. DEANNA (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs

(ASME PAPER 88-GT-18)

A procedure for computing the rotor temperature and stress distributions in a cooled radial turbine is considered. Existing codes for modeling the external mainstream flow and the internal cooling flow are used to compute boundary conditions for the heat transfer and stress analyses. An inviscid, quasi three-dimensional code computes the external free stream velocity. The external velocity is then used in a boundary layer analysis to compute the external heat transfer coefficients. Coolant temperatures are computed by a viscous one-dimensional internal flow code for the momentum and energy equation. These boundary conditions are input to a three-dimensional heat conduction code for calculation of rotor temperatures. The rotor stress distribution may be determined for the given thermal, pressure and centrifugal loading. The procedure is applied to a cooled radial turbine which will be tested at the NASA Lewis Research Center. Representative results from this case are included. Author

A88-54169#

AN EXPERIMENTAL DATA BASE FOR THE COMPUTATIONAL FLUID DYNAMICS OF COMBUSTORS

R. E. CHARLES and G. S. SAMUELSEN (California, University, Irvine) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p. refs

(ASME PAPER 88-GT-25)

A model axisymmetric gas-fired can combustor is used here to establish the sensitivity of the aerodynamic and thermal structure to inlet boundary conditions and to thereby establish a comprehensive data base for the computational fluid dynamics of combustors. The data presented include mean and rms values of the axial and azimuthal velocities as well as Reynolds stress data obtained using two-component laser velocimetry and mean temperatures from thermocouple measurements. Specific results show that the reactor operation is especially sensitive to modest changes in both the inlet geometry and the fuel injection angle. C.D.

A88-54181#

HEAT TRANSFER, PRESSURE DROP, AND MASS FLOW RATE IN PIN FIN CHANNELS WITH LONG AND SHORT TRAILING EDGE EJECTION HOLES

S. C. LAU, J. C. HAN, and T. BATTEN (Texas A & M University, College Station) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(Contract NSF CBT-87-13833)
(ASME PAPER 88-GT-42)

The turbulent heat transfer and friction characteristics in the pin fin channels with small trailing edge ejection holes found in internally-cooled turbine airfoils have been experimentally investigated. It is found that the overall heat transfer increases when the length of the trailing edge ejection holes is increased and when the trailing edge ejection holes are configured such that much of the cooling air is forced to flow further downstream in the radial flow direction prior to exiting. The increase in the overall heat transfer is shown to be accompanied by an increase in the overall pressure drop. R.R.

A88-54185#

LAMINAR FLOW VELOCITY AND TEMPERATURE DISTRIBUTIONS BETWEEN COAXIAL ROTATING DISKS OF FINITE RADIUS

J. F. LOUIS (MIT, Cambridge, MA) and D. T. ORLETSKY ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs
(ASME PAPER 88-GT-49)

Predictions of the laminar flow and temperature distribution between coaxial rotating disks of finite radius have been obtained using a computer model solving the Navier-Stokes equation for a laminar fluid of constant properties. To do this, a stream vorticity model in the r-z plane is used in the solution of the Navier-Stokes equation. The velocity fields were obtained for both shrouded and unshrouded disks with or without radial throughflow for either co-rotating or counter-rotating disks. Velocity profiles predicted by this model were compared to experimental data, to a similarity solution and to a large aspect ratio model. The results obtained by this model closely matched the experimental data, and the large aspect ratio solution for the cases considered. The uncoupled energy equation was then solved using the calculated velocity distribution for the temperature distribution between the disks. This was done for two cases: (1) two isothermal disks, and (2) one isothermal disk and one adiabatic disk. Author

A88-54191#

FLOW IN SINGLE AND TWIN ENTRY RADIAL TURBINE VOLUTES

N. LYMBEROPOULOS, N. C. BAINES, and N. WATSON (Imperial College of Science and Technology, London, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-59)

Flow in the vaneless volute of a radial-inflow turbine is investigated numerically and experimentally for cases of single and twin entry to the volute and for the particular case of unequal flows, or partial admission, to the volutes. The computational model is based on a quasi-three-dimensional solution to the Euler equations, in which the radial and tangential components are fully solved but the axial component is only treated to simulate the mixing of the two streams. In the single entry case, the agreement with experimental data is good. In the twin entry case, the essential features of the flowfield, and particularly the interaction and mixing of the two streams, can be modeled, but the solution is limited by the coarseness of the grid in the axial direction. V.L.

A88-54193#

PREDICTION OF THE PRESSURE DISTRIBUTION FOR RADIAL INFLOW BETWEEN CO-ROTATING DISCS

JOHN W. CHEW and ROBERT J. SNELL (Rolls-Royce, PLC, Derby, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-61)

The problem of radial inflow between two plane co-rotating disks with the angular velocity of the fluid at inlet equal to that of the disks is considered. An integral solution technique for turbulent flow, based on that of von Karman (1921), is described. Solutions are shown to be in good agreement with most of the available experimental data. For incompressible flow the pressure drop coefficient is a function of just two non-dimensional parameters: the radius ratio for the cavity and a throughflow parameter. For air flows compressibility can be important and an additional non-dimensional parameter is needed. Results for a wide range of conditions are presented graphically. These show the sensitivity of the pressure coefficient to the governing parameters and provide a quick method for estimating the pressure drop. Author

A88-54197#

THE EFFECTS OF AN EXCITED IMPINGING JET ON THE LOCAL HEAT TRANSFER COEFFICIENT OF AIRCRAFT TURBINE BLADES

P. J. DISIMILE and D. M. PAULE (Cincinnati, University, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. Research supported by the Charles A. Lindbergh Fund. refs
(ASME PAPER 88-GT-66)

The primary objective of this paper is to present the results of research into the effects of periodic excitation upon the local heat transfer characteristics of a turbine blade cooled by an impinging jet of air. A curved plate (used to simulate the inner leading edge of a turbine blade) was subjected to a two-dimensional jet flow field (Re = 10,000) with a superimposed periodic acoustic disturbance. When compared to the naturally disturbed flow, the excited flow field was found to reduce the local Nusselt number and cool the blade less efficiently (by as much as ten percent in the extreme cases). The results of the study appear to indicate that harmonic disturbances present a serious controlling factor in the quest for optimization of turbine blade cooling techniques. By isolating dominant frequencies in gas turbine engines and working to suppress them, it is believed that significant contributions towards the desired increase in turbine inlet temperature could be possible. Author

A88-54199#

A RADIAL MIXING COMPUTATION METHOD

J. DE RUYCK and CH. HIRSCH (Brussel, Vrije Universiteit, Brussels, Belgium) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 14 p. USAF-supported research. refs
(ASME PAPER 88-GT-68)

A radial mixing calculation method is presented where both convective and turbulent mixing processes are included. The secondary flows needed for the convective mixing are derived from pitch-averaged vorticity equations combined with integral methods for the three-dimensional end-wall boundary layers, profile boundary layers, and asymmetric wakes. The convective transport due to secondary flows is computed explicitly. The method is applied to a cascade and two single-stage rotors. The three test cases show a very different secondary flow behavior which allows the analysis of the relative importance of the different secondary flow effects. Turbulent diffusion is found to be the most important mixing mechanism, whereas convective mixing becomes significant when overall radial velocities exceed about 5 percent of the main velocities. The wake diffusion coefficient is found to be representative for the turbulent radial mixing and is the only empirical constant to be determined. Author

A88-54209#
USE OF CONTROL FEEDBACK THEORY TO UNDERSTAND OTHER OSCILLATIONS
K. J. RUMFORD and R. ANDREJCZYK (Textron, Inc., Avco Lycoming Textron Div., Stratford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p.
(ASME PAPER 88-GT-81)

The TF40B control system and the rotor system of the U.S.Navy LCAC Hovercraft are described. A history of early development problems and their solution is followed by a more obscure problem that was traced by logical deduction to a mechanical vibration of a control component. This vibration resulted in fuel flow oscillations that fed back and amplified the mechanical vibration. The solution to this problem is described and a unique application of classical closed loop control analysis to this unusual and unwanted feedback follows. Author

A88-54223#
FURTHER ASPECTS OF THE UK ENGINE TECHNOLOGY DEMONSTRATOR PROGRAMME
D. W. HUGHES and W. J. CHRISPIN (Ministry of Defence Procurement Executive, London, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p.
(ASME PAPER 88-GT-104)

This paper is a follow-up of the Chrispin (1987) paper on the U.K. engine technology program, which discussed the background to the establishment of this program together with a summary of the program's overall activity. This paper discusses in detail the nature of the individual program elements, with special attention given to stages in the development of a large-military-engine demonstrator program and a small-engine demonstrator program. The management details of the technology demonstrator programs are described. I.S.

A88-54227#
AIR FLOW PERFORMANCE OF AIR SWIRLERS FOR GAS TURBINE FUEL NOZZLES
CHARLES A. MARTIN (Parker Hannifin Corp., Gas Turbine Fuel Systems Div., Cleveland, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-108)

The performance of air swirlers with a range of swirl angles and diameters is examined and discussed in the context of recently published papers. Parameters included in this discussion are swirl number, swirler thrust, swirler torque, and swirler solidity. Results suggest that swirler 'see through' is not necessarily bad, but may be beneficial with respect to swirl number and other parameters. The use of the mean swirler radius to calculate the swirl number and the resulting benefits is discussed and demonstrated. Author

A88-54229*# Indian Inst. of Tech., Madras.
EFFECT OF STAGE LOADING ON ENDWALL FLOWS IN AN AXIAL FLOW COMPRESSOR ROTOR
N. SITARAM (Indian Institute of Technology, Madras, India) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(Contract NSG-3032)
(ASME PAPER 88-GT-111)

This paper reports results from investigations conducted to determine the effect of stage loading on endwall flows in a low speed axial flow compressor. These investigations consisted of two sets of measurements. The first set consisted of radial transverse of flow properties at the rotor inlet and exit, at five flow coefficients. These measurements are used to determine the boundary layer integral parameters. The displacement thicknesses at the rotor hub and tip agree reasonably well with Smith's (1970) correlation for multistage axial compressors. The second set consisted of measurements of static pressures on the rotor blade at four flow coefficients. From these measurements, lift coefficient is determined. Also, loss of lift coefficient near the tip is calculated, and is attributed mainly to the tip leakage flows. Author

A88-54230#
GAS TURBINE STUDIES AT OXFORD 1969-1987
T. V. JONES (Oxford University, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. refs
(ASME PAPER 88-GT-112)

Gas turbine heat transfer studies commenced at Oxford University in 1969 when transient techniques previously used for measurements in hypersonic flows were applied to the gas turbine environment. Shock tubes were employed and subsequently a new form of transient tunnel, the Isentropic Light Piston Tunnel, was developed specifically for turbine heat transfer testing. During the following years further short duration facilities were developed to study blade and vane external aerodynamics, and also the heat transfer in cooling passages was examined using liquid crystal techniques. All these transient facilities are described, and the development of the instrumentation peculiar to these is explained. The results of the work on external and internal heat transfer are summarized. In particular, the film cooling studies, the blade and vane external heat transfer work, and the wake simulation experiments are outlined. Author

A88-54234#
THE VORTEX-FILAMENT NATURE OF THE REVERSE FLOW ON THE VERGE OF ROTATING STALL
Y. N. CHEN, U. HAUPT, and M. RAUTENBERG ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 19 p. DFG-supported research. refs
(ASME PAPER 88-GT-120)

The reverse flow formed from the outlet of the rotor/impeller along the casing/shroud toward the inlet of an axial/centrifugal compressor was investigated using colored dye injected through the shroud at the outlet edge of the impeller. Particular attention was given to the stable spiral vortex filaments that compose the reverse flow. The results indicated that the vortex filaments are composed of Taylor's vortex pairs, but with unequal vortex strengths within the pair; they form the transition range from a laminar to a turbulent three-dimensional boundary layer with a very steep tangential velocity profile. It is shown that the orderly path of the reverse flow is enabled by the cessation of the leakage flow of the rotor tip clearance. I.S.

A88-54236*# United Technologies Research Center, East Hartford, Conn.
THE EFFECTS OF TURBULENCE AND STATOR/ROTOR INTERACTIONS ON TURBINE HEAT TRANSFER. I - DESIGN OPERATING CONDITIONS
M. F. BLAIR, R. P. DRING, and H. D. JOSLYN (United Technologies Research Center, East Hartford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. refs
(Contract NAS3-23717)
(ASME PAPER 88-GT-125)

A combined experimental and analytical program was conducted to examine the effects of inlet turbulence, stator-rotor axial spacing, and relative circumferential spacing of first and second stators on turbine airfoil heat transfer. The experimental portion of the study was conducted in a large-scale (approximately 5X engine), ambient temperature, stage-and-a-half rotating turbine model. The data indicate that while turbine inlet turbulence can have a very strong impact on the first stator heat transfer, its impact in downstream rows is minimal. The effects on heat transfer produced by relatively large changes in stator/rotor spacing or by changing the relative row-to-row circumferential positions of stators were very small. Analytical results consist of airfoil heat transfer distributions computed with a finite-difference boundary layer code. Author

A88-54241#

OPTIMIZATION DESIGN OF THE OVER-ALL DIMENSIONS OF CENTRIFUGAL COMPRESSOR STAGE

QINGHUAN WANG and ZHIQIN SUN (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs
(ASME PAPER 88-GT-134)

A new procedure employed in computer-aided design of centrifugal compressor stage to determine its over-all dimensions is described in this paper. By the use of the COMPLEX METHOD, the arbitrary number of variables to be optimized can be specified to remove the hidden danger of the local optima which stems from adopting a few, for example two or three, variables to be optimized. This procedure is available for any complicated implicit nonlinear objective function and ensures establishment of a true optimum solution. Numerical calculations have been carried out by using the computer program described here to check the ability of the optimization method. The results obtained by the calculations agree fairly well with that obtained by experiments. Author

A88-54245#

A TRANSIENT FLOW FACILITY FOR THE STUDY OF THE THERMOFLUID-DYNAMICS OF A FULL STAGE TURBINE UNDER ENGINE REPRESENTATIVE CONDITIONS

R. W. AINSWORTH, D. L. SCHULTZ, M. R. D. DAVIES, C. J. P. FORTH, M. A. HILDITCH (Oxford University, England) et al. ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 14 p. Research supported by the Ministry of Defence Procurement Executive, Rolls-Royce, PLC, and SERC. refs
(ASME PAPER 88-GT-144)

The design and construction of a new experiment, to investigate the steady and unsteady heat transfer and aerodynamic behavior of a rotating turbine in a transient facility, is described. The need for this experiment is discussed in the context of previous rotating bar wake and shock simulation work carried out in the Oxford transient cascade facility, and research elsewhere on the effects of rotating and three-dimensional flowfields on turbine aerodynamics and heat transfer. The outline concept and mode of operation of the turbine module are given before novel features of the design are presented in detail. The future work program and possible plans for further facility improvements are given. Author

A88-54250#

THE MEASUREMENT OF STRESS AND VIBRATION DATA IN TURBINE BLADES AND AEROENGINE COMPONENTS

D. E. OLIVER (Ometron, Inc., Herndon, VA) and D. J. BERRY (Ometron, Ltd., England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 4 p. refs
(ASME PAPER 88-GT-149)

This paper describes an instrumental set up that utilizes the thermoelastic effect to provide full field stress data and vibration data for aeroengine components and turbine blades, together with the theoretical aspects of the thermoelastic effect upon which the stress measurements are based. It is shown that laser Doppler interferometric techniques can be incorporated into this stress-measuring instrument, called SPATE stress analyzer. Results from typical aeroengine components obtained using SPATE correlated well with strain gages, while yielding benefits of full field data which can be used to provide more comprehensive description of the structure under test. The stress analyzer was applied to a wide range of materials and geometries including weldments, plastic models, and composites. The availability of a laser interferometer attachment to the SPATE system offers the facility to produce vibration and stress data from the same experimental set up. I.S.

A88-54261#

SPRAY AUTOMATED BALANCING OF ROTORS - CONCEPT AND INITIAL FEASIBILITY STUDY

ANTHONY J. SMALLEY, RICHARD M. BALDWIN, and WILBUR R. SCHICK (Southwest Research Institute, San Antonio, TX) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research supported by the Southwest Research Institute.
(ASME PAPER 88-GT-163)

The system design for implementing the spray automated balancing of rotors (SABOR) concept are presented, and the method is used to balance a spinning disk without stopping it. Test results demonstrate the ability of the SABOR method to control both angle of application and rate of application to the extent needed for effective automated balancing. The bond strengths of materials deposited by the fuel air repetitive explosion process for use in small gas turbine engines are found to be suitable for the level of centrifugal stresses expected. R.R.

A88-54263#

THE OIL-FREE SHAFT LINE

BRUNO WAGNER (Societe de Mecanique Magnetique, Saint-Marcel, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 12 p. refs
(ASME PAPER 88-GT-168)

This paper recalls the principles and main features of the active magnetic bearings and especially the advantages for turbomachines, such as oil-free operation and vibration control. Field experiences are described for different shaft line configurations. The trend of the design optimization is the active magnetic bearing in the process gas itself. But at the present stage, the active magnetic bearing is a proven technology. Author

A88-54265#

FULLY SCALED TRANSONIC TURBINE ROTOR HEAT TRANSFER MEASUREMENTS

G. R. GUENETTE, A. H. EPSTEIN, M. B. GILES, R. HAIMES (MIT, Cambridge, MA), and R. J. G. NORTON (Rolls-Royce, Inc., Atlanta, GA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research supported by Rolls-Royce, Inc. and Navy. refs
(ASME PAPER 88-GT-171)

The heat transfer to an uncooled transonic single-stage turbine has been measured in a short duration facility which fully simulates all the nondimensional quantities of interest for fluid flow and heat transfer (the Reynolds, Prandtl, and Rossby numbers; the temperature ratios; and corrected speed and weight flow). Data from heat flux gages about the midspan of the rotor profile, measured from dc to more than 10 times blade passing frequency (60 kHz), is presented in both time-resolved and mean-heat-transfer form. These rotating blade data are compared to previously published heat-transfer measurements on the same profile in a two-dimensional cascade with bar passing to simulate blade-row interaction effects (Ashworth et al., 1985). The results are qualitatively quite similar at midspan. The data are also compared to a two-dimensional Navier-Stokes calculation of the blade mean section, and the implications for turbine design are discussed. Author

A88-54272#

THE FEASIBILITY, FROM AN INSTALLATIONAL VIEWPOINT, OF GAS-TURBINE PRESSURE-GAIN COMBUSTORS

J. A. C. KENTFIELD (Calgary, University, Canada) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p. refs
(Contract NSERC-A-7928)
(ASME PAPER 88-GT-181)

The principles of pressure-gain combustors based on the wave rotor and pulse-combustor concepts were reviewed briefly. A study, based on experimental data, in which current-technology pressure-gain combustors were applied to three aircraft-engine

derivative industrial gas-turbines, covering a power range from 275 kW (370 hp) to 29 MW (39,000 hp), showed that engine power increased by 6.5 to 9.6 percent with corresponding reductions of equal magnitude in specific fuel consumption. it was concluded that pressure-gain combustors appear to offer sufficent improvements in performance without incurring crippling installational penalties, although decreases in engine power/weight ratios were noted, to warrant further research and development.
Author

A88-54273#
BRUSHES AS HIGH PERFORMANCE GAS TURBINE SEALS
J. G. FERGUSON (Rolls-Royce, PLC, Systems and Transmissions Research Dept., Bristol, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p.
(ASME PAPER 88-GT-182)

A brush seal replacing the best currently available finned labyrinth seal in a gas turbine application requiring a clearance of 0.7 mm can reduce leakage to merely 10 percent that of the labyrinth device. This dramatic improvement in performance is associated with its maintenance even during and after transient differential movements. Comparative test results have been obtained with an RB199 engine that demonstrate brush seals' yielding of significant thrust improvements, of the order of 3 percent, for a given stator outlet temperature.
O.C.

A88-54281#
INVESTIGATION INTO THE EFFECT OF TIP CLEARANCE ON CENTRIFUGAL COMPRESSOR PERFORMANCE
JOOST J. BRASZ (United Technologies Corp., Carrier Research Div., Syracuse, NY) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs
(ASME PAPER 88-GT-190)

The effect of the axial clearance between the tip of an unshrouded impeller and its stationary shroud on the overall compressor performance was investigated. The experiments were carried out in a closed-loop centrifugal compressor test rig with the impeller running at a rotational Mach number 1.39. The results indicated that, if a linear relationship is assumed, the pressure ratio decreases by 0.77 percent and the efficiency decreases by 0.33 points for each percent increase in clearance ratio; there are also an input head reduction of about 0.25 percent and an output head reduction of about 0.65 percent. However, the data seem to indicate a nonlinear effect, with stronger performance sensitivity at smaller clearances. A comparison with the results of a clearance-loss model showed that improved performance prediction can be obtained by including the effect of clearance on impeller work input.
I.S.

A88-54291#
ASSESSMENT OF GAS TURBINE VIBRATION MONITORING
ALEXANDER LIFSON, ANTHONY J. SMALLEY (Southwest Research Institute, San Antonio, TX), GEORGE H. QUENTIN (Electric Power Research Institute, Palo Alto, CA), and CHARLES L. KNAUF ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research sponsored by the Electric Power Research Institute. refs
(ASME PAPER 88-GT-204)

This paper discusses the basis for the selection and assessment of vibration monitoring equipment for industrial gas turbines, provides information on the advantages and disadvantages of different vibration transducer types, and describes typical applications of these transducers. Consideration is given to the gas turbine vibration limits and trending, as well as to the typical costs of gas turbine vibration monitoring systems. Special attention is given to the analysis of relevant data from the ERAS (EPRI reliability assessment system developed by Brown and Young, 1984) data base compiled for the years 1982-1986, using data from 13 power plants with a total number of 28 turbines operating in combined cycles and 31 operating as peaking units. Examples of vibration monitoring results are presented. It is shown that vibration-related outages may significantly affect the availability of gas turbine units; some individual vibration problems may cause as many as 300 hours or more of unavailability.
I.S.

A88-54292#
EXPERIMENTAL INVESTIGATION OF ROTATING STALL IN A MISMATCHED THREE STAGE AXIAL FLOW COMPRESSOR
G. L. GIANNISSIS, A. B. MCKENZIE, and R. L. ELDER (Cranfield Institute of Technology, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-205)

This paper reports on an examination of rotating stall in a low speed three stage axial flow compressor operating with various degrees of stage mis-match. The objective of this study was to simulate the mis-matching when operating near surge. The study of the stall zones involved the use of fast response measurement techniques. The study clearly shows how stages can operate in an axi-symmetric fashion even when heavily stalled, rotating stall inception requiring the stall of more than one stage. The study also compares conditions required for full span and part span stall and suggests that the part span stall structure is the more relevant to high speed multistage compressors.
Author

A88-54298#
ROLLING ELEMENT BEARING MONITORING AND DIAGNOSTICS TECHNIQUES
R. G. HARKER and J. L. SANDY (Bently Nevada Corp., Minden) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p.
(ASME PAPER 88-GT-212)

Rolling element bearings require distinctly different techniques for monitoring and diagnostics from those used for fluid-film type bearings. A description of these techniques and the instrumentation used to acquire the necessary data is provided for comparison. Also included are some case studies to illustrate how these techniques are applied.
Author

A88-54299#
THERMOMECHANICAL ADVANCES FOR SMALL GAS TURBINE ENGINES - PRESENT CAPABILITIES AND FUTURE DIRECTION IN GAS GENERATOR DESIGNS
M. PROPEN, H. VOGEL, and S. AKSOY (Textron, Inc., Avco Lycoming Textron, Stratford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-213)

Performance requirements of tomorrow's gas turbines demand major improvements in specific fuel consumption and thrust to weight ratio. These stringent requirements, in turn, drive the need for higher operating temperatures and lighter weight engines. Such technical improvements impose severe thermal, structural, and metallurgical demands upon turbine components. A broad spectrum of technology programs is underway at Textron Lycoming to address these challenging requirements. This paper outlines the thermal, structural, and materials research needed for achieving the goals of the small gas turbines of tomorrow.
Author

A88-54300#
REAL TIME NEUTRON RADIOGRAPHY APPLICATIONS IN GAS TURBINE AND INTERNAL COMBUSTION ENGINE TECHNOLOGY
JOHN T. LINDSAY and C. W. KAUFFMAN (Michigan, University, Ann Arbor) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. refs
(ASME PAPER 88-GT-214)

This paper describes a real-time neutron radiography (RTNR) facility, developed at the University of Michigan for NDT testing of flows generated by gas turbine and internal-combustion engines, together with the results of the RTNR applications. It is shown that RTNR can be used to detect coking and debris deposition in gas turbine nozzles; to image a fuel spray from an injector in an operating single-cylinder diesel engine; to locate a lubrication blockage; and to study lubrication problems in operating standard internal-combustion engines. The RTNR facility can also be applied to measurements not directly related to gas turbine engines, such as monitoring objects or phenomena that are changing and/or moving. Schematic diagrams of RTNR are included. I.S.

A88-54305#

THEORETICAL INVESTIGATION OF THE INTERACTION BETWEEN A COMPRESSOR AND THE COMPONENTS DURING SURGE

JUERGEN BRUMM, HASSAN KALAC, and INGOLF TEIPEL (Hannover, Universitaet, Hanover, Federal Republic of Germany) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. DFG-supported research. refs

(ASME PAPER 88-GT-220)

The surge phenomenon in a compression system consisting of a compressor, a duct, and a plenum is analyzed using a theoretical model based on the application of mass, momentum, and energy conservation equations of one-dimensional flow. The set of hyperbolic differential equations is solved numerically using a predictor-corrector scheme. At the interface between two components, coupling conditions for pressure and flow velocity are taken from the method of characteristics. The performance of the compressor is determined by its performance map, which describes the relationship between pressure and mass flux for all conditions from stable performance to inverse mass flow. The pressure-time history is compared with data in the literature, and the general time dependent surge performance is considered in comparison with the quasi-steady characteristic. V.L.

A88-54311#

COMPARISON OF CERAMIC VS. ADVANCED SUPERALLOY OPTIONS FOR A SMALL GAS TURBINE TECHNOLOGY DEMONSTRATOR

T. BORNEMISZA and J. NAPIER (Sundstrand Turbomach, San Diego, CA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. refs

(ASME PAPER 88-GT-228)

In the pursuit of higher turbine inlet temperatures for next-generation APU gas turbines, a series of comparative tests has been run to ascertain the relative advantages and disadvantages of ceramic radial-inflow turbine rotors vs. air-cooled superalloy ones, at operating temperatures in excess of 2000 F. The ceramic turbine is fabricated from hot-pressed silicon nitride; the air-cooled superalloy turbine is fabricated by isothermal forging from single-crystal, rapid solidification-rate Alloy 'Y', which possesses exceptional creep life. While the ceramic turbine entails higher risks, far greater potential benefits will result from increased development investment. O.C.

A88-54328*# Cornell Univ., Ithaca, N.Y.

NUMERICAL RESULTS FOR AXIAL FLOW COMPRESSOR INSTABILITY

F. E. MCCAUGHAN (Cornell University, Ithaca, NY) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs

(Contract NAG3-349)

(ASME PAPER 88-GT-252)

Using Cornell's supercomputing facilities, an extensive study of the Moore-Greitzer model was carried out, which gives accurate and reliable information about compressor instability. The bifurcation analysis in the companion paper shows the dependence of the mode of compressor response on the shape of the rotating stall characteristic. The numerical results verify and extend this with a more accurate representation of the characteristic. The effect of the parameters on the shape of the rotating stall characteristic is investigated, and it is found that the parameters with the strongest effects are the inlet length, and the shape of the compressor pressure rise vs. mass flow diagram (i.e. tall diagrams vs. shallow diagrams). The effects of inlet guide vane loss on the characteristic are discussed. Author

A88-54342#

LASER - A GAS TURBINE COMBUSTOR MANUFACTURING TOOL

J. TERENCE FEELEY (Laser Fare, Ltd., Inc., Smithfield, RI) and E. JACK SWEET ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 6 p. refs

(ASME PAPER 88-GT-267)

Processes have been developed for the machining and welding of gas turbine engine combustor liners with laser outputs. Major goals of these development efforts encompassed the cutting and drilling of chrome-nickel alloys and refractory ceramics, in order to yield precise dimensions without airflow pattern-disrupting burrs or slag; laser welding operations were required to result in no dimensional distortions and to leave no built-in cracks that might propagate in response to fatigue loading. Results superior to those obtainable with conventional punching, drilling, and welding have been achieved. O.C.

A88-54345#

A NEW SOURCE OF LIGHTWEIGHT, COMPACT MULTIFUEL POWER FOR VEHICULAR, LIGHT AIRCRAFT AND AUXILIARY APPLICATIONS - THE JOINT DEERE SCORE ENGINES

CHARLES JONES (John Deere Technologies International, Inc., Wood-Ridge, NJ) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs

(ASME PAPER 88-GT-271)

Deere & Co. has actively pursued development of the multifuel Wankel-type stratified charge engine since February, 1984. During this period, a new R & D facility has been established where development is in progress for three new engine families having basic displacements of .66, 1.72 and 5.8 liters/rotor, for a 1 to 8 rotor engine output range from 37 to 2250 kW (50 to 3,000 HP). The initial SCORE (stratified charge omniverous rotary engines) production engines are expected to be placed into service next year. This series of three engine families offers the size, weight and low vibration characteristics of small gas turbines and the fuel efficiency and initial cost characteristics of diesel engines. This paper describes the combustion concept, relates relevant history and gives the current development status for all three basic sizes. Author

A88-54354#

WEIBULL ANALYSIS TECHNIQUES ON A DESKTOP COMPUTER

J. L. BYERS (U.S. Navy, Naval Air Development Center, Warminster, PA) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p. refs

(ASME PAPER 88-GT-285)

This paper presents a summary of a task to provide individual U.S. Navy project engineers with analytical tools that enable them to perform Weibull failure and related analyses on a desktop computer. An integrated computer program that allows Navy analysts to perform rigorous trade-off and what-if analyses in an interactive manner without having to send the problem off to a central computer facility. The resulting computer codes exist in several forms to fit the various needs and computer configurations, such as: direct input of data, data file creation and update, and nonprinting versions for those who have no printer available. Included in the codes are three Monte Carlo routines and several test-plan generation codes. Author

A88-54355*# Pratt and Whitney Aircraft, East Hartford, Conn.

CURRENT STATUS AND FUTURE TRENDS IN TURBINE APPLICATION OF THERMAL BARRIER COATINGS

KEITH D. SHEFFLER and DINESH K. GUPTA (Pratt and Whitney, East Hartford, CT) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 9 p. refs

(Contract NAS3-23944)

(ASME PAPER 88-GT-286)

This paper provides an overview of the current status and future trends in application of thermal barrier coatings (TBC) to turbine components, and in particular to high turbine airfoils. Included are descriptions of the favorable results achieved to date with bill-of-material applications of plasma deposited TBC, and recent experience with developmental coatings applied by electron beam-physical vapor deposition. Author

A88-54361#

BOUNDARY-LAYER FLOWS IN ROTATING CAVITIES

C. L. ONG and J. M. OWEN (Sussex, University, Brighton, England) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 10 p. Research supported by SERC, Rolls-Royce, PLC, and Ruston Gas Turbines, PLC. refs

(ASME PAPER 88-GT-292)

Differential boundary layer equations modelling the flow between two corotating air-cooled gas-turbine disks are solved to study the velocity distribution inside the entraining and nonentraining boundary layers and in the inviscid core. The equations are discretized using the box scheme of Keller and Cebeci (1972), and the Cebeci-Smith (1974) eddy-viscosity model is used to treat the turbulent-flow case. Good agreement between the present computations and previous experimental results is obtained for a wide range of flow rates and rotational speeds. R.R.

A88-54385#

FIBER OPTICS BASED JET ENGINE AUGMENTER VIEWING SYSTEM

P. J. MURPHY, D. W. JONES, R. R. JONES, III (Sverdrup Technology, Inc., Arnold AFB, TN), and A. E. LENNERT ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 5 p.

(ASME PAPER 88-GT-320)

An augmenter viewing system employing a coherent fiber-optic array was developed for use in jet engine testing applications at AEDC. Real-time viewing of the test article afterburner was obtained in a severe environment under high temperature and vibration levels. The optical system consisted of a conventional front-end lens assembly coupled with the fiber-optic array, and a solid-state color video camera mounted inside the test cell. The advantages and problems associated with a fiber-optics-based viewing system will be discussed in comparison with more conventional viewing techniques for this application. Author

A88-54566

FAULT DETECTION IN MULTIPLY-REDUNDANT MEASUREMENT SYSTEMS VIA SEQUENTIAL TESTING

ASOK RAY (Pennsylvania State University, University Park) IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, 1988, p. 1400-1405. refs

The theory and application of a sequential test procedure for fault detection and isolation. The test procedure is suited for development of intelligent instrumentation in strategic processes like aircraft and nuclear plants where redundant measurements are usually available for individual critical variables. The test procedure consists of: (1) a generic redundancy management procedure which is essentially independent of the fault detection strategy and measurement noise statistics, and (2) a modified version of sequential probability ratio test algorithm for fault detection and isolation, which functions within the framework of this redundancy management procedure. The sequential test procedure is suitable for real-time applications using commercially available microcomputers and its efficacy has been verified by online fault detection in an operating nuclear reactor. I.E.

A88-55042

DESIGN CONSIDERATIONS IN REMOTE TESTING

EUGENE R. REINHART (Reinhart and Associates, Inc., Austin, TX) Materials Evaluation (ISSN 0025-5327), vol. 46, Sept. 1988, p. 1301-1306, 1308, 1309. refs

A general approach to the design of portable remote systems is described using a remote eddy current/visual inspection system for steam turbine blades and an air-transportable multitechnique turbine rotor inspection system as examples. The design requirements for these systems are examined, and it is shown how unique design solutions have been found in each case to provide transportable reliable remote NDE systems. Based on the experience gained in developing and using the systems described here, the principal steps in developing a portable remote inspection system are identified. V.L.

A88-55154

NEW APPARATUS FOR STUDYING FATIGUE DEFORMATION AT HIGH MAGNIFICATIONS

ROBERT R. STEPHENS and DAVID W. HOEPPNER (Utah, University, Salt Lake City) Review of Scientific Instruments (ISSN 0034-6748), vol. 59, Aug. 1988, pt. 1, p. 1412-1419. Research supported by Rolls-Royce, PLC. refs

One of the steps taken to enhance accurate fatigue life estimations and material modeling is the development of an electrohydraulic, servocontrolled feedback fatigue apparatus that has been joined to a scanning electron microscope. This apparatus allows in situ observations of cyclically loaded specimens undergoing fatigue deformation. Using this apparatus, recordings can be made of the events related to the surface response of materials under different loading conditions, showing how microstructural features influence crack nucleation and propagation behavior. With the development of this apparatus, existing mathematical models describing the fatigue process can be enhanced or improved, and more accurate fatigue life estimation methods can be obtained. The apparatus developed is described herein, as well as a few selected results. Author

A88-55372#

APPLICATION OF THE THEORY OF ANISOTROPIC THIN-WALLED BEAMS AND PLATES FOR WINGS MADE FROM COMPOSITE MATERIAL

N. V. BANICHUK, V. V. KOBELEV, and A. D. LARICHEV (AN SSSR, Moscow, USSR) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p. refs

(IAF PAPER 88-275)

Solutions are presented for divergence and static bending problems for anisotropic wings, which are modeled as anisotropic thin-walled beams of closed cross section. The governing equations are derived using variational principles, with special attention given to coupled torsion-bending effects. The effect of anisotropic tailoring on the critical divergence speed of the wing is investigated analytically. Optimum orientations of anisotropy axes for the wing skin are calculated by the successive optimization method. V.L.

A88-55456

THE NON-DESTRUCTIVE TESTING OF WELDS IN CONTINUOUS FIBRE REINFORCED THERMOPLASTICS

G. R. EDWARDS (Welding Institute, Cambridge, England) IN: Composites evaluation; Proceedings of the Second International Conference on Testing, Evaluation and Quality Control of Composites-TEQC 87, Guildford, England, Sept. 22-24, 1987. Sevenoaks, England and Stoneham, MA, Butterworths, 1987, p. 3-10. refs

Practices used in the nondestructive testing for defects in thermoplastic composite materials are discussed, with special attention given to the current practice for the NDT of composite aircraft structures and the test equipment used in these procedures. The NDT methods applicable for the detection of particular possible defects, such as delamination/disbonds, porosity, inclusions, fiber misalignment, broken fibers, matrix cracking, weak bonds, and fiber/matrix volume are examined. Special consideration is given to tests that include adhesively bonded joints and welded joints. It is emphasized that, for testing welded joints in thermoplastic composites, the existing test procedures must be further developed and include such procedures as computerized ultrasonic immersion tests and thermography. I.S.

N88-29061# Naval Ocean Systems Center, San Diego, Calif.
EFFECT OF PHASE ERRORS IN STEPPED-FREQUENCY RADAR SYSTEMS Final Report, Jan. 1987 - Jan. 1988
H. E. VANBRUNDT Apr. 1988 12 p
(AD-A194476; AD-E500985; NOSC/TR-1211) Avail: NTIS HC A03/MF A01 CSCL 17I

Stepped-frequency waveforms are being considered for inverse synthetic aperture radar (ISAR) imaging from ship and airborne platforms and for detailed radar cross section (RCS) measurements of ships and aircraft. These waveforms make it possible to achieve resolutions of 1.0 foot by using existing radar designs and processing technology. One problem not yet fully resolved in using stepped-frequency waveform for ISAR imaging is the deterioration in signal level caused by random frequency error. Random frequency error of the stepped-frequency source results in reduced peak responses and increased null responses. The resulting reduced signal-to-noise ratio is range dependent. Two of the major concerns addressed in this report are radar range limitations for ISAR and the error in calibration for RCS measurements caused by differences in range between a passive reflector used for an RCS reference and the target to be measured. In addressing these concerns, NOSC developed an analysis to assess the tolerable frequency error in terms of resulting power loss in signal power and signal-to-phase noise. GRA

N88-29110# Scientific Research Associates, Inc., Glastonbury, Conn.
AN EFFICIENT PATCHED GRID NAVIER-STOKES SOLUTION FOR MULTIPLE BODIES, PHASE 1 Final Report No. 1
Y. T. CHAN and BERNARD C. WEINBERG 3 Feb. 1988 32 p
(Contract DAAL03-87-C-0010)
(AD-A194166; SRA-R88-930015-F; ARO-25053.1-EG-SBI) Avail: NTIS HC A03/MF A01 CSCL 12A

A major problem area in current computational fluid dynamics technology concerns flows about complex configurations formed by multiple components in relative motion. Major difficulties encountered in such problems are those associated with the grid. For such applications, the geometric constraints of the component elements often require that patched grids be employed. Herein, a novel and efficient procedure is described to solve the time-dependent, multidimensional Navier-Stokes equations about multiple body configurations. In contrast to existing patched grid approaches, the present method calculates the entire flow field over both grids simultaneously, without iteration. By eliminating iteration within a time step and allowing time steps to be chosen by accuracy considerations, rather than by stability limits, this procedure could lead to a substantial savings in computer run time. In addition, for steady state problems improved convergence rates could be expected. To demonstrate the capabilities and advantages of the new procedure, a problem of current interest in turbomachinery, the flow field in a rotor-stator stage, is investigated using the developed procedure. A steady state flow field about a cascade of displaced tandem Joukowski airfoils is considered. The accuracy of the calculations and CPT time used are compared with a calculation using a continuous deformed grid algorithm and a patched grid with iteration. GRA

N88-29111# Naval Postgraduate School, Monterey, Calif.
FLOW VISUALIZATION BY LASER SHEET M.S. Thesis
JOSEPH S. CHLEBANOWSKI, JR. Mar. 1988 33 p
(AD-A194481) Avail: NTIS HC A03/MF A01 CSCL 14B

A flow visualization system using smoke and a laser sheet for illumination has been designed and developed for use in the 32- x 45-inch low speed wind tunnel. Major design features include a portable smoke rake designed for ease of installation and removal, the use of fiber optics to transport the laser light in a safe and convenient manner, and a portable traversing mechanism to traverse and orient the laser light sheet. The capabilities of the flow visualization system have been demonstrated by producing qualitative photographic recordings of complex flow patterns past an airfoil model and a missile model. GRA

N88-29112# Naval Postgraduate School, Monterey, Calif.
A MAPPING OF THE VISCOUS FLOW BEHAVIOR IN A CONTROLLED DIFFUSION COMPRESSOR CASCADE USING LASER DOPPLER VELOCIMETRY AND PRELIMINARY EVALUATION OF CODES FOR THE PREDICTION OF STALL Ph.D. Thesis
YEKUTIEL ELAZAR Mar. 1988 252 p
(AD-A194490; NPS67-88-001) Avail: NTIS HC A12/MF A01 CSCL 20D

Detailed measurements were made at M=0.25 and Re sub c = 700,000 of the flow through a linear compressor cascade of controlled diffusion (CD) blading using a two-component argon-ion laser Doppler velocimeter system. The measurements included mapping of the inviscid flow in the passage between two adjacent blades, boundary layer surveys, and wake surveys. Viscous flow phenomena such as a laminar separation region with reattachment on the suction surface, and laminar to turbulent transition on the pressure surface were resolved, and the viscous growth to the trailing edge was defined for three inlet angles from design incidence to near stall. Numerical calculations to predict the flow were carried out using a fully developed boundary layer code, a strongly interactive viscous inviscid code and a Navier Stokes code. It was shown that the common weakness of numerical predictors was in the modelling of transition and turbulence. The documented data can be used generally to calibrate compressor cascade analysis codes and thus enable reliable predictions of stall. GRA

N88-29124# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
MODELING OF LARGE STALL IN AXIAL COMPRESSORS [MODELISATION DU GRAND DECROCHAGE DANS LES COMPRESSEURS AXIAUX]
D. BUISINE Feb. 1988 69 p In FRENCH
(VKI-TN-164; ETN-88-92720) Avail: NTIS HC A04/MF A01

A model to describe the behavior of large three-dimensional flow structures in stalled flow, e.g., return, stagnation, and centrifuge zones, is outlined. The interblade channels and spaces are modeled by macroelements which are sufficiently parameterized to take account of structures found in experimental studies. These elements, directed by equations for mass budget, amount of motion, and vorticity, are then assembled. Pressure was calculated by integration over the entire space constituted by the machine of the local elliptic system with respect to the boundary conditions for inflow and outflow. Only the first member operator was tested. Results are encouraging. ESA

N88-29142*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
OPTICAL MEASUREMENT OF UNDUCTED FAN BLADE DEFLECTIONS
ANATOLE P. KURKOV 1988 14 p Proposed for presentation at the 34th International Gas Turbine and Aeroengine Congress and Exposition, Toronto, Ontario, 4-8 Jun. 1989
(NASA-TM-100966; E-4131-1; NAS 1.15:100966) Avail: NTIS HC A03/MF A01 CSCL 14B

A nonintrusive optical method for measuring unducted fan (or propeller) blade deflections is described and evaluated. The measurement does not depend on blade surface reflectivity. Deflection of a point at the leading edge and a point at the trailing edge in a plane nearly perpendicular to the pitch axis is obtained with a single light beam generated by a low-power, helium-neon laser. Quantitiative analyses are performed from taped signals on a digital computer. Averaging techniques are employed to reduce random errors. Measured static deflections from a series of high-speed wind tunnel tests of a counterrotating unducted fan model are compared with available, predicted deflections, which are also used to evaluate systematic errors. Author

N88-29204# Anamet Labs., Inc., Hayward, Calif.
INTERACTIVE PLOTTING OF NASTRAN AERODYNAMIC MODELS USING NPLOT AND DISSPLA Final Report, Jun. - Aug. 1987

STEVEN G. HARRIS Mar. 1988 32 p
(Contract F33615-84-C-3216)
(AD-A194115; REPT-587-1A; AFWL-TR-87-99) Avail: NTIS HC A03/MF A01 CSCL 01A

The computer program NPLOT is extended to permit interactive plotting of NASTRAN doublet lattice aerodynamic models. In addition, a translator is developed between Precision Visuals DI-3000 plot package and ISSCO's DISSPLA plot package to permit NPLOT to be run at facilities that support only DISSPLA. The resulting package is useful as a general debugging tool for NASTRAN aerodynamic analysis and as an integral part of nuclear vulnerability model generation programs developed in previous work. GRA

N88-29996# Army Natick Research and Development Command, Mass.
CONTROL SYSTEMS FOR PLATFORM LANDINGS CUSHIONED BY AIR BAGS Final Technical Report, Jul. - Aug. 1985
EDWARD W. ROSS Jul. 1987 40 p
(AD-A196154; NATICK/TR-88/021) Avail: NTIS HC A03/MF A01 CSCL 15E

This report presents an exploratory mathematical study of control systems for airdrop platform landings cushioned by airbags. The basic theory of airbags is reviewed and solutions to special cases are noted. A computer program is presented, which calculates the time-dependence of the principal variables during a landing under the action of various control systems. Two existing control systems of open-loop type are compared with a conceptual feedback (closed-loop) system for a fairly typical set of landing conditions. The feedback controller is shown to have performance much superior to the other systems. The feedback system undergoes an interesting oscillation not present in the other systems, the source of which is investigated. Recommendations for future work are included. GRA

N88-30006# Air Force Weapons Lab., Kirtland AFB, N. Mex.
EMPTAC (ELECTROMAGNETIC PULSE TEST AIRCRAFT) USER'S GUIDE Final Report, Oct. 1984 - Dec. 1986
DALE R. CLEAVELAND and AVERY BURKHARD Apr. 1988 56 p
(AD-A195072; AFWL-TR-88-28) Avail: NTIS HC A04/MF A01 CSCL 20N

This guide was established to give test managers a way to familiarize themselves with the Air Force Weapons Laboratory's electromagnetic pulse (EMP) test aircraft program located at Kirtland Air Force Base (KAFB), New Mexico. Brief descriptions of the available EMP test facilities at KAFB are also included. This guide should give prospective customers (users) adequate information to scope the magnitude of their test effort and to accomplish general planning without extensive involvement in test execution details. GRA

N88-30064# Rutgers - The State Univ., New Brunswick, N. J. Dept. of Mechanical and Aerospace Engineering.
NUMERICAL SIMULATION OF NOZZLE FLOWS Final Report, May 1984 - Aug. 1987
DOYLE D. KNIGHT and DATTA V. GAITONDE 18 Feb. 1988 91 p
(Contract F33615-84-K-3009)
(AD-A195144; RU-TR-169-MAE-F; AFWAL-TR-87-3110) Avail: NTIS HC A05/MF A01 CSCL 20D

A three-dimensional grid generation code implementing the multisurface technique is developed with major emphasis on the use of color computer graphics. A precise control method is employed to permit grid point control. A significant departure from existing approaches is the extension of user interaction to all phases of grid generation. This facilitates easy and rapid developments of grids especially for 3-D applications. The code is employed to generate grids for a 3-D axisymmetric nozzle and an aircraft type section. The flow is a non-axisymmetric nozzle, computed under the assumptions of horizontal and vertical symmetry. The Mach number of external flow is 1.2. The results are validated by comparison with experiment. Overall good agreement is observed with static pressure comparisons. Preliminary flow analysis indicates the existence of a number of interesting flow structures including shocks, pressure wave systems and regions of flow separation. Viscous-inviscid interactions, Computational fluid dynamics, Navier-stokes equations, Turbulence. GRA

N88-30066*# United Technologies Research Center, East Hartford, Conn.
ASSESSMENT OF A 3-D BOUNDARY LAYER ANALYSIS TO PREDICT HEAT TRANSFER AND FLOW FIELD IN A TURBINE PASSAGE Final Analysis Report
O. L. ANDERSON 29 Aug. 1985 93 p
(Contract NAS3-23716)
(NASA-CR-174894; NAS 1.26:174894; R85-956834) Avail: NTIS HC A05/MF A01 CSCL 20D

An assessment was made of the applicability of a three dimensional boundary layer analysis of heat transfer, total pressure losses, and streamline flow patterns on the surfaces of both stationary and rotating turbine passages. In support of this effort, an analysis was developed to calculate a general nonorthogonal surface coordinate system for arbitrary three dimensional surfaces and also to calculate the boundary layer edge conditions for compressible flow using the surface Euler equations and experimental pressure distributions. Calculations are presented for the pressure, endwall, and suction surfaces of a stationary cascade and for the pressure surface of a rotating turbine blade. The results strongly indicate that the three dimensional boundary layer analysis can give good predictions of the flow field, loss, and heat transfer on the pressure, suction, and endwall surface of a gas turbine passage. Author

N88-30069# Tennessee Univ., Tullahoma.
CONTAMINATION AND DISTORTION OF STEADY FLOW FIELD INDUCED BY DISCRETE FREQUENCY DISTURBANCES IN AIRCRAFT GAS ENGINES Final Report, Jan. - Dec. 1987
M. KUROSAKA Apr. 1988 5 p
(Contract AF-AFOSR-0049-83)
(AD-A195440; AFOSR-88-0640TR) Avail: NTIS HC A02/MF A01 CSCL 20D

The main objective of this program was to acquire fundamental understanding of two aerodynamic effects induced by vortices shed by blades of aircraft gas turbines: (1) the instantaneous separation of total temperature and pressure around vortices in the wake shed and its time averaged effect; and (2) the issue of over 100 percent efficiency measured near the hub section of an advanced turbofan design of the Air Force Aeropropulsion Laboratory. Through the combination of experimental and theoretical investigations, the mechanisms of the two phenomena have been identified. GRA

N88-30091# Rolls-Royce Ltd., Derby (England).
POSITRON EMISSION TOMOGRAPHY: A NEW TECHNIQUE FOR OBSERVING FLUID BEHAVIOR IN ENGINEERING SYSTEMS
P. A. E. STEWART, J. D. ROGERS, R. T. SKELTON, P. SALTER, M. ALLEN, R. PARKER, P. DAVIS, P. FOWLES, M. R. HAWKESWORTH, M. A. ODWYER et al. 17 Sep. 1988 27 p
Presented at the EWD NDT Conference, London, United Kingdom, 13-17 Sep. 1987 Sponsored by the United Kingdom Science and Engineering Research Council
(PNR90471; ETN-88-92698) Avail: NTIS HC A03/MF A01

Positron emission tomography for flow tracing and measurement within metal structures in general and operating engines in particular is introduced. The principles involved are outlined, and a mobile positron camera system is described. Examples of the camera's capability drawn from its use to study annular oil volumes simulated by positron line sources in a power turbine shaft and in a small helicopter engine are presented. ESA

N88-30093*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, Calif.
TECHNIQUES USED IN THE F-14 VARIABLE-SWEEP TRANSITION FLIGHT EXPERIMENT
BIANCA TRUJILLO ANDERSON, ROBERT R. MEYER, JR., and HARRY R. CHILES Jul. 1988 25 p Presented at the 4th AIAA Flight Test Conference, San Diego, Calif., 18-20 May 1988
(NASA-TM-100444; H-1461; NAS 1.15:100444; AIAA-88-2110) Avail: NTIS HC A03/MF A01 CSCL 20D

This paper discusses and evaluates the test measurement techniques used to determine the laminar-to-turbulent boundary layer transition location in the F-14 variable-sweep transition flight experiment (VSTFE). The main objective of the VSTFE was to determine the effects of wing sweep on the laminar-to-turbulent transition location at conditions representative of transport aircraft. Four methods were used to determine the transition location: (1) a hot-film anemometer system; (2) two boundary-layer rakes; (3) surface pitot tubes; and (4) liquid crystals for flow visualization. Of the four methods, the hot-film anemometer system was the most reliable indicator of transition. Author

N88-30107# Aeronautical Research Labs., Melbourne (Australia).
DEVELOPMENT AND INSTALLATION OF AN INSTRUMENTATION PACKAGE FOR GE F404 INVESTIGATIVE TESTING
D. K. STREATFEILD Jan. 1988 36 p
(AD-A196265; ARL/AERO-PROP-TM-446; DODA-AR-004-584) Avail: NTIS HC A03/MF A01 CSCL 21E

The development and installation of an Instrumentation Package for GE F404 Investigative Testing is described. The package is used in conjunction with the ARL MOBILE (Transient) Data Acquisition System (MODAS) and can be used on the F404 engine at both Fixed or Mobile Engine Test locations. GRA

N88-30128*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.
HELICOPTER TRANSMISSION RESEARCH AT NASA LEWIS RESEARCH CENTER
JOHN J. COY, DENNIS P. TOWNSEND, DAVID G. LEWICKI (Army Aviation Systems Command, Cleveland, Ohio.), and HAROLD H. COE 1988 19 p Prepared for presentation at the International Conference on Gearing, Zhengzhou, Peoples Republic of China, 5-10 Nov. 1988; sponsored in part by the Chinese Mechanical Engineering Society
(Contract DA PROJ. 1L1-62209-A-47-A)
(NASA-TM-100962; E-4181; AVSCOM-TM-88-C-003; NAS 1.15:100962) Avail: NTIS HC A03/MF A01 CSCL 13I

A joint helicopter transmission research program between NASA Lewis Research Center and the U.S. Army Aviation Systems Command has existed since 1970. Program goals are to reduce weight and noise and to increase life and reliability. Reviewed are significant advances in technology for gears and transmissions and the experimental facilities at NASA Lewis for helicopter transmission testing are described. A description of each of the rigs is presented along with some significant results from the experiments. Author

N88-30129# Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse (France).
STUDIES OF UNSTEADY AXIAL-COMPRESSOR FUNCTIONING
A. CARRERE 1986 55 p In FRENCH Sponsored by Direction des Recherches, Etudes et Techniques, Paris, France
Avail: NTIS HC E04/MF E04; copy not available from STI Facility

Unsteady functioning of axial flow compressors are studied just before a surge. The ENSAE compressor test bench, consisting of two transonic axial compressor stages, is specially designed to record steady and unsteady measurements at a number of points. Axisymmetric flow in this compressor was first studied and described using experimental methods (study of distribution at the inlet and diagram of the compressor field in the steady mode), then compared to axisymmetric flow calculated by the SNECMA calculation flow and stability code program. A whole series of unsteady measurements were carried out in order to describe the machine's functioning around surge point. Author

N88-30140# Industrial Quality, Inc., Gaithersburg, Md.
DEVELOPMENT OF GRADED REFERENCE RADIOGRAPHS FOR ALUMINUM WELDS, PHASE 1 Final Report, 7 Jul. 1987 - 7 Mar. 1988
DANIEL POLANSKY, EDWARD CRISCUOLO, HAROLD BERGER, and THOMAS S. JONES 7 Mar. 1988 33 p
(Contract DAAK70-87-C-0027)
(AD-A195594) Avail: NTIS HC A03/MF A01 CSCL 11F

The purpose of this Small Business Innovation Research Phase 1 project was to develop a data bank for graded sets of reference radiographs of aluminum welds. Reference radiographic documents of this type are extremely valuable for procurements related to ships, aircraft, other vehicles, construction and similar projects that include aluminum welds. The reference radiographs serve as a recognized way of acceptance or rejection of welds. There are no recognized standards for graded reference radiographs of aluminum welds. The only alternative at present is to use graded sets of reference radiographs for steel welds such as ASTM standard E-390. This is not a technically acceptable alternative because the radiographic contrasts and general appearance are different for steel welds as compared to aluminum welds. During this Phase 1 project, a data bank of production radiographs of aluminum welds was collected. Several thousand radiographs are presently in the data bank. From this data bank, a set of proposed reference radiographs has been assembled. These include five grades of reference radiographs for three types of porosity, fine scattered porosity, coarse scattered porosity and linear porosity. The suggested reference radiograph document also includes three grades of clustered porosity, two illustrations of inadequate penetration, two illustrations of tungsten inclusions, and examples of longitudinal and transverse cracks, lack of fusion and undercut. GRA

N88-30142# California Univ., Berkeley. Dept. of Materials Science and Mineral Engineering.
MODELING OF MICROMECHANISMS OF FATIGUE AND FRACTURE IN HYBRID MATERIALS Annual Report No. 1, 15 Apr. 1987 - 14 Apr. 1988
R. O. RITCHIE, W. YU, and S. C. SIU May 1988 59 p
(Contract AF-AFOSR-0158-87)
(AD-A195604; UCB/R/88/A1053) Avail: NTIS HC A04/MF A01 CSCL 11D

The obvious benefits of the design of aerospace structures using lighter materials with high specific strengths and stiffness has led in recent years to the development of numerous reinforced composite materials, which have become serious commercial competitors to traditional monolithic metallic alloys. While significant advances in processing technology have made the fabrication of such hybrid materials more of an economic reality, their widespread use in airframes or other critical structures has in general been limited by serious deficiencies in particular mechanical properties, such as ductility, toughness and fatigue. This problem is often compounded by the lack of fundamental studies which provide a rational basis for the underlying sources of crack-propagation resistance in these materials, and in particular which define the critical role of composite microstructure. Accordingly, the current program is aimed at studying the physics and micromechanisms of fracture toughness and particularly the fatigue-crack growth resistance in laminate, discontinuously-reinforced and continuously-reinforced metal-matrix composites, with special reference to the role of microstructure. GRA

N88-30143# Grumman Aerospace Corp., Bethpage, N.Y.
AUTOMATED EARLY FATIGUE DAMAGE SENSING SYSTEM Final Report, 5 Dec. 1983 - 6 Sep. 1987
ALAN HENCKEN and MICHAEL HORN Mar. 1988 93 p
(Contract F33615-83-C-3225)
(AD-A195717; AFWAL-TR-88-3008) Avail: NTIS HC A05/MF A01 CSCL 11F

Structural fatigue testing plays a vital role in assuring the long term integrity of aerospace vehicles and components. However, substantial uncertainty involving large-scale complex structural tests does exist due to their inherent one shot nature. Crack propagation not revealed by a catastrophic failure during a single test can cause structural problems later in production aircraft. The overall objective of this program was to develop a reliable nondestructive testing system for the detection of initiating cracks generated during structural fatigue testing. The goals were to: (1) detect cracks as small as 0.050 in. in complex structures, and (2) develop a detection system that could be operated by technician-level personnel typically assigned to structural test areas. GRA

N88-30157# Aeronautical Research Inst. of Sweden, Stockholm. Structures Dept.
STANDARD FATIGUE SPECIMENS FOR FASTENER EVALUATION
BJORN PALMBERG and LARS JARFALL (Saab-Scania, Goteberg, Sweden) Oct. 1987 51 p
(Contract FMV-FFL-82250-85-076-73-001)
(FFA-TN-1987-68; ETN-88-93062) Avail: NTIS HC A04/MF A01
Spectrum fatigue testing was carried out using single shear joints with U-channel splice plates and four different fastener systems. Single column, double row joints were used. The joints frequently developed splice plate failures making the completion of the testing program not worthwhile. Studies of secondary bending, amount of load transfer and fastener flexibility were performed successfully. The base plate material in the joints was 5 mm thick aluminum alloy 7050-T73651. The four different fastener systems included Hi-lok and Hi-tigue fasteners mounted in plain holes, interference fit holes, and cold worked holes. Bending ratio depends slightly on the fastener system used and having a magnitude in the range 0.27 to 0.41. Midpoint supporting increases secondary bending. Load transfer is 49 percent for the single specimen tested with an adequate strain gaging. A large difference in fastener flexibility between Hi-lok and Hi-tigue fasteners is observed. Flexibility ranges from 5.9 to 19.5 mm/MN. ESA

N88-30163# Air Force Inst. of Tech., Wright-Patterson AFB, Ohio. School of Engineering.
AN INVESTIGATION OF CONSTITUTIVE MODELS FOR PREDICTING VISCOPLASTIC RESPONSE DURING CYCLIC LOADING M.S. Thesis
DAVID A. SHAFFER Jun. 1988 95 p
(AD-A194875; AFIT/GAE/AA/87D-21) Avail: NTIS HC A05/MF A01 CSCL 20K
The Air Force's Engine Structural Integrity Program (ENSIP) (Ref 1) requires determination of damage tolerance for jet engine components in order to allow more economical rejection criteria to be adopted. To this end, means have been developed for predicting fatigue crack growth in jet engine components such as turbine disks made of nickel-based superalloys and operating at elevated temperatures. The presence of time-dependent plastic deformation greatly affects crack propagation rates, particularly at elevated temperatures and thus must be accounted for when modelling crack growth in turbine materials. The purpose of this thesis was to investigate the frequency response aspects of the Bodner-Partom constitutive law's behavior and to compare its results with those of other models and to cyclic and non-cyclic uniaxial tensile test data. GRA

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

N88-29258*# Electro Magnetic Applications, Inc., Denver, Colo.
INVESTIGATIONS INTO THE TRIGGERED LIGHTNING RESPONSE OF THE F106B THUNDERSTORM RESEARCH AIRCRAFT
TERENCE H. RUDOLPH, RODNEY A. PERALA, PAUL M. MCKENNA, and STEVEN L. PARKER Washington, D.C. Jun. 1985 215 p
(Contract NAS1-16984)
(NASA-CR-3902; NAS 1.26:3902; EMA-85-R-02) Avail: NTIS HC A10/MF A01 CSCL 04B
An investigation has been conducted into the lightning characteristics of the NASA F106B thunderstorm research aircraft. The investigation includes analysis of measured data from the aircraft in the time and frequency domains. Linear and nonlinear computer modelling has also been performed. In addition, new computer tools have been developed, including a new enhanced nonlinear air breakdown model, and a subgrid model useful for analyzing fine details of the aircraft's geometry. Comparison of measured and calculated electromagnetic responses of the aircraft to a triggered lightning environment are presented. Author

N88-29259*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE 1983 DIRECT STRIKE LIGHTNING DATA, PART 1
MITCHEL E. THOMAS Washington, D.C. Aug. 1985 439 p
(NASA-TM-86426-PT-1; NAS 1.15:86426-PT-1) Avail: NTIS HC A19/MF A01 CSCL 04B
Data waveforms are presented which were obtained during the 1983 direct strike lightning tests utilizing the NASA F106-B aircraft specially instrumented for lightning electromagnetic measurements. The aircraft was operated in the vicinity of the NASA Langley Research Center, Hampton, Virginia, in a thunderstorm environment to elicit strikes. Electromagnetic field data and conduction currents on the aircraft were recorded for attached lightning. Part 1 contains 435 pages of lightning strike data in chart form. Author

N88-29260*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE 1983 DIRECT STRIKE LIGHTNING DATA, PART 2
MITCHEL E. THOMAS Washington, D.C. Aug. 1985 447 p
(NASA-TM-86426-PT-2; NAS 1.15:86426-PT-2) Avail: NTIS HC A19/MF A01 CSCL 04B
Data waveforms are presented which were obtained during the 1983 direct strike lightning tests utilizing the NASA F106-B aircraft specially instrumented for lightning electromagnetic measurements. The aircraft was operated in the vicinity of the NASA Langley Research Center, Hampton, Virginia, in a thunderstorm environment to elicit strikes. Electromagnetic field data and conduction currents on the aircraft were recorded for attached lightning. Part 2 contains 443 pages of lightning strike data in chart form. Author

N88-29261*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
THE 1983 DIRECT STRIKE LIGHTNING DATA, PART 3
MITCHEL E. THOMAS Washington, D.C. Aug. 1985 450 p
(NASA-TM-86426-PT-3; NAS 1.15:86426-PT-3) Avail: NTIS HC A19/MF A01 CSCL 04B
Data waveforms are presented which were obtained during the 1983 direct strike lightning tests utilizing the NASA F106-B aircraft specially instrumented for lightning electromagnetic measurements. The aircraft was operated in the vicinity of the NASA Langley Research Center, Hampton, Virginia, in a

thunderstorm environment to elicit strikes. Electromagnetic field data and conduction currents on the aircraft were recorded for attached lightning. Part 3 contains 446 pages of charts depicting additional lightning strike data. Author

N88-29727*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
A SUMMARY OF ATMOSPHERIC TURBULENCE MEASUREMENTS WITH SPECIALLY-EQUIPPED AIRCRAFT IN THE US
H. N. MURROW *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of the Art in the Description and Modelling of Atmospheric Turbulence 11 p Dec. 1987
Avail: NTIS HC A09/MF A01 CSCL 04B

The technique of measurement of atmospheric turbulence in the form of true gust velocity is summarized. Specific aspects pointed out are related to NASA programs conducted over the last 15 years. Liberal use is made of references for details. Some recommendations resulting from a Spring 1986 workshop on atmospheric turbulence are also presented. Author

N88-29728# Royal Aircraft Establishment, Bedford (England).
MEASUREMENT AND ANALYSIS OF LOW ALTITUDE ATMOSPHERIC TURBULENCE OBTAINED USING A SPECIALLY INSTRUMENTED GNAT AIRCRAFT
G. W. FOSTER and J. G. JONES *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the Art in the Description and Modelling of Atmospheric Turbulence 45 p Dec. 1987
Avail: NTIS HC A09/MF A01

Detailed measurements of atmospheric turbulence made by a specially instrumented Gnat aircraft at altitudes below one thousand feet over a variety of terrains are described. A program of flying yielded about 400 runs for which time histories of the three components of turbulence are available. These runs are analyzed to give parameters which summarize the statistical characteristics of the turbulence encountered. A very strong relationship between two parameters from the Statistical Discrete Gust Analysis technique and one from the Power Spectral Density technique is identified. Author

N88-29734# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
EXTREME GUSTS DISTRIBUTION
GABRIEL COUPRY *In* AGARD, The Flight of Flexible Aircraft in Turbulence: State-of-the-Art in the Description and Modelling of Atmospheric Turbulence 9 p Dec. 1987 In FRENCH; ENGLISH summary Original language document was announced in IAA as A87-44328
Avail: NTIS HC A09/MF A01

A model of extreme atmospheric turbulence is proposed based on 5 years of commercial flight data for events with load factors in encess of 0.5. The Pratt formula is found to lead to incoherent atmospheric descriptions, while the Hall formula, with appropriate choice of scale, is found to lead to a coherent turbulence description which is relatively independent of the type of aircraft considered. For strong turbulences, the average number of overshoots by a nautical mile are found to decrease exponentially with gust amplitude. The incidences of gusts exceeding a threshold value are found to obey a Poisson distribution whose mean decreases exponentially with amplitude, indicating that the probability of the occurrence of big gusts can be represented by Gumbel's extreme value theory. Author

N88-30266*# National Aeronautics and Space Administration, Washington, D.C.
A DIGITAL SIMULATION TECHNIQUE FOR THE DRYDEN ATMOSPHERIC MODEL
ZHENYAN ZHAO, YELUN XIAO, and YIJIAN SHI Aug. 1988 20 p Transl. into ENGLISH from Acta Aeronautica et Astronautica Sinica (Peoples Republic of China), v. 7, no. 5, Oct. 1986 p 433-443 Original language document was announced in IAA as A87-24715 Transl. by SCITRAN, Inc., Santa Barbara, Calif. Original document was prepared by Beijing Inst. of Aeronautics and Astronautics (Peoples Republic of China)
(Contract NASW-4307)
(NASA-TT-20342; NAS 1.77:20342) Avail: NTIS HC A03/MF A01 CSCL 04B

The Dryden model is usually used in studying the response of flight vehicles to atmospheric turbulence. For a modern flight simulator, it is necessary to generate random winds (in Dryden model or sometimes others) with a digital computer. A theoretically strict new method to meet this purpose is proposed. By this method, a three dimensional atmospheric turbulence can be obtained which contains three components of wind velocity and three components of wind velocity gradient. The reliability of this method is checked by comparing the theoretical autocorrelation value. A numerical example has shown a satisfactory result. Finally, some proposals concerning the use of this mathematical model in a flight simulator are given. Author

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MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A88-52823
PREDICTION OF THE EXTREME VALUES OF THE PHASE COORDINATES OF STOCHASTIC SYSTEMS [PROGNOZIROVANIE EKSTREMAL'NYKH ZNACHENII FAZOVYKH KOORDINAT STOKHASTICHESKIKH SISTEM]
A. N. BALABUSHKIN and F. B. GUL'KO Avtomatika i Telemekhanika (ISSN 0005-2310), June 1988, p. 70-77. In Russian. refs

The paper is concerned with the problem of estimating the minimum (maximum) value of a coordinate of a linear dynamic object along the path of its further motion, with allowance made for small stochastic perturbations. It is shown how such estimates can be used for the control of systems with constraints on the phase coordinates. An example of such an application is the prediction of the minimum altitude during a second approach to landing. V.L.

A88-53631#
MULTIPLE FRAME RATE INTEGRATION
A. HARALDSDOTTIR (Applied Dynamics International, Ann Arbor, MI) and R. M. HOWE (Michigan, University, Ann Arbor) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 26-35. refs
(AIAA PAPER 88-4579)

The multiple frame-rate method is introduced, including techniques for converting slow data sequence outputs from slow subsystems to fast data sequence inputs for fast systems. The suitability of various integration algorithms for multiple framing is discussed. The implementation of multiple frame-rate integration using the simulation language ADSIM for the AD 100 computer is described, including sofware which allows, without program recompiling, choice of multiple-frame ratios and choice of different interpolation or extrapolation algorithms for slow-to-fast system interfacing. The paper concludes with an example of multiple framing applied to the simulation of a combined air frame and flight control system in order to improve both the accuracy and stability of the simulation. Author

A88-53637#
ARTIFICIAL INTELLIGENCE SYSTEMS FOR AIRCRAFT TRAINING - AN EVALUATION
THOMAS G. HOLZMAN and ROBERT W. PATTERSON (Lockheed Aeronautical Systems Co., Marietta, GA) IN: AIAA, Flight

Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 73-81.
(AIAA PAPER 88-4588)

This paper summarizes aircraft operation and maintenance training problems and suggests how they might be remedied through intelligent computer-assisted instruction (ICAI). The paper focuses on a rigorous evaluation methodology designed to facilitate selection of the best artificial intelligence (AI) system for meeting an organization's ICAI needs. A recent application of this methodology revealed that at least a half dozen AI system possessed the majority of features identified as conducive to good maintenance training. However, no candidate system excelled on all dimensions of value to ICAI. Widespread deficiencies were noted in the areas of interactive videodisc and authoring systems. Trade-offs in features were found between two major classes of computers, known as general purpose work-stations and LISP machines. Author

A88-53654*# Psycho-Linguistic Research Associates, Menlo Park, Calif.
SMART COMMAND RECOGNIZER (SCR) - FOR DEVELOPMENT, TEST, AND IMPLEMENTATION OF SPEECH COMMANDS
CAROL A. SIMPSON (Psyco-Linguistic Research Associates, Woodside, CA), JOHN W. BUNNELL (NASA, Ames Research Center; SYRE, Inc., Moffett Field, CA), and ROBERT R. KRONES (Sterling Software, Informatics Div., Palo Alto, CA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 215-221. refs
(Contract NAS2-12425; NAS2-11555; NAS2-11631)
(AIAA PAPER 88-4612)

The SCR, a rapid prototyping system for the development, testing, and implementation of speech commands in a flight simulator or test aircraft, is described. A single unit performs all functions needed during these three phases of system development, while the use of common software and speech command data structure files greatly reduces the preparation time for successive development phases. As a smart peripheral to a simulation or flight host computer, the SCR interprets the pilot's spoken input and passes command codes to the simulation or flight computer. K.K.

A88-53671#
SOME BENEFITS OF DISTRIBUTED COMPUTING ARCHITECTURES FOR TRAINING SIMULATORS
WILLIAM B. FORBES and JEFFREY B. KAUFFMAN (Digital Equipment Corp., Marlboro, MA) IN: AIAA, Flight Simulation Technologies Conference, Atlanta, GA, Sept. 7-9, 1988, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 354-360.

It is shown that using real-time accelerator (RTA) processors to handle the I/O processing requirements of an avionics simulation application can produce substantial improvements in the predictability of system performance. The RTA is a small low-cost processor running a low overhead real-time system kernel; it is well suited as a dedicated processor for low-level time-critical tasks. The RTA processors are true general-purpose processors in that they are programmable in high-level languages, they are multitasking, and they conform to a well-established processor architecture. K.K.

A88-53876
A PROBLEM OF OPTIMAL CONTROL WITH CONSTRAINTS ON THE COORDINATES OF THE CENTER OF MASS [OB ODNOI ZADACHE OPTIMAL'NOGO UPRAVLENIIA PRI OGRANICHENIIAKH NA KOORDINATY TSENTRA MASS]
V. G. GIURDZHIEV and M. T. SAKSONOV (Dushanbinskii Gosudarstvennyi Pedagogicheskii Institut, Dushanbe, Tadzhik SSR) Akademiia Nauk Tadzhikskoi SSR, Doklady (ISSN 0002-3469), vol. 31, no. 2, 1988, p. 79-82. In Russian.

Consideration is given to the motion of a flight vehicle in the vertical plane under the effect of gravity, thrust force, and aerodynamic lift and drag forces. A criterion for the optimal control of the vehicle with constraints on the center-of-mass coordinates is established. B.J.

A88-54202*# Texas A&M Univ., College Station.
ACTIVE CONTROL OF TRANSIENT ROTORDYNAMIC VIBRATION BY OPTIMAL CONTROL METHODS
A. B. PALAZZOLO, R. R. LIN, R. M. ALEXANDER (Texas A & M University, College Station), and A. F. KASCAK (NASA, Lewis Research Center, Cleveland, OH) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 8 p. Research supported by Texas A & M University. refs
(Contract NAG3-763)
(ASME PAPER 88-GT-73)

Although considerable effort has been put into the study of steady state vibration control, there are few methods applicable to transient vibration control of rotorbearing systems. In this paper optimal control theory has been adopted to minimize rotor vibration due to sudden imbalance, e.g., blade loss. The system gain matrix is obtained by choosing the weighting matrices and solving the Riccati equation. Control forces are applied to the system via a feedback loop. A seven mass rotor system is simulated for illustration. A relationship between the number of sensors and the number of modes used in the optimal control model is investigated. Comparisons of responses are made for various configurations of modes, sensors, and actuators. Furthermore, spillover effect is examined by comparing results from collocated and noncollocated sensor configurations. Results show that shaft vibration is significantly attenuated in the closed loop system. Author

A88-54426
RULE-BASED MECHANISMS OF LEARNING FOR INTELLIGENT ADAPTIVE FLIGHT CONTROL
ROBERT F. STENGEL (Princeton University, NJ) and DAVID A. HANDELMAN IN: 1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, 1988, p. 208-213. refs
(Contract DAAG29-84-K-0048)

The authors investigate how certain aspects of human learning can be used to characterize learning in intelligent adaptive control systems. Reflexive and declarative memory and learning are described. It is shown that model-based systems-theoretic adaptive control methods exhibit attributes of reflexive learning, whereas the problem-solving capabilities of knowledge-based systems of artificial intelligence are naturally suited for implementing declarative learning. Issues related to learning in knowledge-based control systems are addressed, with particular attention given to rule-based systems. A mechanism for real-time rule-based knowledge acquisition is suggested, and utilization of this mechanism within the context of failure diagnosis for fault-tolerant flight control is demonstrated. I.E.

N88-29313# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Fluid Dynamics Panel.
THREE DIMENSIONAL GRID GENERATION FOR COMPLEX CONFIGURATIONS: RECENT PROGRESS
JOSEPH F. THOMPSON, J. L. STEGER, and H. YOSHIHARA, ed. (Boeing Military Airplane Development, Seattle, Wash.) Mar. 1988 162 p
(AGARD-AG-309; ISBN-92-835-0451-8; AD-A196776) Avail: NTIS HC A08/MF A01

Some of the capabilities of the Computational Fluid Dynamics (CFD) community are surveyed for griding complex three dimensional configurations. The intent is to provide some insight as to the present state of grid generation for aircraft configurations in order to help assess whether this task presents a long term stumbling block to routine use of CFD in aerodynamic applications. A brief review is given of some of the techniques that are available for generating body conforming curvilinear grids. In order to assess capabilities in grid generation, colleagues at selected institutions were solicited to describe their experiences and difficulties in grid generation of complex configurations.

N88-29314# Boeing Military Airplane Development, Seattle, Wash.
LESSONS LEARNED IN THE MESH GENERATION FOR PN/S CALCULATIONS
H. YOSHIHARA *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 15-22 Mar. 1988
Avail: NTIS HC A08/MF A01

Experiences encountered in the 2D mesh generation with the elliptic differential equation method are described for the parabolized Navier-Stokes calculations over a generic fighter at a supersonic Mach number and for a wing/fuselage at hypersonic Mach numbers. Importance of the mesh quality is stressed, and the need of an improved cost effective treatment of the shocks is pointed out. Author

N88-29315*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, Calif.
THREE-DIMENSIONAL ELLIPTIC GRID GENERATION FOR AN F-16
REESE L. SORENSON *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 23-28 Mar. 1988
Avail: NTIS HC A08/MF A01 CSCL 09B

A case history depicting the effort to generate a computational grid for the simulation of transonic flow about an F-16 aircraft at realistic flight conditions is presented. The flow solver for which this grid is designed is a zonal one, using the Reynolds averaged Navier-Stokes equations near the surface of the aircraft, and the Euler equations in regions removed from the aircraft. A body conforming global grid, suitable for the Euler equation, is first generated using 3-D Poisson equations having inhomogeneous terms modeled after the 2-D GRAPE code. Regions of the global grid are then designated for zonal refinement as appropriate to accurately model the flow physics. Grid spacing suitable for solution of the Navier-Stokes equations is generated in the refinement zones by simple subdivision of the given coarse grid intervals. That grid generation project is described, with particular emphasis on the global coarse grid. Author

N88-29316# Aircraft Research Association Ltd., Bedford (England).
COMPONENT ADAPTIVE GRID GENERATION FOR AIRCRAFT CONFIGURATIONS
N. P. WEATHERILL and J. A. SHAW *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 29-39 Mar. 1988
Avail: NTIS HC A08/MF A01

A method is presented which is capable of generating component adaptive grids. The approach is illustrated using wing-body-canard geometries but is applicable to a wide range of complex aerodynamic configurations. The new method of topology generation, combined with the approach taken to grid control, provide a powerful means of exploring the most suitable topology for a given geometry. Grid control parameters are available to the user to modify the grids for particular geometries but the system does not require the user to partake in long interactive sessions on a workstation to generate grids. The suitability of the component adaptive grids for flow simulation is demonstrated by comparing theoretical predictions with experiment. Author

N88-29317# General Dynamics Corp., Fort Worth, Tex.
GENERATION OF MULTIPLE BLOCK GRIDS FOR ARBITRARY 3D GEOMETRIES
J. P. STEINBRENNER, S. L. KARMAN, JR., and J. R. CHAWNER *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 40-55 Mar. 1988
Avail: NTIS HC A08/MF A01

A grid generation procedure was developed to create complex block grid systems, beginning with the generation of block surfaces, up to the generation of the full block volume grids. The multiple block concept is shown to facilitate the gridding of very complex geometries and also to allow larger sized grids to be run with a multiple block Euler solver. The entire grid generation process is broken into logical steps, each step is described in detail. Three examples of grid systems generated with these techniques are given, thereby validating the procedure. Finally, current research topics in grid generation and future plans are discussed. Author

N88-29318*# National Aeronautics and Space Administration. Langley Research Center, Hampton, Va.
GRID GENERATION ON AND ABOUT A CRANKED-WING FIGHTER AIRCRAFT CONFIGURATION
ROBERT E. SMITH, JOAN I. PITTS, LARS-ERIK ERIKSSON, and MICHAEL R. WIESE (Computer Sciences Corp., Hampton, Va.) *In* AGARD, Three Dimensional Grid Generation for Complex Configuration: Recent Progress p 56-64 Mar. 1988
Avail: NTIS HC A08/MF A01 CSCL 09B

Experiences at the NASA Langley Research Center generating grids about a cranked wing fighter aircraft configuration is described. A single block planar grid about the fuselage and canard used with a finite difference Navier-Stokes solver is also described. A dual block nonplanar grid about the complete configuration and used with a finite volume Euler solver is presented. The very important aspect of computing the aircraft surface grid, starting with a standardized model description, is also presented. Author

N88-29319# Messerschmitt-Boelkow G.m.b.H., Munich (West Germany). Helicopter and Military Aircraft Group.
GRID GENERATION FOR AN ADVANCED FIGHTER AIRCRAFT
A. EBERLE and W. SCHWARZ *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 65-76 Mar. 1988
Avail: NTIS HC A08/MF A01

The grid generation process for a realistic and complex fighter type aircraft is described. The method is based on the solution of biharmonic equations and uses a single block concept. Only a few user specified input parameters are necessary for the construction of the space grid and therefore this grid generation system is very simple to handle. The grid is intended for calculations with an Euler code at transonic and supersonic speeds. Author

N88-29320# Tennessee Univ. Space Inst., Tullahoma. Dept. of Engineering Science and Mechanics.
ALGEBRAIC GRID GENERATION FOR FIGHTER TYPE AIRCRAFT
JOHN STEINHOFF *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 77-84 Mar. 1988
Avail: NTIS HC A08/MF A01

A systematic procedure is presented for synthesizing a complex computational grid for fighter type aircraft out of a number of simpler elementary grids. This method is useful when a grid is required over an object which, though complex, consists of a number of simpler pieces, such as an aircraft with a number of lifting surfaces. The procedure presented allows a smooth complex grid to be generated which becomes exactly equal to each elementary grid as the surface corresponding to that elementary grid is approached. In this way, methods which may have previously been developed for each piece do not have to be changed and can be used as black boxes, whether they are algebraic, partial differential equation based, or whether the grids are just given numerically. This blending technique is only one of several tools which was used to generate effective grids. Other techniques include projection methods for generating surface grids. Some advantages and limitations of the method are discussed and examples are given of its use in generating complex fighter grids. Author

N88-29321# Mississippi State Univ., Mississippi State. Dept. of Aerospace Engineering.
COMPOSITE GRID GENERATION FOR AIRCRAFT CONFIGURATIONS WITH THE EAGLE CODE

JOE F. THOMPSON and LAWRENCE E. LIJEWSKI (Air Force Armament Lab., Eglin AFB, Fla.) *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 85-95 Mar. 1988
Avail: NTIS HC A08/MF A01

A general three dimensional grid generation code based on a composite block structure is discussed. The code can operate either as an algebraic generation system or as an elliptic generation system. Provision is made for orthogonality at boundaries and complete continuity at block interfaces. The code can operate in two or three dimensions, or on a curved surface. The input is structured to be user oriented, and arbitrary block configurations can be treated. Author

N88-29322# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (West Germany). Inst. for Theoretical Fluid Mechanics.
ANALYTICAL SURFACES AND GRIDS
HELMUT SOBIECZKY *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 96-105 Mar. 1988
Avail: NTIS HC A08/MF A01

The use of analytical shape generation is described for wing-body configurations and flow boundary conditions. Flexibility in geometry definition allows for simple computational grid interpolation. A test case for experiment and code validation is illustrated. Author

N88-29323# Dornier-Werke G.m.b.H., Friedrichshafen (West Germany). Theoretical Aerodynamics.
MESH GENERATION FOR INDUSTRIAL APPLICATION OF EULER AND NAVIER STOKES SOLVERS
W. FRITZ, W. HAASE, and W. SEIBERT *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 106-123 Mar. 1988
Avail: NTIS HC A08/MF A01

A considerable increase has been made in recent years in the ability to compute flow fields about three dimensional configurations. In order to reach their full potential, robust grid generation techniques for complicated aerodynamic configurations must be developed. Three different methods are presented which can be characterized as automatic grid generation for complete aircraft configurations, completely interactive grid generation and generation of solution adaptive grids for Navier-Stokes calculations. Although all the presented grid generation techniques use only elliptical grid generation, they show already that there is no unique grid generation technique. E.R.

N88-29324# Calspan Field Services, Inc., Arnold AFS, Tenn.
EXPERIENCE WITH THREE DIMENSIONAL COMPOSITE GRIDS
J. A. BENEK, T. L. DONEGAN, and N. E. SUHS *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 124-138 Mar. 1988 Previously announced as N87-26021
Avail: NTIS HC A08/MF A01

Experience with the three dimensional, chimera grid embedding scheme is described. Applications of the inviscid version to a multiple body configuration, a wing-body-tail configuration, and an estimate of wind tunnel wall interference are described. Applications to viscous flows include a 3-D cavity and another multi-body configuration. A variety of grid generators is used, and several embedding strategies are described. Author

N88-29325# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany). Inst. fuer Entwurfsaerodynamik.
GRID GENERATION AROUND TRANSPORT AIRCRAFT CONFIGURATIONS USING A MULTI-BLOCK STRUCTURED COMPUTATIONAL DOMAIN
R. RADESPIEL *In* AGARD, Three Dimensional Grid Generation for Complex Configurations: Recent Progress p 139-153 Mar. 1988
Avail: NTIS HC A08/MF A01

A new grid generation code is described which is based on the multi-block approach. Grid generation around 3-D configurations is divided into 3 major parts, namely, surface definition, surface grid generation and field grid generation. Coons' patches are used to define the surfaces and their intersection lines. Surface grids and field grids are generated using the numerical solution of an elliptic system. An effective means for the control of the grid spacing was developed which is based on an iterative determination of the source terms in the elliptic system. The code is used to generate grids around a wing-body combination and a high bypass nacelle configuration. Author

N88-29337# Naval Postgraduate School, Monterey, Calif.
FEASIBILITY STUDY OF A MICROPROCESSOR CONTROLLED ACTUATOR TEST MECHANISM M.S. Thesis
GREGORY L. GOODE Mar. 1988 102 p
(AD-A194654) Avail: NTIS HC A06/MF A01 CSCL 12F

This thesis describes the investigation of the feasibility of using a commercially available microcomputer to control and test a missile fin actuator. Topics discussed include system modelling, automated data acquisition, system identification, simulation and controller design. Modularity, both functional and conceptual, is stressed in the design process as well as integration of modules during the modelling and simulation process. Verification of the computer simulation is used extensively as an interactive tool to modify the system model. The hybrid system under investigation contains analog and discrete components, some of which are both nonlinear and discontinuous. The use of digital systems, their limitations and advantages are highlighted in the modelling of these components and the development of a control system
Author (GRA)

N88-29489*# George Washington Univ., Hampton, Va.
TWO BIASED ESTIMATION TECHNIQUES IN LINEAR REGRESSION: APPLICATION TO AIRCRAFT
VLADISLAV KLEIN Jul. 1988 41 p
(NASA-TM-100649; NAS 1.15:100649) Avail: NTIS HC A03/MF A01 CSCL 12A

Several ways for detection and assessment of collinearity in measured data are discussed. Because data collinearity usually results in poor least squares estimates, two estimation techniques which can limit a damaging effect of collinearity are presented. These two techniques, the principal components regression and mixed estimation, belong to a class of biased estimation techniques. Detection and assessment of data collinearity and the two biased estimation techniques are demonstrated in two examples using flight test data from longitudinal maneuvers of an experimental aircraft. The eigensystem analysis and parameter variance decomposition appeared to be a promising tool for collinearity evaluation. The biased estimators had far better accuracy than the results from the ordinary least squares technique. Author

N88-30378# Mississippi State Univ., Mississippi State. Dept. of Aerophsyics and Aerospace Engineering.
GENERATION OF SURFACE GRIDS THROUGH ELLIPTIC PARTIAL DIFFERENTIAL EQUATIONS FOR AIRCRAFT AND MISSILE CONFIGURATIONS Final Report, Jun. 1987 - Mar. 1988
Z. U. WARSI 16 May 1988 27 p
(Contract AF-AFOSR-0143-85)
(AD-A195639; ASE-88-6; AFOSR-88-0636TR) Avail: NTIS HC A03/MF A01 CSCL 12A

The main aim of the project was to develop a set of partial differential equations which are the most optimum for the generation of grid lines in arbitrary surfaces. Equations have been developed on the basis of differential-geometric concepts which are elliptic in character and look to be the most optimum among the class of equations which can be used to generate the surface coordinates. The developed equations require a specification of the forcing function which depends on the geometry of the given surface. The surface in which the coordinates are to be introduced is usually given in discrete data form. Methods have been developed which fit a function over the given data to evaluate the forcing function for complicated shapes, e.g., an airplane, the functional fit and the eventual grid generation for the fuselage and wings are done separately and then integrated to obtain the grid lines on the surface. GRA

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PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

N88-29514*# Duke Univ., Durham, N. C. Dept. of Mechanical Engineering and Materials Science.
ASYMPTOTIC MODAL ANALYSIS AND STATISTICAL ENERGY ANALYSIS Progress Report, 15 Oct. 1987 - 14 Apr. 1988
EARL H. DOWELL 21 Jul. 1988 110 p
(Contract NAG1-709)
(NASA-CR-183077; NAS 1.26:183077) Avail: NTIS HC A06/MF A01 CSCL 20A

Statistical Energy Analysis (SEA) is defined by considering the asymptotic limit of Classical Modal Analysis, an approach called Asymptotic Modal Analysis (AMA). The general approach is described for both structural and acoustical systems. The theoretical foundation is presented for structural systems, and experimental verification is presented for a structural plate responding to a random force. Work accomplished subsequent to the grant initiation focusses on the acoustic response of an interior cavity (i.e., an aircraft or spacecraft fuselage) with a portion of the wall vibrating in a large number of structural modes. First results were presented at the ASME Winter Annual Meeting in December, 1987, and accepted for publication in the Journal of Vibration, Acoustics, Stress and Reliability in Design. It is shown that asymptotically as the number of acoustic modes excited becomes large, the pressure level in the cavity becomes uniform except at the cavity boundaries. However, the mean square pressure at the cavity corner, edge and wall is, respectively, 8, 4, and 2 times the value in the cavity interior. Also it is shown that when the portion of the wall which is vibrating is near a cavity corner or edge, the response is significantly higher. Author

N88-29520# Aeronautical Research Inst. of Sweden, Stockholm. Structures Dept.
ANALYSIS OF THE TRANSMISSION OF SOUND INTO THE PASSENGER COMPARTMENT OF A PROPELLER AIRCRAFT USING THE FINITE ELEMENT METHOD
PETER GORANSSON Mar. 1988 16 p Presented at the 3rd International Conference on Advances in Structural Dynamics, Southampton, England, Jul. 1988
(Contract FFA-STU-HU-2812)
(FFA-TN-1988-15; ETN-88-92809) Avail: NTIS HC A03/MF A01

The double wall construction of an aircraft cabin was analyzed to see if sound transmission phenomena found in experiments can be reproduced. The eigenvalues and eigenmodes of the plane cross section were calculated, with and without the inner trim pannels, emphasizing the effects of different attachment of the trim panels to the frames and also of the weight and stiffness of the trim panels. The calculated modes were used to calculate the sound levels arising from an external pressure field acting on the outer shell. The analysis is performed with the finite element system ASKA-acoustics. The intervention between the structural parts and the fluid in the different cavities is modeled with a symmetric coupling formulation with pressure and displacement potential as fluid degrees of freedom. The acoustic field is modeled with special acoustic finite elements and the coupling to the structure is handled with interface elements. Analysis of an aircraft cross section shows that the transmission of low frequency sound is strongly dependent on the dynamics of the fuselage-air-trim-air system. The maximum SPL may vary from 123 down to 118 dB in the extreme cases where only attachment and density of the trim panel are changed. The results also show that a porous absorbent in the air space may give an additional decrease down to a maximum of 114 dB by carefully tuning the mass density of the porous material. ESA

N88-29523# Southampton Univ. (England). Inst. of Sound and Vibration Research.
A COMPARISON OF SIMPLE ANALYTICAL MODELS FOR REPRESENTING PROPELLER AIRCRAFT STRUCTURAL AND ACOUSTIC RESPONSES
A. J. BULLMORE Feb. 1988 127 p Sponsored by the Department of Trade and Industry, London, England
(ISVR-TR-153; ETN-88-92824) Avail: NTIS HC A07/MF A01

The effectiveness of active noise control applied to reduce the internal sound pressure levels in the cabin of propeller driven aircraft, specifically the BAe 748 aircraft, was examined. The model is required only to produce results for frequencies below 200 Hz, the range of the greatest effectiveness of the noise control system. The chosen model consists of a finite aluminum cylinder, 16 m long, 1.3 m radius, with a structural damping factor of 0.3. It is excited by an external pressure field. The internal acoustic field is modeled by a cylindrical room acoustics model excited by the normal vibrations of the shell wall, but only over a region extending from z=1.5 to 12.5 m, and from theta = 60 to 300 deg. The cylindrical room is assumed to have the same length and radius as the structural cylinder model. ESA

N88-29524 National Physical Lab., Teddington (England). Div. of Radiation Science and Acoustics.
NOISE LEVELS FROM A JET-ENGINED AIRCRAFT MEASURED AT GROUND LEVEL AND AT 1.2 M ABOVE THE GROUND
R. C. PAYNE Jan. 1988 42 p
(NPL-AC-114; ISSN-0143-7143; ETN-88-93141) Avail: National Physics Laboratory, Teddington, Middlesex, TW11 0LW, United Kingtom

During flight tests using a British Aerospace HS125-700, noise measurements were obtained using microphones close to the ground plane and at a height of 1.2 m. Substantial differences from ground level to 1.2 m in measurements of perceived noise level and effective perceived noise level were observed. The differences depend on ground cover and flight maneuver. The ground-plane microphones generally produce noise levels which closely approximate pressure-doubled values. A procedure for correcting 1/3-octave band sound pressure levels measured 1.2 m above the ground, to obtain pressure-doubled levels, was examined. The procedure is successful when used in adjustments of perceived noise levels but, because of inaccurate estimates of duration corrections, is less suitable in the case of effective perceived noise level, especially for aircraft in approach to landing. It is concluded that to avoid significant variations in measured noise levels measurements should be made using a ground-plane microphone. ESA

N88-30398# Aeronautical Research Labs., Melbourne (Australia).
THE DEVELOPMENT OF ACOUSTIC EMISSION FOR STRUCTURAL INTEGRITY MONITORING OF AIRCRAFT
C. M. SCALA, S. J. BOWLES, and L. G. SCOTT Jan. 1988 35 p
(AD-A196264; ARL/MAT-R-120; DODA-AR-004-585) Avail: NTIS HC A03/MF A01 CSCL 14B

This paper reviews procedures for distinguishing between acoustic emission (AE) from fatigue crack propagation and from spurious sources in aircraft applications. Particular emphasis is placed on the development of procedures applicable during AE monitoring of complex-shaped components. First, procedures to eliminate extraneous sources are evaluated, including the use of guard sensors and source location systems. The capabilities of additional signal-processing (which in principle can range from adaptive to non-adaptive) for identifying and locating AE from fatigue crack propagation are then evaluated. The problems in applying adaptive processing are illustrated by AE results from a Macchi aircraft in-flight and Mirage aircraft during full-scale fatigue testing. The ARL development of semi-adaptive processing based on background research on AE sources, sensors, calibration and other techniques is described. Successful application of this processing to the Mirage test above is then detailed, and the value of using reduced adaptation in processing is demonstrated. GRA

N88-30399*# Planning Research Corp., Hampton, Va. System Services.
AIRCRAFT NOISE PREDICTION PROGRAM PROPELLER ANALYSIS SYSTEM IBM-PC VERSION USER'S MANUAL VERSION 2.0
SANDRA K. NOLAN Aug. 1988 236 p
(Contract NAS1-18000)
(NASA-CR-181689; NAS 1.26:181689) Avail: NTIS HC A11/MF A01 CSCL 20A

The IBM-PC version of the Aircraft Noise Prediction Program (ANOPP) Propeller Analysis System (PAS) is a set of computational programs for predicting the aerodynamics, performance, and noise of propellers. The ANOPP-PAS is a subset of a larger version of ANOPP which can be executed on CDC or VAX computers. This manual provides a description of the IBM-PC version of the ANOPP-PAS and its prediction capabilities, and instructions on how to use the system on an IBM-XT or IBM-AT personal computer. Sections within the manual document installation, system design, ANOPP-PAS usage, data entry preprocessors, and ANOPP-PAS functional modules and procedures. Appendices to the manual include a glossary of ANOPP terms and information on error diagnostics and recovery techniques. Author

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SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

A88-53788
USE OF A DETAIL COST MODEL TO PERFORM CONCEPTUAL PHASE COST ANALYSIS
PAUL SCHWARTZ (Grumman Corp., Aircraft Systems Div., Bethpage, NY) SAWE, Annual Conference, 46th, Seattle, WA, May 18-20, 1987. 13 p.
(SAWE PAPER 1784)

A detail cost model which can be used in cost analysis and at higher levels of the work breakdown structure is examined. The model was developed to perform cost versus system parameter evaluations early in the design cycle. The use of up-front parametric models, the costing concept of this model, and calibrating the model against development costs are discussed. The model is compared with other development cost models with good results. The model does not include elements such as flight test in its development costs. R.B.

A88-54365#
THE CFM56 ENGINE FAMILY - AN INTERNAL DEVELOPMENT
L. M. SPENCE (CFM International, Inc., Cincinnati, OH) and GEORGES SANGIS (CFM International, S.A., Paris, France) ASME, Gas Turbine and Aeroengine Congress and Exposition, Amsterdam, Netherlands, June 6-9, 1988. 7 p.
(ASME PAPER 88-GT-296)

The joint effort by General Electric of the United States and Societe Nationale d'Etude et de Construction de Moteurs d'Aviation (SNEGMA) of France to develop the CFM56 turbofan engine family is described. In particular, attention is given to the organization of the joint company, CFM International, current status of the CFM56 program, and commercial and military product support. The discussion also covers quality assurance, component improvement program, and configuration management. V.L.

N88-30471# Army War Coll., Carlisle Barracks, Pa.
CHINA'S ACQUISITION AND USE OF FOREIGN AVIATION TECHNOLOGY
MARY VONBRIESEN 30 Mar. 1988 26 p
(AD-A194827) Avail: NTIS HC A03/MF A01 CSCL 05D

Following the establishment of diplomatic relations between the United States and the People's Republic of China in 1979, many people in both countries looked forward to the rapid transfer of technology between the two countries. On the Chinese side, the hopes were to modernize rapidly, leapfrogging the slow development process followed by most other nations. For their part, many Americans saw not only a potential market of over one billion but also a chance to play the China card against the Soviet Union. This study focuses on China's acquisition and use of foreign technology in the aviation industry, pointing out the patterns of Chinese behavior in these transactions. GRA

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GENERAL

A88-53773#
FLIGHT TESTING OF FIGHTERS DURING THE WORLD WAR II ERA
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An account is given of the features of three typical flight test programs conducted by Allied countries during World War II: (1) at NACA-Langley, for the P-51; (2) at San Diego, for a repaired A6M2 'Zero' fighter captured after a crash landing in the Aleutians and flown in simulated combat against the F4F-4 USN carrier fighter and the P-51A USAAF fighter; and (3) for the FW-190A-3 at RAE-Farnborough. Attention is given to the quantitative results of comparative studies of roll capability for the various fighters tested. O.C.

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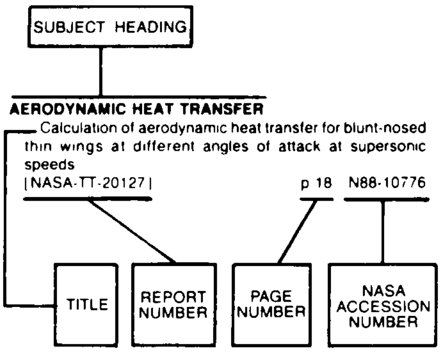

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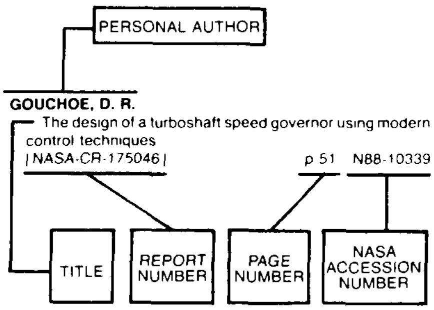

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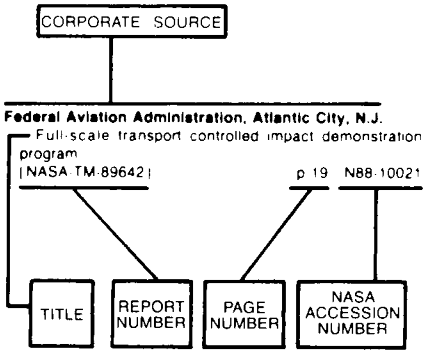

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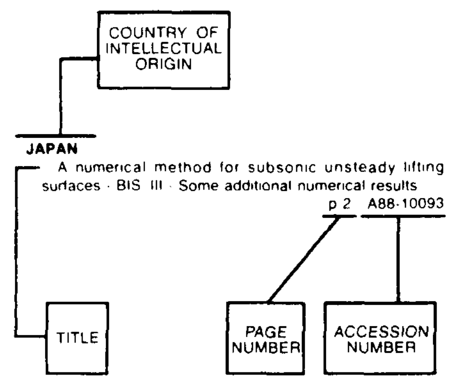

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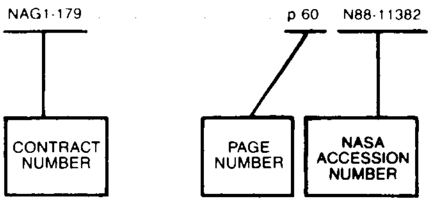

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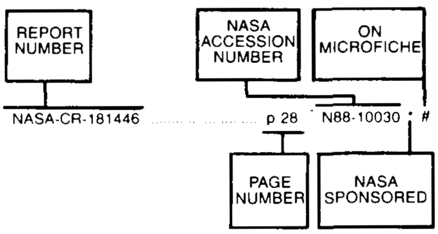

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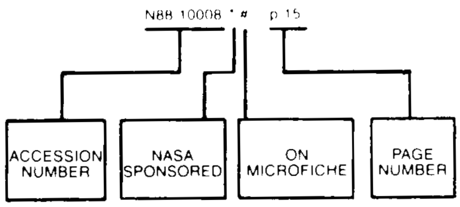

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