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November 1991

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

NASA STI PROGRAM
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National Aeronautics and Space Administration
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INTRODUCTION

This issue of *Aeronautical Engineering—A Continuing Bibliography* (NASA SP-7037) lists 666 reports, journal articles, and other documents originally announced in October 1991 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA).*

Accession numbers cited in this issue are:

STAR (N-10000 Series)	N91-27120 — N91-29138
IAA (A-10000 Series)	A91-44485 — A91-48444

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 publication 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.

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

A cumulative index for 1991 will be published in early 1992.

Information on availability of documents listed, addresses of organizations, and NTIS price schedules are located at the back of this issue.

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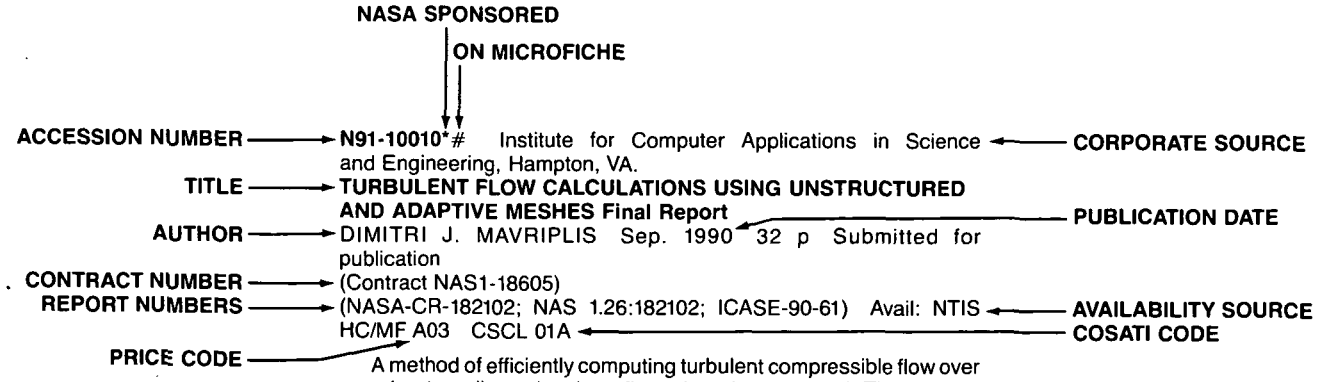
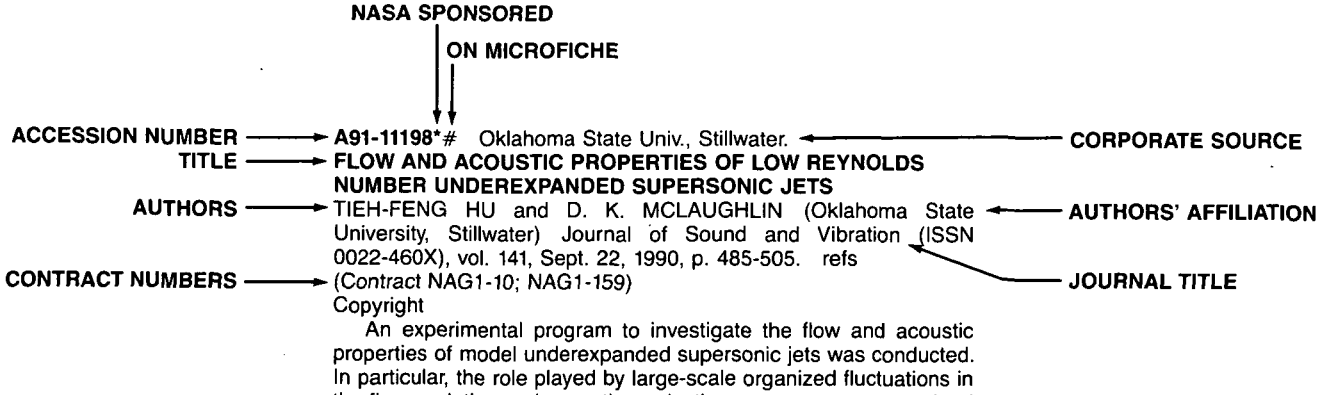
TYPICAL REPORT CITATION AND ABSTRACT



TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 271)

NOVEMBER 1991

01

AERONAUTICS (GENERAL)

A91-44603#
STEALTH AIRCRAFT - HISTORY, TECHNOLOGY AND OUTLOOK
BILL SWEETMAN (Jane's Information Group, Alexandria, VA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs (ASME PAPER 90-GT-172)

A development history and current status evaluation is presented for U.S. stealth aircraft programs; attention is given to the ways in which experience with the SR-71 influenced design practices evident in the F-117A stealth fighter and the B-2 stealth bomber, as well as the Navy A-12 and USAF F-22 and F-23 designs. Stealth technologies are also a major factor in the LHX attack helicopter, which like the stealth fighters and bomber will make use of internal weapons carriage in association with radar-absorbent surface materials to minimize radar reflectivity. It is argued that stealth, in virtue of being the integration of numerous techniques for IR emission and radar echo minimization, cannot be defeated by a single countermeasure technology. O.C.

A91-45399#
INTEGRATED LOGISTIC SUPPORT IN THE NH90 PROJECT
H. VAN DEVENTER (Royal Netherlands Navy, The Hague) and PROVO KLUIT (Fokker Aircraft, Amsterdam, Netherlands) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p.

The purpose of the study is to justify the principle of integrated logistic support (ILS) and show its implementation in the NATO Helicopter for the 1990s (NH90) program. It is pointed out that ILS requires close cooperation of design, operational user, and maintenance areas; this 'triangle' consultation should be established prior to the definition of design requirements and continue through the total life cycle of the system. Emphasis is placed on system reliability, availability, maintainability, and testability at the start of the conceptual design phase. It is noted that in-service costs form a major part of the system life cycle costs and therefore, is an attractive area of cost reduction. Attention is given to logistic reviews to be conducted by national and international working groups as an effective instrument for providing a better understanding between designers and logisticians. V.T.

A91-45401#
CREW AND COCKPIT EQUIPMENT FOR NOE NIGHT FLIGHT - PRACTICAL SOLUTIONS AS SEEN BY AEROSPATIALE
B. FOUQUES (Aerospatiale, Division Helicopteres, Marignane, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 9 p.

Extreme illumination ranges for different external conditions in daytime and nighttime are outlined along with the estimated average occurrence of different nighttime brightness categories. The photopic and scotopic characteristics and performance of the human eye are analyzed along with the principal types of electromagnetic radiation, light intensification, and thermal imaging. The use of the third-generation night-vision goggles and night-vision compatibility issues associated with cockpit visibility and equipment and interior/exterior lighting are covered. Solutions proposed by Aerospatiale, including ultraviolet cockpit lighting, fluorescent yellow paint for basic markings on certain instruments in addition to the standard color markings, and night-vision compatible interior and exterior lighting are considered. V.T.

A91-45402#
ESCORT HELICOPTER (BSH) CONCEPT AND OPERATIONAL ASPECTS
H.-J. SCHIROP (BMVg, Bonn, Federal Republic of Germany) and B. BEHRINGER (MBB GmbH, Munich, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 33 p.

The concept of air-mobile forces capable of reacting to changing situations quickly, concentrating over major distances, and shifting their concentrations during crises and war is reviewed, and the concept of escort helicopters providing the guarantee of active protection during missions is outlined. The essential characteristics required from such a helicopter result from its escort or protective function: besides reduced detectability, high mobility, and long range, its armament must be designed to attack light armored and anarmored point and area targets on the ground as well as slow- and fast-moving airborne targets. The first-generation escort helicopter BSH-1 based on the MBB BO 105 model and its mission equipment consisting of the ATAS components prepared in the U.S. are discussed, and plans for the second-generation BSH-2 helicopter are outlined. V.T.

A91-47801
AIAA FLIGHT SIMULATION TECHNOLOGIES CONFERENCE, NEW ORLEANS, LA, AUG. 12-14, 1991, TECHNICAL PAPERS
Washington, DC, American Institute of Aeronautics and Astronautics, 1991, 514 p. For individual items see A91-47802 to A91-47852.
Copyright

Papers are presented on in-flight simulation, simulation for training, crewstation design, flight testing for simulator validation, modeling techniques, and simulation networks. Also considered are turbulence and windshear, numerical methods and simulation software, pilot cuing, simulation system architecture, and simulator sickness. R.E.P.

N91-27120*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VIBRATORY LOADS DATA FROM A WIND-TUNNEL TEST OF STRUCTURALLY TAILORED MODEL HELICOPTER ROTORS
WILLIAM T. YEAGER, JR., M-NABIL H. HAMOUDA, ROBERT F. IDOL (Bell Helicopter Co., Fort Worth, TX.), PAUL H. MIRICK, JEFFREY D. SINGLETON, and MATTHEW L. WILBUR Washington Aug. 1991 121 p
(Contract NAG3-55; DA PROJ. 1L1-62211-A-47AB)
(NASA-TM-4265; L-16873; NAS 1.15:4265;
AVSCOM-TR-91-B-001) Avail: NTIS HC/MF A06 CSCL 01B

An experimental study was conducted in the Langley Transonic Dynamics Tunnel to investigate the use of a Bell Helicopter Textron (BHT) rotor structural tailoring concept, known as rotor nodalization, in conjunction with advanced blade aerodynamics as well as to

evaluate rotor blade aerodynamic design methodologies. A 1/5-size, four-bladed bearingless hub, three sets of Mach-scaled model rotor blades were tested in forward flight from transition up to an advance ratio of 0.35. The data presented pertain only to the evaluation of the structural tailoring concept and consist of fixed-system and rotating system vibratory loads. These data will be useful for evaluating the effects of tailoring blade structural properties on fixed-system vibratory loads, as well as validating analyses used in the design of advanced rotor systems. Author

N91-27123# National Transportation Safety Board, Washington, DC.
ANNUAL REVIEW OF AIRCRAFT ACCIDENT DATA, US GENERAL AVIATION, CALENDAR YEAR 1988
27 Mar. 1991 88 p
(PB91-156851; NTSB/ARG-91/01) Avail: NTIS HC/MF A05 CSCL 01A

A statistical compilation and review of general aviation accidents which occurred in 1988 in the United States, its territories and possessions, and in international waters are presented. The accidents reported are all those involving U.S. registered aircraft not conducting operations under 14 CFR 121, 14 CFR 125, 14 CFR 127, or 14 CFR 135. The report is divided into five sections: All Accidents; Fatal Accidents; Serious injury Accidents; Property Damage Accidents and Midair Collision Accidents. Several tables present accident parameters for 1988 accidents only, and each section includes tabulations which present comparative statistics for 1988 and for the five-year period 1983 to 1987. GRA

02

AERODYNAMICS

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

A91-44508#
ADVANCES IN THE NUMERICAL ANALYSIS OF LINEARIZED UNSTEADY CASCADE FLOWS
W. J. USAB, JR. and J. M. VERDON (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(Contract F33615-84-C-2445)
(ASME PAPER 90-GT-11)

This paper describes two new developments in the numerical analysis of linearized unsteady cascade flows, that have been motivated by the need for an accurate analytical procedure for predicting the onset of flutter in highly loaded compressors. In previous work, results were determined using a two-step or single-pass procedure in which a solution was first determined on a rectilinear-type cascade mesh to determine the unsteady flow over an extended blade-passage solution domain and then on a polar-type local mesh to resolve the unsteady flow in high-gradient regions. In the present effort a composite procedure has been developed in which the cascade- and local-mesh equations are solved simultaneously. This allows the detailed features of the flow within the local-mesh region to impact the unsteady solution over the entire domain. In addition, a new transfinite local mesh has been introduced to permit a more accurate modeling of unsteady shock phenomena. Numerical results are presented for a two-dimensional compressor-type cascade operating at high subsonic inlet Mach number and high mean incidence to demonstrate the impact of the new composite- and local-mesh analyses on unsteady flow predictions. Author

A91-44509#
THREE-DIMENSIONAL ROTATIONAL FLOW IN TRANSONIC TURBOMACHINES. I - SOLUTION OBTAINED BY USING A NUMBER OF S1 STREAM FILAMENTS OF REVOLUTION AND A CENTRAL S2 STREAM FILAMENT
CHUNG-HUA WU, ZHENGMING WANG, and HONGJI CHEN (Chinese Academy of Sciences, Beijing, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 13 p. refs
(ASME PAPER 90-GT-12)

Wu's (1952) theory of 3D flows in subsonic and supersonic turbomachines is extended to 3D rotational flow in transonic turbomachines, using an assumption that the S1 stream filaments can be approximated as filaments of revolution. The 3D solution is obtained by an iterative solution between a number of S1 stream filaments and a single S2 stream filament. Good agreement is found between the calculated 3D field and the DLR experimental data on the character of the flowfield and the streamwise variation of the flow variables in the middle of the flow channel. I.S.

A91-44510#
THREE-DIMENSIONAL ROTATIONAL FLOW IN TRANSONIC TURBOMACHINES. II - FULL 3D FLOW IN CAS ROTOR OBTAINED BY USING A NUMBER OF S1 AND S2 STREAM FILAMENTS
CHUNG-HUA WU, XIAOLU ZHAO, and LISEN QIN (Chinese Academy of Sciences, Beijing, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-13)

Based on the theory developed by Wu et al. (1990) for 3D rotational flow in transonic turbomachines, quasi-3D and full 3D solutions of transonic flow in the Chinese Academy of Sciences' rotor are obtained by iterative calculation between a number of S1 stream filaments and a central S2 stream filament or a number of S(2m) stream filaments. The 3D flowfields obtained in the quasi-3D and full 3D solutions are found to be similar. The character of the transonic flow including the 3D shock structure was found to be in good agreement with Laser-2-Focus measurements, but the measured velocity is somewhat higher than the calculated velocity over most of the flowfield. A practical CAD and analysis system based on the general S1 code and general S2 code described here is presented. I.S.

A91-44511*# United Technologies Research Center, East Hartford, CT.
ANALYSIS OF UNSTEADY COMPRESSIBLE VISCOUS LAYERS
G. D. POWER, J. M. VERDON, and K. A. KOUSEN (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(Contract NAS3-23717)
(ASME PAPER 90-GT-14)

The development of an analysis to predict the unsteady compressible flows in blade boundary layers and wakes is presented. The equations that govern the flows in these regions are transformed using an unsteady turbulent generalization of the Levy-Lees transformation. The transformed equations are solved using a finite difference technique in which the solution proceeds by marching in time and in the streamwise direction. Both laminar and turbulent flows are studied, the latter using algebraic turbulence and transition models. Laminar solutions for a flat plate are shown to approach classical asymptotic results for both high and low frequency unsteady motions. Turbulent flat-plate results are in qualitative agreement with previous predictions and measurements. Finally, the numerical technique is also applied to the stator and rotor of a low-speed turbine stage to determine unsteady effects on surface heating. The results compare reasonably well with measured heat transfer data and indicate that nonlinear effects have minimal impact on the mean and unsteady components of the flow. Author

A91-44512#
INVISCID-VISCOUS INTERACTION ANALYSIS OF COMPRESSOR CASCADE PERFORMANCE
M. BARNETT, D. E. EDWARDS (United Technologies Research Center, East Hartford, CT), and D. E. HOBBS (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 16 p. Research supported by United Technologies Corp. refs
(ASME PAPER 90-GT-15)

An inviscid-viscous interaction technique for the analysis of quasi-three-dimensional turbomachinery cascades has been developed. The inviscid flow is calculated using a time-marching, multiple-grid Euler analysis. An inverse, finite-difference viscous-layer analysis, which includes the wake, is employed so that boundary-layer separation can be modeled. This analysis has been used to predict the performance of a transonic compressor cascade over the entire incidence range. The results of the numerical investigation in the form of cascade total pressure loss, exit gas angle and blade pressure distributions are compared with existing experimental data and Navier-Stokes solutions for this cascade, and show that this inviscid-viscous interaction procedure is able to accurately predict cascade loss and airfoil pressure distributions. Several other aspects of the present interaction analysis are examined, including transition and wake modeling, through comparisons with data. Author

A91-44517#
SECONDARY FLOW MEASUREMENTS IN A TURBINE CASCADE WITH HIGH INLET TURBULENCE
D. G. GREGORY-SMITH and J. G. E. CLEAK (Durham, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 14 p. Research supported by Rolls-Royce, PLC and SERC. refs
(ASME PAPER 90-GT-20)

Results are presented of the mean and turbulent flowfield in a high turning cascade of axial flow turbine blades. The inlet turbulence was increased by 5 percent by a grid placed upstream of the cascade, and the secondary flow region was traversed within and downstream of blades using a five-hole probe and crossed hot wires. The results showed that high inlet turbulence had little effect on the mean flowfield. The Reynolds stresses were found to be very high, particularly in the loss core, and the eddy viscosity calculated from two independent shear stresses was found to be fairly isotropic in the loss core. The frequency spectra obtained showed no significant resonant peaks. I.S.

A91-44526#
A COMPUTATIONAL PROCEDURE FOR DIFFUSER-COMBUSTOR FLOW INTERACTION ANALYSIS
K. C. KARKI, V. L. OECHSLE, and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-35)

This paper describes a diffuser-combustor flow interaction analysis procedure for gas turbine combustion systems. The method is based on the solution of the Navier-Stokes equations in a generalized nonorthogonal coordinate system. The turbulence effects are modeled via the standard two-equation (k-epsilon) model. The method has been applied to a practical gas turbine combustor-diffuser system that includes support struts and fuel nozzles. Results have been presented for a 3D simulation, as well as for a simplified axisymmetric simulation. The flow exhibits significant 3D behavior. The axisymmetric simulation is shown to predict the static pressure recovery and the total pressure losses reasonably well. Author

A91-44527#
MECHANICS ON THE TIP CLEARANCE LOSS OF IMPELLER BLADES
YASUTOSHI SENOO (Miura Co., Ltd., Matsuyama, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-37)

The pressure loss due to poor tip clearance is presently examined on the basis of a macroscopic balance of forces. Both pressure losses due to the drag generated by the leaked flow and the pressure losses due to axial pressure difference without blades in the tip-clearance zone are covered. It is established that while the former derives from induced drag, which is parallel to the blade, the former is due to the missing blade force normal to the blade in the clearance zone. Because of the perpendicularity of these forces, the losses are entirely different in nature. A relationship between leaked flow kinetic energy and the clearance flow's induced drag is quantitatively defined. O.C.

A91-44539#
THE INFLUENCE OF BLADE LEAN ON TURBINE LOSSES
S. HARRISON (Cambridge, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. Research supported by Ministry of Defence Procurement Executive and SERC. refs
(ASME PAPER 90-GT-55)

Three linear cascades of highly loaded low-aspect-ratio turbine blades have been tested in order to investigate the mechanisms by which blade lean (dihedral) influences loss generation. Lean has a marked effect upon blade loading, on the distribution of loss generation, and on the state of boundary layers on the blade suction surfaces and the endwalls, but its effect upon overall loss coefficient was found to be minimal. It was found, however, that compound lean reduced the downstream mixing losses, and reasons for this are proposed. Compound lean also has the beneficial effect of substantially reducing spanwise variations of mean exit flow angle. In a turbine this would be likely to reduce losses in the downstream bladerow as well as making matching easier and improving off-design performance. Author

A91-44540#
THREE-DIMENSIONAL FLOW IN AN AXIAL TURBINE. I - AERODYNAMIC MECHANISMS
DAVID JOSLYN and ROBERT DRING (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(Contract F49620-86-C-0020)
(ASME PAPER 90-GT-56)

The 3D nature of the flow in a one-and-one-half stage axial turbine is investigated. The aerodynamic results include: (1) airfoil and endwall surface flow visualization, (2) fullspan airfoil pressure distributions, and (3) radial circumferential distributions of the total and static pressures, and of the yaw and pitch angles in the flow. It is concluded that although the flow in each airfoil row possesses a degree of three-dimensionality, that in the rotor is the strongest. Surface flow visualization indicates that hub and tip secondary flows are the main causes of three-dimensionality both in the stators and in the rotors. O.G.

A91-44541#
THREE-DIMENSIONAL FLOW IN AN AXIAL TURBINE. II - PROFILE ATTENUATION
DAVID JOSLYN and ROBERT DRING (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(Contract F49620-86-C-0020)
(ASME PAPER 90-GT-57)

An exhaustive experimental documentation of the 3D nature of the flow in a one-and-one-half stage axial signal is presented. The flow within, and downstream of, both the stator and rotor airfoil rows is examined in order to delineate the dominant physical mechanisms. Documentation of the mixing, or attenuation, of a simulated spanwise inlet temperature profile as it passed through the turbine includes the simulated combustor exit-turbine inlet temperature profile, surface measurements on the airfoils and

endwalls of the three airfoil rows, and radial-circumferential distributions downstream of each airfoil. It is concluded that the major source of radial mixing is the radial flow in its wake due to the radial static pressure and the endwall secondary flows. O.G.

A91-44544#
THERMOGASDYNAMIC EFFECTS OF THE ENGINE TURBINES WITH THE CONTRA-ROTATING ROTORS
IU. V. SOTSENKO (Tsentral'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-63)

There were carried out the experimental invetigations of the gas dynamic features and the analysis of the thermodynamic characteristics of the advanced engine turbines, designed with allowance for effects of the contra-rotating rotors. The investigations were performed on 12 rectilinear cascades with the different fluid deflection and meridional opening. The comparison of the obtained characteristics and the analysis of the flow pattern show the cascades for contra-rotating rotors have specific features which are necessary to take account while its designing. Author

A91-44545*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN ANALYSIS OF THE VISCOUS FLOW THROUGH A COMPACT RADIAL TURBINE BY THE AVERAGE PASSAGE APPROACH
JAMES D. HEIDMANN (NASA, Lewis Research Center, Cleveland, OH) and TIMOTHY A. BEACH (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. Previously announced in STAR as N90-14206. refs
(ASME PAPER 90-GT-64)

A steady, three-dimensional viscous average passage computer code is used to analyze the flow through a compact radial turbine rotor. The code models the flow as spatially periodic from blade passage to blade passage. Results from the code using varying computational models are compared with each other and with experimental data. These results include blade surface velocities and pressures, exit vorticity and entropy contour plots, shroud pressures, and spanwise exit total temperature, total pressure, and swirl distributions. The three computational models used are inviscid, viscous with no blade clearance, and viscous with blade clearance. It is found that modeling viscous effects improves correlation with experimental data, while modeling hub and tip clearances further improves some comparisons. Experimental results such as a local maximum of exit swirl, reduced exit total pressures at the walls, and exit total temperature magnitudes are explained by interpretation of the flow physics and computed secondary flows. Trends in the computed blade loading diagrams are similarly explained. Author

A91-44546#
PERFORMANCE PREDICTION OF SUBSONIC SEPARATED CASCADES
G. A. GEROLYMOS, J. CHAUVIN (Paris VI, Universite, France), N. YAZIGI, and M. H. CHARLIER ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(Contract DRET-87-227)
(ASME PAPER 90-GT-65)

A rapid and reliable prediction method is developed for 2D cascades with varying blade height. The flow physics are modeled, including laminar separation bubbles and turbulent separation, so that a personal computer with moderate computing times can be employed. The method shows very good agreement with experimental data on pressure distributions, deviation angles, and loss coefficients for a wide range of Reynolds numbers and subsonic Mach numbers. C.D.

A91-44547#
DESIGN METHODOLOGY FOR SPLITTERED AXIAL COMPRESSOR ROTORS
K.-L. TZUOO, S. S. HINGORANI, and A. K. SEHRA (Textron Lycoming, Stratford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-66)

Recent trend toward lightweight, compact compression systems for advanced aircraft gas turbine engines has created a need for very high pressure ratio fan and compressor stages. One way of achieving pressure ratio in excess of 3:1 in an axial blade row is to introduce splitters (partial vanes) between the principal blades, a concept pioneered by Wennerstrom during early 70s for application in a 3:1 pressure ratio single axial stage. This paper presents an advanced methodology for high pressure ratio splittered rotor design. The methodology centers around combining a meridional flow calculation, an arbitrary meanline blade generation procedure, and 3D inviscid and viscous analyses. Methods for specifying work distribution, solidity, loss, and deviation distributions, as well as the airfoil generation and splitter vane placement are discussed in detail. Importance of 3D viscous effects along with results from a 3D viscous calculation for Wennerstrom's splittered rotor are also presented. Author

A91-44548#
APPLICATION OF AN INVERSE DESIGN PROCEDURE TO AXIAL COMPRESSOR BLADING
MOHAMED ZEDAN and ARUN SEHRA (Textron Lycoming, Stratford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-67)

A blade-to-blade inverse design procedure is presented for use in a quasi-3D design system for multistage axial flow compressors. The procedure is appliable to transonic rotor and stator airfoil sections along axisymmetric stream surfaces. It accounts for the streamtube thickness and radius variations, and can be used in the analysis, fully inverse, and mixed inverse modes. Steady state Euler equations are implemented and formulated in terms of density and local displacement normal to streamline as dependent variables. Three test cases are presented in this paper to illustrate the application of this inverse design technique for optimizing rotor and stator airfoils of highly loaded, high pressure ratio compressor stages. These test cases demonstrate the capability of this procedure to optimize airfoil geometry for minimizing shock and diffusion losses without compromising the airfoil structural integrity. Author

A91-44549#
THREE-DIMENSIONAL PRESCRIBED VELOCITY BLADE ROW DESIGN
V. MOLNAR, F. RIDZON, and V. ADAME (Slovak Technical University, Bratislava, Czechoslovakia) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Research supported by CKD Prague Compressor Works. refs
(ASME PAPER 90-GT-68)

A method for 3D turbomachine blade row design is presented as a subsequent tasks loop. The design follows the concept of the S1 and S2 streamsurfaces. A set of S1 surfaces is used for blade profile modification and a S2 mid-surface is used for hub and casing flow surface modification. A difference between target and actual flow velocity distribution is used to control iteration procedures for successive geometry changes of an initial (original) blade row geometry. The design suboutlines are added to standard direct codes. Results for several design cases are presented and discussed. Author

A91-44551#
AERODYNAMIC ANALYSIS OF A TWO STAGE TRANSONIC COMPRESSOR WITH VARIABLE STATOR VANES
K.-D. BROICHHAUSEN and P. HARSTER (MTU Motoren- und

Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. BMVg-supported research. refs
(ASME PAPER 90-GT-73)

An experimental investigation has been made of the aerodynamic performance of a highly loaded two-stage compressor with variable inlet guide vane (IGV) and variable stator settings. It is established that the IGV and first stator influence overall characteristics to nearly the same extent. A detailed analysis with time-resolving measurement techniques further reveals that, even in the case of the highest Mach numbers, the position and intensity of the airfoil bow shocks generated are affected by the back pressure. This change of inlet flow field causes a variation of the mass flow. The bow shocks of downstream rotors are not axisymmetric with respect to each blade passage, due to unsteady interaction with the upstream rotors. O.C.

A91-44552#
THE TURBINE REGIME OF A REAR AXIAL COMPRESSOR STAGE
VACLAV CYRUS (National Research Institute for Machine Design, Prague, Czechoslovakia) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-74)

A detailed investigation of three-dimensional flow has been carried out in a low speed rear axial compressor stage with aspect ratio of one at the extreme off-design condition-turbine regime. Measurements were performed by means of both stationary and rotating pressure probes. The mechanism of flow in the rotor and stator blade row in the turbine regime is analyzed. Comparison is made with flow mechanism at the design condition. Author

A91-44553#
LDV MEASUREMENTS OF TURBULENT STRESSES IN RADIAL TURBINE GUIDE VANES
HASAN EROGLU and WIDEN TABAKOFF (Cincinnati, University, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. DOE-supported research. refs
(ASME PAPER 90-GT-75)

The results of LDV measurements, in particular, turbulent stresses in radial turbine guide vanes are presented in order to provide experimental data for the numerical predictions. The results are presented as contour plots of turbulent stresses. The LDV system consists of a 5-watt argon-ion laser, the seeding particle atomizer, and the optical and the data acquisition systems. Frequency shifts were used on both components to determine the flow direction. The results indicate a significant transport of higher turbulence fluid into the suction surface-end wall corner by the end wall cross flows inside the passage. High turbulent stress gradients show that there is considerable flow mixing downstream of the flow passages. Turbulence was found to be locally anisotropic everywhere. Author

A91-44554#
VISCOUS FLOW COMPUTATIONS IN TURBOMACHINE CASCADES
P.-A. CHEVRIN and C. VUILLEZ (SNECMA, Moissy-Cramayel, France) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. Research supported by SNECMA and DRET. refs
(ASME PAPER 90-GT-76)

A two-dimensional Navier-Stokes solver developed at ONERA for the calculation of the flow in turbine and compressor cascades was adapted to run on different types of grid. The solver uses an explicit, time-marching, finite-volume technique with a multigrid acceleration scheme. A multidomain approach is used to handle difficulties due to the geometry of the flow. The flow in a transonic compressor cascade and in a subsonic and a transonic turbine cascade are computed and compared with experiments. Author

A91-44562#
FLOW BEHAVIOR IN A DUMP DIFFUSER WITH DISTORTED FLOW AT THE INLET
SHINJI HONAMI (Tokyo, Science University, Japan) and TADASHI MORIOKA (Ishikawajima System Technology Co., Ltd., Tokyo, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-90)

The flow behavior with a dump diffuser with and without inlet distortion is studied. It is found that both the prediffuser geometry and the dump gap are dominant parameters affecting diffuser performance. A small dump gap causes insufficient pressure recovery in the prediffuser, resulting in a drop in overall pressure recovery and loss of total pressure in the diffuser. The distribution of the flow rate to the branched channels is relatively insensitive to the velocity profile with distortion at the diffuser inlet. C.D.

A91-44573#
LAMINAR BOUNDARY LAYER INTERACTION WITH AN UNSTEADY PASSING WAKE
D. E. PAXSON and R. E. MAYLE (Rensselaer Polytechnic Institute, Troy, NY) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-120)

An investigation was conducted to study the unsteady effects of a moving wake as it passes over a laminar boundary layer in a stagnation region. Arguments are presented which show that in this region, the wake-induced unsteadiness may be treated, for the most part, as an inviscid, unsteady freestream which impresses itself on the boundary layer flow. As a result, the boundary layer equations remain valid and, for relatively small oscillations, a solution to the equations may be obtained using standard perturbation techniques. A related experiment is then described and the results are examined in light of this analytical approach. Author

A91-44578#
CENTRIFUGAL COMPRESSOR IMPELLER AERODYNAMICS - AN EXPERIMENTAL INVESTIGATION
H. D. JOSLYN, ROBERT P. DRING (United Technologies Research Center, East Hartford, CT), and JOOST J. BRASZ (Carrier Corp., Syracuse, NY) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(ASME PAPER 90-GT-128)

The ability to acquire blade loadings (surface pressure distributions) and surface flow visualization on an unshrouded centrifugal compressor impeller is demonstrated. Circumferential and streamwise static pressure distributions acquired on the stationary shroud are also presented. Data was acquired in a new facility designed for centrifugal compressor aerodynamic research. Blade loadings calculated with a blade-to-blade potential flow analysis are compared with the measured results. Surface flow visualization reveals some complex aspects of the flow on the surface of the impeller blading and hub. Author

A91-44579#
WAKE MEASUREMENTS AND LOSS EVALUATION IN A CONTROLLED DIFFUSION COMPRESSOR CASCADE
R. P. SHREEVE, Y. ELAZAR, J. W. DREON, and A. BAYDAR (U.S. Naval Postgraduate School, Monterey, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. U.S. Navy-supported research. refs
(ASME PAPER 90-GT-129)

The results of two component laser-Doppler velocimeter (LDV) surveys made in the near wake (to one fifth chord) of a controlled diffusion (CD) compressor blade in a large scale cascade wind tunnel, are reported. The measurements were made at three positive incidence angles from near-design to angles thought to approach stall. Comparisons were made with calibrated pressure

probe and hot-wire wake measurements and good agreement was found. The flow was found to be fully attached at the trailing edge at all incidence angles and the wake profiles were found to be highly skewed. Despite the precision obtained in the wake velocity profiles, the blade loss could not be evaluated accurately without measurements of the pressure field. The blade trailing edge surface pressures and velocity profiles were found to be consistent with downstream pressure probe measurements of loss, allowing conclusions to be drawn concerning the design of the trailing edge. Author

A91-44582#
THE EFFECTS OF WAKE MIXING ON COMPRESSOR AERODYNAMICS
ROBERT P. DRING (United Technologies Research Center, East Hartford, CT) and DAVID A. SPEAR (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(ASME PAPER 90-GT-132)

A methodology based on wake mixing has been developed that enables more accurate predictions of compressor airfoil pressure distributions when the airfoil is operating downstream of an airfoil row that has strong wakes. The methodology has an impact on through-flow analysis, on airfoil-to-airfoil flow analysis, and on the interpretation of experimental data. It is demonstrated that the flow in the endwall region is particularly sensitive to mixing due to the strong wakes caused by the secondary flow and corner separation that commonly occur in this region. It is also demonstrated that wake mixing can have a strong impact on both airfoil incidence and deviation as well as on loading. Differences of up to 13 and 30 percent in loading are demonstrated. Author

A91-44583#
PRESSURE LOSSES IN COMBINING SUBSONIC FLOWS THROUGH BRANCHED DUCTS
N. I. ABOU-HAIDAR (University of Manchester Institute of Science and Technology, England) and S. L. DIXON (Liverpool, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-134)

An investigation of the additional total pressure losses occurring in combining flow through several sharp-edged three-leg junctions has been made. Experimental results covering a wide speed range are presented for three flow geometries of a lateral branch off a straight duct using dry air as the working fluid. A new theoretical flow model results in fairly good agreement with experimental data. Flow visualization of the high speed flow using the schlieren method revealed the presence of normal shock waves in the combined flow about one duct diameter downstream of the junction. The highest attainable Mach number (M3) of the averaged downstream (combined) flow was 0.66 for several of the flow geometries. This value of M3 appears to be the maximum possible and is the result of a combination of flow separation and local flow choking. Author

A91-44589#
THE ROLE OF PRIMARY JETS IN THE DOME REGION - AERODYNAMICS OF A MODEL CAN COMBUSTOR
C. D. RICHARDS and G. S. SAMUELSEN (California, University, Irvine) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. U.S. Navy-supported research. refs
(Contract F08635-86-C-0309)
(ASME PAPER 90-GT-142)

The role of the primary jets in the aerothermal behavior and overall performance of a gas turbine combustor is investigated using a model laboratory combustor operated on JP-4 at atmospheric pressure. The aerodynamic and thermal fields are characterized using laser anemometry and a thermocouple probe, respectively. Extractive probe sampling is used to acquire species concentrations. The results demonstrate that the location, number, and size of the primary jets are important to combustor performance. Jet row location substantially influences the percent mass recirculated into the dome region, the overall uniformity of mixing, and combustion efficiency. The momentum ratio of the incoming primary jet stream to that of the approaching crossflow of reacting dome gases has a direct impact on the mixing patterns. An increase in the number of primary jets leads to more uniform mixing. O.G.

A91-44594#
THE DEVELOPMENT OF AXIAL TURBINE LEAKAGE LOSS FOR TWO PROFILED TIP GEOMETRIES USING LINEAR CASCADE DATA
JEFFREY P. BINDON and GEORGE MORPHIS (Natal, University, Durban, Republic of South Africa) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-152)

Tip clearance loss measurements were carried out in a linear cascade for three different gap geometries. The major objectives of the study include clarifying the flow phenomena that give rise to rotor loss, developing an experimental procedure to assess rotor efficiency based on detailed stationary cascade anemometry, and identifying tip shapes for improved performance. It is shown that radiusing and contouring the leakage gap geometry to prevent the formation of the separation bubble significantly reduced the internal gap loss formed from 35 percent to 38 percent of the overall cascade total pressure deficit. A method is presented whereby detailed stationary cascade flow field data can be converted into a simulated rotor flow, to calculate work transfer and efficiency. The usefulness of the method is demonstrated by comparing the endwall region performance of the tip clearance geometries. O.G.

A91-44595#
PREDICTION OF TIP-LEAKAGE LOSSES IN AXIAL TURBINES
M. I. YARAS and S. A. SJOLANDER (Carleton University, Ottawa, Canada) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Pratt and Whitney Canada-supported research. refs
(Contract NSERC-A-1671)
(ASME PAPER 90-GT-154)

Existing methods for predicting the tip-leakage losses in turbomachinery are based on a variety assumptions, many of which have not been fully verified experimentally. Recently, several detailed experimental studies in turbine cascades have helped to clarify the physics of the flow and provide data on the evolution of the losses. The paper examines the assumptions underlying the prediction methods in the light of these data. An improved model for the losses is developed, using one of the existing models as the starting point. Author

A91-44597#
PASSIVE CONTROL OF UNSTABLE CHARACTERISTICS OF A HIGH SPECIFIC SPEED DIAGONAL-FLOW FAN BY AN ANNULAR WING
KENJI KANEKO, TOSHIAKI SETOGUCHI (Saga University, Japan), and MASAHIRO INOUE (Kyushu University, Fukuoka, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. Research supported by MOESC and Harada Memorial Foundation. refs
(ASME PAPER 90-GT-159)

A passive control of the unstable characteristics of a high specific speed diagonal-flow fan has been proposed. It is possible to eliminate the unstable characteristics of pressure-flow rate curve in a low flow region without deterioration of performance at design point. The control action is done naturally (passively) without any energy input. The inlet nozzle of an ordinary diagonal-flow fan was replaced by an annular wing with Goettingen 625 airfoil section. The mechanism of the passive control and the optimum geometrical parameter are discussed on the basis of the performance tests and internal flow measurements. Author

A91-44598# Michigan Univ., Ann Arbor.
ESSENTIAL INGREDIENTS FOR THE COMPUTATION OF STEADY AND UNSTEADY BLADE BOUNDARY LAYERS
H. M. JANG (Michigan, University, Ann Arbor), J. A. EKATERINARIS (U.S. Navy-NASA, Joint Institute of Aeronautics, Moffett Field, CA), M. F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA), and T. CEBECI (California State University, Long Beach) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. Research supported by U.S. Navy and NASA. refs
(Contract F47920-85-C-0063)
(ASME PAPER 90-GT-160)

Two methods are described for calculating pressure distributions and boundary layers on blades subjected to low Reynolds numbers and ramp-type motion. The first is based on an interactive scheme in which the inviscid flow is computed by a panel method and the boundary layer flow by an inverse method that makes use of the Hilbert integral to couple the solutions of the inviscid and viscous flow equations. The second method is based on the solution of the compressible Navier-Stokes equations with an embedded grid technique that permits accurate calculation of boundary layer flows. Studies for the Eppler and NACA-0012 airfoils indicate that both methods can be used to calculate the behavior of unsteady blade boundary layers at low Reynolds numbers, provided that the location of transition is computed with the e-exp-n method and the transitional region is modeled properly. Author

A91-44618#
A FULLY COMPRESSIBLE THREE DIMENSIONAL INVERSE DESIGN METHOD APPLICABLE TO RADIAL AND MIXED FLOW TURBOMACHINES
M. ZANGENEH (University College, London, England) and W. R. HAWTHRONE (Churchill College, Cambridge, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. Research sponsored by Holset Turbochargers, Ltd. and Saint John's College. refs
(ASME PAPER 90-GT-198)

A fully 3D compressible inverse design method for the design of radial and mixed flow machines is described. In this method, the distribution of the circumferentially averaged swirl velocity on the meridional geometry of the impeller is prescribed and the corresponding blade shape is computed iteratively. Two approaches are presented for solving the compressible flow problem. In the approximate approach, the pitchwise variation in density is neglected, and as a result the algorithm is simple and efficient. In the exact approach, the velocities and density are computed throughout the 3D flowfield by employing fast Fourier transform in the tangential direction. The results of the approximate and exact approach are compared for the case of a high-speed (subsonic) radial-inflow turbine, and it is shown that the difference between the blade shapes computed by the two methods is well within the manufacturing tolerances. Author

A91-44622#
ANALYTICAL STATISTICS OF FORCED RESPONSE OF A MISTUNED BLADED DISK ASSEMBLY IN SUBSONIC FLOW
S. CHEN and A. SINHA (Pennsylvania State University, University Park) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(Contract AF-AFOSR-87-0142)
(ASME PAPER 90-GT-205)

The statistics of the forced response of a structurally and aerodynamically coupled bladed disk assembly have been computed efficiently by the analytical technique. The validity of the analytical technique has been corroborated by comparison with the results from numerical simulations. Lastly, the effects of the following parameters on the statistics of the maximum amplitude have been studied: aerodynamic coupling, fluid density, and stagger angle. Author

A91-44624#
AN EXPERIMENTAL INVESTIGATION OF LOSS REDUCTION WITH RIBLETS ON CASCADE BLADE SURFACES AND ISOLATED AIRFOILS
FANG CHEN (Chinese Academy of Sciences, Institute of Mechanics, Beijing, People's Republic of China), YAN-PING TANG, and MAO-ZHANG CHEN (Beijing University of Aeronautics and Astronautics, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-207)

Experimental investigations of loss reduction with riblets have been made. Riblets were put on the blade surfaces in different ways in a compressor cascade or on an isolated airfoil. More than 8 percent drag-reduction benefits for an isolated airfoil and more than 10 percent loss-reduction benefits for the compressor cascade have been obtained by using riblets only on blade pressure surfaces, rather than on both pressure and suction surfaces. The mechanism underlying these results has been discussed. Author

A91-44625#
EFFECTS OF SURFACE ROUGHNESS, FREESTREAM TURBULENCE, AND INCIDENCE ANGLE ON THE PERFORMANCE OF A 2-D COMPRESSOR CASCADE
W. C. ELROD, P. I. KING, and E. M. PONIATOWSKI (USAF, Institute of Technology, Wright-Patterson AFB, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-208)

The effects of surface roughness, freestream turbulence, and incidence angle on the performance of a two-dimensional compressor cascade were investigated. The test section consisted of seven NACA 65-A506 airfoils arranged in a linear cascade. Four different surface roughness conditions were applied to the first 25 percent chord on the suction surface of each of the five middle blades in the cascade. Freestream turbulence levels of approximately one and seven percent were used. Incidence angles of -3, zero and +3 degrees were investigated. Of the three parameters tested, freestream turbulence exerted the largest influence on blade performance. The total pressure loss coefficient increased with increased roughness and was reduced for large turbulence. Changes in flow incidence had a lesser effect on the performance of the blade. Author

A91-44628#
BASIC FEATURES OF SPEED INDUCED TRANSIENT BEHAVIOUR OF AXIAL FLOW COMPRESSORS
GUO-CAI TANG (Nanjing Aeronautical Institute, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-211)

An investigation is presented of basic features of speed induced transient behaviors of axial compression system. A nonlinear model is developed for prediction of the transient response due to speed variation. Generally, the operating point forms a loop during an accelerating process. A small B or great rate of change in speed leads to a large loop. In the hysteresis region of the characteristic of the compressor, there are four possible solutions: steady flow with the compressor working on the unstalled part of the characteristic; steady flow with the operating point first getting across the stall limit then going back to the initial point; rotating stall and surge. Two critical values of the B parameter are identified, on which the system response depends. They are: Br, at which transition from rotating stall to surge occurs, and Bs, at which that from surge to steady flow takes place. Br and Bs are found to vary with some factors concerned. Their variation with the initial point, rate of the change in speed and the time lag constant are also studied. Author

A91-44629#
FLOWFIELD CALCULATION IN COMPRESSOR OPERATING WITH DISTORTED INLET FLOW

H. JOUBERT (SNECMA, Centre de Villaroche, Moissy-Cramayel, France) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(ASME PAPER 90-GT-212)

An evaluation is made of the effectiveness of two methods for predicting the effects of distorted inlet flows on compressor stability. In the first of these, the Euler equations are integrated in a 2D blade-to-blade surface with a distorted inlet flow. This method is used to compare different profiles, giving attention to the influence of the blade chord length. In the second method, the aerodynamic behavior of a multistage compressor operating in distorted inlet flow is obtained in light of a 3D model based on Euler equation resolutions external to the blade rows. These methods are evaluated in view of their results for a three-stage axial compressor, which are compared with experimental data. O.C.

A91-44630#
CENTRIFUGAL COMPRESSOR IMPELLER AERODYNAMICS - A NUMERICAL INVESTIGATION
DANIEL J. DORNEY and ROGER L. DAVIS (United Technologies Research Center, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. Research supported by Carrier and United Technologies Corp. refs
(ASME PAPER 90-GT-213)

A three-dimensional, Navier-Stokes analysis is presented for the prediction of viscous flows through centrifugal impellers. Based on the Navier-Stokes rotor/stator interaction procedure developed by Rai, the present analysis uses a zonal grid methodology to discretize the impeller flow field and to facilitate the relative motion of the impeller. A blade surface oriented O-grid generated from an elliptic partial differential equation solution procedure is patched into an algebraically generated H-grid which is used to discretize the inlet, exit and blade-to-blade regions. The equations of motion are integrated using a spatially third-order accurate, implicit, iteractive, upwind, finite difference, time-marching technique. Predicted results are presented for flow through a low speed centrifugal compressor impeller operating at design flow conditions. Comparisons of these predicted results with experimental data demonstrates the capability of this procedure to predict impeller blade loading and provide insight into the secondary flow structure within the impeller blade passage. Author

A91-44631#
MEASURED AND PREDICTED EFFECTS OF INLET DISTORTION ON AXIAL COMPRESSORS
J. P. LONGLEY (Cambridge, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-214)

Encouraging developments have recently been made both in the understanding and the modeling of compressor flowfields. This paper describes an experimental investigation undertaken to assess the validity of the assumptions made in the simple nonlinear model for a bladerow operating in an unsteady or nonuniform flowfield. The results show that the basic fluid dynamics of the problem have been correctly modeled and that meaningful predictions may be made. The measurements also indicate that inlet guide vanes may be more sensitive to incidence variations than had been previously thought. The effects of inter-bladerow gaps are also discussed. Author

A91-44632#
INLET FLOW DISTORTION EFFECTS ON ROTATING STALL
J. FORTIN and W. C. MOFFATT (Royal Military College of Canada, Kingston) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. DND-supported research. refs
(ASME PAPER 90-GT-215)

Inlet-flow distortions are investigated in terms of their influence on rotating stall/surge phenomena in an axial engine compressor. Screen-induced inlet pressure distortions are applied to the first stage rotor of a 10-stage compressor, and the effects are monitored with hot-film probe measurements. The speed of the rotating stall pattern is not affected by the employment of distortion screens, although the presence of the screens coincides with the increased likelihood of low frequency flow fluctuations. Based on the increased intensity of fluctuations observed when the sensing probe is moved tangentially from a distortion screen in the direction of rotor rotation, the conclusion is offered that the screens have a localized damping effect on the surge phenomenon. C.C.S.

A91-44634#
WAKE MIXING IMPROVEMENTS IN A LINEAR COMPRESSOR CASCADE WITH CRENULATED TRAILING EDGES
J. L. VEESART, P. I. KING, W. C. ELROD (USAF, Institute of Technology, Wright-Patterson AFB, OH), and A. J. WENNERSTROM (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-218)

Trailing edge crenulations offer one possible way of energizing the trailing edge wakes from a gas turbine engine compressor blade by creating small vortices as a result of the pressure differential between the suction surface and pressure surface. The effect of crenulated trailing edges on wake dissipation and mixed-out total pressure loss in a linear, subsonic, compressor cascade was investigated for three low aspect ratio blade configurations: one with no crenulations and two others with large and small crenulation patterns, respectively. The effect of crenulations was to improve the wake mixing and reduce the velocity deficit. Larger crenulations dissipated the wake most rapidly, and both crenulation configurations offered an improvement in total pressure loss and some improvement in flow turning. Author

A91-44636#
THE EFFECT OF LOW REYNOLDS NUMBER ON STRAIGHT COMPRESSOR CASCADES
JAN CITAVY (National Research Institute for Machine Design, Bechovice, Czechoslovakia) and JAROMIR JILEK (Air Technique Research Institute, Prague, Czechoslovakia) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. CKD Kompresory-supported research. refs
(ASME PAPER 90-GT-221)

New low-speed experimental results are presented concerning the effect of very low Reynolds number on the aerodynamic performance of a straight compressor cascade having a NACA 65-1210 profile. The effect of Reynolds number on loss coefficient, deviation angle, pressure distribution, and axial velocity ratio within the range of Re = 10,000-100,000 is demonstrated, including 3D effects. Blade surface flow visualization has also been obtained. The results are compared with previous ones, e.g., by Roberts (1975) and are used for constructing a new model of very low Re effect on incompressible flow in a straight compressor cascade. Author

A91-44642*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PREDICTION OF THE AERODYNAMIC AND THERMAL ENVIRONMENT IN TURBINES
LISA W. GRIFFIN (NASA, Marshall Space Flight Center, Huntsville, AL) and KELLY A. BELFORD (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(Contract NAS8-36950)
(ASME PAPER 90-GT-227)

A numerical study of the steady, viscous flow prediction capabilities of the three-dimensional turbine stage code ROTOR3 is presented. Computations were performed with RAI3DC, a cascade version of ROTOR3 capable of being run in a planar or annular mode. Computed results are compared with experimental

data obtained for Hodson's cascade, Kopper's cascade, and United Technologies Research Center's Large Scale Rotating Rig (LSRR) first-stage stator. The code's predictive capability is assessed in terms of the accuracy of predicted airfoil loadings, performance (including secondary flows in the LSRR case), boundary layers, and heat transfer. A grid refinement study was conducted in the LSRR case in an effort to more accurately model the boundary layers on the airfoil and endwall surfaces. The effects of the inlet total pressure profile in secondary flow prediction were also assessed. Author

A91-44643#
VORTEX CONTROL OVER END WALL FLOW IN COMPRESSOR CASCADES
YAN-PING TANG and MAO-ZHANG CHEN (Beijing University of Aeronautics and Astronautics, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-228)

Three methods of vortex control over the end wall flow in compressor cascades have been investigated experimentally. The total pressure loss at the exit of a linear compressor cascade is reduced 6.5 percent, 10.5 percent and 26.5 percent, respectively, by these methods for different incidences over a range of moderate-high values. The physics of these methods has been discussed and some new concepts of vortex-control techniques in compressor cascades have been proposed. Author

A91-44644#
ENERGY EXCHANGE AND SECONDARY LOSSES PREDICTION IN HIGH SPEED AXIAL AND RADIAL COMPRESSORS
J. K. KALDELLIS, D. E. KODOSSAKIS (Piraeus, University, Athens, Greece), and P. D. KTENIDIS (Athens, National Technical University, Greece) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 14 p. refs
(ASME PAPER 90-GT-229)

The present secondary flow calculation method is amplified in order to estimate the energy exchange and the secondary losses in axial and radial compressors. A new theory is developed to extend the basic principles of Mellor (1971). A coherent model for the real work exchange between the fluid and the machine is designed, as well as for the distribution of secondary losses, not only at the compressor's exit but also at every station through the machine. An expression for the added work due to the secondary field is also given. The influence of secondary losses in the overall efficiency is well estimated. The present work was successfully applied to a highly loaded compressor cascade, as well as to a transonic axial compressor and to a radial single-stage one. A comparison between theoretical and experimental results is also presented. P.D.

A91-44646#
FLOW INVESTIGATION IN A SMALL HIGH SPEED IMPELLER PASSAGE USING LASER ANEMOMETRY
N. A. AHMED and R. L. ELDER (Cranfield Institute of Technology, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. SERC-supported research. refs
(ASME PAPER 90-GT-233)

The paper describes experimental results obtained using laser velocimetry in a small high-speed centrifugal impeller. The formation of wakes and the effect of varying speed and mass flow rate on the flow within the impeller passages are presented. In addition, an indication of the three dimensional nature of the impeller flow is discussed (the three dimensional results being obtained using a novel Doppler anemometer). Author

A91-44647*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
A PREDICTION OF 3-D VISCOUS FLOW AND PERFORMANCE OF THE NASA LOW-SPEED CENTRIFUGAL COMPRESSOR
JOHN MOORE and JOAN G. MOORE (Virginia Polytechnic Institute and State University, Blacksburg) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(Contract NAG3-919)
(ASME PAPER 90-GT-234)

A prediction of the three-dimensional turbulent flow in the NASA Low-Speed Centrifugal Compressor Impeller has been made. The calculation was made for the compressor design conditions with the specified uniform tip clearance gap. The predicted performance is significantly worse than that predicted in the NASA design study. This is explained by the high tip leakage flow in the present calculation and by the different model adopted for tip leakage flow mixing. The calculation gives an accumulation of high losses in the shroud/pressure-side quadrant near the exit of the impeller. It also predicts a region of meridional backflow near the shroud wall. Both of these flow features should be extensive enough in the NASA impeller to allow detailed flow measurements, leading to improved flow modeling. Recommendations are made for future flow studies in the NASA impeller. Author

A91-44648#
BOUNDARY LAYER AND NAVIER-STOKES ANALYSIS OF A NASA CONTROLLED-DIFFUSION COMPRESSOR BLADE
Y. K. HO, P. STOW (Rolls-Royce, PLC, Derby, England), and G. J. WALKER (University of Tasmania, Hobart, Australia) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 13 p. refs
(ASME PAPER 90-GT-236)

Performance calculations for a NASA controlled-diffusion compressor blade have been carried out with a coupled inviscid-boundary layer code and a time-marching Navier-Stokes solver. Comparisons with experimental test data highlight and explain the strengths and limitations of both these computational methods. The boundary layer code gives good results at and near design conditions. Loss predictions, however, deteriorated at off-design incidences. This is mainly due to a problem with leading edge laminar separation bubble modeling; coupled with an inability of the calculations to grow the turbulent boundary layer at a correct rate in a strong adverse pressure gradient. Navier-Stokes loss predictions, on the other hand, are creditable throughout the whole incidence range, except at extreme positive incidence where turbulence modeling problems similar to those of the coupled boundary layer code are observed. The main drawback for the Navier-Stokes code is the slow rate of convergence for these low Mach number cases. Plans are currently under review to address this problem. Both codes give excellent predictions of the blade surface pressure distributions for all the cases considered. Author

A91-44649#
SEMI-INVERSE DESIGN OF COMPRESSOR CASCADES, INCLUDING SUPERSONIC INFLOW
A. KIRSCHNER and H. STOFF (Asea Brown Bovery Power Plants, Ltd., Baden, Switzerland) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-237)

A cascade design-method is presented which complements the meridional through-flow design procedure of turbomachines. Starting from an axisymmetric flow field and the streamline geometry in the meridional plane this simple method produces a solution for the quasi three-dimensional flow field and the blade-element geometry on corresponding stream surfaces. In addition, it provides intra-blade data on loss and turning required for a consistent design and a convenient means of optimizing blade loading. The purpose of this paper is to describe the theoretical basis of the method and to illustrate its application in the design of transonic compressors. Author

A91-44657#
EFFECTS OF CHORDWISE DISPLACEMENT AND NONRIGID SECTION DEFORMATION ON UNSTEADY AERODYNAMIC RESPONSE OF SUBSONIC AND SUPERSONIC OSCILLATING CASCADES
MASANOBU NAMBA and KAZUHIKO TOSHIMITSU (Kyushu University, Fukuoka, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-246)

The double linearization theory is applied to lightly loaded two-dimensional subsonic and supersonic cascades undergoing oscillation with chordwise displacement or nonrigid section deformation. Numerical examples demonstrating parametric dependence of unsteady aerodynamic work on blades are presented. The chordwise displacement can be favorable or unfavorable for stabilizing the translational oscillation, depending upon the phase difference between the chordwise and normal components of the blade motion. For supersonic cascades the role of the effect of displacement of shock reflection points on unsteady aerodynamic response is significantly enhanced by the chordwise blade motion. The unsteady aerodynamic work for nonrigid section deformation is substantially influenced by steady loading. Author

A91-44660#
INFLUENCE OF PERIODICALLY UNSTEADY WAKE FLOW ON THE FLOW SEPARATION IN BLADE CHANNELS
G. H. DIBELIUS and E. AHLERS (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-253)

A test rig is used to test the influence of periodically unsteady perturbations on the turbulent flow along the suction side of turbine blades. An LDV with high spatial resolution is employed to measure averaged and fluctuating components of the velocity inside the boundary layer flow down to a distance of 0.05 mm from the plate surface determining the boundary layer parameters as well as the wall shear stress. The periodically unsteady wake flow in a turbomachine was found to cause a significant downshift of the separation zone on the blade suction side and thus to have a stabilizing effect on the blade channel flow. The downshift is linked to the energization of the boundary layer flow by turbulent mixing processes. The increased energy transport between the core flow and the boundary layer is associated with the conversion of periodic into stochastic parts of the velocity fluctuations. P.D.

A91-44665#
A ZONAL APPROACH FOR NAVIER-STOKES COMPUTATIONS OF COMPRESSIBLE CASCADE FLOW FIELDS USING A TVD FINITE VOLUME METHOD
M. FURUKAWA, M. YAMASAKI, and M. INOUE (Kyushu University, Fukuoka, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-260)

The novel approach presented for the computation of compressible viscous flows in cascades achieves robustness in its cell-centered finite-volume formulation by evaluating the inviscid fluxes at cell interfaces with a precise TVD scheme that employs Roe's approximate Riemann solver. A composite zonal grid system is adopted for simplicity in which the computational domain is divided into nonoverlapping zones; structured grids are generated independently in each zone. Communication among zones is accomplished by numerical fluxes across the zonal boundary. Numerical examples are presented for viscous flows through a transonic turbine cascade. O.C.

A91-44666*# Pennsylvania State Univ., University Park.
PREDICTION OF CASCADE PERFORMANCE USING AN INCOMPRESSIBLE NAVIER-STOKES TECHNIQUE
G. V. HOBSON and B. LAKSHMINARAYANA (Pennsylvania State University, University Park) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 15 p. refs
(Contract NSG-3266)
(ASME PAPER 90-GT-261)

A fully elliptic, control volume solution of the two-dimensional incompressible Navier-Stokes equations for the prediction of cascade performance over a wide incidence range is presented. The numerical technique is based on a new pressure substitution method. A Poisson equation is derived from the pressure weighted substitution of the full momentum equations into the continuity equation. The analysis of a double circular arc compressor cascade is presented, and the results are compared with the available experimental data at various incidence angles. Good agreement is obtained for the blade pressure distribution, boundary layer and wake profiles, skin friction coefficient, losses and outlet angles. Turbulence effects are simulated by the Low-Reynolds-Number version of the k-epsilon turbulence model. Author

A91-44667#
INVISCID AND VISCOUS SOLUTIONS FOR AIRFOIL/CASCADE FLOWS USING A LOCALLY IMPLICIT ALGORITHM ON ADAPTIVE MESHES
C. J. HWANG and J. L. LIU (National Cheng Kung University, Tainan, Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-262)

A numerical solution procedure, which includes a locally implicit finite volume scheme and an adaptive mesh generation technique, has been developed to study airfoil and cascade flows. The Euler/Navier-Stokes, continuity and energy equations, in conjunction with Baldwin-Lomax model for turbulent flow, are solved in Cartesian coordinate system. To simulate physical phenomena efficiently and correctly, a mixed type of mesh, the unstructured triangular cell for the inviscid region and structured quadrilateral cell for the viscous, boundary layer and wake regions, is introduced in this work. The inviscid flows passing through a channel with circular arc bump and the laminar flows over a flat plate with/without shock interaction are investigated to confirm the accuracy, convergence and solution-adaptibility of the numerical approach. To further prove the reliability and capability of the present solution procedure, the inviscid/viscous results for flows over the NACA 0012 airfoil, NACA 65-(12)10 compressor and one advanced transonic turbine cascade are compared to the numerical and experimental data given in related papers and reports. Author

A91-44668#
DETAILED BOUNDARY LAYER MEASUREMENTS ON A TRANSONIC TURBINE CASCADE
D. J. MEE, M. L. G. OLDFIELD (Oxford, University, England), and N. C. BAINES (Imperial College of Science, Technology, and Medicine, London, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC. refs
(ASME PAPER 90-GT-263)

The boundary layers of a transonic turbine blade have been measured in detail. The full velocity profiles have been measured at a number of stations on both the suction and pressure surfaces, at conditions representative of engine operation, using a pitot traverse technique and a large scale (300 mm chord) linear cascade. This information has made it possible to follow the development of the boundary layers, initially laminar, through a region of natural transition to a fully developed turbulent layer. Comparisons with other, less detailed, measurements on the same profile using pitot traverse and surface mounted thin films confirm the essential features of the boundary layers. Author

A91-44669#
AN EXAMINATION OF THE CONTRIBUTIONS TO LOSS ON A TRANSONIC TURBINE BLADE IN CASCADE
D. J. MEE, M. L. G. OLDFIELD, T. E. DICKENS (Oxford, University,

England), and N. C. BAINES (Imperial College of Science, Technology, and Medicine, London, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC. refs
(ASME PAPER 90-GT-264)

Experiments to measure losses of a linear cascade of transonic turbine blades are reported. Detailed measurements of the boundary layer at the rear of the suction surface of a blade and examination of wake traverse data enable the individual components of boundary layer, shock and mixing loss to be determined. Results indicate that each component contributes significantly to the overall loss in different Mach number regimes. Traverses in the near wake of the blade indicate the way in which the wake develops and facilitate examination of the development of the mixing loss. Author

A91-44683#
LASER TWO-FOCUS ANEMOMETRY INVESTIGATION OF THE FLOW FIELD WITHIN A SUPERSONIC AXIAL COMPRESSOR ROTOR

ISABELLE TREBINJAC and ANDRE VOUILLARMET (Lyon, Ecole Centrale, Ecully, France) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. DRET-supported research. refs
(ASME PAPER 90-GT-298)

The 3D flow field of a supersonic single-stage high-pressure compressor has been studied with laser anemometry at a maximum relative Mach number that varies from 1.1 at the rotor blade hub to 1.3 at the tip. Stage total pressure ratio is 1.84, at a specific mass flow of 180 kg/sec per sq m. The present evaluation of the global flow field gives attention to the shock pattern; experimental results are compared with both viscous and inviscid 3D numerical simulation. The viscous computation, based on the Navier-Stokes solution for a mixing length turbulence model, yielded notably close agreement with experimental data. O.C.

A91-44688#
DAWES AND DENTON CODES APPLIED TO A TRANSONIC COMPRESSOR ROTOR

T. W. VON BACKSTROEM (Stellenbosch, University, Republic of South Africa) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-304)

The three-dimensional viscous transonic time marching Denton code LOSS3D, and Dawes code BTOB3D are applied to the first stage rotor of the NACA 5-stage transonic compressor. Computing time per solution on a mini-supercomputer was about 9 hours for a mesh of 65,000 points. LOSS3D predicted pressure ratio and loss distributions reasonably well at design point, but did not quite satisfy the convergence criteria. BTOB3D tended to overpredict the total pressure ratio over the outer half of span due to an underprediction of loss in the complicated separated flow region triggered by shock boundary layer interaction on the suction surface, but prediction was good at 90 percent speed where shock boundary layer interaction was less severe. The use of a computationally convenient excessively large tip clearance is not recommended when shock-boundary layer interaction is expected, especially at off-design conditions. Author

A91-44691#
NOZZLE GUIDE VANE SHOCK WAVE PROPAGATION AND BIFURCATION IN A TRANSONIC TURBINE ROTOR

A. B. JOHNSON, M. L. G. OLDFIELD (Oxford, University, England), M. J. RIGBY (Rolls Royce, PLC, Derby, England), and M. B. GILES (MIT, Boston, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Rolls-Royce, PLC-supported research. refs
(Contract F33615-84-C-2475)
(ASME PAPER 90-GT-310)

A study of the propagation of a Nozzle Guide Vane (NGV) trailing edge shock wave through a transonic turbine rotor passage is presented. The work was based on experimental tests carried out in the Isentropic Light Piston Tunnel in Oxford University using a rotating bar NGV shock wave simulator, together with schlieren photography and wide band width surface pressure and heat transfer rate measurements. The study identifies a previously unexplained interaction between the incoming wave and the rotor leading edge, which causes the nucleation of a Vortical Bubble. This bubble has been shown to enhance the thermal loading on the early pressure surface of the blade. A method of controlling this bubble and heat loading is also considered. A previously unseen 'Lambda' interaction between the shock wave and the rotor pressure surface is also identified. Author

A91-44692#
NUMERICAL PREDICTION OF TURBINE PROFILE LOSS

L. XU (Beijing University of Aeronautics and Astronautics, People's Republic of China) and J. D. DENTON (Cambridge, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Research sponsored by Rolls-Royce, PLC. refs
(ASME PAPER 90-GT-311)

A simple numerical method for predicting the profile loss of turbine blades in subsonic and transonic flows is presented. A time marching Euler solver is used to obtain the main flow through the blade passages, the loss due to the surface friction is calculated using an integral boundary layer method, the total mixed out loss is evaluated from the mass flow and momentum balances between the trailing edge plane and an imaginary downstream plane where the flow is uniform. The base pressure acting on the trailing edge of the blade is calculated directly from the inviscid calculation without empirical correlations. The spurious numerical loss in the Euler calculation is separated from the real loss. The rationality of the approach is justified by the agreement of the prediction with a wide range of experimental measurements. Author

A91-44693#
OVERTIP PRESSURE MEASUREMENTS IN A COLD-FLOW TURBINE RIG

R. C. KINGCOMBE, I. M. SMITH, and R. V. STEEDEN (Royal Aerospace Establishment, Propulsion Dept., Farnborough, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-312)

A row of high-frequency-response miniature pressure transducers is mounted in the casing of a cold flow turbine rig in the region swept by rotor blade tips in order to investigate the structure of overtip flow in shroudless axial turbines. Using a once-per-revolution timing pulse as a trigger, the pressure signals from all the transducers were recorded for a number of blade revolutions. A description is presented of the data acquisition system, which includes equipment for digitally sampling and storing the data synchronously with passage of the rotor blades, leading to the derivation of the periodic and random elements of the pressure variation. The results are presented and compared with those from other researchers with the objective of achieving a better understanding of overtip flow phenomena. Good agreement was observed over the front part of the blade, indicating little or no overtip leakage flow. From about 40-percent cord, differences appeared within the tip gap until, at 50-percent chord, the profiles were different across the entire passage. P.D.

A91-44694#
EXPERIMENTAL ANALYSIS DATA ON THE TRANSONIC FLOW PAST A PLANE TURBINE CASCADE

M. STASTNY (SKODA Concern Enterprise, Power Machinery Plant, Plzen, Czechoslovakia) and P. SAFARIK (Czechoslovak Academy of Sciences, Institute of Thermomechanics, Prague, Czechoslovakia) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Research supported by Czechoslovak Academy of

Sciences and SKODA Concern Enterprise. refs
(ASME PAPER 90-GT-313)

The paper presents results from aerodynamic tests on a transonic rotor turbine profile cascade, including interferograms of the flow field and aerodynamic data measured downstream from the cascade. The dimensions and aerodynamic data on the cascade are given in detail. Analysis following the experimental data collection was aimed at investigating the sensitivity of transonic flow in the vicinity of the throat and related conditions leading to the compression effect. Further, the development of the flow structure and the cascade parameters over a wide range of exit Mach numbers, as well as incidence angles are shown. The experimental data are compared with results of calculations based on mathematical models. Author

A91-44695#
OFF-DESIGN PERFORMANCE OF A LINEAR CASCADE OF TURBINE BLADES
B. TREMBLAY, S. A. SJOLANDER (Carleton University, Ottawa, Canada), and S. H. MOUSTAPHA (Pratt and Whitney Canada, Montreal) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Research supported by NSERC and Pratt and Whitney Canada. refs
(ASME PAPER 90-GT-314)

This study presents measurements of the low-speed two-dimensional performance of a linear cascade of turbine blades with a turning angle of 87 degrees. The incidence was varied between -25 and +25 degrees in 5-degree steps. The blade surface pressures, total pressure loss coefficients and trailing-edge deviations are presented for all values of incidence. The influence of incidence on the critical Reynolds number is also examined. Surface flow visualization is presented for different values of Reynolds number and incidence to aid in the physical interpretation of the measurements. Author

A91-44723#
ANALYSIS OF VISCOUS FLOWFIELD OVER TACTICAL AIRCRAFT FOREBODY AND INLETS
W. TSENG and D. FINDLAY (U.S. Navy, Naval Air Development Center, Warminster, PA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-387)

The use of a computational methodology to investigate the flowfield of the F/A-18 forebody, the X-31A inlet, the YF-16 inlet, and the integrated forebody-inlet flow of the YF-16 is discussed. A discussion of the preprocessor is presented which prepares the input grid for the flow solver and generates a graphic display of the model for viewing examination. The solution methodology of the governing equation is considered. Four configurations are analyzed, namely the F/A-18 forebody, X-31A inlet, YF-16 inlet, and the YF-16 inegrated forebody-inlet, with results presented utilizing a post-processor. Author

A91-44758#
MULTIGRID SOLUTIONS OF 3-D INVISCID FLOWS THROUGH CIRCULAR-TO-RECTANGULAR DUCTS
CHUNHUA SHENG (Nanjing Aeronautical Institute, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 5-11. In Chinese. refs

The 3D inviscid subsonic and transonic flows through circular-to-rectangular transition ducts for nonaxisymmetric nozzles are solved here using a multigrid method. Ni's (982) 2D finite volume integration scheme is expanded to solve the 3D Euler flow equations, and the 'prediction-correction' method is successfully used to handle the boundary conditions of the complex 3D nozzle flows. In order to improve stability of the scheme, the first-order time rate change of the flow variable at the grid points is obtained using cell volume average instead of the arithmetic average. The results show that a better convergence rate can be obtained by updating the flow variables immediately after corrections in each coarse grid are calculated and interpolated into the finest grid. Solutions to the 3D inviscid flows in two nozzle configurations are presented and compared with experimental results. C.D.

A91-44759#
NUMERICAL SOLUTION OF TURBULENT FLOW FIELD THROUGH A TANDEM CASCADE USING FINITE ANALYTIC METHOD
DIAO XU and GUOCHUAN WU (Nanjing Aeronautical Institute, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 12-18. In Chinese. refs

The finite analytic method is used here to calculate the turbulent flow field described by Navier-Stokes equations in a body-fitted curvilinear coordinate system. The method uses the analytic solution of the governing partial differential equation to formulate the algebraic equation that relates a nodal value in an element to its neighboring nodal values. The major feature of the method is its ability to simulate automatically the upwind influence of neighboring modal values according to the direction and the magnitude of convection. It is shown that the method has good numerical stability and accuracy. The turbulent flow fields through a two-dimensional tandem cascade of airfoils with incident angles of 0, 10, and -10 deg, are numerically simulated. Good agreement with experimental results is found. C.D.

A91-44768#
AN IMPROVED METHOD OF AIRFOIL DESIGN
CAIWEN ZHANG (Institute of Pilotless Aircraft, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 125-129. In Chinese. refs

An improved method of airfoil design is proposed in this paper which transfers the design problem into the solution of the minimum value problem of a multivariable function. It can be applied to subcritical airfoil design, taking viscosity into consideration. Author

A91-45094
AERODYNAMICS OF BODIES WITH INJECTION [AERODINAMIKA TEL SO VDUVOM]
VIKTOR A. ANTONOV, VIKTOR D. GOL'DIN, and FEDOR M. PAKHOMOV Tomsk, Izdatel'stvo Tomskogo Universiteta, 1990, 193 p. In Russian. refs
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Methods are presented for solving the problem of supersonic flow past bodies with injection in the presence of a second phase and radiation. Results of the application of these methods to the study of axisymmetric and three-dimensional flows are reported. An analysis is made of the effect of injection parameters, angle of attack, and solid particles in the flow on the flow structure and aerodynamic characteristics of bodies. Calculations of radiative heat and mass transfer between blunt bodies and flow of a hydrogen-helium mixture are presented. V.L.

A91-45101#
INTERACTIVE AIRFOIL CALCULATIONS WITH HIGHER-ORDER VISCOUS-FLOW EQUATIONS
D. W. ZINGG and G. W. JOHNSTON (Toronto, University, Canada) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1033-1040. Previously cited in issue 16, p. 2482, Accession no. A90-38678. refs
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A91-45102#
EFFECTS OF THREE-DIMENSIONAL AERODYNAMICS ON BLADE RESPONSE AND LOADS
KI-CHUNG KIM and INDERJIT CHOPRA (Maryland, University, College Park) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1041-1050. Previously cited in issue 12, p. 1775, Accession no. A89-30767. refs
(Contract DAAL03-88-C-0002)
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A91-45110*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATION OF LAMINAR HYPERSONIC COMPRESSION-CORNER FLOWS
DAVID H. RUDY, JAMES L. THOMAS, AJAY KUMAR, PETER A. GNOFFO (NASA, Langley Research Center, Hampton, VA), and SUKUMAR R. CHAKRAVARTHY (Rockwell International Science Center, Thousand Oaks, CA) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1108-1113. Previously cited in issue 18, p. 2756, Accession no. A89-42066. refs
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A91-45115#
CONTROL OF SEPARATED FLOW BY A TWO-DIMENSIONAL OSCILLATING FENCE
J. J. MIAU, J. H. CHOU (National Cheng Kung University, Tainan, Republic of China), K. C. LEE, and M. H. CHEN AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1140-1148. Sponsorship: National Science Council of the Republic of China. refs
(Contract NSC-77-0401-E006-38)
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Control of separated flow behind a backward-facing step using a two-dimensional oscillating fence installed upstream has been investigated. Parameters of the flow considered included the reduced frequency of the oscillating fence, the distance from the oscillating fence to the backward-facing step, the ratio of the maximum height of the oscillating fence to the step height, and the Reynolds number. It was found that with the experimental parameters properly selected, the time-mean reattachment length of the separation region could be reduced over 40 percent, compared to the case without the presence of an oscillating fence. The evolution of unsteady flow behind a backward-facing step was further studied in detail by a phase-averaging measurement technique. The results obtained indicate that suppression of the separated flow behind the step is mainly due to the downwash motion induced by the vortical structure released upstream from the oscillating fence, when it convects over the step. Author

A91-45118#
COMPUTATIONAL PREDICTION OF STALL FLUTTER IN CASCADED AIRFOILS
F. SISTO, S. THANGAM, and A. ABDEL-RAHIM (Stevens Institute of Technology, Hoboken, NJ) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1161-1167. Previously cited in issue 11, p. 1607, Accession no. A90-29388. refs
Copyright

A91-45121# Texas Univ., Arlington.
UPSTREAM-INFLUENCE SCALING OF SHARP FIN INTERACTIONS
FRANK K. LU (Texas, University, Arlington) and GARY S. SETTLES (Pennsylvania State University, University Park) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1180, 1181. Previously cited in issue 06, p. 757, Accession no. A90-19822. refs
(Contract AF-AFOSR-86-0082; NCA2-192; NAG1-891)
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A91-45151
CURVATURE EFFECTS ON THE WAKE OF AN AIRFOIL AND OTHER BODIES
V. RAMJEE and D. NEELAKANDAN (Indian Institute of Technology, Madras, India) Fluid Dynamics Research (ISSN 0169-5983), vol. 6, June 1990, p. 1-13. Research supported by Aeronautical Research and Development Board of India. refs
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Measurements of mean velocity and turbulent stresses are carried out in the wake of an airfoil, in a straight duct and in two curved ducts. A comparison is made on the variation of turbulent shear stress in the wakes of bluff bodies and that of an airfoil in curved and straight ducts. The turbulent shear stress is increased on one side of the curved wake centerline compared to that of the straight wake, and on the other side it is reduced. It is found that the turbulent shear stress is more sensitive to curvature than the normal stresses. Author

A91-45161
ORGANIZATION IN A TURBULENT NEAR-WAKE
R. A. ANTONIA (Newcastle, University, Australia) Fluid Dynamics Research (ISSN 0169-5983), vol. 7, June 1991, p. 139-149. Research supported by Australian Research Council. refs
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The streamwise evolution of the turbulence structure in the near-wake of a cylinder has been quantified using data from an array of eight X-probes in the plane of mean shear. The relative probability of detections of large scale vortical structures on opposite sides of the centerline indicates that the spatial arrangement of these structures can vary in a continuous manner between a dominant alternating (antisymmetric) mode and an opposing (symmetric) code. At a distance of 10 diameters from the cylinder, the contributions from the alternating mode to the lateral turbulence intensity and Reynolds shear stress are appreciable. These contributions are discussed in the context of the main topological features of this mode. Author

A91-45178*# Engineering Analysis, Inc., Ames, IA.
THREE-DIMENSIONAL UPWIND, PARABOLIZED NAVIER-STOKES CODE FOR CHEMICALLY REACTING FLOWS
PHILIP E. BUELOW, JOHN C. TANNEHILL, JOHN O. LEVALTS (Engineering Analysis, Inc., Ames, IA), and SCOTT L. LAWRENCE (NASA, Ames Research Center, Moffett Field, CA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 5, July-Sept. 1991, p. 274-283. Previously cited in issue 06, p. 758, Accession no. A90-19831. refs
(Contract NAS2-12861)
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A91-45181*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL AND PREDICTED PRESSURE AND HEATING DISTRIBUTIONS FOR AEROASSIST FLIGHT EXPERIMENT VEHICLE
JOHN R. MICOL (NASA, Langley Research Center, Hampton, VA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 5, July-Sept. 1991, p. 301-307. Previously cited in issue 18, p. 2762, Accession no. A89-43245. refs
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A91-45290#
CALCULATION OF TRANSONIC FLOWS BY A FIELD INTEGRAL EQUATION METHOD
C. P. CHEN and M. J. SHEU (National Tsing Hua University, Hsinchu, Republic of China) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 360-364. refs
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A field integral equation method is developed to solve the two-dimensional compressible potential equation for transonic flow over airfoils with embedded shocks at subsonic freestream Mach numbers. The perturbation velocities are induced by linear internal source and vorticity distributions on the mean camber line of the airfoil and nonlinear field source distributions external to the airfoil surface. Derivatives are calculated in the computational plane, and those in the physical plane are determined by using the Jacobian of the transformation. An O-type grid is applied to reduce the numerical errors in the region close to the location where the shock wave occurs. The calculations have been carried out for NACA 0012, parabolic arc, and circular arc airfoils at various subcritical freestream Mach numbers. The results of the present method are compared with earlier results and are shown to be in good agreement. Author

A91-45291#
EXPERIMENTAL AND NUMERICAL STUDY OF THE PROPELLER/FIXED WING INTERACTION
DANIEL FAVIER, CHRISTIAN MARESCA (Aix-Marseille II,

Universite, Marseille, France), and GILLES FRATELLO Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 365-373. Previously cited in issue 16, p. 2595, Accession no. A88-40742. refs
(Contract DRET-85-115)
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A91-45292*# Rockwell International Science Center, Thousand Oaks, CA.
NUMERICAL SOLUTIONS OF FORWARD-FLIGHT ROTOR FLOW USING AN UPWIND METHOD
C. L. CHEN (Rockwell International Science Center, Thousand Oaks, CA), W. J. MCCROSKEY, and S. OBAYASHI (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 374-380. Previously cited in issue 18, p. 2756, Accession no. A89-42074. refs
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A91-45293*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSONIC NAVIER-STOKES SOLUTIONS ABOUT A GENERIC HYPERSONIC CONFIGURATION
FARHAD GHAFFARI, JAMES M. LUCKRING, JAMES L. THOMAS (NASA, Langley Research Center, Hampton, VA), and BRENT L. BATES (Vigyan, Inc., Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 381-388. Previously cited in issue 06, p. 759, Accession no. A90-19844. refs
(Contract NAS1-18585)
Copyright

A91-45294#
COMPUTED EULER FLOWFIELD FOR A TRANSONIC AIRCRAFT WITH STORES
J. H. FOX, T. L. DONEGAN, J. L. JACOCKS, and R. H. NICHOLS (Calspan Corp., Arnold AFB, TN) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 389-396. Previously cited in issue 21, p. 3252, Accession no. A89-47676. refs

A91-45295*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACCURACY OF AN UNSTRUCTURED-GRID UPWIND-EULER ALGORITHM FOR THE ONERA M6 WING
JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 397-402. refs
Copyright

Improved algorithms for the solution of the three-dimensional, time-dependent Euler equations are presented for aerodynamic analysis involving unstructured dynamic meshes. The improvements have been developed recently to the spatial and temporal discretizations used by unstructured-grid flow solvers. The spatial discretization involves a flux-split approach that is naturally dissipative and captures shock waves sharply with at most one grid point within the shock structure. The temporal discretization involves either an explicit time-integration scheme using a multistage Runge-Kutta procedure or an implicit time-integration scheme using a Gauss-Seidel relaxation procedure, which is computationally efficient for either steady or unsteady flow problems. With the implicit Gauss-Seidel procedure, very large time steps may be used for rapid convergence to steady state, and the step size for unsteady cases may be selected for temporal accuracy rather than for numerical stability. Steady flow results are presented for both the NACA 0012 airfoil and the Office National d'Etudes et de Recherches Aerospatiales M6 wing to demonstrate applications of the new Euler solvers. The paper presents a description of the Euler solvers along with results and comparisons that assess the capability. Author

A91-45296*# Bell Helicopter Co., Fort Worth, TX.
COMPUTATIONAL AND EXPERIMENTAL EVALUATION OF HELICOPTER ROTOR TIPS FOR HIGH-SPEED FLIGHT
MATTHEW T. SCOTT, DAVE SIGL (Bell Helicopter Textron, Inc., Fort Worth, TX), and ROGER C. STRAWN (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 403-409. Previously cited in issue 18, p. 2756, Accession no. A89-42073. refs
Copyright

A91-45318#
VISUAL STUDY ON WAKES BEHIND SOLID AND SLOTTED AXISYMMETRIC BLUFF BODIES
HIROSHI HIGUCHI (Syracuse University, NY) Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 427-430. Previously cited in issue 14, p. 2115, Accession no. A89-35215. refs
Copyright

A91-45323*# North Carolina State Univ., Raleigh.
NEW DEVICE FOR CONTROLLING ASYMMETRIC FLOWFIELDS ON FOREBODIES AT LARGE ALPHA
CARY A. MOSKOVITZ, F. R. DEJARNETTE (North Carolina State University, Raleigh), and ROBERT M. HALL (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 456-462. Previously cited in issue 06, p. 754, Accession no. A90-19665. refs
Copyright

A91-45346#
ASSESSMENT OF MODELING AND DISCRETIZATION ACCURACY FOR HIGH-SPEED AFTERBODY FLOWS
ROBERT E. CHILDS and STEVEN C. CARUSO (Nielsen Engineering and Research, Inc., Mountain View, CA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 607-616. Previously cited in issue 09, p. 1282, Accession no. A89-25425. refs
(Contract DAAL03-86-C-0002; F33615-88-C-3020)
Copyright

A91-45347#
SURVEY OF VALIDATION DATA BASE FOR SHOCKWAVE BOUNDARY-LAYER INTERACTIONS IN SUPERSONIC INLETS
A. HAMED (Cincinnati, University, OH) and J. S. SHANG (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 617-625. Previously cited in issue 20, p. 3084, Accession no. A89-47183. refs
(Contract F49620-88-C-0053)
Copyright

A91-45348*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL TRANSITION INVESTIGATION OF A FREE-SHEAR LAYER ABOVE A CAVITY AT MACH 3.5
RUDOLPH A. KING, THEODORE R. CREEL, JR., and DENNIS M. BUSHNELL (NASA, Langley Research Center, Hampton, VA) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 626-634. Previously cited in issue 18, p. 2754, Accession no. A89-42043. refs
Copyright

A91-45354#
EXPERIMENTAL AND NUMERICAL STUDY OF THE FLOW AROUND A HELICOPTER FUSELAGE - DETERMINATION OF DRAG COEFFICIENT
C. GLEYZES, X. DE SAINT-VICTOR (ONERA, Centre d'Etudes et de Recherches de Toulouse, France), and G. FALEMPIN (ONERA, Chatillon, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p. DRET-supported research. refs

The flow around a simplified helicopter fuselage is studied. A model is developed and studied in the F2 wind tunnel. Comparisons are made with boundary layer calculations which show that simple inviscid flow calculations can provide boundary conditions giving reasonable overall agreement upstream of separation. K.K.

A91-45355#
HIGH-SPEED DAUPHIN FUSELAGE AERODYNAMICS

A. CLER (Aerospatiale, Division Helicopteres, Marignane, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p.

Fuselage aerodynamics research which led to the design of the high-speed Dauphin is described. Analytical methods and wind tunnel tests were used to optimize the rotor head fairing, the general shape of the highly streamlined upper cowlings, the semistatic engine air intakes, and the engine exhaust ducts. The modifications resulted in a 20 percent drag reduction in comparison to the standard SA-365N Dauphin. K.K.

A91-45356#
AN INTEGRATED APPROACH TO ROTORCRAFT AERODYNAMIC DESIGN AND DEVELOPMENT
GIUSEPPE PAGNANO (Agusta S.p.A., Samarate, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p. refs

Current work by a major European helicopter manufacturer on aerodynamic tools development and application is presented and discussed. In the computational area, the present effort is described as part of a research program within a proposal for a European collaborative program. The integration between CAD systems, computer requirements, and CFD methods is also examined. Progress with respect to a recent contribution to wind-tunnel testing is presented. The development of advanced powered models for rotor testing and aerodynamic studies based on model rotors is described. Consideration is given to plans for long- and short-term aerodynamic tool development, with emphasis on the requirements for integration of model testing, development of prediction methods, and flight testing. P.D.

A91-45357#
A CONSIDERATION OF LOW-SPEED DYNAMIC STALL ONSET
M. W. GRACEY, A. J. NIVEN, and R. A. MCD. GALBRAITH (Glasgow, University, Scotland) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 23 p. Research supported by Department of Energy and Department of Defence of England. refs
(Contract MOD-2048/XR/STR; SERC-GR/D/41064)

The paper discusses relevant and contemporary criteria for the onset of low-speed dynamic stall. A new correlation is proposed which attempts to relate an aerofoil's dynamic stall onset incidence to particular parameters which describe its static stall behavior. The correlation is derived from two parameters which are obtained under steady conditions from experimental data: the static-stall incidence, and an additional variable related to the trailing-edge separation characteristics. To generate the coefficients in the resulting equation, a large amount of aerodynamic data was analyzed from experiments performed under static, ramp, and sinusoidal motions in the University of Glasgow's 'Handley-Page' wind tunnel, and stored in a database. A number of aerofoils from two families have been tested: the NACA four-digit series of symmetrical sections, and a new family of four profiles, developed at the University, which has the NACA 23012 as the generic shape. The paper also discusses the outcome of a comparison between an indicial-response dynamic stall model and the experimental data specific to one of the modified NACA 23012 sections. Author

A91-45358#
AN ANALYTICAL MODEL OF UNSTEADY PROFILE AERODYNAMICS AND ITS APPLICATION TO A ROTOR SIMULATION PROGRAM
B. G. VAN DER WALL (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 20 p. refs

The steady and unsteady aerodynamic forces and moments of a profile, including sweep effects are described by an analytical model. The model is implemented in a rotor simulation program coupled with a code representing unsteady aerodynamic coefficients and two higher-order wake models. All degrees of freedom are included in the form of an uncoupled modal description in a flap, lag, and torsion. Two downwash models are investigated: the model of Manger up to the sixth harmonic and a simple prescribed distorted wake geometry of Beddoes in a modified version. The results of calculations show that unsteady aerodynamics are influencing the vibratory airloads strongly, and that a high vibration level and correct control angles at low speeds can be calculated correctly only when blade/vortex interaction is under consideration. V.T.

A91-45359*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THREE-DIMENSIONAL VISCOUS ROTOR FLOW CALCULATIONS USING BOUNDARY-LAYER EQUATIONS
CHING S. CHEN (NASA, Ames Research Center, Moffett Field, CA) and JOHN O. BRIDGEMAN (Woodside Summit Group, Inc., Mountain View, CA) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 25 p. refs

A three-dimensional viscous-inviscid interaction analysis has been developed to predict the performance of rotors in hover and forward flight at subsonic and transonic tip speeds. The analysis solves the full-potential and boundary-layer equations by finite-difference numerical procedures. Calculations were made for several different model rotor configurations in hover and forward flight at subsonic and transonic tip speeds. The results were compared with predictions from a two-dimensional integral method and with experimental data. The comparisons show good agreement between test data and predictions. Author

A91-45360#
CORRELATION OF PUMA AIRLOADS - EVALUATION OF CFD PREDICTION METHODS
ROGER C. STRAWN (U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA), ANDRE DESOPPER (ONERA, Chatillon, France), JUDITH MILLER, and ALAN JONES (Royal Aerospace Establishment, Farnborough, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 20 p. refs

The paper addresses a program comparing predictions with experimental data for flight tests of a research Puma helicopter with rectangular and swept-tip blades. Computed results from three CFD codes are compared for flight-test cases where all three codes use the same partial-angle boundary conditions, and the results of one of the CFD codes iteratively coupled with a helicopter-performance code are compared with experimental data and with an uncoupled helicopter-performance code solution. The iterative coupling procedure and its influence on the final set of results are examined. The importance of conveying unsteady information accurately to the CFD codes is found to be even more important if the CFD-computed drag and pitching moments are to be coupled to the performance codes. Alternate boundary conditions are suggested in order to model this unsteadiness in the CFD codes properly. V.T.

A91-45361#
APPLICATION OF 3D-EULER CODE TO ROTOR BLADE TIPS
H. STAHL-CUCINELLI (MBB GmbH, Munich, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 21 p. refs

A 3D steady Euler code, developed for fixed wings, has been modified for steady rotor flow conditions. This code is applied to two different planforms and profiles of rotor blades for steady flow conditions at psi = 90 deg and mu = 0.34. The results shows that the planform has a strong influence on the pitching moment distribution and the extension of the supersonic region. Because the flow is really unsteady for mu greater than 0, the Euler code was extended to include 3D unsteady flow conditions. Preliminary results are presented for a sinusoidal change of the angle of attack. For validation, the flow of a hovering model rotor is calculated and compared with measurements. Author

A91-45362#
GLAUERT AUGMENTATION OF ROTOR INFLOW DYNAMICS
R. BRADLEY, C. G. BLACK, and D. J. MURRAY-SMITH (Glasgow, University, Scotland) European Rotorcraft Forum, 15th,

Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 24 p. Sponsorship: Ministry of Defence of England. refs
(Contract MOD-2048/46/XR/STR)

The parameters of a state-space type of model representing rotor flapping and induced velocity for a Puma helicopter are estimated by utilizing a frequency-domain output-error system identification technique. A first-order blade-flapping model with basic induced-flow dynamics and its modification are discussed, and a more complex representation of the rotor surface used in the momentum-inflow theory, incorporating effects due to blade flap and blade pitch is considered. The fundamental physical parameters in the extended model structure are estimated with values that are physically realistic and constant for a range of frequencies. The introduction of two distinct time constants associated with the induced-flow dynamics is found to be a valid modeling step. V.T.

A91-45363#
EXPERIMENTAL VERIFICATION OF AN IMPROVED ACTUATOR DISC CONCEPT
G. A. M. VAN KUIK (Stork Product Engineering, Amsterdam, Netherlands) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 17 p.

The study focuses on an assumption in the momentum theory, based on Froude's concept: it is pointed out that the theory does not distinguish the total thrust and the thrust converting power. A proof of principle showing that the assumption is not valid when applied to rotors is presented. It is shown experimentally that the distinction between the total thrust and the thrust converting power can be significant: the effective thrust can be 87 pct of the total thrust; therefore, the distinction between the total thrust and the effective thrust is necessary in the physical interpretation of a rotor flow by the means of the momentum theory. V.T.

A91-45377*# Florida Atlantic Univ., Boca Raton.
EFFECTS OF ROTATING FRAME TURBULENCE AND DYNAMIC STALL ON GUST RESPONSE OF HELICOPTER BLADES
R. MADHAVAN and G. H. GAONKAR (Florida Atlantic University, Boca Raton) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 25 p. Research supported by U.S. Army and NASA. refs

The instantaneous or frequency-time spectrum of rotating frame turbulence (RFT) is presented. This spectrum makes it possible to predict the transfer of energy with respect to frequencies and the periodically varying nonstationarity with respect to time. Attention is also given to the RFT effects on the response statistics of an isolated rotor blade for low-advance-ratio and low-altitude conditions. It is noted that spectral density, rms values, and threshold-crossing expectation rates are significantly influenced by RFT. K.K.

A91-45420
EXPERIMENTAL AND NUMERICAL STUDIES OF WEAK BLAST WAVES IN AIR
H. HONMA, D. Q. XU (Chiba University, Japan), I. I. GLASS, C. H. WONG, and O. HOLST-JENSEN (Toronto, University, Canada) Shock Waves (ISSN 0938-1287), vol. 1, June 1991, p. 111-119. NSERC-supported research. refs
Copyright

Effects of viscosity and vibrational nonequilibrium on the profile of a weak, spherical N-wave in air were studied in a series of experiments and numerical simulations. Experiments revealed that, for N-waves with less than 100 Pa peak overpressure, the peak overpressure delta pf and the duration of the positive phase td+ varied with the radial distance from the source r as delta pf is proportional to r exp -1.38 and td+ is proportional to r exp 0.19. The blast wave data are compared with numerical simulations results. The resultant N-wave profiles are found to be in good agreement with the experimental results. The numerical results indicate that the wave-easing process due to the dispersive effect of vibrational relaxation plays a dominant role in determining the rise time of the N-wave. O.G.

A91-45548*# Toledo Univ., OH.
FLUTTER ANALYSIS OF CASCADES USING A TWO DIMENSIONAL EULER SOLVER
T. S. R. REDDY, MILIND A. BAKHLE (Toledo, University, OH), DENNIS L. HUFF (NASA, Lewis Research Center, Cleveland, OH), and TIMOTHY W. SWAFFORD (Mississippi State University, Mississippi State) AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 22nd, Honolulu, HI, June 24-26, 1991. 21 p. refs
(Contract NAG3-3139; NAG3-1137; NAG3-983)
(AIAA PAPER 91-1681) Copyright

Flutter analysis of a cascade of blades in compressible flow is presented, with each blade of the cascade modeled as a typical section having pitching and plunging degrees of freedom. The aerodynamic forces are obtained from an unsteady, 2-D cascade solver based on the Euler equations. To reduce the computational time, an influence coefficient technique and a pulse response technique are also used to obtain the unsteady force coefficients for any frequency and phase angle. The predicted steady and unsteady aerodynamic forces for selected cascade geometries and flow conditions correlate well with the available experimental and analytical data. R.E.P.

A91-45607#
THREE-DIMENSIONAL UNSTEADY FLOW COMPUTATION THROUGH A TRANSONIC AXIAL FLOW TURBINE STAGE WITH VISCOUS EFFECTS - COMPARISON WITH EXPERIMENTAL DATA
ALAIN LE MEUR (ONERA, Chatillon, France) (European Conference on Turbomachinery, London, England, Mar. 19, 20, 1991) ONERA, TP no. 1991-24, 1991, 9 p. refs
(ONERA, TP NO. 1991-24)

A time-accurate three-dimensional code that solves the complete set of Euler equations is developed. It is shown that this code gives a good estimate of turbine stage performances. The average values obtained with the code are in good agreement with experimental data. K.K.

A91-45614#
BLADE-VORTEX INTERACTION NOISE OF A HELICOPTER MAIN ROTOR [BRUIT D'INTERACTION PALE-TOURBILLON D'UN ROTOR PRINCIPAL D'HELICOPTERE]
G. RAHIER and P. SPIEGEL (ONERA, Chatillon, France) (Colloque d'Aeroacoustique et Hydroacoustique, 12th, Chatillon, France, Apr. 16-18, 1991) ONERA, TP no. 1991-32, 1991, 15 p. In French. DRET-supported research. refs
(ONERA, TP NO. 1991-32)

A 2D aerodynamic model focusing on the calculation of pressure on blades interacting with an edge vortex produced by the rotor is presented. The model reduces the calculation time and permits a good prediction of the transient pressure. It also shows the role of the viscous core and the vortex distortion during strong interaction with the profile. Application is made to a theoretical case of rotor blade interaction with a line vortex that is parallel to the blade. An example is given of radiating noise, calculated by an acoustic code adapted to pulsed signals. R.E.P.

A91-45620#
HYPERSONIC DELTA WING FLOW CALCULATIONS USING A MULTIDOMAIN MUSCL EULER SOLVER
L. LE TOULLEC and PH. GUILLEN (ONERA, Chatillon, France) (INRIA, Hypersonic Workshop, Paris, France, Apr. 15-19, 1991) ONERA, TP no. 1991-38, 1991, 10 p.
(ONERA, TP NO. 1991-38)

Fine-grid computations for a high supersonic flow over a delta wing with a blunt nose at Mach number 8.7 and 30 deg of incidence are presented. The numerical method employed is described, and the boundary treatment on a solid surface and on a matching interface between two computational domains is analyzed. Both mesh adaptation and grid refinement through the use multidomain concept are used in order to improve the accuracy of the solution. The final grid obtained and the resulting Mach-number contours are presented. V.T.

A91-45633#
VALIDATION OF THE CANARI CODE BY CALCULATING 3D TURBULENT FLOW THROUGH A TURBINE REACTOR [VALIDATION DU CODE 'CANARI' PAR LE CALCUL DE L'ECOULEMENT TRIDIMENSIONNEL TURBULENT DANS UN DISTRIBUTEUR DE TURBINE]
BEATRICE ESCANDE and LAURENT CAMBIER (ONERA, Chatillon, France) (NATO, AGARD, Symposium on CFD Techniques for Propulsion Applications, San Antonio, TX, May 27-31, 1991) ONERA, TP no. 1991-52, 1991, 8 p. In French. DRET-supported research. refs
(ONERA, TP NO. 1991-52)

The CANARI code, developed at ONERA, solves the Reynolds-averaged compressible 3D Navier-Stokes equations. It is applied here to calculating the flow through a high-pressure turbine annular cascade. This calculation is characterized by the use of a highly stretched O-mesh around the blade and by the use of H-meshes for the upstream and downstream regions, in order to achieve an accurate description of the leading and trailing edge phenomena. L.M.

A91-45634#
HELICOPTER AERODYNAMICS - PROBLEMS AND PROSPECTS [L'AERODYNAMIQUE DES HELICOPTERES - DIFFICULTES ET PERSPECTIVES]
JEAN-JACQUES PHILIPPE (ONERA, Chatillon, France) and MICHEL POLYCHRONIADIS (Aerospatiale, Departement Programmes Recherches, Marignane, France) (Entretiens 'Science et Defense 91', Paris, France, May 14, 15, 1991) ONERA, TP no. 1991-53, 1991, 18 p. In French. refs
(ONERA, TP NO. 1991-53)

The development of aerodynamic computations used for helicopter main rotor and fuselage design is described and characteristic results obtained with certain specific tools are discussed. Attention is given to the difficulties involved in the aerodynamic design of the main rotor, the objectives and definition of rotor parameters, and fuselage design considerations. Major problems yet to be resolved, including computation methods for hovering and flight movement, 3D unsteady airflows, and rotor and fuselage wakes, are addressed. R.E.P.

A91-45640#
INFLUENCE OF UNSTEADY EFFECTS ON THE MEASUREMENTS IN A TRANSONIC AXIAL COMPRESSOR
JACQUES PAULON (ONERA, Chatillon, France), ZHIFANG ZHANG, PINGFANG JIA, and JINGFEI MENG (Shenyang Aeroengine Research Institute, People's Republic of China) ONERA, TP no. 1991-60, 1991, 9 p. refs
(ONERA, TP NO. 1991-60)

An axial transonic compressor stage is used to study the flow field through a turbomachine. The computational results of a three-dimensional Euler code with loss simulation applied to this transonic compressor are analyzed. It is shown that significant flow parameter variations can exist in front of stator blades. K.K.

A91-45642#
SOLUTION OF 3D EULER EQUATIONS WITH UNSTRUCTURED MESHES FOR AEROELASTICITY PROBLEMS
G. D. MORTCHELEWITCZ and A. S. SENS (ONERA, Chatillon, France) (International Forum on Aeroelasticity and Structural Dynamics, Aachen, Federal Republic of Germany, June 3-6, 1991) ONERA, TP no. 1991-62, 1991, 9 p. refs
(ONERA, TP NO. 1991-62)

A numerical method has been developed at ONERA in order to study the transonic aeroelastic properties of aircraft. The 3D unsteady Euler equations are solved using unstructured meshes made up of tetrahedra. In this context, the finite element method is used to construct the space of approximation. The flow solver involves an explicit-implicit scheme with implicit equation to be solved approximately using two Jacobi iterations. With this solver, artificial viscosity is added explicitly to prevent oscillations near shock waves. For unsteady applications, a small displacement hypothesis is used to simulate the motion of the airfoil which allows us to keep a fixed mesh. Steady and unsteady results are presented for a civil aircraft and are compared with experimental values. Author

A91-45646#
MESH GENERATION IN AERODYNAMICS [LA CONSTRUCTION DES MAILLAGES EN AERODYNAMIQUE]
OLIVIER-PIERRE JACQUOTTE (ONERA, Direction de l'Aerodynamique, Chatillon, France) (Entretiens Science et Defense 91, Paris, France, May 14, 15, 1991, Proceedings. Vol. 1, p. 126-136) ONERA, TP no. 1991-68, 1991, 12 p. In French. refs
(ONERA, TP NO. 1991-68)

Several problems encountered when generating grids for numerical aerodynamics are discussed. Methods that have been developed to overcome these problems are then introduced, including structured, unstructured, or multiblock grids; and optimization and adaptation methods. The discussion is illustrated by grids obtained by advanced specialists in grid generation. A surface mesh for the Falcon aircraft, a mesh adapted to the ASTER missile, and a mesh adapted to a supersonic flow in a wind tunnel are considered as examples. L.M.

A91-45650#
A 3D COMPRESSIBLE FLOW COMPUTATION CODE FOR CHANNELS AND CAVITIES OF COMPLEX SHAPE [PRESENTATION D'UN CODE DE CALCUL D'ECOULEMENTS COMPRESSIBLES 3-D DANS DES CANAUX ET DES CAVITES DE FORME COMPLEXE]
D. DUTOYA, M. ERRERA, P. J. MICHARD, and A. RISTORI (ONERA, Chatillon, France) (NATO, AGARD, Symposium on CFD Techniques for Propulsion Applications, San Antonio, TX, May 27-31, 1991) ONERA, TP no. 1991-73, 1991, 21 p. In French. refs
(ONERA, TP NO. 1991-73)

A computation code named MATHILDA has been developed at ONERA to study mass and energy transfer through internal cooling systems composed of complex shaped channels and cavities in which the flow is controlled by the interaction between inertial forces and irreversible phenomena. This code integrates the 3D time dependent Navier-Stokes equations, along with some additional transfer equations. The fluid is compressible, and the flow may vary from low subsonic to supersonic. The turbulence model can be either a two-equation model or an algebraic model. R.E.P.

A91-45651#
STEADY AND UNSTEADY 3D FLOW COMPUTATIONS FOR A TRANSONIC TURBINE STAGE [CALCULS 3D STATIONNAIRE ET INSTATIONNAIRE DANS UN ETAGE DE TURBINE TRANSSONIQUE]
ALAIN LE MEUR (ONERA, Chatillon, France) (NATO, AGARD, Symposium on CFD Techniques for Propulsion Applications, San Antonio, TX, May 27-31, 1991) ONERA, TP no. 1991-75, 1991, 24 p. In French. refs
(ONERA, TP NO. 1991-75)

Information is provided on the best approach to obtain the average characteristics of the flow field by directly using a 3D computation on a complete turbomachinery stage. The real flow is absolutely unsteady and 3D, thus implying that numerical simulation of the flow must be unsteady. It is shown that to analytically compute a highly loaded turbine stage, each iteration of the average flow between the rows must be redistributed to obtain the average steady solution. In the unsteady approach, it is necessary to make a time average over a given period to obtain the 3D flow field average. R.E.P.

A91-45667
AN UPWIND FORMULATION FOR HYPERSONIC NONEQUILIBRIUM FLOWS
M. PANDOLFI (Torino, Politecnico, Turin, Italy) and S. BORRELLI (Centro Italiano Ricerche Aerospaziali, Capua, Italy) IN: Modern

research topics in aerospace propulsion - In honor of Corrado Casci. New York, Springer-Verlag, 1991, p. 213-226. refs
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The interaction between fluid dynamics and nonequilibrium chemistry for air in the hypersonic regime is investigated and a methodology for achieving the numerical predictions of flows of this kind is proposed. Transport phenomena, leading to the viscosity, thermal conductivity, and diffusion of chemical species are neglected so the fluid dynamics is described by the Euler equations. The chemical nonequilibrium is based upon a classical 5 species and 17 reactions model. The flux-difference splitting formulation is assumed to be the basis of the algorithm for the Euler equations and is extended to include the nonequilibrium chemical phenomena. Some numerical experiments are presented about the chemical relaxation occurring behind a shock in a nozzle and the attention is focused on the effects of the Damkoehler number. Author

A91-45670
UNSTEADY FLOW IN AXIAL FLOW COMPRESSORS
F. A. E. BREUGELMANS (von Karman Institute for Fluid Dynamics, Rhode-Saint-Genese, Belgium) IN: Modern research topics in aerospace propulsion - In honor of Corrado Casci. New York, Springer-Verlag, 1991, p. 275-295. refs
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A review is made of the experimental rotating stall work on a lowspeed compressor stage. The instantaneous flow field inside the cell is explored using multiple hot wires in the absolute frame of reference. Rotor blade stall and radial drift of the boundary layer is investigated by on-rotor blade instrumentation. The large flow variations suggest a strong unsteady behavior of the blades, which is demonstrated by the unsteady loss-incidence curve as measured with fast response instrumentation in the relative motion. Author

A91-45689
SOLVABILITY CONDITION AND ITS APPLICATION TO FAST NUMERICAL SOLUTION OF OVERPOSED INVERSE PROBLEMS IN COMPRESSIBLE FLOWS
PRABIR DARIPA (Texas A & M University, College Station) Journal of Computational Physics (ISSN 0021-9991), vol. 95, Aug. 1991, p. 436-449. refs
(Contract NSF DMS-88-03669)
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Compatibility condition-restricted solutions to overposed inverse-design problems are satisfactorily obtained by the present treatment of the generation of a profile which will yield a specified speed distribution at a given freestream Mach number. The overposedness of this problem, whose solution is equivalent to the specification of a pressure distribution, is due to the specification of the freestream Mach number. The relation between the specified speed distribution and the freestream Mach number is usefully approximated through numerical experiments. An efficient solution of the overposed problem is thus obtained. O.C.

A91-45792*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE EFFECT OF VARYING MACH NUMBER ON CROSSING, GLANCING SHOCKS/TURBULENT BOUNDARY-LAYER INTERACTIONS
W. R. HINGST (NASA, Lewis Research Center, Cleveland, OH) and K. E. WILLIAMS AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 12 p. refs
(AIAA PAPER 91-2157) Copyright

Two crossing side-wall shocks interacting with a supersonic tunnel wall boundary layer have been investigated over a Mach number range of 2.5 to 4.0. The investigation included a range of equal shock strengths produced by shock generators at angles from 4.0 to 12.0 degrees. Results of flow visualization show that the interaction is unseparated at the low shock generator angles. With increasing shock strength, the flow begins to form a separated region that grows in size and moves forward and eventually the model unstarts. The wall static pressures show a symmetrical compression that merges on the centerline upstream of the inviscid shock locations and becomes more 1D downstream. The region of the 1D pressure gradient moves upstream with increasing shock strengths until it coincides with the leading edge of the shock generators at the limit before model unstart. At the limiting conditions the wall pressure gradients are primarily in the axial direction throughout. O.G.

A91-45813*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MIXING OF MULTIPLE JETS WITH A CONFINED SUBSONIC CROSSFLOW - SUMMARY OF NASA-SUPPORTED EXPERIMENTS AND MODELING
JAMES D. HOLDEMAN (NASA, Lewis Research Center, Cleveland OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 49 p. Previously announced in STAR as N91-24202. refs
(AIAA PAPER 91-2458) Copyright

Experimental and computational results on the mixing of single, double, and opposed rows of jets with an isothermal or variable temperature mainstream in a confined subsonic crossflow are summarized. The studies were performed to investigate flow and geometric variations typical of the complex 3D flowfield in the dilution zone of combustion chambers in gas turbine engines. The principal observations from the experiments were that the momentum-flux ratio was the most significant flow variable, and that temperature distributions were similar (independent of orifice diameter) when the orifice spacing and the square-root of the momentum-flux ratio were inversely proportional. The experiments and empirical model for the mixing of a single row of jets from round holes were extended to include several variations typical of gas turbine combustors. Author

A91-45818*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RESULTS FROM COMPUTATIONAL ANALYSIS OF A MIXED COMPRESSION SUPERSONIC INLET
J. D. SAUNDERS (NASA, Lewis Research Center, Cleveland, OH) and T. G. KEITH, JR. (Ohio Aerospace Institute, Brook Park) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 17 p. refs
(AIAA PAPER 91-2581) Copyright

A numerical study was performed to simulate the critical flow through a supersonic inlet. This flowfield has many phenomena such as shock waves, strong viscous effects, turbulent boundary layer development, boundary layer separations and mass flow suction through the walls (bleed). The computational tools used in this study were two full Navier-Stokes (FNS) codes. The supersonic inlet that was analyzed in this study is the Variable Diameter Centerbody (VDC), inlet. This inlet is a candidate concept for the next generation supersonic transport. Application of the code to the inlet geometry involved effort in generating an efficient grid geometry and specifying boundary conditions, particularly in the bleed region and at the outflow boundary. Results for a critical inlet operation compare favorably to Method of Characteristics predictions and experimental data. Author

A91-45819*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION OF PANEL CODE PREDICTIONS WITH EXPERIMENTAL RESULTS OF INLET PERFORMANCE FOR A 17-INCH DUCTED PROP/FAN SIMULATOR OPERATING AT MACH 0.2
D. R. BOLDMAN, C. IEK, D. P. HWANG, R. J. JERACKI (NASA, Lewis Research Center, Cleveland, OH), M. LARKIN (Pratt and Whitney Group, East Hartford, CT) et al. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 18 p. Previously announced in STAR as N91-25106. refs
(AIAA PAPER 91-3354) Copyright

An axisymmetric panel code was used to evaluate a series of ducted propeller inlets. The inlets were tested in the Lewis 9 by

15 Foot Low Speed Wind Tunnel. Three basic inlets having ratios of shroud length to propeller diameter of 0.2, 0.4, and 0.5 were tested with the Pratt and Whitney ducted prop/fan simulator. A fourth hybrid inlet consisting of the shroud from the shortest basic inlet coupled with the spinner from the largest basic inlet was also tested. This later configuration represented the shortest overall inlet. The simulator duct diameter at the propeller face was 17.25 inches. The short and long spinners provided hub-to-tip retios of 0.44 at the propeller face. The four inlets were tested at a nominal free stream Mach number of 0.2 and at angles of attack from 0 degrees to 35 degrees. The panel code method incorporated a simple two-part separation model which yielded conservative estimates of inlet separation. Author

A91-46073
BASE PRESSURE MEASUREMENTS ON A CONICAL CYLINDER AT FREE-STREAM MACH NUMBERS FROM 3.15 TO 6.83 [BASISDRUCKMESSUNGEN AN EINEM KEGEL-ZYLINDER BEI MACHZAHLEN VON M/INFINITY/ = 3,15 BIS 6,83]
M. TANNER (DLR, Institut fuer Theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 15, June 1991, p. 192-196. In German. refs
Copyright

Wind tunnel base pressure measurements were conducted on a conical cylinder in the free-stream Mach number (FSMN) range 3.15 to 6.83 and angle of incidence ranging from 0 to 15 deg. The results show that the base pressure increased with increasing Mach number and with increasing bluntness of the cylinder nose. The p(B)/p(infinity) has a minimum value at FSMN = 5. At FSMN = 3.15 the c(pB) value becomes markedly smaller. C.D.

A91-46151#
EXPERIMENTAL STUDY ON CASCADE SIMILARITY TRANSFORMATION RULES
NIANGUO ZHU, LIPING XU, and MAOZHANG CHEN (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 193-198. In Chinese. refs

In order to verify the similarity transformation rules in real flow situation, two sets of low-speed cascades similar to the high-speed NACA65- (12) 10 and DCA cascades are designed according to the similarity rules developed by the authors and tested in a two-dimensional low-speed cascade tunnel. The distributions of pressure coefficient on blade surfaces are measured. The results show that the measured similarity precision is of the same order of magnitude as the design similarity precision. Therefore, further improvement of the similarity precision of blade profiles can be achieved by the improvement of the design similarity precision. Author

A91-46152#
THE NUMERICAL SIMULATION AND ANALYSIS OF PASSAGE VORTICES IN 3-D COMPRESSOR CASCADE
GUOTAI FENG, JIEXIAN SU, GUAN YU, and DEYONG JIAO (Harbin Institute of Technology, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 199-202. In Chinese. refs

A simplified numerical simulation method for calculating passage vortices in a compressor cascade is presented, which can reduce computer time and save computer storage. The calculation employs the parabolized Navier-Stokes equation. In order to analyze and investigate the passage vortices in the compressor cascade, the calculation has been carried out for a divergent curved channel similar to compressor cascade. It can be seen from obtained results that the passage vortices are composed of four parts, and the flow behavior near the suction surface on both ends of the straight compressor stator is deteriorated severely. For this reason the application of curved blades to the compressor is one of important means for improving the end-wall flow behavior. Author

A91-46154#
ANALYTICAL METHOD FOR SUBSONIC CASCADE PROFILE
BO LIU (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 207-210. In Chinese. refs

A method of subsonic cascade design for axial-flow compressor is provided. The equations of continuity and quasi-irrotationality are transformed into the potential-stream function coordinates. Then a Laplace equation can be deduced for an aerodynamic parameter 'Q'. The boundary conditions thereby are given as the distributions of velocity coefficients on the stagnation streamlines of both suction and pressure sides of a flow channel. The flow field is obtained from the analytical solution of the Laplace equation. Subsequently, the field is turned back into the physical plane by diffraction and integration. Then the blade profile coordinates and the geometry of the cascade result from this analysis. The method has an advantage over other inverse methods in the fact that the flow field parameter 'Q' can be easily obtained from the analytical solution of the Laplace equation instead of the numerical solution of a complex differential equation. To illustrate the validity of the design method, two compressor stator blade profile with subsonic inlet Mach number were designed and compared with a method reported in literature. Author

A91-46155#
AN EXPERIMENTAL STUDY OF 3-D FLOW IN A CASCADE
CHUNJUN JI, ZHUGUO ZHU, QIANZHI LIU, and XINHAI ZHOU (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 211-215. In Chinese. refs

A 3D flow in a cascade was studied using flow visualization and detailed measurements, and the results were compared with the predictions of inviscid 3D flow calculations. The comparison of experimental data with the results of computations show that the inviscid flow calculations can predict correctly the major features of 3D flow in cascades. The flow visualization revealed the formation and development of vortex systems in the cascade passage and in the end-wall and corner regions, making it possible to explain the phenomena of complicated secondary flow in cascades. I.S.

A91-46157#
NUMERICAL STUDY OF END-WALL BOUNDARY LAYER AND BLADE FORCE DEFECT IN CASCADES
HU WU, SONGLING LIU, and FUQUN CHEN (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 219-221. In Chinese. refs

A detailed research has been completed for the calculation of end-wall boundary layers within an axial compressor cascade. A new calculation model for blade force defect is proposed, which is associated with development of primary flow and transverse flow. A unique feature of this method lies not only in capability to calculate the development of end-wall boundary layers inside the cascade passage without any assumption about the exit of cascade, but also in ability to take into account the influence of its tip clearance. The calculational results of three heavily loaded cascades show that this model is superior to other existing models. Author

A91-46158#
NUMERICAL STUDY OF VISCOUS FLOWS IN COMPLEX GEOMETRIES
FENG SHI, ZHONG XU, and YONGMIAO MIAO (Xian Jiaotong University, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 222-224. In Chinese. refs

The program SIMPLEC has been adopted to calculate the viscous flows at all Mach numbers inside a plane cascade and nozzle. In order to treat both the incompressible and the compressible flows, pressure is chosen as a primary dependent variable in preference to density. The effect of the pressure on the density is implicitly included in the pressure correction equation.

Further, the covariant velocity components are chosen as the dependent variables in the momentum equations, which makes the pressure-velocity coupling relatively easy to handle. Comparisons of the calculated results with experimental data show that the present method exhibits much better stability and covergence behavior, and is applicable to a variety of the incompressible and compressible flows, ranging from subsonic to supersonic. Author

A91-46178*# MCAT Inst., San Jose, CA.
CONVERGENCE ACCELERATION OF VISCOUS AND INVISCID HYPERSONIC FLOW CALCULATIONS
S. CHEUNG (MCAT Institute, San Jose, CA), A. CHEER, M. HAFEZ (California, University, Davis), and J. FLORES (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1214-1222. Previously cited in issue 18, p. 2758, Accession no. A89-42100. refs
Copyright

A91-46180*# Louisiana State Univ., Baton Rouge.
SOLUTION-ADAPTIVE GRID PROCEDURE FOR HIGH-SPEED PARABOLIC FLOW SOLVERS
ALBERT D. HARVEY, III, SUMANTA ACHARYA (Louisiana State University, Baton Rouge), SCOTT L. LAWRENCE (NASA, Ames Research Center, Moffett Field, CA), and SAMSON CHEUNG (MCAT Institute, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1232-1240. Previously cited in issue 16, p. 2555, Accession no. A90-38706. refs
(Contract NCA2-326)
Copyright

A91-46181*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PRIMITIVE VARIABLE, STRONGLY IMPLICIT CALCULATION PROCEDURE FOR VISCOUS FLOWS AT ALL SPEEDS
K.-H. CHEN (NASA, Lewis Research Center, Cleveland; Toledo, University, OH) and R. H. PLETCHER (Iowa State University of Science and Technology, Ames) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1241-1249. Previously cited in issue 16, p. 2482, Accession no. A90-38666. refs
(Contract AF-AFOSR-89-0403)
Copyright

A91-46182*# Vigyan Research Associates, Inc., Hampton, VA.
HYPERSONIC RAREFIED FLOW ABOUT PLATES AT INCIDENCE
VIRENDRA K. DOGRA (Vigyan, Inc., Hampton, VA) and JAMES N. MOSS (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1250-1258. Previously cited in issue 18, p. 2762, Accession no. A89-43227. refs
Copyright

A91-46195#
SIMPLE ALGEBRAIC TECHNIQUE FOR NEARLY ORTHOGONAL GRID GENERATION
S. SAHA and B. C. BASU (Indian Institute of Technology, Kharagpur, India) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1340, 1341. refs
Copyright

It is widely recognized that the most efficient way of dividing the domain for external flow problems is by generating an O-type grid for a 2D case, or an O-O topology grid for a 3D one. A method is presented for generating an O-type grid about airfoils, and an O-O topology grid about wings, incorporating an arbitrary amount of clustering near the body surface. The grid exhibits good orthogonality properties, and its generation procedure requires little computer time in virtue of the obviation of iterations. O.C.

A91-46196#
RATE OF FORMATION OF OBLIQUE SHOCK WAVES
D. WEIHS and C. J. FREITAS (Southwest Research Institute, San Antonio, TX) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1342-1344. refs
Copyright

The present, comparatively simple oblique shock wave configuration, which allows for an analytic solution and encompasses all significant factors involved in phenomena of this type, a two-dimensional wedge of 2-delta opening angle is suddenly and instantaneously accelerated to a variety of supersonic speed values M(1). For each value of M(1), only a limited range of deflection angles is shown; the shock Mach number is seen to go through a maximal value that is different for each M(1). This maximum is explained by the fact that there are two competing effects which influence formation speed: shock strength, and shock angle. O.C.

A91-46198
TOPOLOGY OF A COMPUTED INCOMPRESSIBLE THREE-DIMENSIONAL SEPARATED FLOW FIELD AROUND A HIGH-ANGLE-OF-ATTACK CONE-CYLINDER
KOJIRO SUZUKI (Tokyo, University, Japan) Computers and Fluids (ISSN 0045-7930), vol. 19, no. 3-4, 1991, p. 315-334. refs
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The concept of 'topology' of a continuous vector field is introduced to numerical studies on the structure of a three-dimensional separated flowfield. In this paper, the flow structure is regarded as the topological properties of the streamlines and described as a composition of finite types of basic elements correlated with some typical flow features. The present topological studies are made in four vector fields defined in the flow around a body with regard to some physical aspects. All possible basic elements are formulated as a critical point or line in each vector field by use of the eigenvalues and eigenvectors for a local velocity gradient tensor. The former represents the quantitative topological properties and the latter determines the direction of a critical line. The method used to identify these basic elements from numerical flow data is also presented. Computational studies on a separated flowfield around a high-angle-of-attack cone-cylinder demonstrate that the present topological approaches have great potential for revealing the essential properties of flow phenomena with three-dimensional separation. Author

A91-46199
COMPUTATION OF TURBULENT CONICAL DIFFUSER FLOWS USING A NON-ORTHOGONAL GRID SYSTEM
NAM-HYO CHO and C. A. J. FLETCHER (Sydney, University, Australia) Computers and Fluids (ISSN 0045-7930), vol. 19, no. 3-4, 1991, p. 347-361. Research supported by Australian Research Council. refs
Copyright

An algebraic Reynolds stress (ASM) turbulence model using a simplified pseudoviscosity is incorporated with a nonorthogonal and nonstaggered grid system using Cartesian velocity components with finite volume discretization. The accuracy and robustness of the method is shown by the prediction of complex turbulent flows in 8-deg and 20-deg included angle conical diffusers, with and without swirl. Both the ASM and the k-epsilon turbulence models predict the mean velocities accurately, while the ASM turbulence model gives better predictions of the Reynolds stresses than the k-epsilon turbulence model. Author

A91-46288#
SUPERSONIC SEPARATED FLOW OVER A SWEPT COMPRESSION CORNER
O. OZCAN, M. O. KAYA, and H. UNALMIS (Istanbul Technical University, Turkey) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 2.1-2.3. Research supported by Istanbul Technical University. refs

An experimental study of the shock wave boundary layer interaction ahead of a compression corner mounted on a flat plate was made. Three characteristic flow regimes (cylindrical, conical and mixed) were observed. Results of the study give support to the 'Shock Detachment Hypothesis' which predicts the transition between the cylindrical and conical flow regimes. Author

A91-46289#
THE STRUCTURE OF THE INSTANTANEOUS DENSITY FIELD IN SUPERSONIC BOUNDARY LAYERS
MICHAEL SMITH, VINOD KUMAR, ALEXANDER SMITS, and RICHARD MILES (Princeton University, NJ) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 2.5-2.8. refs
(Contract AF-AFOSR-88-0120; AF-AFOSR-86-0191)

Rayleigh scattering in the far UV is used to visualize the instantaneous two-dimensional density field in a Mach 2.5 high Reynolds number turbulent boundary layer. Images are obtained in planes normal and parallel to the wall. The technique gives quantitative density information, and it is possible to construct the rms intensity distribution, probability density distributions, and space correlations. The preliminary results shed new light on the large-scale structure of high-speed turbulent boundary layers.
Author

A91-46290#
MEASUREMENTS OF GLANCING SHOCK WAVE/BOUNDARY LAYER INTERACTION FROM MACH 1.9 TO 3.8
C. H. B. STACEY and J. M. SIMMONS (Queensland, University, Saint Lucia, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 2.9-2.12. Research supported by Australian Research Council. refs

Surface pressure measurements have been made to investigate glancing shock wave/turbulent boundary layer interaction over the Mach number range, 1.95 to 3.74. They indicate a growth of upstream influence at low Mach numbers that is consistent with the interaction characteristics theory of Stalker. At higher Mach numbers it appears that significant separation occurs, even though the angle of the shock generating wedge is only 5 deg. Author

A91-46297#
NUMERICAL SIMULATION OF LAMINAR HYPERSONIC BOUNDARY LAYER FLOWS
M. L. SAWLEY, S. WUETHRICH, and J. B. VOS (Lausanne, Ecole Polytechnique Federale, Switzerland) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 3.37-3.40. Research supported by Dassault Aviation and Commission pour l'Encouragement de la Recherche Scientifique of Switzerland. refs

A study of the physical modellization and calculation of hypersonic boundary layer flow relevant to high temperature re-entry conditions is presented. A model for air comprised of a mixture of five chemical species is considered, with the transport coefficients determined using a simplified formulation of kinetic theory. Consideratons is given to the influence of equilibrium and non-equilibrium chemistry and radiative transfer, as well as the choice of boundary conditions. Solutions for the laminar, compressible, boundary layer flow over the windward surface of a Shuttle-like axisymmetric body are presented; the calculated wall heat fluxes are compared with those obtained from flight data.
Author

A91-46298#
INVESTIGATION OF HYPERSONIC INJECTION
R. CASEY and R. J. STALKER (Queensland, University, Saint Lucia, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 3.41-3.44. refs

Weinstein et al. (1956) proposed a model for the diffusion of momentum from a slot jet into a moving secondary medium which dealt with isothermal incompressible flows. In this paper the model will be extended to encompass compressible flows by incorporating the Howarth transformation. The Schwarb Zeldovich transformations are then used to extend the model to combustion flows. This is then used to give a first order estimate of the combusting flow of a slot jet issuing into a free stream of nominal Mach number 3.5 which is compared to experimental results through interferograms. Results for predictions of similar flows at hypersonic Mach numbers (greater than 5) are then presented.
Author

A91-46302*# Sandia National Labs., Livermore, CA.
THE TOPOLOGY AND VORTICITY DYNAMICS OF A THREE-DIMENSIONAL PLANE COMPRESSIBLE WAKE
JACQUELINE H. CHEN (Sandia National Laboratories, Livermore, CA), BRIAN J. CANTWELL (Stanford University, CA), and NAGI N. MANSOUR (NASA, Ames Research Center, Moffett Field, CA) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 5.1-5.4. refs
(Contract DE-AC04-76DP-00789)

The three-dimensional aspects of transition in a low Mach number plane compressible wake are studied numerically. Comparisons are made between the topology of the velocity field and the vorticity dynamics of the flow based on results from direct numerical simulations of the full compressible Navier-Stokes equations. The velocity field is integrated to obtain instantaneous streamlines at different stages in the evolution. A generalized three-dimensional critical point theory is applied to classify the critical points of the velocity field. Author

A91-46307*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE SIMULATION OF HYPERSONIC FLOW USING A ZONAL APPROACH
JOLEN FLORES (NASA, Ames Research Center, Moffett Field, CA) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 6.33-6.36. refs

The development of a Navier-Stokes code for the simulation of hypersonic flow will be described. The code uses a zonal philosophy which helps alleviate the grid generation problem for complex configurations and allows an efficient solution procedure. The code has been used to simulate equilibrium flow past a simple generic hypersonic configuration. Validation of the code on a blunt cone has also been conducted. Author

A91-46308*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
HYPERSONIC 3-D FLOW PAST WINGED BODIES
DENNY S. CHAUSSEE (NASA, Ames Research Center, Moffett Field, CA) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 6.37-6.40. refs

The hypersonic flow past winged bodies is calculated using the 3D Navier-Stokes equations in both a space- and time-marching finite difference code. The bodies are a blunt ogive-cylinder with a delta wing planform and an elliptical body referred to as the allbody configuration. Laminar flow solutions for the ogive-cylinder-wing body and for the allbody configuration are presented. It is shown that the present technique has an excellent shock-capturing capability for all speed regimes. An axial zonal capability is incorporated to make the procedure more versatile. The grid system is created offline using an efficient hyperbolic grid generator which can handle the rapid variations in the body cross sections. P.D.

A91-46309#
VORTEX SHEDDING FROM CYLINDERS IN NEAR AXIAL FLOW
M. K. BULL and W. A. DEKKERS (Adelaide, University, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 6.41-6.44. Research supported by Australian Research Council. refs

Results of an investigation of vortex shedding from cylinders

having very large length-to-diameter ratios, with their axes yawed at small angles beta to the flow direction are presented. Yaw angles varied from 0 deg to 10 deg, a range not previously investigated; the range of flow Reynolds number was 100 to 5000. It was found that, over a range of Reynolds number depending on yaw angle, vortices can be shed at much smaller yaw angles than previously expected. The dependence of the measured vortex-shedding frequencies on Reynolds number and yaw angle shows that relationships previously established between shedding frequency and cylinder Reynolds number for large angles of yaw become invalid at very small yaw angles. Author

A91-46319*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TRANSONIC VISCOUS FLOW COMPUTATIONS ABOUT A COMPLETE AIRCRAFT USING THE NAVIER-STOKES EQUATIONS
NEAL M. CHADERJIAN and JOLEN FLORES (NASA, Ames Research Center, Moffett Field, CA) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 8.11-8.14. refs

A numerical approach for simulating the viscous transonic flow about the complete F-16A fighter aircraft is presented using the Navier-Stokes equations. This finite difference approach utilizes a body conforming zonal grid system to provide appropriate viscous clustering near all body surfaces. A comparison between computational and experimental pressure coefficients is good, and integrated quantities such as lift and drag are within 2.6 percent and 1.6 percent, respectively. The versatility of the method is demonstrated by further modeling the flow inside the inlet up to the compressor face and the exhaust nozzle plume. Results for the F-16A in sideslip are also presented and indicate the proper trends. Author

A91-46321#
THIN UNCAMBERED AEROFOILS WITH A LEADING-EDGE SEPARATION BUBBLE
B. G. NEWMAN and M.-C. TSE (McGill University, Montreal, Canada) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 8.23-8.26. refs

A theory is developed for predicting the characteristics of the flow about a flat-plate aerofoil with a leading edge separation bubble for Reynolds numbers greater than 500,000. The bubble length x(R) was determined using both 2D and 3D tufts attached to the surface; the lift was obtained from measurements of the pressure distribution; and the drag was determined from wake transverses near, and downstream of, the trailing edge using Jones method. It is shown that the length of the separation bubble is proportional to the angle of incidence squared, alpha-square. The drag and lift coefficients could be predicted fairly accurately when the rate of entrainment beneath the bubble was obtained from the slope of the x(R)/alpha-square curve. I.S.

A91-46322*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EVOLUTION OF COHERENT STRUCTURES IN THE REATTACHMENT REGION OF A SEPARATED FLOW
S. JOVIC (NASA, Ames Research Center, Moffett Field; Eloret Institute, Sunnyvale, CA) and L. W. B. BROWNE (Newcastle, University, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 8.31-8.34. refs

An experimental investigation of the evolution of coherent structures in a turbulent flow over a backward facing step has been made. Downstream of reattachment the large scale structures do not return rapidly to equilibrium boundary layer conditions and their coherent contribution to the Reynolds stresses continue to increase for some distance. Author

A91-46326#
OPEN SEPARATION AND VORTEX FORMATION - NUMERICAL SIMULATION AND ANALYSIS OF A DELTA WING FLOW
A. HILGENSTOCK, H. VOLLMERS, and U. DALLMANN (DLR, Institut fuer theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 9.9-9.12. refs

The determination of vortex cores is investigated to improve the understanding of 3D separated flows in general and the predicting of flow separation from smooth bodies. A perspective view of the wing's starboard side and the leeward vortex flow is shown. For free-stream conditions, the flow around a delta wing is dominated by a primary vortex separating close to the leading edge of the wing. P.D.

A91-46327#
NEAR WAKE STUDIES OF AN AIRFOIL WITH MICRO-GROOVES
ANWAR AHMED, JOSE M. CARAM, and C. OSTOWARI (Texas A & M University, College Station) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 9.23-9.26. refs

Measurements were made in the near and intermediate wake regions of an NACA 0012 airfoil with and without microgrooves (MG) at a freestream Reynolds number of 250,000. The MG were the symmetric v-grooved type, 0.152 mm in height. Experiments were conducted in the Texas A and M University suction-type, open-return low-speed wind tunnel. To ensure turbulent flow on the airfoil, a transition strip was applied at 10 percent of the chord. Wake velocity profiles and turbulence parameters were measured with the help of a temperature compensated hot film x-probe. The growth of the wake was found to be similar for the clean airfoil and the airfoil with MG; however, MG effectiveness was indicated by a marked decrease in turbulence levels in the wake. Author

A91-46328#
OBSERVATIONS ON TURBULENT BOUNDARY LAYER AND THE NEAR WAKE OF AN AFTERBODY
V. KRISHNAN (National Aeronautical Laboratory, Bangalore, India) and K. S. YAJNIK (Council of Scientific and Industrial Research, Centre for Mathematical Modelling and Computer Simulation, Bangalore, India) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 9.27-9.29. refs

Measurements of mean velocity and velocity fluctuations have been carried out in the incompressible turbulent boundary layer and the near wake of a circular arc boat-tailed afterbody. Results show significant departure of the boundary layer mean velocity profiles in the adverse pressure gradient region from the universal characteristics. The mean velocity profiles and the center line velocity variation in the near wake show similarity. A mean velocity in the near wake is deduced from these observations. Author

A91-46334#
VISUALISATION OF VORTEX FLOWS AROUND CANARD CONFIGURATIONS WITH HIGHLY-SWEPT LEADING EDGES
D. H. THOMPSON (Defence Science and Technology Organisation, Aeronautical Research Laboratory, Melbourne, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 10.31-10.34. refs

A wing/canard configuration with sharp, highly swept leading edges was tested in a small towing tank. Flow visualization was used to study the effects of canard position on vortex interactions and vortex breakdown. A canard above or co-planar with the wing delayed wing vortex breakdown. A canard below the wing produced a strong interaction between the wing and canard vortices and

could cause early wing vortex breakdown. Depending on its longitudinal position, the low canard could seriously disrupt the wing flow. Author

A91-46341#
AN EXPERIMENTAL STUDY OF TRANSONIC FLOW PAST A SPHERE
S. S. W. LAM and N. POLLOCK (Defence Science and Technology Organisation, Aeronautical Research Laboratory, Melbourne, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 11.13-11.16. refs

Detailed measurements of the pressure distribution around a sphere were made in the ranges of freestream Mach number values between 0.4 and 1.0 and Reynolds numbers between 170,000 and 1,200,000. Distinctions have been made of the distributions before and after the critical Reynolds number. The effects of the freestream Mach number in the region of the critical Mach number have also been investigated. The presence of the shock near the surface of the sphere has profound interactions with the boundary layer and consequently plays an important role in the resulting pressure profile. The experiment has provided new data for transonic flow around a sphere in the ranges of critical Mach and Reynolds numbers. Author

A91-46343#
BASE FLOW BEHIND A CASTELLATED BLUNT TRAILING EDGE AEROFOIL IN SUPERSONIC FLOW
ERIC C. MAGI and SUDHIR L. GAI (University College, Canberra, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 11.21-11.24. refs

A study of the near-wake flow of castellated blunt trailing edge aerofoils at Mach 2 was undertaken to increase the available data base and to understand the mechanism of base pressure recovery. This paper presents some of the results obtained during the course of this study. Flow visualization studies included oil flow, shadowgraphs, schlieren photography, and holographic interferometry looking at the near wake flow onto and along the span of the aerofoils. These showed that the base flow is three-dimensional in nature, and have large spanwise pressure gradients. Base pressure measurements confirm the existence of these gradients. Author

A91-46344#
GENERATION OF SWIRL IN AN OPEN-CIRCUIT WIND TUNNEL
P. V. LANSPEARY and M. K. BULL (Adelaide, University, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 11.25-11.28. refs

Flow visualization experiments with streamers have shown that, in the test section of a particular open-circuit wind tunnel at low flow speeds, there is an unacceptable degree of swirl. This swirl which is apparently a random function of time, usually takes the form of a single forced vortex occupying the entire cross section of the test section and has an axis aligned with the flow. It is not prevented by the honeycombs in the wind tunnel inlet. At air speeds of 10 m/s, the swirl changes the direction of the air velocity vector by typically 1 or 2 deg. The directional changes become more severe as the flow speed is reduced. Measurements indicate that the maximum acceptable temperature variation for satisfactory performance of the wind tunnel over the speed range 1.5 to 10 m/s is in the order of 0.02 C. Production of a temperature distribution which is uniform within these limits requires very efficient mixing of the wind tunnel inlet air. The only effective method of providing this kind of mixing, which has been discovered so far, is to use a centrifugal blower to deliver the air through an inlet diffuser in the manner of an open-circuit 'blower' wind tunnel. Author

A91-46356#
REAL GAS EFFECTS IN HYPERVELOCITY FLOWS OVER AN INCLINED CONE
R. M. KREK, K. HANNEMANN, and D. I. PULLIN (Queensland, University, Saint Lucia, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 12.25-12.28. refs

The present study adduces measurements obtained from experiments on a cone with a half angle of 15 deg at angles of incidence of 0 and 30 deg in a hypervelocity flow with a nominal Mach number of 5. Results are reported of a 1D model of dissociation/recombination chemistry in the windward flow about a cone at incidence in a hypervelocity stream. The pressure results agree well with Newtonian theory and Taylor-Maccol theory and with detailed 3D calculations when the flow is frozen. P.D.

A91-46359#
DISSOCIATING FLOWS IN HYPERVELOCITY AERODYNAMICS
R. J. STALKER (Queensland, University, Saint Lucia, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. KS9.1-KS9.6. Research supported by Australian Research Council. refs

Order of magnitude arguments are used to identify and explain some of the special effects associated with chemical dissociation in inviscid hypervelocity aerodynamics. This leads to three simplified, approximate, concepts, in the form of a constant temperature approximation, thermodynamic decoupling of the temperature from the flow, and pressure gradient reaction quenching. These concepts are illustrated by application to a range of classical problems in hypervelocity aerodynamics, namely, prediction of shock stand-off on a blunt body, the development of shock detachment on a wedge, the variation of shock stand-off on a delta wing, and the density variation along a streamline downstream of a curved shock. Author

A91-46361#
INTERFERENCE BETWEEN TWO TWO-DIMENSIONAL CIRCULAR CYLINDERS IN TURBULENT FLOW
H. ZHANG and W. H. MELBOURNE (Monash University, Clayton, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 13.13-13.16. refs

Results are presented from wind-tunnel studies on the interference between 2D smooth circular cylinders for tandem and side-by-side arrangements in turbulent flow. Alongwind and crosswind interference factors on one of the cylinders are presented for different cylinder arrangements. The effects of cylinder arrangement and turbulence intensity on interference factors and force spectra are examined. P.D.

A91-46365#
INVESTIGATION INTO THE WAKES OF BLUNT TRAILING EDGE AEROFOILS AT LOW REYNOLDS NUMBERS
M. PETRUSMA and S. L. GAI (University College, Canberra, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 13.35-13.38. refs

Results are reported from an experimental study examining the wakes of a plain and segmented blunt trailing edge aerofoil at low Reynolds numbers. A laminar discontinuity in the Strouhal-Reynolds number curve, similar to that in the case of the circular cylinder, was also present in the case of the blunt trailing edge aerofoils. Partial conversion of nominally 2D spanwise vorticity into streamwise vorticity was found to be the main mechanism for drag reduction of segmented blunt trailing edge aerofoils. P.D.

A91-46372*# Queensland Univ., Saint Lucia (Australia).
HYPERVELOCITY FLOW IN AXISYMMETRIC NOZZLES
P. A. JACOBS and R. J. STALKER (Queensland, University, Saint

Lucia, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 15.25-15.28. Research supported by Australian Research Council. refs
(Contract NAGW-674)

A simple procedure for the design of axisymmetric supersonic nozzles for use in reflected-mode shock tunnels is described. This method has been used to design a moderate Mach number (M = 4) nozzle and a high Mach number (M = 10) nozzle. Both nozzles have been calibrated by measuring the pitot profiles near the nozzle exit planes and, although the M = 4 nozzle performs well, the M = 10 appears to have reached a Mach number - pressure limit in which the unsteady nozzle boundary layers significantly affect the test flow. Author

A91-46393
DEVELOPMENT OF AN UPWIND RELAXATION METHOD TO SOLVE THE 3D EULER AND NAVIER-STOKES EQUATIONS FOR HYPERSONIC FLOW
BERNHARD MUELLER (DLR, Institut fuer Theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T413-T416. refs
Copyright

The three-dimensional Euler and thin-layer Navier-Stokes equations are solved for the steady state by an upwind relaxation method for hypersonic flow over simple pointed and blunt bodies. Space marching is used by iterating the time-dependent difference equations in crossflow plates to the steady state, starting from a conical solution near the apex. Thus, linearization and factorization errors inherent in conventional implicit parabolized Navier-Stokes solvers can be reduced to arbitrary low levels at the cost of more iterations. C.D.

A91-46398
SINGLE-PARAMETER METHOD FOR CALCULATING TRANSONIC FLOW [UEBER DAS EINPARAMETRIGE VERFAHREN ZUR BERECHNUNG DER TRANSSONISCHEN STROEMUNG]
M. J. CIALKOWSKI (Poznan Technical University, Poland) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T434-T437. In German. refs
Copyright

A single-parameter method for calculating transonic flows is discussed. The weak form of the entropy condition and the mass balance in the finite supersonic element are analyzed. Numerical examples are given. C.D.

A91-46399
THEORETICAL PREDICTION OF AERODYNAMIC CHARACTERISTICS OF DELTA WINGS WITH SUPERSONIC LEADING EDGES IN SUPERSONIC-HYPERSONIC FLOW AND ITS AGREEMENT WITH EXPERIMENTAL RESULTS
ADRIANA NASTASE and ANDREAS HONERMANN (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T437-T441. refs
Copyright

Previous theoretical solutions for the axial disturbance velocities on the thin and the thick-symmetrical components of a thick lifting delta wing with supersonic leading edges, based on the hydrodynamic analogy of Carafoli et al. (1969), are presently compared with experimentally determined values for freestream Mach numbers in the 2.4-4.0 range. Very good agreement is obtained over a range of angles of incidence. O.C.

A91-46400
AN ORIGINAL THREE-DIMENSIONAL PRESENTATION OF THEORETICAL AND EXPERIMENTAL AERODYNAMICAL CHARACTERISTICS OF DELTA WINGS WITH SUBSONIC LEADING EDGES, IN TRANSONIC-SUPERSONIC FLOW
ADRIANA NASTASE and ROGER JAKOBS (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T441-T446. refs
Copyright

A91-46401
TRANSONIC POTENTIAL FLOW BY LEAST SQUARES AND FINITE ELEMENT METHOD
JACEK ROKICKI (Warsaw University of Technology, Poland) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T446-T450. refs
Copyright

The present treatment of the inviscid and compressible transonic flow past an airfoil assumes the shock waves to be weak, so that the entropy generation is negligible and the flow remains quasi-isentropic and irrotational. Fully subsonic, freestream Mach number = 0.6 flow past a NACA-0012 airfoil, calculated for different values of external circle radius R, confirms that the present formula for the boundary condition at the outer boundary works well. The transonic result computed is also presented. O.C.

A91-46402
VISCOUS FLOW AROUND AN AIRFOIL INCLUDING WALL EFFECTS
S. TSANGARIS and M. THOMADAKIS (Athens, University, Greece) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T450-T452. refs
Copyright

The two-dimensional inviscid and laminar viscous flow around a NACA 0012 airfoil, placed in the test section of a wind tunnel with solid upper and lower walls, is presently considered on the basis of compressible, unsteady Navier-Stokes governing equations. Proper simulation is obtained for this geometry through the use of boundary-fitted coordinates. Attention is given to the boundary conditions for the inviscid and viscous calculations performed. It is concluded that more physical conditions must be incorporated on the sidewall. O.C.

A91-46403
INVERSE CALCULATION OF TRANSONIC CASCADE FLOWS ON A ROTATING FLOW PLANE OF VARIABLE THICKNESS [INVERSE BERECHNUNG TRANSONISCHER GITTERSTROEMUNGEN AUF ROTATIONSSTROEMFLAECHEN VARIABLER DICKE]
E. SCHMIDT (Stuttgart, Universitaet, Federal Republic of Germany) and F. KLIMETZEK (Daimler-Benz AG, Stuttgart, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T459-T461. In German. refs
Copyright

A method for the inverse calculation of transonic cascade flows on a rotating flows plane of variable thickness, useful in handling modern turbomachines with high performance densities, is discussed. A comparison with experimental results is made. C.D.

A91-46405
INVESTIGATION OF AN UPWIND-TVD METHOD FOR NUMERICAL SIMULATION OF HYPERBOLIC EQUATIONS WITH SOURCE TERMS [UNTERSUCHUNG EINES UPWIND-TVD-VERFAHRENS ZUR NUMERISCHEN SIMULATION VON HYPERBOLISCHEN GLEICHUNGEN MIT QUELLTERMEN]
URSULA DUENZEBACH (DLR, Institut fuer Theoretische Stroemungsmechanik, Goettingen, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T477-T479. In German. refs
Copyright

The aerodynamic design of reusable reentry vehicles such as Hermes and of hypersonic aircraft like Saenger require modeling the flow field with equations for atmospheric chemical species with strongly nonlinear source terms. In this paper, a scalar 1D

model equation for this purpose is considered whose numerical solution uses the Upwind-TVD method of Harten (1989) and of Yee (1989). C.D.

A91-46406
CALCULATION OF FRICTIONAL TRANSONIC FLOWS USING A TIME-STEPPING METHOD [BERECHNUNG REIBENDER TRANSSONISCHER STROEMUNGEN MITTELS EINES ZEITSCHRITTVERFAHRENS]
H.-J. PREISIGKE (Hannover, Universitaet, Hanover, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T480, T481. In German. refs
Copyright

A calculative method is briefly discussed which will in the future be applied to cascade flows in turbomachines. The flow around a NACA0012 profile is addressed to show the accuracy of the method. C.D.

A91-46407
IMPROVING THE CONVERGENCE OF A TIME-STEPPING SCHEME FOR CALCULATING INTERNAL FLOW [VERBESSERUNG DER KONVERGENZ EINES ZEITSCHRITTVERFAHRENS ZUR BERECHNUNG VON INNENSTROEMUNGEN]
ALEXANDER WIEDERMANN (Hannover, Universitaet, Hanover, Federal Republic of Germany) Zeitschrift fuer angewandte Mathematik und Mechanik (ISSN 0044-2267), vol. 71, no. 5, 1991, p. T482-T485. In German. refs
Copyright

Two approaches for accelerating the convergence of the explicit MacCormack scheme for calculating internal flow are described. The approaches emphasize the use of local time steps and a multicascade scheme. C.D.

A91-46451
NUMERICAL METHOD FOR SOLVING THE EULER EQUATION FOR UNSTEADY TRANSONIC FLOWS OVER OSCILLATING AIRFOILS
FENGWEI LI (Northwestern Polytechnical University, Xian, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 4, Feb. 1991, p. 1-10. refs
Copyright

Through transformations, the time-dependent boundary condition on the airfoil contour and the boundary condition at infinity are brought fixed to the boundaries of a finite domain. The boundary conditions can thus be satisfied exactly without increasing the computational time. The scheme is useful for computing unsteady transonic flows with high reduced frequencies. The scheme makes use of curvefitted orthogonal meshes and the lattice control technique to obtain the optimal grid distribution. The numerical results are satisfactory. Author

A91-46600#
NUMERICAL AERODYNAMICS SIMULATION TECHNIQUES FOR AEROSPACE ENGINEERING
NAOKI HIROSE and KOJI ISOGAI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 441, 1990, p. 507-515. In Japanese. refs

The features of numerical aerodynamics simulation based on computational fluid dynamics (CFD) are reviewed. Various applications of this approach are considered, including the USB-STOL and the HOPE H-2 vehicle. B.J.

A91-46603
STREAMWISE VORTICES IN AN UNDEREXPANDED AXISYMMETRIC JET
A. KROTHAPALLI, G. BUZYNA, and L. LOURENCO (Florida Agricultural and Mechanical University; Florida State University, Tallahassee) Physics of Fluids A (ISSN 0899-8213), vol. 3, Aug. 1991, p. 1848-1851. refs
Copyright

The existence of streamwise vortices in a jet emanating from a convergent axisymmetric nozzle is investigated when the pressure ratio is 5.1 and the Reynolds number is 1.8 x 10 to the 6th. The vortices are identified by shadowgraph photographs in the supersonic region and are characterized as being very strong. The vortices intensify the mixing between ambient and jet fluids in the zone between the jet boundary and the intercepting shock, and vortex merging increases the scale of the vortices downstream. C.C.S.

A91-46624#
NUMERICAL CALCULATION OF HYPERSONIC FLOWS WITH NONEQUILIBRIUM AIR CHEMISTRY AROUND A REENTRY VEHICLE
MICHIO NISHIDA (Kyushu University, Fukuoka, Japan) and YOSHITAKA SAKAMURA Kyushu University, Faculty of Engineering, Memoirs (ISSN 0023-6160), vol. 51, March 1991, p. 33-52. refs

Numerical studies of hypersonic flows with thermal and chemical nonequilibrium around a blunt body have been conducted to reentry at high altitudes (70, 80 and 90 km). A two-temperature model of translational-rotational and vibrational temperatures is employed and nonequilibrium air chemistry is considered. The analysis is performed using axisymmetric viscous shock layer equations for a multicomponent gas. The effect of thermal nonequilibrium of the flowfield is demonstrated by comparing the present results with thermal equilibrium results. It is more significant at a higher altitude and makes the wall heat flux and wall temperature decrease compared with thermal equilibrium results. The effect of the vibrational temperature on the flowfield is also investigated for four different wall conditions for vibrational temperature. The vibrational temperature profile is similar for four wall conditions except in the vicinity of the wall at the altitudes of 70 and 80 km. However, the wall condition for the vibrational temperature considerably affects the vibrational temperature profiles at the altitude of 90 km. The obtained wall heat flux and wall temperature are influenced by surface catalycity rather than the wall condition of the vibrational temperature. The effect of radiation on the wall heat flux is discussed briefly. Author

A91-46625#
EXPERIMENTAL STUDY ON INTERACTING FLOW FIELDS INDUCED BY NORMALLY INJECTED SECONDARY FLOW THROUGH A SLOT NOZZLE INTO SUPERSONIC FLOW
SHIGERU ASO (Kyushu University, Fukuoka, Japan), YASUNORI ANDO (Ishikawajima-Harima Heavy Industries Co., Ltd., Yokohama, Japan), and SATOSHI OKUYAMA Kyushu University, Faculty of Engineering, Memoirs (ISSN 0023-6160), vol. 51, March 1991, p. 53-62. refs

The complex flowfields induced by gaseous secondary flow injected into supersonic flow have been studied experimentally. A gaseous nitrogen jet is injected normally into the external flow through a transverse slot nozzle mounted on the flat plate model. Experiments are conducted under the conditions of free stream Mach number of 3.8, total pressure of 1.2 MPa, Reynolds number of 2.0 x 10 to the 7th. The results show that the bow shock wave/turbulent boundary layer interaction induces the boundary layer separation in front of the injection. In the interacting flow, barrel shock waves and Mach disk are observed clearly. As the total pressure ratio or thickness of nozzle is increased, the separation region, the extent of the interaction region and shock structures become significantly large. Author

A91-47050#
HYPERSONIC TRANSITIONAL FLOW ABOUT BLUNT CONES USING DIRECT SIMULATION MONTE-CARLO METHOD
PRASAD R. GOGINENI (Lockheed Research Laboratories, Palo Alto, CA) AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 22nd, Honolulu, HI, June 24-26, 1991. 9 p. Research supported by Lockheed Independent Research and Development Program. refs
(AIAA PAPER 91-1704) Copyright

The aerodynamic characteristics of Blunt cones in the transitional flow regime have been computed using the Direct

Simulation Monte Carlo (DSMC) method both for axisymmetric flow and flow at angle of attack. The predictions were improved by modifying the grid in the nose region, and the choice of weighting factors. The effect of these improvements was assessed by studying the flowfield data. The computational times are also presented. Comparisons were made with other predictions. No significant advantage was found in using the weighting factors for predicting the aerodynamic characteristics of blunt cones. The user is cautioned about the round-off errors that occur on VAX8650 machine. The use of subcells around the cone is recommended for the flow at angle of attack. Author

A91-47152*# Pennsylvania State Univ., University Park.
VALIDATION OF ENGINEERING METHODS FOR PREDICTING HYPERSONIC VEHICLE CONTROLS FORCES AND MOMENTS
M. MAUGHMER, D. STRAUSSFOGEL, L. LONG (Pennsylvania State University, University Park), and L. OZOROSKI (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 1-16. refs
(Contract NAG1-849)
(AIAA PAPER 91-2845) Copyright

This work examines the ability of the aerodynamic analysis methods contained in an industry standard conceptual design code, the Aerodynamic Preliminary Analysis System (APAS II), to estimate the forces and moments generated through control surface deflections from low subsonic to high hypersonic speeds. Predicted control forces and moments generated by various control effectors are compared with previously published wind-tunnel and flight-test data for three vehicles: the North American X-15, a hypersonic research airplane concept, and the Space Shuttle Orbiter. Qualitative summaries of the results are given for each force and moment coefficient and each control derivative in the various speed ranges. Results show that all predictions of longitudinal stability and control derivatives are acceptable for use at the conceptual design stage. Author

A91-47159#
TRANSONIC EULER SOLUTIONS OF A WING-PYLON-FINNED BODY CONFIGURATION USING BLOCKED AND OVERLAPPING GRID SCHEMES
LAWRENCE E. LIJEWSKI (USAF, Wright Laboratory, Eglin AFB, FL) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 80-88. refs
(AIAA PAPER 91-2854)

Flow solutions are obtained in the transonic regime for various combinations of a wing-pylon-finned store configuration. Two grid schemes are used to demonstrate the versatility in modeling complex configurations. Mutual interference effects are explored, as well as the resulting rigid body aerodynamics. Exceptional agreement is observed between predictions and wind tunnel data. Author

A91-47160*# Ballistic Research Labs., Aberdeen Proving Ground, MD.
NAVIER-STOKES PREDICTIONS OF PITCH DAMPING FOR AXISYMMETRIC SHELL USING STEADY CONING MOTION
PAUL WEINACHT, WALTER B. STUREK (U.S. Army, Ballistic Research Laboratory, Aberdeen Proving Ground, MD), and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 89-100. refs
(AIAA PAPER 91-2855)

Previous theoretical investigations have proposed that the side force and moment acting on a body of revolution in steady coning motion could be related to the pitch-damping force and moment. In the current research effort, this approach is applied to produce predictions of the pitch damping for axisymmetric shell. The flow fields about these projectiles undergoing steady coning motion are successfully computed using a parabolized Navier-Stokes computational approach which makes use of a rotating coordinate frame. The governing equations are modified to include the centrifugal and Coriolis force terms due to the rotating coordinate frame. From the computed flow field, the side moments due to coning motion, spinning motion, and combined spinning and coning motion are used to determine the pitch-damping coefficients. Computations are performed for two generic shell configurations, a secant-ogive-cylinder and a secant-ogive-cylinder-boattail. Author

A91-47161#
WING-BODY CARRYOVER AND FIN CENTER OF PRESSURE FOR MISSILES WITH NONCIRCULAR FUSELAGE CROSS SECTIONS
BRIAN E. EST (Dynetics, Inc., Huntsville, AL) and H. F. NELSON (Missouri-Rolla, University, Rolla) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 101-112. Research supported by McDonnell Douglas Missile Systems Co. refs
(AIAA PAPER 91-2856) Copyright

The wing-body carryover parameter K sub W(B), a measure of upwash on the undeflected wing due to the presence of the body, and fin center of pressure are investigated for supersonic missiles with square and triangular fuselage cross sections. The fins are assumed to be infinitely thin delta wings and are arranged in a cruciform configuration. The numerical calculations are performed using ZEUS, a finite volume Euler code. K sub W(B) and fin center of pressure were found to be sensitive to Mach number, wing leading edge semi-vertex angle, and body cross-sectional shape for cruise flight conditions. Predicted K sub W(B) values are shown to compare favorably to slender body theory. The fin center of pressure is shown to be located very close to the fin geometric centroid. Author

A91-47162#
COMPARISONS OF TVD SCHEMES FOR TURBULENT TRANSONIC PROJECTILE AERODYNAMICS COMPUTATIONS WITH A TWO-EQUATION MODEL OF TURBULENCE
CHING-CHANG CHIENG (National Tsing Hua University, Hsinchu, Republic of China), HERNG LIN, and CHE C. CHUANG IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 113-123. refs
(AIAA PAPER 91-2858) Copyright

The development of a computer program to solve the axisymmetric full Navier-Stoke equations with the k-epsilon two equation model of turbulence using various TVD schemes is considered. The computations are performed for turbulent transonic viscous flow over a projectile with/without supporting sting at zero angle of attack. The predicted results, as well as the convergence characteristics, obtained with the various TVD schemes and turbulence models are compared. It is shown that the TVD schemes of higher order accuracy do not necessarily imply better agreement with available measured data. Author

A91-47163#
VARIOUS OPTIMAL CLIMB PROFILES
BERNT JARMARK (Saab-Scania, AB, Linkoping, Sweden) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 124-130. refs
(AIAA PAPER 91-2859) Copyright

Realistic aircraft trajectories are optimized by a numerical method. Large differences are obtained between time optimal energy climb, maximal energy on a given amount of fuel, and time optimal flight to a given curve in altitude versus distance. The value of optimizing flight trajectories is also demonstrated in sensitive problems close to the flight envelope. Author

A91-47168*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UNSTEADY NAVIER-STOKES COMPUTATIONS ON A WING-BODY CONFIGURATION IN RAMP MOTIONS
SHIGERU OBAYASHI, GURU P. GURUSWAMY, and EUGENE L. TU (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 167-176. refs
(AIAA PAPER 91-2865) Copyright

Unsteady Navier-Stokes computations are conducted for transonic flows over a wing-body configuration undergoing prescribed ramp motions. The ramp motion from 0 to 15 deg includes angles of attack where vortex breakdown is observed experimentally. The vortex breakdown is found to be delayed until after the ramp motion ends. The dynamic effects on the loads are also demonstrated. The moment coefficient is found to be sensitive to the effect of the virtual mass of the fluid. To verify the numerical results, a grid refinement study has been performed for both steady and unsteady flow conditions, by using up to approximately one million grid points. The results show that the coarse grid can give integrated quantities reasonably well, whereas the finer grids give a more detailed flow structure. Comparisons are also made with available steady-state experimental data. Author

A91-47169#
NONLINEAR NORMAL FORCE INDICIAL RESPONSES FOR A 2-D AIRFOIL
G. M. GRAHAM, M. ISLAM (Ohio University, Athens), and J. E. JENKINS (USAF, Wright Laboratory, Wright-Patterson AFB, OH) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 177-187. refs
(Contract AF-AFOSR-89-0502)
(AIAA PAPER 91-2866) Copyright

The normal force response of a 2D NACA 0015 airfoil to small step changes in angle of attack has been measured in a two tank. The airfoil was pitched about the quarter chord and the Reynolds number was 95,000. The angle of attack prior to the step onset was held constant and was varied in the range 0-60 deg. The step responses have been integrated numerically to compute the loading during a ramp-up motion. The results indicate that, for pitch rates below 0.01, the first order responses predict dynamic loads with reasonable accuracy. The term 'first order' refers to the constant angle of attack prior to step onset condition. For pitch rates above 0.01 first order responses may not accurately predict the loading for high pitch rates. Author

A91-47170*# Kansas Univ., Lawrence.
FOURIER FUNCTIONAL ANALYSIS FOR UNSTEADY AERODYNAMIC MODELING
SUEI CHIN and C. E. LAN (Kansas, University, Lawrence) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 188-198. Previously announced in STAR as N91-18064. refs
(Contract NAG1-1087)
(AIAA PAPER 91-2867) Copyright

A method based on Fourier analysis is developed to analyze the force and moment data obtained in large amplitude forced oscillation tests at high angles of attack. The aerodynamic models for normal force, lift, drag, and pitching moment coefficients are built up from a set of aerodynamic responses to harmonic motions at different frequencies. Based on the aerodynamic models of harmonic data, the indicial responses are formed. The final expressions for the models involve time integrals of the indicial type advocated by Tobak and Schiff. Results from linear two- and three-dimensional unsteady aerodynamic theories as well as test data for a 70-degree delta wing are used to verify the models. It is shown that the present modeling method is accurate in producing the aerodynamic responses to harmonic motions and the ramp type motions. The model also produces correct trend for a 70-degree delta wing in harmonic motion with different mean angles-of-attack. However, the current model cannot be used to extrapolate data to higher angles-of-attack than that of the harmonic motions which form the aerodynamic model. For linear ramp motions, a special method is used to calculate the corresponding frequency and phase angle at a given time. The calculated results from modeling show a higher lift peak for linear ramp motion than for harmonic ramp motion. The current model also shows reasonably good results for the lift responses at different angles of attack. Author

A91-47171*# Stanford Univ., CA.
VORTICAL FLOW CONTROL ON A SLENDER BODY AT HIGH ANGLES OF ATTACK
ZEKI Z. CELIK and LEONARD ROBERTS (Stanford University, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 199-211. refs
(Contract NCC2-55)
(AIAA PAPER 91-2868) Copyright

Attention is given to the possibility of using tangential blowing to control vortical flow on a missile-like slender body at high angles of attack. Emphasis is placed on smoke- and surface oil-flow visualization, force measurements, and velocity and pressure measurements using a 5-hole probe. It is shown that the tangential blowing significantly alters the flow field downstream of the slot and creates large side forces and yawing moments to very high angles of attack. Effectiveness of the tangential blowing is discussed in terms of jet momentum, blowing location, slot area, and Reynolds number. The concept proved to be efficient at small blowing rates and at high angles of attack. O.G.

A91-47172#
NUMERICAL INVESTIGATION OF SUBSONIC AND SUPERSONIC ASYMMETRIC VORTICAL FLOW
K. J. VANDEN and D. M. BELK (USAF, Wright Laboratory, Eglin AFB, FL) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 212-222. refs
(AIAA PAPER 91-2869)

The high angle of attack flow about a slender body in supersonic and subsonic flow was computed for an angle of attack of 38.5 degrees to study the phenomena associated with vortex asymmetry. A laminar thin-layer Navier-Stokes algorithm was used to determine whether vortex asymmetry in numerical computations are the result of a numerically induced perturbation or a property of the governing equations. The fully upwind code used in this study was symmetric in the cross-flow plane to 12 orders of magnitude, the level of roundoff error on the CRAY Y-MP. It was found that with a completely symmetric grid and algorithm with respect to the crossflow plane a bump was needed to perturb the flow to asymmetry. When the bump was taken away the flow returned to a symmetric state. This corroborates the previous assertion of other investigators that vortex asymmetry at high angles of attack on slender bodies is due to a convective instability. Author

A91-47255#
AERODYNAMICS OF A THIN AIRFOIL FLYING OVER AND IN PROXIMITY TO A WAVY-WALL SURFACE - LIFTING SURFACE THEORY
SHIGENORI ANDO (Nagoya University, Japan) and MASAMI ICHIKAWA (Government Industrial Research Institute, Nagoya, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 34, May 1991, p. 1-11. refs

Presented in this paper are aerodynamic characteristics of a thin airfoil flying over and in proximity to a wavy-wall surface which moves in the same direction as the free stream but with a different velocity. Lifting surface technique is adopted, based on an inviscid and incompressible flow. Supposing the wall to be sinusoidal, a number of numerical calculations are made with a set of important parameters such as airfoil height from the wall, wave length of

wall surface, and the wall velocity. The whole effect of wavy-wall proximity is divided into the first and second ones. The first one is just Kemp's upwash problem. The second one becomes clear through the present investigation. Author

A91-47481
IMPLICIT UNFACTORIZED METHOD FOR COMPUTING THE TURBULENT VISCOUS HEAT-CONDUCTING GAS FLOWS IN TURBOMACHINE CASCADES [NEIAVNYI NEFAKTORIZOVANNYI METOD RASCHETA TURBULENTNYKH TECHENII VIAZKOGO TEPLOPROVODNOGO GAZA V RESHETKAKH TURBOMASHIN]
M. IA. IVANOV and V. G. KRUPA Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 31, May 1991, p. 754-766. In Russian. refs
Copyright

Numerical integration of the Re-averaged Navier-Stokes equations is carried out using the two-parameter turbulence model. Use is made of the unfactorized relaxational variant of the implicit divergent Godunov difference scheme, based on the principle of monotonicity in the problem of the decay of an arbitrary discontinuity. The effectiveness of the proposed numerical approach is illustrated in connection with the calculation of the 2D viscous heat-conducting gas flow in turbomachine cascades. L.M.

A91-47482
AN ITERATIVE METHOD FOR CALCULATING SUBSONIC AND TRANSONIC INTERNAL FLOWS [OB ODNOM ITERATSIONNOM METODE RASCHETA DO- I TRANSZVUKOVYKH VNUTRENNIKH TECHENII]
A. M. LATYPOV and A. V. SHIPILIN Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 31, May 1991, p. 767-776. In Russian. refs
Copyright

The equations of steady potential two-dimensional gas flows are reduced to a single second-order equation whose unknown function is one of the Cartesian coordinates in the plane case or the radial coordinate in the axisymmetric case. The numerical algorithm developed to solve this equation is applied to the calculation of subsonic and transonic internal flows. L.M.

A91-47483
SOLUTION OF THE INVERSE PROBLEM FOR THE INTERNAL FLOWS OF A VISCOUS GAS WITH A SUPERSONIC CORE [K RESHENIIU OBRATNOI ZADACHI DLIA VNUTRENNIKH TECHENII VIAZKOGO GAZA SO SVERKHZVUKOVYM IADROM]
S. G. KARATAEV and V. N. KOTEROV Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ISSN 0044-4669), vol. 31, May 1991, p. 790-793. In Russian. refs
Copyright

A method is developed for solving inverse problems for viscous-fluid flows in channels. The numerical methold for solving the simplified Navier-Stokes equation is based on the use of stream function/orthogonal complement variables. Results are presented on channel profiling, assuring a prescribed pressure distribution on the channel wall. L.M.

A91-47621* University Coll. of Swansea (Wales).
AN IMPLICIT FINITE-ELEMENT METHOD FOR HIGH-SPEED FLOWS
O. HASSAN, K. MORGAN (Swansea, University College, Wales), and J. PERAIRE (Imperial College of Science, Technology, and Medicine, London, England) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 32, no. 1, July 1991; p. 183-205. Research supported by Dassault Aviation. Previously cited in issue 10, p. 1485, Accession no. A90-26943. refs
(Contract NAGW-1089; SERC-GR/E/6404/6)
Copyright

A91-48035* Stanford Univ., CA.
SURVEY OF RESEARCH ON UNSTEADY AERODYNAMIC LOADING OF DELTA WINGS
H. ASHLEY, T. VANECK (Stanford University, CA), J. KATZ (San Diego State University, CA), and M. A. JARRAH (Jordan University of Science and Technology, Irbid) Journal of Fluids and Structures (ISSN 0889-9746), vol. 5, July 1991, p. 363-390. refs
(Contract NCC2-596; NCA2-287; AF-AFOSR-84-0099)
Copyright

For aeronautical applications, there has been recent interest in accurately determining the aerodynamic forces and moments experienced by low-aspect-ratio wings performing transient maneuvers which go to angles of attack as high as 90 deg. Focusing on the delta planform with sharp leading edges, the paper surveys experimental and theoretical investigations dealing with the associated unsteady flow phenomena. For maximum angles above a value between 30 and 40 deg, flow details and airloads are dominated by hysteresis in the 'bursting' instability of intense vortices which emanate from the leading edge. As examples of relevant test results, force and moment histories are presented for a model series with aspect ratios 1, 1.5 and 2. Influences of key parameters are discussed, notably those which measure unsteadiness. Comparisons are given with two theories: a paneling approximation that cannot capture bursting but clarifies other unsteady influences, and a simplified estimation scheme which uses measured bursting data. Author

A91-48252
MEASUREMENTS AND INTERPRETATION OF 3-D HIGH SPEED FLOWS
C. BERNER (Saint-Louis, Institut Franco-Allemand de Recherches, France) IN: Laser anemometry - Advances and applications; Proceedings of the 3rd International Conference, Swansea, Wales, Sept. 26-29, 1989. Oxford, England/Berlin and New York, BHRA (Information Services)/Springer-Verlag, 1990, p. 3-16. refs
Copyright

Investigations of the flow field in the near-wake of axisymmetric afterbodies at an angle of attack of five deg are presented. Models employed consist of a conical boattail and a cylindrical afterbody. An attempt is made to visualize and describe velocity characteristics in the form of 3D graphic representations. Results include boundary layer profiles, static pressure distributions and the mean and turbulent flow fields. R.E.P.

A91-48268
ON THE EFFECTS OF QUASI-ISOTROPIC TURBULENCE ON THE AERODYNAMIC PERFORMANCE OF SINGLE AND MULTI-ELEMENT AIRFOILS
G. D. CATALANO, C. M. FREMAUX, and E. B. ZIMMERMAN (Louisiana State University, Baton Rouge) IN: Laser anemometry - Advances and applications; Proceedings of the 3rd International Conference, Swansea, Wales, Sept. 26-29, 1989. Oxford, England/Berlin and New York, BHRA (Information Services)/Springer-Verlag, 1990, p. 403-416. Research sponsored by U.S. Military Academy. refs
Copyright

The effects of quasi-isotropic turbulence on the aerodynamic performance of single and multi-element airfoils are investigated. Different levels of free stream turbulence are generated using varying mesh sizes in two different wind tunnel facilities. The turbulent velocity fields are measured using a laser Doppler velocimeter incorporating a frequency tracker processor. An increase in turbulent intensity resulted in a decrease in the value of the lift coefficient at zero angle of attack except for the symmetric airfoil case and observable changes in the lift curve slope. A perturbation analysis is described that allows for small changes in the free stream turbulence level and predicts the altered lift and pitching moment coefficients. The credibility of using the velocity field measurements as a means to calculate the aerodynamic coefficients is established through comparison with existing data. Author

A91-48275
EXPERIMENTAL STUDY OF VORTEX FLOW BY LDA
D. PAGAN, J.-L. SOLIGNAC, and P. MOLTON (ONERA, Chatillon, France) IN: Laser anemometry - Advances and applications; Proceedings of the 3rd International Conference, Swansea, Wales, Sept. 26-29, 1989. Oxford, England/Berlin and New York, BHRA (Information Services)/Springer-Verlag, 1990, p. 695-706. refs
Copyright

A study of the vortical flow created by a sharp leading edge delta wing is conducted with the object of constituting a detailed and reliable set of experimental data based on one case with vortex breakdown and another without vortex breakdown. The study of a 75-deg-sweep-angle delta wing set at an angle of attack of 20 deg allows the formation of an experimental data base that can be used for the thorough validation of computational codes. Results obtained in the case of a 70-deg-swept delta wing at an angle of attack of 26 deg reveal the existence of vortex breakdown. It is indicated that the principal modifications introduced in the outer field flow by vortex breakdown do not affect significantly the upper surface skin-friction pattern. R.E.P.

A91-48286* *High Technology Corp., Hampton, VA.*
ON THE STABILITY OF COMPRESSIBLE FLOW PAST AXISYMMETRIC BODIES
M. R. MALIK and R. E. SPALL (High Technology Corp., Hampton, VA) Journal of Fluid Mechanics (ISSN 0022-1120), vol. 228, July 1991, p. 443-463. refs
(Contract NAS1-18240)
Copyright

Compressible linear stability theory for axisymmetric flows is presented. The theory is applied to flow past a cylinder and a sharp cone at a Mach number of 5 with adiabatic wall conditions. The effect of transverse curvature and body divergence is studied. It is found that transverse curvature has a stabilizing influence on axisymmetric (first and second mode) disturbances while it has a destabilizing influence on the asymmetric (oblique first mode) disturbances. The body divergence effects are stabilizing for both symmetric and asymmetric disturbances. Comparisons made with the results of planar stability theory show that, for a cylinder, curvature effects become more pronounced with increasing distance along the cylinder. For a sharp cone, these effects become less significant further away from the cone tip since the body radius increases faster than the growth of the boundary layer. The effect of cone angle on stability is also studied. Author

N91-27125 Pennsylvania State Univ., University Park.
LINEAR MODELS FOR THE SHOCK CELL STRUCTURE OF SUPERSONIC JETS WITH NONCIRCULAR EXIT GEOMETRIES Ph.D. Thesis
THONSE R. S. BHAT 1990 191 p
Avail: Univ. Microfilms Order No. DA9104852

The development of models to predict the shock structure of imperfectly expanded supersonic jets with noncircular exit geometry is discussed. Numerical methods to obtain solutions for these models are also developed. Two different models to predict the shock cell structure are developed using a linearized analysis. The Vortex-Sheet Shock Cell Model assumes that the jet mixing layer can be represented by a vortex-sheet. The boundary element method is used to predict the shock spacing and the frequency of the screech tones. The results are compared with analysis and experiment and it is shown that agreement is good. The second model, the Finite Thickness Shear Layer Model, takes into account the finite thickness of the jet shear layer and the effects of the turbulence. Two different numerical schemes are developed to obtain predictions using this model. In the first method, a body-fitted coordinate system is used to set up the governing equations. The second numerical method uses a series of conformal mappings to transform the physical space to a rectangular computational domain. The results obtained are in reasonable agreement with the experimental data. This is especially true for the gross features of the shock cells. Dissert. Abstr.

N91-27126*# California Polytechnic State Univ., San Luis Obispo.
A WATER TUNNEL FLOW VISUALIZATION STUDY OF THE VORTEX FLOW STRUCTURES ON THE F/A-18 AIRCRAFT Final Report, 1 Jul. 1989 - 31 Mar. 1991
DORAL R. SANDLIN and EDGAR J. RAMIREZ Jul. 1991 124 p
(Contract NCC2-620)
(NASA-CR-186938; NAS 1.26:186938) Avail: NTIS HC/MF A06 CSCL 01A

The vortex flow structures occurring on the F/A-18 aircraft at high angles of attack were studied. A water tunnel was used to gather flow visualization data on the forebody vortex and the wing leading edge extension vortex. The longitudinal location of breakdown of the leading edge vortex was found to be consistently dependent on the angle of attack. Other parameters such as Reynolds number, model scale, and model fidelity had little influence on the overall behavior of the flow structures studied. The lateral location of the forebody vortex system was greatly influenced by changes in the angle of sideslip. Strong interactions can occur between the leading edge extension vortex and the forebody vortex. Close attention was paid to vortex induced flows on various airframe components of the F/A-18. Reynolds number and angle of attack greatly affected the swirling intensity, and therefore the strength of the studied vortices. Water tunnel results on the F/A-18 correlated well with those obtained in similar studies at both full and sub scale levels. The water tunnel can provide, under certain conditions, good simulations of realistic flows in full scale configurations. Author

N91-27127*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NASP AEROSERVOTHERMOELASTICITY STUDIES
ROBERT V. DOGGETT, JR., RODNEY H. RICKETTS, T. E. NOLL, and JOHN B. MALONE Apr. 1991 26 p
(NASA-TM-104058; NAS 1.15:104058) Avail: NTIS HC/MF A03 CSCL 01A

Some illustrative results obtained from work accomplished under the aerothermoelasticity work breakdown structure (WBS) element of the National Aerospace Plane (NASP) Technology Maturation Program (TMP) are presented and discussed. The objectives of the aerothermoelasticity element were to develop analytical methods applicable to aerospace plane type configurations, to conduct analytical studies to identify potential problems, to evaluate potential solutions to problems, and to provide an experimental data base to verify codes and analytical trends. Work accomplished in the three areas of experimental data base, unsteady aerodynamics, and integrated analysis methodology are described. Some of the specific topics discussed are: (1) transonic wind tunnel aeroelastic model tests of cantilever delta wing models, of an all-moveable delta-wing model, and of aileron buzz models; (2) unsteady aerodynamic theory correlation with experiment and theory improvements; and (3) integrated analysis methodology results for thermal effects on vibration, for thermal effects on flutter, and for improving aeroelastic performance by using active controls. Author

N91-27128*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUGGESTIONS FOR CAP-TSD MESH AND TIME-STEP INPUT PARAMETERS
SAMUEL R. BLAND Jun. 1991 24 p
(NASA-TM-104083; NAS 1.15:104083) Avail: NTIS HC/MF A03 CSCL 01A

Suggestions for some of the input parameters used in the CAP-TSD (Computational Aeroelasticity Program-Transonic Small Disturbance) computer code are presented. These parameters include those associated with the mesh design and time step. The guidelines are based principally on experience with a one-dimensional model problem used to study wave propagation in the vertical direction. Author

N91-27130*# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
AN INITIAL INVESTIGATION INTO METHODS OF COMPUTING TRANSONIC AERODYNAMIC SENSITIVITY COEFFICIENTS Semiannual Progress Report, Jan. - Jun. 1991
LELAND A. CARLSON Jul. 1991 39 p
(Contract NAG1-793)
(NASA-CR-188644; NAS 1.26:188644; TAMRF-5802-91-02)
Avail: NTIS HC/MF A03 CSCL 01A

Continuing studies associated with the development of the quasi-analytical (QA) sensitivity method for three dimensional transonic flow about wings are presented. Furthermore, initial results using the quasi-analytical approach were obtained and compared to those computed using the finite difference (FD) approach. The basic goals achieved were: (1) carrying out various debugging operations pertaining to the quasi-analytical method; (2) addition of section design variables to the sensitivity equation in the form of multiple right hand sides; (3) reconfiguring the analysis/sensitivity package in order to facilitate the execution of analysis/FD/QA test cases; and (4) enhancing the display of output data to allow careful examination of the results and to permit various comparisons of sensitivity derivatives obtained using the FC/QA methods to be conducted easily and quickly. In addition to discussing the above goals, the results of executing subcritical and supercritical test cases are presented. Author

N91-27131*# Pennsylvania State Univ., University Park. Dept. of Aerospace Engineering.
ANALYSIS AND DESIGN OF PLANAR AND NON-PLANAR WINGS FOR INDUCED DRAG MINIMIZATION Semiannual Status Report, Dec. 1990 - Jun. 1991
DENNIS M. STRAUSSFOGEL and MARK D. MAUGHMER Jul. 1991 17 p
(Contract NAG1-1198)
(NASA-CR-188656; NAS 1.26:188656) Avail: NTIS HC/MF A03 CSCL 01A

Improvements in the aerodynamic efficiency of commercial transport aircraft will reduce fuel usage with subsequent reduced cost, both monetary and environmental. To this end, the current research is aimed at reducing the overall drag of these aircraft with specific emphasis on reducing the drag generated by the lifting surfaces. The ultimate goal of this program is to create a wing design methodology which optimizes the geometry of the wing for lowest total drag within the constraints of a particular design specification. The components of drag which must be considered include profile drag, and wave drag. Profile drag is dependent upon, among other things, the airfoil section and the total wetted area. Induced drag, which is manifested as energy left in the wake by the trailing vortex system is mostly a function of wing span, but also depends on other geometric wing parameters. Wave drag of the wing, important in the transonic flight regime, is largely affected by the airfoil section, wing sweep, and so forth. The optimization problem is that of assessing the various parameters which contribute to the different components of wing drag, and determining the wing geometry which generates the best overall performance for a given aircraft mission. The primary thrust of the research effort to date was in the study of induced drag. Results from the study are presented. Author

N91-27132*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RWF ROTOR-WAKE-FUSELAGE CODE SOFTWARE REFERENCE GUIDE
JOHN D. BERRY (Army Aviation Systems Command, Hampton, VA.) Jul. 1991 38 p
(NASA-TM-104078; NAS 1.15:104078; AVSCOM-TR-91-B-008)
Avail: NTIS HC/MF A03 CSCL 01A

The RWF (Rotor-Wake-Fuselage) code was developed from first principles to compute the aerodynamics associated with the complex flow field of helicopter configurations. The code is sized for a single, multi-bladed main rotor and any configuration of non-lifting fuselage. The mathematical model for the RWF code is based on the integration of the momentum equations and Green's theorem. The unknowns in the problem are the strengths of prescribed singularity distributions on the boundaries of the flow. For the body (fuselage) a surface of constant strength source panels is used. For the rotor blades and rotor wake a surface of constant strength doublet panels is used. The mean camber line of the rotor airfoil is partitioned into surface panels. The no-flow boundary condition at the panel centroids is modified at each azimuthal step to account for rotor blade cyclic pitch variation. The geometry of the rotor wake is computers at each time step of the solution. The code produces rotor and fuselage surface pressures, as well as the complex geometry of the evolving rotor wake. Author

N91-27133*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL DYNAMIC AND AEROELASTIC CONSIDERATIONS FOR HYPERSONIC VEHICLES
F. W. CAZIER, JR., ROBERT V. DOGGETT, JR., and RODNEY H. RICKETTS Jun. 1991 15 p Presented at AIAA/ASME/ASCE/AHS/ASC 32d Structures, Structural Dynamics, and Materials Conference, Baltimore, MD, 8-10 Apr. 1991 Previously announced as A91-32133
(NASA-TM-104110; NAS 1.15:104110) Avail: NTIS HC/MF A03 CSCL 01A

The specific geometrical, structural, and operational environment characteristics of hypersonic vehicles are discussed with particular reference to aerospace plane type configurations. A discussion of the structural dynamic and aeroelastic phenomena that must be addressed for this class of vehicles is presented. These phenomena are in the aeroservothermoelasticity technical area. Some illustrative examples of recent experimental and analytical work are given. Some examples of current research are pointed out. Author

N91-27135# Titan Systems, Inc., Princeton, NJ.
CONCEPTS FOR CAVITATION ALLEVIATION OF BANDED AND DUCTED ROTOR TIPS Final Report
JOHN E. YATES and STEPHEN F. PARKER 15 Apr. 1991 5 p
(Contract N00014-88-C-0269)
(AD-A236254) Avail: NTIS HC/MF A01 CSCL 13/10

This study explored concepts and recommend geometries for alleviating the cavitation sensitivity of blade-band junctions of banded and ducted underwater propellers. A lifting surface model of the tip region of the blade, the band and the duct wall was used to calculate in detail the blade load carry-over onto the band and the duct wall. Geometry modifications of the blade tip and the band camber were made to alleviate cavitation sensitivity. Two-dimensional models were used to assess the effect of blade and band thickness. Both design and analysis type codes were used. It is concluded that, with proper use of band camber, the suction pressure in the blade band junction can be tailored to alleviate cavitation. GRA

N91-27138# Naval Postgraduate School, Monterey, CA.
A FLOW VISUALIZATION STUDY OF LEX GENERATED VORTICES ON A SCALE MODEL OF A F/A-18 FIGHTER AIRCRAFT AT HIGH ANGLES OF ATTACK M.S. Thesis
ODILON V. CAVAZOS, JR. Jun. 1990 164 p
(AD-A236534) Avail: NTIS HC/MF A08 CSCL 01/1

A water tunnel flow visualization investigation was performed into the high angle of attach aerodynamics of a 2 percent scale model of the F/A-18 fighter aircraft. The main focus of this study was the effect of pitch rate on the development and bursting of vortices generated from the leading edge extension in the high angle of attack range with and without yaw. Results of this investigation indicate that the vortex bursting point (relative to the static case) moves rearward with increasing pitch-up motion and forward with increasing pitch-down motion. For the same pitch rate, vortex bursting was found to occur earlier for the pitch-down motion than for the pitch-up motion, implying aerodynamic hysteresis effects. Yawing the model generated significant vortex asymmetries due to the delayed vortex breakdown on the leeward

side for yaw angles of less than 10 deg. The presence of these asymmetric vortices led to undesirable side forces and yawing moments. GRA

N91-27139* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SELECTABLE TOWLINE SPIN CHUTE SYSTEM Patent
DANIEL M. VAIRO, inventor (to NASA) and RAYMOND D. WHIPPLE, inventor (to NASA) 4 Jun. 1991 22 p Filed 25 Oct. 1990
(NASA-CASE-LAR-14322-1; US-PATENT-5,020,739; US-PATENT-APPL-SN-603335; US-PATENT-CLASS-244-75R; US-PATENT-CLASS-244-113; US-PATENT-CLASS-244-139; INT-PATENT-CLASS-B64C-17/00) Avail: US Patent and Trademark Office CSCL 01/1

An emergency spin recovery parachute is presented that is housed within a centrally mounted housing on the aft end of an aircraft and connected to a ring fitting within the housing. Two selectively latching shackles connected to separate towlines are openly disposed adjacent the ring fitting. The towlines extend in opposite directions from the housing along the aircraft wing to attachment points adjacent the wing-tips where the other end of each towline is secured. Upon pilot command, one of the open shackles latches to the ring fitting to attach the towline connected thereto, and a second command signal deploys the parachute. Suitable break-away straps secure the towlines to the aircraft surface until the parachute is deployed and the resulting force on the towline attached to the parachute overcomes the straps and permits the towline to extend to the point of attachment to exert sufficient drag on the spinning aircraft to permit the pilot to regain control of the aircraft. To employ the parachute as a drag chute to reduce landing speeds, both shackles and their respective towlines are latched to the ring fitting.
Official Gazette of the U.S. Patent and Trademark Office

N91-28131*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A METHODOLOGY FOR USING NONLINEAR AERODYNAMICS IN AEROSERVOELASTIC ANALYSIS AND DESIGN
WALTER A. SILVA May 1991 15 p Previously announced as A91-32025
(NASA-TM-104087; NAS 1.15:104087) Avail: NTIS HC/MF A03 CSCL 01/1

A methodology is presented for using the Volterra-Wiener theory of nonlinear systems in aeroservoelastic (ASE) analyses and design. The theory is applied to the development of nonlinear aerodynamic response models that can be defined in state-space form and are, therefore, appropriate for use in modern control theory. The theory relies on the identification of nonlinear kernels that can be used to predict the response of a nonlinear system due to an arbitrary input. A numerical kernel identification technique, based on unit impulse responses, is presented and applied to a simple bilinear, single-input single-output (SISO) system. The linear kernel (unit impulse response) and the nonlinear second-order kernel of the system are numerically-identified and compared with the exact, analytically-defined and linear and second-order kernels. This kernel identification technique is then applied to the CAP-TSD (Computational Aeroelasticity Program-Transonic Small Disturbance) code for identification of the linear and second-order kernels of a NACA64A010 rectangular wing undergoing pitch at $M = 0.5$, $M = 8.5$ (transonic), and $M = 0.93$ (transonic). Results presented demonstrate the feasibility of this approach for use with nonlinear, unsteady aerodynamic responses. Author

N91-28132*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSONIC SHOCK-INDUCED DYNAMICS OF A FLEXIBLE WING WITH A THICK CIRCULAR-ARC AIRFOIL
ROBERT M. BENNETT, BRYAN E. DANSBERRY, MOSES G. FARMER, CLINTON V. ECKSTROM, DAVID A. SEIDEL, and JOSE A. RIVERA, JR. May 1991 12 p Presented at the 32d Structures, Structural Dynamics and Materials Conference, Baltimore, MD, 7-10 Apr. 1991 Previously announced as A91-32023
(NASA-TM-104088; NAS 1.15:104088; AIAA-PAPER-91-1107) Avail: NTIS HC/MF A03 CSCL 01/1

Transonic shock boundary layer oscillations occur on rigid models over a small range of Mach numbers on thick circular-arc airfoils. Extensive tests and analyses of this phenomena have been made in the past but essentially all of them were for rigid models. A simple flexible wing model with an 18 pct. circular arc airfoil was constructed and tested in the Langley Transonic Dynamics Tunnel to study the dynamic characteristics that a wing might have under these circumstances. In the region of shock boundary layer oscillations, buffeting of the first bending mode was obtained. This mode was well separated in frequency from the shock boundary layer oscillations. A limit cycle oscillation was also measured in a third bending like mode, involving wind vertical bending and splitter plate motion, which was in the frequency range of the shock boundary layer oscillations. Several model configurations were tested, and a few potential fixes were investigated. Author

N91-28133# Sandia National Labs., Albuquerque, NM.
AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF VORTEX GENERATORS ON THE AERODYNAMIC CHARACTERISTICS OF A NACA 0021 AIRFOIL UNDERGOING LARGE AMPLITUDE PITCH OSCILLATIONS
M. L. RUEGER and G. M. GREGOREK (Ohio State Univ., Columbus.) Apr. 1991 153 p
(Contract DE-AC04-76DP-00789)
(DE91-012102; SAND-90-7111) Avail: NTIS HC/MF A08

A NACA 0021 14-chord airfoil was subjected to large amplitude pitch oscillations in The Ohio State University Low Speed Wind Tunnel at a Reynolds number of 1.2 times 10(exp 6). Surface pressures were measured with an electronically scanned pressure measurement system at sampling rates up to 50 Hz. Data were acquired for the clean airfoil and for the airfoil with vortex generators located at 0.1 and 0.3 chord distances aft of the leading edge. The vortex generators increase the maximum lift coefficient and the lift curve slope for both the static and dynamic tests. The magnitude and detail of the vortex generator effects were found to depend on the amplitude and frequency of the pitch oscillations. DOE

N91-28134*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ROTOR AND CONTROL SYSTEM LOADS ANALYSIS OF THE XV-15 WITH THE ADVANCED TECHNOLOGY BLADES
JOSEPH J. TOTAH and JOHN F. MADDEN, III Apr. 1991 23 p Presented at the American Helicopter Society National Technical Specialists' Meeting on Innovations in Rotorcraft Test Technologies for the 90's, Scottsdale, AZ, Oct. 1990 Previously announced as A91-31291
(NASA-TM-102876; A-90316; NAS 1.15:102876) Avail: NTIS HC/MF A03 CSCL 01/1

An analysis of the rotor and control system loads of the XV-15 with the Advanced Technology Blades (XV-15/ATB) was conducted to study the effects of modifications designed to alleviate high collective actuator loads encountered during initial flight tests. Rotor loads predictions were correlated with flight data to establish accuracies of the methodology used in the analysis. Control system loads predictions were then examined and were also correlated with flight data. The results showed a significant reduction in 3/rev collective actuator loads of the XV-15/ATB when the control system stiffness was increased and the rotor blade chord balance and tip twist were modified. Author

N91-28137*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL FLUTTER BOUNDARIES WITH UNSTEADY PRESSURE DISTRIBUTIONS FOR THE NACA 0012 BENCHMARK MODEL
JOSE A. RIVERA, JR., BRYAN E. DANSBERRY, MOSES G. FARMER, CLINTON V. ECKSTROM, DAVID A. SEIDEL, and ROBERT M. BENNETT Jul. 1991 9 p Presented at the 32nd

Structures, Structural Dynamics, and Materials Conference, Baltimore, MD, 8-10 Apr. 1991; cosponsored by AIAA, ASME, ASCE, AHS, and ASC Previously announced in IAA as A91-31900
(NASA-TM-104072; NAS 1.15:104072) Avail: NTIS HC/MF A02 CSCL 01/1

The Structural Dynamics Div. at NASA-Langley has started a wind tunnel activity referred to as the Benchmark Models Program. The objective is to acquire test data that will be useful for developing and evaluating aeroelastic type Computational Fluid Dynamics codes currently in use or under development. The progress is described which was achieved in testing the first model in the Benchmark Models Program. Experimental flutter boundaries are presented for a rigid semispan model (NACA 0012 airfoil section) mounted on a flexible mount system. Also, steady and unsteady pressure measurements taken at the flutter condition are presented. The pressure data were acquired over the entire model chord located at the 60 pct. span station. Author

N91-28138*# Vigyan Research Associates, Inc., Hampton, VA.
A STUDY OF RESIDUAL INTERFERENCE EFFECTS IN ADAPTIVE WALL TESTING OF A 7-INCH CHORD CAST-10-2/DOA 2 AIRFOIL MODEL
A. V. MURTHY Washington Aug. 1991 62 p
(Contract NAS1-18585)
(NASA-CR-4390; NAS 1.26:4390) Avail: NTIS HC/MF A04 CSCL 01/1

The residual interferences present in the testing of a CAST10-2/DOA2 airfoil model in the Langley 0.3 m Transonic Cryogenic Tunnel (0.3 m TCT) is examined. The 7.1 inch chord airfoil model was tested in the 0.3 m TCT adaptive wall test section with a nominal 13 inch square cross section. The test data obtained on the same model during different tunnel entries showed different levels of residual interference. The present study shows that for valid comparison of the test data from adaptive wall tunnels, it is necessary to account for residual interferences, in particular the blockage correction to the Mach number. Author

N91-28139 Tel-Aviv Univ. (Israel). Dept. of Fluid Mechanics and Heat Transfer.
AN ACTIVE DELAY OF SEPARATION ON TWO-DIMENSIONAL AIRFOILS M.S. Thesis
DORON NEUBURGER Apr. 1989 117 p In HEBREW; ENGLISH summary
(ITN-91-85142) Copyright Avail: Tel-Aviv Univ., Exact Sciences Library, Ramat Aviv 69978, Israel

Experiments were performed on delaying the onset of stall on airfoils at high angles of attack. Small, 2-D, periodic perturbations were induced on the upper surface of the airfoil, at the point of natural boundary layer separation. Amplification of these perturbations by the shear layer between the separated boundary layer and the free air stream increases the mixing between the fluid in the neighborhood of the airfoil and the free stream. Thus, fluid with high kinetic energy is brought closer to the airfoil surface, resulting in improved performance. The experiments were performed on a NACA-0015 airfoil with a stubby trailing edge and on a Wortmann FX63-137 airfoil. A subsonic wind tunnel was used, with free stream velocities of 10, 15 and 20 m/sec, corresponding to Reynolds numbers of 200,000, 300,000 and 400,000. Measurements of pressure distributions along the airfoil chord enabled the lift and pitching moment coefficients to be calculated. The total drag coefficient was calculated from the measured velocity distribution of the wake. Implementation of the control method increased the stall angle, enabling the maximum lift coefficient to be achieved with reduced drag. The governing factors were found to be the Reynolds number and the frequency and intensity of the perturbation. An optimal flap vibration frequency was found for all free stream velocities, and a linear relationship was found between the maximum lift coefficient and the angle of stall, when the optimum vibration frequency was applied. The improvement in lift coefficient increased with increasing free stream velocity and flap vibration amplitude. ISA

N91-28140 North Carolina State Univ., Raleigh.
AN ABBREVIATED REYNOLDS STRESS TURBULENCE MODEL FOR AIRFOIL FLOWS Ph.D. Thesis
RICHARD LEE GAFFNEY, JR. 1990 164 p
Avail: Univ. Microfilms Order No. DA9112157

An abbreviated Reynolds stress turbulence model is presented for solving turbulent flow over airfoils. The model consists of two partial differential equations, one for the Reynolds shear stress and the other for the turbulent kinetic energy. The normal stresses and the dissipation rate of turbulent kinetic energy are computed from algebraic relationships having the correct asymptotic near wall behavior. This allows the model to be integrated all the way to the wall without the use of wall functions. Results for a flat plate at zero angle of attack, a NACA 0012 airfoil, and a RAE 2822 airfoil are presented. Flat plate results are compared to the law of the wall and the experimental data of Klebanoff. Airfoil results are compared favorably with the pressure distributions found experimentally and from the eddy viscosity model. The predicted skin friction is found to be too high over the front portion of the airfoil but then relaxes down to give good agreement with experimental values. The behavior of the skin friction is attributed to an inadequate representation of the normal stresses.
Dissert. Abstr.

N91-28142# New York Univ., New York. Inst. of Mathematical Sciences.
A COMPARISON OF THE POTENTIAL AND THE EULER FORMULATIONS OF THE EQUATIONS OF MOTION FOR TRANSONIC FLOW
K. MCGRATTAN May 1991 100 p
(Contract DE-FG02-88ER-25053)
(DE91-014731; DOE/ER-25053/4) Avail: NTIS HC/MF A05

This report discusses the following topics: models of transonic flow; the BGKM computer code; wave drag and the entropy inequality; supercritical airfoil computations; and vortex dynamics.
DOE

N91-28143*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A SUBSONIC, ENERGY-EFFICIENT TRANSPORT CONFIGURATION IN THE NATIONAL TRANSONIC FACILITY
PETER F. JACOBS and BLAIR B. GLOSS Aug. 1989 70 p
(NASA-TP-2922; L-16569; NAS 1.60:2922) Avail: NTIS HC/MF A04 CSCL 01/1

The Reynolds number, aeroelasticity, boundary layer transition, and nonadiabatic wall temperature effects, and data repeatability was determined in the National Transonic Facility (NTF) for a subsonic, energy efficient transport model. The model was tested over a Mach number range of 0.50 to 0.86 and a Reynolds number range of 1.9 million to approximately 23.0 million (based on mean geometric chord). The majority of the data was taken using cryogenic nitrogen (data at 1.9 million Reynolds number was taken in air). Force and moment, wing pressure, and wing thermocouple data are presented. The data indicate that increasing Reynolds number resulted in greater effective camber of the supercritical wing and horizontal tail, resulting in greater lift and pitching moment coefficients at nearly all angles of attack for $M = 0.82$. As Reynolds number was increased, untrimmed L/D increased, the angle of attack for maximum L/D decreased, drag creep was reduced significantly, and drag divergence Mach number increased slightly. Data repeatability for both modes of operation of the NTF (air and cryogenic nitrogen) was generally very good, and nonadiabatic wall effects were estimated to be small. Transition-free and transition-fixed configurations had significantly different force and moment data at $M = 0.82$ for low Reynolds number, and very small differences were noted at high Reynolds numbers. Author

03

AIR TRANSPORTATION AND SAFETY

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

A91-45289*# Continuum Dynamics, Inc., Princeton, NJ.
PROPOSED MODIFICATIONS TO ICE ACCRETION/ICING SCALING THEORY
ALAN J. BILANIN (Continuum Dynamics, Inc., Princeton, NJ) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 353-359. FAA-supported research. Previously cited in issue 07, p. 944, Accession no. A88-22150. refs
(Contract NAS1-18302)
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A91-45322*# Akron Univ., OH.
IMPACT ICE STRESSES IN ROTATING AIRFOILS
R. J. SCAVUZZO, M. L. CHU, and C. J. KELLACKEY (Akron, University, OH) Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 450-455. Previously cited in issue 06, p. 762, Accession no. A90-19735. refs
(Contract NAG3-479)

A91-45606#
A 3-D FINITE DIFFERENCE SOLUTION OF THE EXTERNAL AND INTERNAL RESPONSES OF AN AIRCRAFT DURING IN-FLIGHT LIGHTNING STRIKES
J. C. ALLIOT, J. GRANDO (ONERA, Chatillon, France), and X. FERRIERES (SLX Informatique, Courbevoie, France) (International Symposium on Electromagnetic Compatibility, Zurich, Switzerland, Mar. 12-14, 1991) ONERA, TP no. 1991-23, 1991, 7 p. refs
(ONERA, TP NO. 1991-23)

Experimental transient electromagnetic fields measurements have been performed on a Transall C160 aircraft during in-flight lightning strikes. The data allow a test of the predictive capabilities of a three-dimensional time domain finite-difference code (ALICE) set up at ONERA in order to investigate lightning aircraft interactions. Comparison of experimental and numerical results have been made for several lightning channel attachments on the aircraft. Skin current density and electromagnetic fields distributions are discussed in detail. Author

A91-45610#
CURRENT WAVE-FORM OBSERVED DURING LIGHTNING STRIKES ON AIRCRAFT
J.-L. BOULAY (ONERA, Chatillon, France) (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-28, 1991, 13 p. refs
(ONERA, TP NO. 1991-28)

In-flight data regarding electric and magnetic fields observed during lightning strikes is reviewed, and it is pointed out that the lightning-strike process begins with an attachment phase. Relight phases are also discussed, and a physical model explaining the physical mechanisms involved in the lightning preparation, attachment, connection, and relight phases is presented. Validation tests of these mechanisms, including long-arc tests in a laboratory environment, triggered lightning tests at an altitude, and observation of natural lightning strikes using an electromagnetic interferometer are considered. It is concluded that the pulse phases of lightning strikes should be simulated for correctly qualification tests of the aircraft equipment. V.T.

A91-45611#
DESCRIPTION AND INTERPRETATION OF AIRCRAFT LIGHTNING ATTACHMENT FROM ELECTRIC AND MAGNETIC FIELD MEASUREMENTS AND VIDEO OBSERVATION
J. P. MOREAU and S. LARIGALDIE (ONERA, Chatillon, France) (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-29, 1991, 12 p. refs
(ONERA, TP NO. 1991-29)

Phases of the lightning discharge process (except the initiation phase) are described using the observation of analog electromagnetic waveforms and a fast (200 f/s) video image-processed pictures. During lightning attachment, the aircraft remains connected electrically to the lightning channel where such physical processes as recoil streamers, return strokes, and other initiation processes of secondary discharges take place. No extinction of the continuous current throughout the discharge process is observed. Channel luminosity is computed by integrating the light of the channel in every image; the value obtained is then plotted versus the time when the picture was actually taken by the camera. Satisfactory results are obtained for the representation of two of the typical waveforms found in the recoil streamer process. V.T.

A91-45612#
APPLICATION OF SURFACE ELECTRICAL DISCHARGES TO THE STUDY OF LIGHTNING STRIKES ON AIRCRAFT
J. L. BOULAY and S. LARIGALDIE (ONERA, Chatillon, France) (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-30, 1991, 11 p. refs
(ONERA, TP NO. 1991-30)

The purpose of the study is to consider the characterization of surface discharges which provide a facility complimentary to that of artificially triggered lightning. General characteristics of a simplified surface discharge, including current waveforms and the constitution of a surface discharge are outlined, and the application of this approach to the study of aircraft lightning strikes is considered. Representations of leader-streamer and return-stroke phases are discussed, and the application to the two-dimensional discharge phase is covered. It is pointed out that the fact that the initiation times of surface discharges could be controlled, and the path followed by the discharge channels could be predetermined, indicates that it is possible to produce a highly dedicated high-performance instrumentation system. V.T.

A91-45619#
FD-TD NUMERICAL SIMULATION OF AN ENTIRE LIGHTNING STRIKE ON THE C160 AIRCRAFT
J.-C. ALLIOT, J. GRANDO, J.-D. MULLER (ONERA, Chatillon, France), and X. FERRIERES (SLX Informatique, Courbevoie, France) (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-37, 1991, 12 p. refs
(ONERA, TP NO. 1991-37)

Experimental transient electromagnetic fields measurements have been performed on a Transall C160 aircraft during in-flight lightning strikes. The data allow a test of the predictive capabilities of a three dimensional time-domain finite-difference code (ALICE) developed at ONERA in order to investigate lightning aircraft interactions. Using a transfer function technique in the 3D code it is shown that a bi-leader attached to an aircraft can be simulated by a linear model and so electromagnetic fields can be calculated everywhere on the vehicle. Comparison of experimental and numerical results have been made for several lightning strikes. Skin current density and electromagnetic fields distributions are discussed in detail. Author

A91-45673* Rice Univ., Houston, TX.
PERSPECTIVES ON WIND SHEAR FLIGHT
A. MIELE, T. WANG, and G. D. WU (Rice University, Houston, TX) IN: Modern research topics in aerospace propulsion - In honor of Corrado Casci. New York, Springer-Verlag, 1991, p. 355-375. Research supported by NASA, Boeing Commercial Airplanes, Air Line Pilots Association, and Texas Advanced Technology Program. refs
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Wind shears originating from downbursts have been the cause of many aircraft accidents in the past two decades. In turn, this has led to considerable research on wind shear avoidance systems

and wind shear recovery systems. This paper reviews recent advances in wind shear recovery systems. It summarizes the work done at Rice University on trajectory optimization and trajectory guidance for two basic flight conditions: takeoff and abort landing. It appears that, in the relatively near future, an advanced wind shear control system can be developed, that is, capable of functioning in different wind models and covering the spectrum of flight conditions having interest in a wind shear encounter.
Author

A91-48349
NO END TO AIR INCIDENTS? II [LUFTZWISCHENFAELLE UND KEIN ENDE? II]
JOACHIM F. BENTZIEN Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 40, June 1991, p. 144-162. In German. refs
Copyright
Significant air incidents of recent years involving shoot-downs and force-downs are reviewed. The legal aspects of such incidents are addressed. C.D.

N91-27142# Federal Aviation Administration, Washington, DC. Air Traffic Rules and Procedures Service.
OBSTRUCTION MARKING AND LIGHTING
1 Aug. 1991 57 p
(AC-70/7460-1H) Avail: NTIS HC/MF A04
This Advisory Circular (AC) describes the Federal Aviation Administration's (FAA) standards for marking and lighting structures to promote aviation safety. The topics covered include: (1) administrative procedures; (2) marking; (3) lighting; (4) red obstruction lighting standards; (5) medium intensity flashing white lighting systems standards; (6) high intensity flashing white lighting systems standards; (7) dual lighting with red/medium intensity white systems; (8) dual lighting with red/high intensity flashing white systems; (9) marking and lighting catenary support structures with medium intensity flashing white lights; (10) marking and lighting catenary support structures with high intensity flashing white lights; (11) marking and lighting moored balloons and kites; and (12) marking and lighting equipment and information. Author

N91-27143# National Transportation Safety Board, Washington, DC.
ANNUAL REVIEW OF AIRCRAFT ACCIDENT DATA. US AIR CARRIER OPERATIONS, CALENDAR YEAR 1987
29 Nov. 1990 80 p
(PB91-119693; NTSB/ARC-90/01) Avail: NTIS HC/MF A05 CSCL 01/3
The report is presented of aviation accidents involving revenue operations of U.S. Carriers including Commuter Air Carriers and On Demand Air Taxis for calendar year 1987. The report is divided into three major sections according to the Federal regulations under which the flight was conducted. In each section of the report tables are presented to describe the losses and characteristics of 1987 accidents to enable comparison with prior years. Author

N91-27144*# Miami Univ., Coral Gables, FL.
HUMAN FACTORS OF FLIGHT-DECK CHECKLISTS: THE NORMAL CHECKLIST
ASAF DEGANI (San Jose State Univ., CA.) and EARL L. WIENER May 1991 70 p
(Contract NCC2-377)
(NASA-CR-177549; A-90183; NAS 1.26:177549) Avail: NTIS HC/MF A04 CSCL 01/3
Although the aircraft checklist has long been regarded as the foundation of pilot standardization and cockpit safety, it has escaped the scrutiny of the human factors profession. The improper use, or the non-use, of the normal checklist by flight crews is often cited as the probable cause or at least a contributing factor to aircraft accidents. An attempt is made to analyze the normal checklist, its functions, format, design, length, usage, and the limitations of the humans who must interact with it. The development of the checklist from the certification of a new model to its delivery and use by the customer are discussed. The influence of the government, particularly the FAA Principle Operations Inspector, the manufacturer's philosophy, the airline's culture, and the end user, the pilot, influence the ultimate design and usage of this device. The effects of airline mergers and acquisitions on checklist usage and design are noted. In addition, the interaction between production pressures and checklist usage and checklist management are addressed. Finally, a list of design guidelines for normal checklists is provided. Author

N91-28146# Arizona State Univ., Tempe. Dept. of Mechanical and Aerospace Engineering.
COMPUTER SIMULATION OF AN AIRCRAFT SEAT AND OCCUPANT(S) IN A CRASH ENVIRONMENT: PROGRAM SOM-LA/SOM-TA USER MANUAL Final Report, Jul. 1989 - Feb. 1990
DAVID H. LAANANEN May 1991 229 p
(Contract DTFA03-89-A-00004)
(CR-R-90026; DOT/FAA/CT-90/4) Avail: NTIS HC/MF A11
A three-dimensional mathematical model of a seat, occupant(s), and restraint system was developed for use in aircraft crashworthiness analysis. Programs SOM-LA (Seat/Occupant Model - Light Aircraft) and SOM-TA (Seat/Occupant Model - Transport Aircraft) combine a lumped parameter model of aircraft occupants with a finite element model of the seat structure. The intent of these programs is to aid in evaluation of the performance of aircraft seat and restraint systems in crash environments. Four different cases are described, and the listing of input data is presented for each. Author

N91-28147# Argonne National Lab., IL.
ASSESSING THE RISK OF TRANSPORTING HAZARDOUS MATERALS BY AIRCRAFT: A CASE STUDY
M. J. DAVIS and L. A. HAROUN 1991 10 p Presented at the 84th Annual Meeting and Exhibition of the Air and Waste Management Association (AWMA), Vancouver, British Columbia, 16-21 Jun. 1991
(Contract W-31-109-ENG-38)
(DE91-014016; ANL/CP-71294; CONF-910659) Avail: NTIS HC/MF A02
The risk assessment discussed involves the transport of polychlorinated biphenyls (PCBs) by aircraft. It resulted from the need to transport a large quantity of PCBs and PCB-contaminated equipment from Canada to the United States following closure of various radar stations in the CADIN-Pinetree line. As part of the planning process conducted prior to shipping the material, an assessment of the upper bounds of potential risks associated with the operation was carried out. The results apply to air shipments of the material to the United States. The major concern associated with the transport of these materials by aircraft involved the potential for release of PCBs and trichlorobenzene (TCB), which was also present in some of the fluids being transported. Therefore, the focus of the assessment was on accidents that could potentially result in the release of these toxic compounds and their by-products to the environment. The approach used is based on conservative assumptions that allow placing an upper bound on the risks associated with a severe accident. DOE

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

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

A91-44765#
A FEDERATED FILTER STRUCTURE AND ALGORITHM FOR A FAULT-TOLERANT NAVIGATION SYSTEM
YONGXI NI and XIN YUAN (Nanjing Aeronautical Institute, People's

Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 70-78. In Chinese. refs

A decentralized algorithm for the federated Kalman filter has been presented. The algorithm, which can be parallelly implemented in the environment of multiprocessors, efficiently satisfies real-time requirements of navigation systems with multisubsystems. Common state estimates can be optimally obtained by the state fusion algorithm of the master filter. A failure detection and isolation (FDI) algorithm, based on the federated structure has also been presented. The FDI decisions can be made to isolate the influence of the fault subsystem on the entire system. The FDI algorithm has been simplified by means of the common state concept. Author

A91-45144*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN AND EVALUATION OF AN AIR TRAFFIC CONTROL FINAL APPROACH SPACING TOOL
THOMAS J. DAVIS, HEINZ ERZBERGER, STEVEN M. GREEN (NASA, Ames Research Center, Moffett Field, CA), and WILLIAM NEDELL (San Jose State University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 848-854. refs
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This paper describes the design and simulator evaluation of an automation tool for assisting terminal radar approach controllers in sequencing and spacing traffic onto the final approach course. The automation tool, referred to as the Final Approach Spacing Tool (FAST), displays speed and heading advisories for arriving aircraft as well as sequencing information on the controller's radar display. The main functional elements of FAST are a scheduler that schedules and sequences the traffic, a four-dimensional trajectory synthesizer that generates the advisories, and a graphical interface that displays the information to the controller. FAST has been implemented on a high-performance workstation. It can be operated as a stand-alone in the terminal radar approach control facility or as an element of a system integrated with automation tools in the air route traffic control center. FAST was evaluated by experienced air traffic controllers in a real-time air traffic control simulation. simulation results summarized in the paper show that the automation tools significantly reduced controller work load and demonstrated a potential for an increase in landing rate. Author

A91-45618#
INTEGRATION OF PILOTING AND LANDING SYSTEM AIDS FOR CARRIER AIRCRAFT [INTEGRATION DU PILOTAGE ET DES SYSTEMES D'AIDE A L'APPONTAGE POUR LES AVIONS EMBARQUES]
B. D. VU (ONERA, Chatillon, France) ONERA, TP no. 1991-36, 1991, 26 p. In French. refs
(ONERA, TP NO. 1991-36)

A review is presented of diverse onboard aids for carrier landing operations under development for the future French aircraft carrier. This paper focuses on an advanced laser landing aid and a system for stabilizing deck movements. The system consists of the real-time presentation of guidance information whereby the trajectory angle and the speed of the aircraft are modified as a function of the speed and deck conditions forecast for the time of touchdown, with flare and touchdown speed taken into account. Digital simulation results have demonstrated an improvement in landing performance. R.E.P.

A91-45631#
INTEGRATION OF FLIGHT AND LANDING AID SYSTEMS FOR SHIPBOARD OPERATIONS [INTEGRATION DU PILOTAGE ET DES SYSTEMES D'AIDE A L'APPONTAGE POUR LES OPERATIONS EMBARQUEES]
B. D. VU, T. LE MOING, and P. COSTES (ONERA, Chatillon, France) (NATO, AGARD, Symposium on Aircraft/Ship Operations, Seville, Spain, May 20-23, 1991) ONERA, TP no. 1991-50, 1991, 18 p. In French. refs
(ONERA, TP NO. 1991-50)

A review of the state-of-the-art landing aid systems available for shipboard approach and landing operations is presented. To extend flight operational limits aboard French aircraft carriers, various systems have been developed that include flight deck stabilization, the prediction of flight deck movements, and all-weather aircraft relative position flight deck landing indicators. Attention is given to the factors involved in developing these systems, including the various limitations inherent in the aircraft, restrictions of the landing approach trajectory, the angle of attack of differing aircraft configurations, and the integration of flight deck and aircraft input parameters during approach and touchdown. R.E.P.

A91-47082* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TERRAIN MODELING FOR MICROWAVE LANDING SYSTEM
M. M. POULOSE (NASA, Ames Research Center, Moffett Field, CA) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 27, May 1991, p. 540-549. refs
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A powerful analytical approach for evaluating the terrain effects on a microwave landing system (MLS) is presented. The approach combines a multiplate model with a powerful and exhaustive ray tracing technique and an accurate formulation for estimating the electromagnetic fields due to the antenna array in the presence of terrain. Both uniform theory of diffraction (UTD) and impedance UTD techniques have been employed to evaluate these fields. Innovative techniques are introduced at each stage to make the model versatile to handle most general terrain contours and also to reduce the computational requirement to a minimum. The model is applied to several terrain geometries, and the results are discussed. I.E.

N91-27145# Systems Control Technology, Inc., Arlington, VA.
DECISION-HEIGHT WINDOWS FOR DECELERATING APPROACHES IN HELICOPTERS: PILOT/VEHICLE FACTORS AND LIMITATIONS Final Report, Jan. 1989 - May 1991
R. H. HOH, S. BAILLIE, S. KERELIUK, and J. J. TRAYBAR (Federal Aviation Administration, Atlantic City, NJ.) Apr. 1991 63 p Prepared in cooperation with Hoh Aeronautics, Inc., Lomita, CA and Starmark Corp., Arlington, VA
(Contract DTFA01-87-C-00014; WORK ORDER-5E)
(DOT/FAA/CT-90/14) Avail: NTIS HC/MF A04

A combined analysis and flight test program was conducted to investigate the characteristics of the decision height (DH) window for helicopter decelerating instrument approaches. The concept of an effective flight path angle has been employed to define the DH window in terms of basic rotorcraft performance data. Exploratory flight tests were conducted to validate this approach and to define the approximate dimensions of the DH window 50 feet above ground level. The flight test experiment included an instrument meteorological conditions (IMC) decelerating instrument approach with errors built into the flight director to cause the helicopter to arrive at the decision-height with some glideslope and groundspeed errors. The pilots were required to visually maneuver the rotorcraft from decision-height. The results indicate that the high speed boundary of the DH window is a function of the minimum usable torque, and related to maximum acceptable pitch altitude during deceleration. Some margin is required to account for pilot delay or control misapplication after breakout. The upper glideslope error boundary is based on the maximum negative aerodynamic flight path angle that can be flown at low airspeeds. Poor visual cuing after breakout tends to emphasize the need for margins from the helicopter performance. The low speed boundary of the DH window is based on rotorcraft handling qualities at very low airspeeds. The low glideslope boundary is dependent on obstruction avoidance and ability to see the heliport environment upon breakout at decision-height. Author

N91-27146# Federal Aviation Administration, Atlantic City, NJ.
NEW YORK AREA CONTROL FACILITY/METROPLEX CONTROL FACILITY VULNERABILITY ANALYSIS Technical Report, Oct. 1990 - Feb. 1991
ALFRED L. ADKINS and ARTHUR P. POMERANTZ Apr. 1991

42 p
(Contract F-2006E)
(DOT/FAA/CT-TN91/21) Avail: NTIS HC/MF A03

The results are presented of an analysis of the impact of a New York Area Control Facility (ACF) or Metroplex Control Facility (MCF) failure under three different MCF configurations. This analysis was conducted using the National Airspace System Performance Analysis Capability (NASPAC) simulation model to assist ATR-310 and the Eastern Region on defining end-state configurations for the New York ACF/MCF. A discussion is presented of the facilities and procedures involved in an ACF/MCF failure along with the analysis approach, and the results of the analysis. Author

N91-27147# Massachusetts Inst. of Tech., Lexington. Lincoln Lab.
TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS). COCKPIT DISPLAY OF TRAFFIC INFORMATION (CDTI) INVESTIGATION. PHASE 1: FEASIBILITY STUDY Report, Feb. - Jun. 1990
JOHN A. SORENSEN, WALTER HOLLISTER, MALCOLM BURGESS, and DEAN DAVIS Apr. 1991 97 p
(Contract F19628-85-C-0002)
(AD-A236109; DOT/FAA/RD-91/8) Avail: NTIS HC/MF A05 CSCL 01/5

The possibility of the TCAS traffic sensor and display being used for meaningful CDTI applications has resulted in the Federal Aviation Administration initiating a project to establish the technical and operational requirements to realize this potential. A summary is presented of Phase 1. Phase 1 was organized to define specific CDTI applications for aviation safety in the terminal area, to determine what was already learned about CDTI technology relevant to these applications, and to define the engineering required to supply the remaining TCAS-CDTI technology for capacity benefit realization. The CDTI applications examined were limited to those appropriate to the final; approach and departure phases of flight. With the advent of the TCAS II airborne collision avoidance system, an airborne display of surrounding aircraft traffic is about to become generally available in the cockpit. It was proposed that this cockpit display of traffic information provides the mechanism whereby flight crews can assist the controller in tightening the spacing tolerances that are maintained between adjacent aircraft for many phases of flight. GRA

N91-27149# Weapons Systems Research Lab., Adelaide (Australia).
A GENERIC INERTIAL NAVIGATION SYSTEM MODEL FOR COMPUTER SIMULATION STUDIES
D. A. FOGG and R. T. JANUS Sep. 1990 41 p
(AD-A236849; WSRL-TM-30/90; DODA-AR-006-454) Avail: NTIS HC/MF A03 CSCL 17/7

A number of Inertial Navigation System (INS) models ranging from simple forced harmonic oscillator models to three-gyro, three-accelerometer systems were studied to ascertain a compromise between accuracy and computation time on the one hand and model complexity suitable for use in avionics system models for effectiveness studies on the other. INS position and orientation errors for various cruise and acceleration conditions were predicted by these models and the results shown graphically. The importance of various INS characteristics has been determined and the effects of the relevant error sources have been isolated and their propagation in time plotted. GRA

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A91-44761#
A BRIEF ANALYSIS OF DESIGN AND MANUFACTURE OF MAJOR COMPONENTS OF SOME AIRCRAFT LANDING GEARS
LANGQIN ZHOU (Liaoyuan Mechanical Factory, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 26-34. In Chinese. refs

This paper describes progress in the design and manufacture of major components of current foreign landing gear. The material selection, which adopts vacuum remelted integral forging and durability of design, are emphasized. Author

A91-44766#
CONTROL LAW DESIGN OF GUST RESPONSE ALLEVIATION FOR HELICOPTERS
YIDONG YANG and HUAJUN GONG (Nanjing Aeronautical Institute, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 79-84. In Chinese. refs

A design method of the optimal control law to suppress gust disturbance in helicopters is presented in this paper. The optimization requires the minimization of the normal acceleration overload at the position of pilot, the attitude variation, and the control energy consumption under gust disturbance. Based on the original attitude control system, the result system can be easily realized by adding the vertical speed feedback. In order to follow up the general trend of developing the real-time operational flight control software by means of high-order languages during the 1990's, the optimized control law is written in C language. It is proved by hybrid simulation that the performance of gust response alleviation and efficiency of digitalization are all satisfactory. Author

A91-45143#
IDENTIFIABILITY OF HELICOPTER MODELS INCORPORATING HIGHER-ORDER DYNAMICS
STEWART S. HOUSTON (Royal Aerospace Establishment, Bedford, England) and COLIN G. BLACK (Glasgow, University, Scotland) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 840-847. refs
Copyright

This paper examines the identification of a linearized mathematical model of a Puma helicopter from experimental data gathered during flight tests in hover. The objective has been to study the sensitivities of the model parameters to the choice of approach available. The model of the helicopter represents the vertical response of the aircraft to collective pitch, but has been extended to incorporate higher-order rotor dynamics associated with blade flapping and induced velocity degrees of freedom. The approaches used in the identification of the model are frequency-domain based: output error and transfer function matching of frequency responses identified using time series methods. Examples of the identification of helicopter models incorporating higher-order rotor dynamics using rotor measurements from flight data are new. It is concluded that models of helicopter behavior that include higher-order dynamics can be identified successfully from flight data, but engineering judgment is the key to successful application of the methods and interpretation of the results. Author

A91-45147#
DYNAMIC DECREASE OF DRAG BY OPTIMAL PERIODIC CONTROL
GOTTFRIED SACHS (Muenchen, Technische Universitaet, Munich,

Federal Republic of Germany) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 860-863. refs

For aircraft whose thrust-specific fuel consumption is proportional to speed, optimal periodic cruise is considered. When compared with the minimum drag possible in steady-state flight, it is shown that optimal periodic control of thrust and lift yields a decrease of the average of drag. The underlying physical mechanism for the dynamic decrease of drag is described, and numerical results for improvements are presented for a wide range of aircraft performance parameters. V.I.

A91-45320*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WING LEADING-EDGE DROOP/SLOT MODIFICATION FOR STALL DEPARTURE RESISTANCE
H. M. ROSS, L. P. YIP (NASA, Langley Research Center, Hampton, VA), J. N. PERKINS, R. J. VESS (North Carolina State University, Raleigh), and D. B. OWENS Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 436-442. Previously cited in issue 21, p. 3263, Accession no. A89-47691. refs

A91-45324#
INSIGHTS ON THE WHIRL-FLUTTER PHENOMENA OF ADVANCED TURBOPROPS AND PROPFANS
FRED NITZSCHE (Empresa Brasileira de Aeronautica, S.A., Sao Jose dos Campos, Brazil) Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 463-470. Previously cited in issue 12, p. 1781, Accession no. A89-30721. refs

A91-45364#
ROTOR LOADINGS IN HOVER - CORRELATION OF THEORY AND EXPERIMENT
P. C. TARTTELIN (Royal Aerospace Establishment, Flight Dynamics Div., Bedford, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. refs

This paper describes the analysis and results of a flight experiment designed to obtain estimates of rotor blade incidence and deformations from detailed flight test measurements at RAE Bedford using a Puma helicopter as the test vehicle. The focus of attention is on a series of hover flights; the derived results are evaluated to examine the contributions of blade vortex interaction, tail rotor interference, and blade deformation to the load distribution on the main rotor for a range of thrust coefficients. The accuracy of various derived parameters is discussed. The results are used to derive the inflow distribution at the rotor disk for one of these cases. The paper demonstrates the importance of blade vortex interaction and blade flexibility, and highlights the differences between the distribution of derived loading, and those obtained from a rotor loads prediction program. The general aim of the work is to support improvements to the representation of the rotor dynamics in the RAE generic simulation model. Author

A91-45372#
THE A129 LAH PROJECT
GENNARO SERGIO (Joint European Helicopter, Rome, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 23 p.

The principles of a 2-year program for a Light Attack Helicopter (LAH) are outlined, and attention is focused on the feasibility and cost definition phase of the program. The operational roles and requirements of the helicopter and the roles of government and industry organizations are reviewed, and the main characteristics of its weapon system are analyzed. It is noted that the proposed helicopter represents a comprehensive high-performance attack-helicopter weapon system capable of day and night operations in adverse weather conditions. With its emphasis on overall weapon system performance including battlefield agility and availability, the helicopter is found to be an effective third-generation attack helicopter capable of operating and surviving in a developing threat environment. Focus is placed on the extensive range of mission avionics, integrated electronic cockpit and man/machine interface, and optically signaled avionics architecture. V.T.

A91-45374#
V-22 DEVELOPMENTAL STATUS
STANLEY MARTIN, JR. and RICHARD OSTLUND (Bell Boeing Joint Program Office, Arlington, VA) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 12 p.

The status of the V-22 full-scale development, emphasizing its digital flight controls, composite structure, and drive system is summarized. The triplex digital electronic flight controls, which mix and schedule helicopter and fixed wing control functions, and which were developed with the help of a flight control system integration rig are discussed. It is shown how the design of the wing illustrates the advantages of composites, not only in saving weight, but also in permitting the designer to tailor the stiffness of the structure to demand aeroelastic stability and vibration design criteria. The development of the drive system, which must operate through a wide range of attitudes and speeds, and how this development relied heavily on variable-attitude bench test rigs and a ground test article is also described. Finally, the flight tests are discussed. Author

A91-45376#
DYNAMICS HEALTH AND USAGE MONITORING SYSTEM - PROGRAMME UPDATE
MARTIN KAYE (Hawker Siddeley Dynamics Engineering, Ltd., Welwyn Garden City, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 12 p.

The Dynamics Health and Usage Monitoring System intended to improve safety and reduce life cycle costs of helicopters is described. Particular attention is given to the functionality, architecture, and hardware involved in the Dynamics system; handling techniques; and the extension of the system by including a Flight Data Recorder. Major functions of the system include vibration analysis of the gears and bearings in rotor gearboxes; chip detection in the main, intermediate, and tail rotor gear boxes; track and balance of main rotor and balance of the tail rotor; and power assurance topping check, and comprehensive usage logging functions for both engines. The system can contribute to improvement of the airworthiness and safety of the aircraft by warning of component degradation and making fast fault diagnosis with fewer maintenance flights. O.G.

A91-45381#
HELICOPTER COUPLED ROTOR-FUSELAGE ANALYSIS THROUGH MODIFIED BLADE ROOT BOUNDARY CONDITIONS
W. R. WALKER (Royal Aerospace Establishment, Farnborough, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p. refs

A method is described by which a multibladed rotor system mounted on a flexible fuselage may be analyzed through modification of the root boundary conditions for a single blade. The method effectively enables hub-fixed equations of motion for the blade to be used directly without modification. If a transfer matrix solution technique is adopted, integrations from the blade tip to root remain identical to their hub-fixed form. It is only when the root boundary conditions are applied that the added complexity of the coupled system is introduced. In this way, the computation is kept to a minimum. The method has application to axial flight eigenvalue analysis only. Author

A91-45382#
INVESTIGATION OF HELICOPTER ROTOR BLADE MOTION STABILITY BY DIRECT LIAPUNOV METHOD
JANUSZ NARKIEWICZ and WIESLAW LUCJANEK (Warsaw University of Technology, Poland) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 10 p. refs

The present study examines a new method for investigating helicopter rotor blade motion stability that is based on a theorem

which states sufficient conditions for boundedness of the solutions of the system of ordinary differential equations with periodic right-hand sides. The theorem's proof makes it possible to construct an algorithm and a computer code for stability investigation using properties of the Liapunov function. The stability of the single rotor blade in helicopter hover and forward flight is studied using this method. The steady 2D aerodynamic model is applied with Glauert's induced velocity distribution and static aerodynamic characteristics of blade airfoil sections. The stability of periodic steady motion is investigated. The calculated regions of instabilities are in good qualitative agreement with the phenomena observed in helicopter flight. P.D.

A91-45384#
CALCULATED DYNAMIC RESPONSE AND LOADS FOR AN ADVANCED TIP ROTOR IN FORWARD FLIGHT
PHILIPPE BENQUET (Ministere de la Defense, Departement Helicopteres, Paris, France) and INDERJIT CHOPRA (Maryland, University, College Park) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 26 p. refs

The effect of tip sweep and droop on loads and response of a hingeless blade in forward flight are investigated. A finite element formulation based on Hamilton's principle is adopted and each element consists of fifteen degrees of freedom. The vehicle trim and blade steady responses are calculated iteratively as one coupled solution using a modified Newton method. Parametric studies of tip sweep and drop are carried out on a four-bladed soft-inplane hingeless rotor. Tip sweep has a powerful influence on the torsional dynamic behavior of the blade, due to the pitch-flap coupling. A small aft-sweep angle of 5 deg reduces vibratory hub loads by 14 percent for vertical hub forces, 5 percent for longitudinal hub forces and 17 percent for lateral hub forces. Tip droop causes pitch-lag coupling and has a substantial effect on steady as well as vibratory hub loads. Author

A91-45385#
COUPLED ROTOR/AIRFRAME VIBRATION ANALYSIS
SHMUEL FLEDEL, OMRI RAND, and INDEJIT CHOPRA (Maryland, University, College Park) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 40 p. refs

The paper presents a consistent finite-element formulation, developed for the prediction of vibration in rotor/body helicopter systems in forward flight, taking into account interactional rotor/body loads and dynamic coupling. The rotor and the body are assumed to be elastic beams undergoing transverse, torsion and axial deflections. The coupled analysis is formulated retaining consistently nonlinear terms in the structural, inertial and aerodynamic analysis. Rotor excitation includes rotor/body interactional loads in addition to the fuselage dynamic couplings. Effects of several parameters on vibratory hub loads and body vibration are investigated including blade stiffness, rotor/body clearance, hub location, fuselage stiffness and advance ratio. Significant influence of body upwash on rotor disk in causing vibratory hub shear is shown, which generally increases with smaller rotor/body clearance. By tuning rotor and body natural modes, vibration levels can be substantially reduced. Author

A91-45386#
ACTIVE EXPANSION OF HELICOPTER FLIGHT ENVELOPE
MARCEL KRETZ (Giravions Dorand Industries, Suresnes, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. refs

The use of active controls is considered analytically for the optimization of load factors and speed with respect to helicopters in combat situations. Rotor lift capability and rotor instability are examined for a region above the stall barrier in which the rotor must be stabilized by the pilot or by active control. The rotor control method is based on the lift variation over the rotor region of the advancing blade and over the fore and aft disk sectors. The rotor is stabilized by an active control system which processes detection signals determined by local pressure pick-ups and blade-flapping sensors. Power gains of 17.3 percent of rotor power are demonstrated as a result of rotor stabilization. It is concluded that the helicopter flight envelope can be expanded by implementing the active control technology to overcome stall effects and stabilize dynamic rotor behavior. C.C.S.

A91-45393*# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.).
TIME AND FREQUENCY-DOMAIN IDENTIFICATION AND VERIFICATION OF BO-105 DYNAMIC MODELS
JUERGEN KALETKA, WOLFGANG VON GRUENHAGEN (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany), MARK B. TISCHLER, and JAY W. FLETCHER (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 26 p. Previously announced in STAR as N90-18389. refs

Mathematical models for the dynamics of the DLR BO 105 helicopter are extracted from flight test data using two different approaches: frequency-domain and time-domain identification. Both approaches are reviewed. Results from an extensive data consistency analysis are given. Identifications for 6 degrees of freedom (DOF) rigid body models are presented and compared in detail. The extracted models compare favorably and their prediction capability is demonstrated in verification results. Approaches to extend the 6 DOF models are addressed and first results are presented. System identification is broadly defined as the deduction of system characteristics from measured data. It provides the only possibility to extract both non-parametric (e.g., frequency responses) and parametric (e.g., state space matrices) aircraft models from flight test data and therefore gives a reliable characterization of the dynamics of the actually existing aircraft. Main applications of system identification are seen in areas where higher accuracies of the mathematical models are required: Simulation validation, control system design (in particular model-following control system design for in-flight simulation), and handling qualities. Author

A91-45394#
ON THE IDENTIFIABILITY OF HELICOPTER MODELS INCORPORATING HIGHER ORDER DYNAMICS
S. S. HOUSTON (Royal Aerospace Establishment, Flight Dynamics Div., Bedford, England) and C. G. BLACK (Glasgow, University, Scotland) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 20 p. refs

Linearized mathematical models of the Puma helicopter operated by RAE Bedford have been identified from flight tests conducted in the hover. The test database includes collective pitch frequency sweep and step inputs. The aim has been to identify a 3 degree-of-freedom model of coupled body/coning/inflow response to collective. Two frequency-domain identification methods have been used with the data, and the paper explores how the identified stability and control derivatives vary with method, frequency range, parameter constraint, a priori estimates and test run. It is concluded that models of helicopter behavior that include higher order dynamics can be identified successfully from flight, but care is required in the application of the methods and particularly in the interpretation of the results. Author

A91-45395#
IDENTIFICATION OF ROTOR DYNAMIC EFFECTS IN FLIGHT DATA
J. BLACKWELL, R. A. FEIK, and R. H. PERRIN (Defence Science and Technology Organization, Aeronautical Research Laboratory, Melbourne, Australia) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. refs

A time-domain maximum likelihood identification program for general nonlinear systems is used in the investigation of rotor dynamic effects apparent in helicopter flight data. Models developed for the response to cyclic inputs, plus rotor-speed and blade-lagging dynamics for collective response maneuvers are outlined. The consequences of lagging effects on rotor-speed records are illustrated, and the importance of representing rotor-speed transients is emphasizes. For the cyclic response, the need to include higher-order effects for obtaining time history

matches is analyzed. It is pointed out that a priori expressions are utilized in order to minimize the number of parameters to be identified, and a stage approach is developed for ensuring algorithm convergence. V.T.

A91-45404#
WIND EFFECTS ON HELICOPTER TAKEOFF AND LANDING
N. TRAENAPP (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p. refs
(Contract DFG-SFB-212)

Normal takeoff and landing simulations within a ground boundary wind profile are discussed (only winds without turbulence are considered). Danger induced by trailing vortices from heavy transport aircraft in terminal areas is considered. It is noted that the stronger circulation of the ground vortex in the wind-induced ground boundary layer gives rise to an increase in power required for hover in low horizontal wind velocities and a decrease in the same power in the ground vortex regime. The distance for normal takeoff and rejected takeoff is found to be dependent on different head wind velocities. It is concluded that the workload passed on the pilot or automatic control system in the case of the trailing vortices can reach an extraordinary level. V.T.

A91-45405#
THE BERP ROTOR MANEUVER TRIAL
C. KEATING (Westland Helicopters, Ltd., Yeovil, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p. Ministry of Defence Procurement Executive-supported research.

The British Experimental Rotor Program (BERP) aimed at the investigation of the use of composite structures and advanced airfoils is outlined. The trial objective was to conduct a scientific experimental flight trial in order to explore and define the improvement in maneuverability and controllability of a combat helicopter fitted with BERP blades to the limits the demonstrator airframe and to blade loading levels well beyond the capability of the standard metal blades. The test method used for building a rotor maneuver database is discussed, and it is noted that the aircraft and rotor system demonstrated to have a 360-deg capability in pitch and roll, and the semirigid rotor system gives a freedom from the danger of main-rotor-blade strike irrespective of the aircraft normal acceleration and magnitude of control input. V.T.

A91-45408#
ELECTRO-EXPULSIVE DE-ICER FLIGHT TESTS
N. A. WEISEND (BF Goodrich Aerospace, Uniontown, OH) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 11 p.

The basic principles of the electro-expulsive de-icing system are explained. Installation of a test panel and natural icing flight tests in a DeHavilland DHC-6 turbo prop aircraft are discussed. Also covered is the installation of the electro-expulsive de-icer on the engine inlet of a McDonnell-Douglas F/A-18 jet fighter and the subsequent icing tanker tests. Author

A91-45412#
AN ADVANCED STRUCTURAL CONCEPT FOR THE NH90 COMPOSITE FUSELAGE
K. STITZELBERGER and U. RAMM (MBB GmbH, Munich, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p.

The fuselage concept of the NH90 helicopter is outlined, and it is shown that the fuselage structure takes into account the functional and operational aspects of the aircraft as well as the design features of a composite structure. The application of composite materials leads to a layout with fewer frames and longerons, because these elements are used only as main load paths. Requirements and regulations influencing the design envelope, material selection, and airframe structure concepts are discussed. Analytical and experimental investigations carried out during the preliminary design phase are covered, and manufacturing aspects related to the center fuselage, upper deck, side and subfloor panels, and structural joints are considered. V.T.

A91-45413#
THE APPLICATION OF ELASTOMERIC PRODUCTS ON THE V-22 TILTROTOR AIRCRAFT
J. L. POTTER (Lord Corp., Aerospace Products Div., Erie, PA) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 32 p. refs

Elastomeric bearings, dampers and springs have been well established as a key ingredient in improving the reliability and maintainability criteria established over the past several years for various worldwide helicopter programs, such as the UH/SH-60, CH-53D, OH-58D, AH-1, AH-64, EH-101, AS-332, A-129, BO-108, S-76, B-222, B-412, H-269, and H-500. Virtually maintenance free, on-condition inspection service lives up to 5000 hours have been demonstrated. The V-22 Osprey's proprotors contain 54 elastomeric assemblies functioning as bearings and springs as well as the proprotor-to-mast drive coupling. Some unique design and materials innovations were necessary to meet the stringent space, weight, and life requirements. The uniqueness of the V-22's elastomeric products, particularly the hub spring and proprotor drive-link coupling are presented. Author

A91-45414*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CRASHWORTHY DESIGN OF HELICOPTER COMPOSITE AIRFRAME STRUCTURES
RICHARD L. BOITNOTT (NASA, Langley Research Center; U.S. Army, Army Aviation Research and Technology Activity, Hampton, VA) and CHRISTOF KINDERVATER (DLR, Institut fuer Bauweisen- und Konstruktionsforschung, Stuttgart, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 25 p. refs

The crashworthy behavior of composite materials and generic structural elements is investigated. Cruciform structural elements are crushed in order to determine their energy absorption capability to rotorcraft crash-type loads, and quasi-static compression tests are conducted on a series of aluminum and composite cruciform elements. These elements are representative of keel beam and bulkhead intersections in the subfloor of rotorcraft. Various designs of 'trigger mechanisms' reducing initial peak failure loads and initiating stable crushing failure modes are considered. It is shown that a carbon-fiber-composite/aramid-fiber-composite hybrid element with a columnlike midsection behaves more like a well-designed tubular composite element. Specimens which fail primarily in bending are typical of structural components used in the upper and lower portions of rotorcraft airframes. V.T.

A91-45874
THERMAL PROTECTION FOR HYPERSONIC TRANSPORTS
Aerospace Engineering (ISSN 0736-2536), vol. 11, July 1991, p. 9-11.
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A review is presented of the various approaches being studied to provide a thermal protection system (TPS) to accommodate the extreme surface temperatures generated by hypersonic transport vehicles. In an efficient TPS, all of the heat transfer modes, i.e., solid construction, gas conduction, gas convection, and radiation, are minimized, and designers are placing special emphasis on at least one of the phenomena. Consideration is given to the five concepts selected for further investigation: microporous insulation, flexible insulation, multiwall insulation, vacuum cassette, and xenon cassette. It is indicated that both the multiwall and microporous insulation concepts are considered to be strong candidates for providing thermal protection for future hypersonic transportation vehicles. R.E.P.

A91-46189#
DYNAMIC BEHAVIOR OF FLUTTERING TWO-DIMENSIONAL PANELS ON AN AIRPLANE IN PULL-UP MANEUVER
SLOBODAN R. SIPCIC (Boston University, MA) and LUIGI MORINO (Roma I, Universita, Rome, Italy) AIAA Journal (ISSN 0001-1452),

vol. 29, Aug. 1991, p. 1304-1312. refs
(Contract F49620-86-C-0040)
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The governing equations, derived using Lagrangian mechanics, include geometric nonlinearities associated with the occurrence of tensile stresses, as well as coupling between the angular velocity of the maneuver and the elastic degrees of freedom. Longtime histories, phase plane plots, and power spectra of the response are the dynamics tools used in studying the system considered here. The effect of the maneuver on the flutter speed and on the amplitude of the limit cycle are presented for different load conditions. A new type of limit cycle has been observed for the nonmaneuvering case. It is also shown that the presence of a maneuver can transform the panel response from a fixed point into a simple periodic or even chaotic state. It can also suppress the periodic character of the motion, transforming the response into a fixed point. For a prescribed time-dependent maneuver, a remarkable response transition between the different types of limit cycles is presented. Author

A91-46453
THE FUZZY SYNTHETIC JUDGEMENT OF CORRELATING PARAMETER OF FIGHTER DESIGN
HONG CUI and YONG ZAO (Beijing University of Aeronautics and Astronautics, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 4, Feb. 1991, p. 20-25. refs
Copyright

Correlating-parameter expression is developed which can be used to synthetically express the close combat maneuverability of fighters by the method of fuzzy mathematics. By analyzing fighter-maneuvering performances, two parameters and SEP are proposed to measure performance. The linear weighted method is used to determine the form of the correlating parameter expression. The primary objective is to determine the weight coefficients of maneuvering performances in the expression, for which the inverse problem of synthetic judgment in fuzzy mathematics is employed. The development of the equation of the fuzzy relationship is based on judgment data. The correlating-parameter expression developed in this paper can be used in the conceptual design of aircraft and the judgment of synthetic measurements of the maneuverability of fighters.
Author

A91-46592#
DEVELOPMENT OF THE INTERMEDIATE JET TRAINER (XT-4)
HIROYASU TAKAO, KOHKI ISOZAKI, and NORIO TODA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 434, 1990, p. 111-123. In Japanese. refs

Aircraft design and flight testing are reviewed for the XT-4 program. Particular emphasis is placed on reliability analysis and maintenance characteristics. B.J.

A91-47158#
ON THE USE OF THE COHERENCE FUNCTION FOR A COMPARISON OF TEST SIGNALS FOR FREQUENCY DOMAIN IDENTIFICATION
R. J. PATTON, M. MILES (York, University, England), and P. TAYLOR (Westland Helicopters, Ltd., Yeovil, England) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 71-79. refs
(AIAA PAPER 91-2851) Copyright

The coherence function allows first, a comparison of the amount of contamination of results due to noise inside the loop and second, a classification of system nonlinearities. Some parameters can be optimized with the aid of the coherence function. As the length of test signal is increased the accuracy of results is improved. However, to reduce mechanical fatigue and running costs, shorter signals are desired for tests and anyway continual increases in signal length yield decreasing improvements. The variance of the coherence function shows this tradeoff graphically and allows a suitable length to be chosen. The signal which is most appropriate for finding a linear representation of the system (the multifrequency signal) may have its peak factor lowered in order to improve the accuracy of results. The coherence function again shows graphically this improvement. Author

A91-47176*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
IDENTIFICATION AND SIMULATION EVALUATION OF AN AH-64 HELICOPTER HOVER MATH MODEL
J. A. SCHROEDER, D. C. WATSON (NASA, Ames Research Center, Moffett Field, CA), M. B. TISCHLER, and M. M. ESHOW (U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 264-297. refs
(AIAA PAPER 91-2877) Copyright

Frequency-domain parameter-identification techniques were used to develop a hover mathematical model of the AH-64 Apache helicopter from flight data. The unstable AH-64 bare-airframe characteristics without a stability-augmentation system were parameterized in the convectional stability-derivative form. To improve the model's vertical response, a simple transfer-function model approximating the effects of dynamic inflow was developed. Additional subcomponents of the vehicle were also modeled and simulated, such as a basic engine response for hover and the vehicle stick dynamic characteristics. The model, with and without stability augmentation, was then evaluated by AH-64 pilots in a moving-base simulation. It was the opinion of the pilots that the simulation was a satisfactory representation of the aircraft for the tasks of interest. The principal negative comment was that height control was more difficult in the simulation than in the aircraft.
Author

A91-47187*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WIND TUNNEL INVESTIGATION OF AERODYNAMIC AND TAIL BUFFET CHARACTERISTICS OF LEADING-EDGE EXTENSION MODIFICATIONS TO THE F/A-18
GAUTAM H. SHAH (NASA, Langley Research Center, Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 395-412. refs
(AIAA PAPER 91-2889) Copyright

The impact of leading-edge extension (LEX) modifications on aerodynamic and vertical tail buffet characteristics of a 16-percent scale F/A-18 model has been investigated in the NASA Langley 30-foot by 60-foot tunnel. Modifications under consideration include variations in LEX chord and span, addition of upper surface fences, and removal of the LEX. Both buffeting and high-angle-of-attack aerodynamics are found to be strongly dependent upon the LEX geometry, which directly influences the strength, position, and breakdown characteristics of the vortex flow field. Concepts aimed at influencing the development of vortical flow field are considered to have much greater potential in design application than those geared toward altering already established flow fields. It is recommended that configuration effects on structural and aerodynamic characteristics be evaluated in parallel, so that trade-off studies can be conducted to ensure adequate structural fatigue life and desired high-angle-of-attack stability and control characteristics in the design of future high performance aircraft.
O.G.

A91-47188*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF LIFT-TO-DRAG RATIO UPON PILOT RATING FOR A PRELIMINARY VERSION OF THE HL-20 LIFTING BODY
E. B. JACKSON, ROBERT A. RIVERS (NASA, Langley Research Center, Hampton, VA), and MELVIN L. BAILEY (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug.

12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 413-419. refs
(AIAA PAPER 91-2890) Copyright

A man-in-the-loop simulation study of the handling qualities of the HL-20 lifting body vehicle has been performed in a fixed-base simulation cockpit. The study was aimed at identifying opportunities to improve the original design of the vehicle from a handling qualities and landing performance perspective. A subsonic aerodynamic model of the HL-20 was used as a baseline, and visual approaches and landings were made at various vehicle lift-to-drag (L/D) ratios. It is concluded that there is a high degree of correlation between maximum L/D ratio and pilot rating. Using the pilot ratings Level 1, flying qualities were found to be possible for configurations with a maximum L/D ratio of 3.8 or higher.
O.G.

A91-47802#
FLIGHT TESTING OF THE CALSPAN VARIABLE STABILITY LEARJET 25 IN-FLIGHT SIMULATOR
PAUL R. DEPPE (Arvin/Calspan Corp., Buffalo, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 1-6.
(AIAA PAPER 91-2915) Copyright

This paper describes the flight testing of the Calspan Variable Stability Learjet 25B, N102VS. This is the second variable stability Learjet which Calspan has developed. A description of the Learjet Model 25 and Variable Stability System (VSS) is presented, followed by a discussion of the scope of the tests. The results of the flight tests are presented, including basic aircraft systems tests, initial variable stability system engagement and checkout, envelope expansion, and gain configuration development. The potential applications and planned future improvements to the aircraft are also briefly discussed. Author

A91-47803*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
IN-FLIGHT SIMULATION AT THE NASA DRYDEN FLIGHT RESEARCH FACILITY
MARY F. SHAFER (NASA, Flight Research Center, Edwards, CA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 7-23. refs
(AIAA PAPER 91-2916) Copyright

An account of the in-flight simulation at the Dryden Flight Research Facility is presented and various aircraft and tests performed are discussed. In-flight simulation has been utilized for a variety of flying quality investigations including low-lift-to-drag ratio approach characteristics for vehicles like the X-15, the lifting bodies, and the Space Shuttle. Consideration is given to the effects of time delays on controllability of aircraft with digital flight-control systems, flight control systems for such aircraft as the X-29, and the causes and cures of pilot-induced oscillation in diverse aircraft. R.E.P.

A91-47805#
VISTA - AN ESSENTIAL TOOL FOR THE FUTURE
DAVID E. FREARSON (USAF, Wright Laboratory, Wright-Patterson AFB, OH) and PHILIP A. REYNOLDS (Calspan Corp., Buffalo, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 37-43. refs
(AIAA PAPER 91-2918)

The Variable Stability In-Flight Simulator Test Aircraft (VISTA) under development by the USAF to replace the NT-33A aircraft widely used as an in-flight simulator since 1957, is described. VISTA, based on an F-16D, will uniquely support future test pilot training, aircraft development, avionic integration research, and flight control/display investigations. The VISTA configuration provides the experimental control, realism, hardware/software flexibility, and growth potential essential to long-term cost-effective utilization. Increases in altitude, speed, normal acceleration, and thrust-to-weight offer a significantly larger simulation envelope, allowing duplication of a wider range of fighter trajectories.
R.E.P.

A91-47806#
THE VISTA/F-16 SIMULATION CAPABILITIES
K. S. COVINDARAJ (Arvin/Calspan Corp., Buffalo, NY) and B. NGUYEN (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 44-55. refs
(AIAA PAPER 91-2919) Copyright

An analysis effort was carried out to investigate the Variable Stability In-Flight Simulator Test Aircraft (VISTA) capability to simulate various dynamic characteristics by employing both frequency and time domain methods. The frequency domain method represented the F-16 VISTA aircraft by a transfer function model whereas the time domain method used a simulation software consisting of the full F-16 nonlinear equations of motion. For every feedback gain set, the time response of the VISTA was computed for a command input and matched to the time response of a lower model for the same command input. R.E.P.

A91-47817#
FLIGHT TEST PROGRAM FOR ANALYSIS AND VALIDATION OF HELICOPTER SIMULATOR AERODYNAMICS
SUSAN C. GARING and ANDREW S. RYCHNOWSKI (CAE-Link Corp., Binghampton, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 148-158. refs
(AIAA PAPER 91-2928) Copyright

Suggestions are offered for flight test data processing and gathering intended to improve the utility of test data for simulator analysis and correlation. An outline is presented for a dedicated flight test project consistent with simulator development requirements, designed to support both simulator aerodynamic model analysis and training simulator acceptance. A description is given of alternative subsets of the specified tests and parameters that will serve as test data requirements when limitations in time or budget limit the availability of the complete preferred data set.
R.E.P.

A91-47818#
THE USER/OPERATOR ROLE IN DEVELOPMENT OF A FLIGHT TEST DATA PACKAGE FOR THE VALIDATION AND VERIFICATION OF A FLIGHT SIMULATOR FOR COMMERCIAL PILOT TRAINING AND CHECKING
ROBERT D. FOSTER IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 159-167. refs
(AIAA PAPER 91-2929) Copyright

The role is examined of the simulator user/operator in obtaining flight test data required to design and design-validate a flight simulator as well as qualify it for use in training and checking of airmen. The flight simulator qualification/approval process is reviewed, and the determination of the flight test program scope is addressed. The main characteristics of the data package content are summarized, and the items which must be an intrinsic part of the flight test plan are outlined. C.D.

A91-47819#
FLIGHT TESTING FOR SIMULATOR DATA
F. C. HALL (Boeing Commercial Airplanes, Seattle, WA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 168-175.
(AIAA PAPER 91-2930) Copyright

The content of simulator flight testing for two aircraft models is described. Maneuvers used to validate the model for crew training

simulators and those used to develop the aerodynamic data are discussed. Conditions and flight test hours are given for the maneuvers. C.D.

A91-47820#
FLIGHT TEST REQUIREMENTS FOR ADVANCED SIMULATOR DESIGN AND VALIDATION
D. L. GRAHAM (Ferranti Simulation and Training, Orange Park, FL) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 176-180.
(AIAA PAPER 91-2932) Copyright

This paper discusses the quality and quantity of measurements, and the types of test maneuvers required for gathering validation and design data to meet the specific data requirements of flight simulators. Flight test programs of this kind may be conducted by airflame manufacturers, simulator manufacturers, end-user aircraft operators, or independent contractors. A review of existing and proposed U.S. and international regulatory standards is included. The benefits of generating aerodynamic, propulsion, and flight controls design data totally from flights tests are explored. Summary recommendations are made for the design and specification of flight test plans for simulator data acquisition. Author

A91-47821#
FLIGHT TEST DATA FOR SIMULATOR VALIDATION - AN FAA PERSPECTIVE
R. C. PADGETT and HILTON G. SMITH (FAA, Washington, DC) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 181-184. refs
(AIAA PAPER 91-2933)

The requirements and need for improved quality flight test data for simulator validation are discussed. Some guidance is given for the acquisition of flight test data that will comply with FAA aircraft simulator qualification requirements for the evaluation of advanced simulators. The presentation of validation data is addressed. C.D.

A91-47824*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
PROPULSION MODELING TECHNIQUES AND APPLICATIONS FOR NASA DRYDEN X-30 REAL-TIME SIMULATOR
JOHN W. HICKS (NASA, Flight Research Center, Edwards, CA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 210-223.
(AIAA PAPER 91-2937) Copyright

An overview is given of the flight planning activities to date in the current National Aero-Space Plane (NASP) program. The government flight-envelope expansion concept and other design flight operational assessments are discussed. The NASA Dryden NASP real-time simulator configuration is examined and hypersonic flight planning simulation propulsion modeling requirements are described. The major propulsion modeling techniques developed by the Edwards flight test team are outlined, and the application value of techniques for developmental hypersonic vehicles are discussed. C.D.

A91-47877#
ANATOMY OF A WINNER
RICHARD DEMEIS Aerospace America (ISSN 0740-722X), vol. 29, Aug. 1991, p. 24-27.
Copyright

A number of company design engineering and development innovations in the F-22 Lightning II prototype are described to emphasize the concurrent engineering concept approach that was used. Early in the program it was decided to design the prototype aircraft as close to what would be proposed at engineering/manufacturing development (formerly, full-scale development) as possible. A large jump in developing an integrated avionics system was taken with all sensors and avionics tested in a 757 flying laboratory to complement ground testing. The enineering team relied heavily on its own concurrent engineering product development teams, individual, multidiscipline groups given the reponsibility for specific parts of the aircraft, and coordinated with all three major manufacturers. R.E.P.

A91-48075
AIRCRAFT PERFORMANCE ENGINEERING
JOOP WAGENMAKERS New York, Prentice Hall, 1991, 174 p. refs
Copyright

The present volume gives attention to those aspects of aircraft performance engineering related to ther safe and economic operation of commercial aircraft fleets, emphasizing issues which are either not generally appreciated or warrant further study. Among the topics discussed are airworthiness and certified performance, operation on wet and contaminated runways, takeoff performance and obstacle clearance, aircraft noise problems, and extended-range operation with two-engine aircraft. Also discussed are fuel conservation, aircraft performance monitoring, performance computers and flight-management systems, weight/balance management, and professional organizations' responsibilities for performance engineering-related developments. O.C.

A91-48225
YAK-141 FREESTYLE
ROY BRAYBROOK Air International (ISSN 0306-5634), vol. 41, Aug. 1991, p. 64-67.
Copyright

A review is presented of the new Yak-41 Freestyle aircraft which appears destined to become the world's first supersonic V/STOL fighter. Described as a multipurpose aircraft intended for close air combat, interception and strike duties, this aircraft is basically a faster, larger and potentially more useful derivative of the currently operational Yak-38 Forger. Following the three-engine design of the Yak-38 results in a long fuselage, but the rear end is split into two tail-carrying booms, possibly to keep open the option of limited thrust-vectoring in flight. The thrust-vectoring system for the lift/cruise engine has the thrust bearings arranged to allow an angular travel of 95 deg although the energy losses are such that the vertical thrust generated equates to only 80 percent of the horizontal maximum. Some details and diagrams are provided for the powerplants, aircraft weights, dimensions and performance. R.E.P.

N91-27150# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.). Hubschrauber und Flugzeuge.
MONOLITHIC CFC-MAIN LANDING GEAR DOOR FOR TORNADO
W. HARTMANN, M. MICHALAK, and W. PITZL 12 Dec. 1989 15 p Previously announced in IAA as A90-50136
(MBB/FE212/CFK/PUB/014/1; ETN-91-99250) Copyright
Avail: NTIS HC/MF A03

The objective of the development program for the monolithic CFC Main Landing Gear Door (MLGD) is to produce fifteen lefthand CFC (Carbon Fiber Composite) MLGD's for long term in service testing on German air force Tornados to build up experience for the future European Fighter Aircraft (EFA). The CFC MLGD is designed with an internal spar-stringer structure covered by two skins and all these structural elements are made from Narmco 5245C/T800. The design and manufacturing work on the CFC MLGD are addressed and an outlook on the airworthiness testing and the planned in service test program is presented. ESA

N91-27151# Naval Air Development Center, Warminster, PA. Air Vehicle and Crew Systems Technology Dept.
FUNDAMENTALS AND METHODS OF HIGH ANGLE-OF-ATTACK FLYING QUALITIES RESEARCH Final Report, Jan. 1987 - Jan. 1988
ROBERT M. SELTZER and GLENN R. RHODESIDE Jan. 1988 228 p
(AD-A235994; NADC-88020-60) Avail: NTIS HC/MF A11
CSCL 01/3

This report is intended: (1) for use as a collection and analysis of diverse data gathering, empirical, and analytical approaches to the high angle of attack aircraft stability and control problem; (2) as a compendium of several methods of defining aircraft departure and spin susceptibility; (3) as a reference for spin definition and spin recovery enhancement; (4) as a review of specifications, regulations, and design guides as they pertain to high angle of attack flight; and (5) as a medium for expounding where tomorrow's high angle of attack investigative attention should focus. The design of safe, effective fighter aircraft in the high angle of attack combat environment is reaching a critical point. Accepted flying qualities design guidelines (necessary to establish stability and control requirements) must be established to address flight operations in the high angle of attack flight regime. Most of the research to date has focused on aircraft departure. Parameters/criteria to define desired high angle of attack flying qualities in the post-stall region (outside the realm of departure) are still unanswered. GRA

N91-27152# Aeronautical Research Labs., Melbourne (Australia).
A REVIEW OF AUSTRALIAN AND NEW ZEALAND INVESTIGATIONS ON AERONAUTICAL FATIGUE DURING THE PERIOD APRIL 1989 TO MARCH 1991 Aircraft Structures Report
G. S. JOST Apr. 1991 50 p
(AD-A236016; ARL-STRUC-TM-578; DODA-AR-006-593) Avail: NTIS HC/MF A03 CSCL 01/3

Major topics discussed include the fatigue of both civil and military aircraft structures, fatigue damage detection, analysis and repair and fatigue life monitoring and assessment. Stress analysis of thermoelasticity, crack propagation, effects on fiber reinforced composites and stress strain relations are also reviewed. GRA

N91-27153# Aeronautical Research Labs., Melbourne (Australia).
F-111C FLIGHT DATA REDUCTION AND ANALYSIS PROCEDURES Flight Mechanics Report
M. I. COOPER, J. S. DROBIK, and C. A. MARTIN Dec. 1990 104 p
(AD-A236025; ARL-FLIGHT-MECH-R-187; DODA-AR-005-639) Avail: NTIS HC/MF A06 CSCL 01/1

A series of flight trials was performed on the F-111C aircraft at the RAAF's Aircraft Research and Development Unit in February and October 1987. Data obtained from the tests were analyzed at the Aeronautical Research Laboratory to determine the aircraft aerodynamic and control derivatives. This report describes the methods and computer programs which are used to process and analyze the flight test data. Data handling procedures, pre-analysis flight data processing and the methods used to make corrections to air sensor measurements are described. Although the test program was conducted on a F-111C aircraft, with minor alterations the computer programs and procedures can be used for other aircraft test programs. GRA

N91-27154# Aeronautical Research Labs., Melbourne (Australia).
PROGRAMMABLE COCKPIT: INTER-COMPUTER COMMUNICATIONS AND DATA FLOW Aircraft Systems Technical Memorandum
D. A. CRAVEN Mar. 1990 21 p
(AD-A236028; ARL-SYS-TM-139; DODA-AR-006-079) Avail: NTIS HC/MF A03 CSCL 01/3

The Programmable Cockpit is a multi computer system which is used for research into display design, cockpit layouts, crew workload and other human factors issues. It currently consists of four closely arranged screens onto which different cockpit instruments can be displayed, all driven from a common aircraft model. This provides a test-bed for determining the effectiveness of new or modified instruments, as they can be assessed in an environment simulating the cockpit as a whole. The system incorporates a distributed processing network of five processors, each performing a distinctive part of the simulation. The tasks are broken up as follows: FDM (Flight Dynamic Model); CD (Control Display); HUD (Head Up Display); HDD (Head Down Display); and MMD (Moving Map Display). GRA

N91-27155# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EVALUATION OF THE CONCEPT OF PRESSURE PROOF TESTING FUSELAGE STRUCTURES
CHARLES E. HARRIS and OSCAR ORRINGER Jul. 1991 8 p
(DOT/FAA/CT-TN91/31) Avail: NTIS HC/MF A02

The FAA and NASA have recently completed independent technical evaluations of the concept of pressure proof testing the fuselage of commercial transport airplanes. The results of these evaluations are summarized. The objectives of the evaluations were to establish the potential benefit of the pressure proof test, to quantify the most desirable proof test pressure, and to quantify the required proof test interval. The focus of the evaluations was on multiple-site cracks extending from adjacent rivet holes of a typical fuselage longitudinal lap splice joint. The FAA and NASA do not support pressure proof testing the fuselage of aging commercial transport aircraft. The argument against proof testing is as follows: (1) a single proof test does not insure an indefinite life; therefore, the proof test must be repeated at regular intervals; (2) for a proof factor of 1.33, the required proof test interval must be below 300 flights to account for uncertainties in the evaluation; (3) conducting the proof test at a proof factor of 1.5 would considerably exceed the fuselage design limit load; therefore, it is not consistent with accepted safe practices; and (4) better safety can be assured by implementing enhanced nondestructive inspection requirements, and adequate reliability can be achieved by an inspection interval several times longer than the proof test interval. Author

N91-27156* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PASSIVE VENTING TECHNIQUE FOR SHALLOW CAVITIES Patent
ROBERT L. STALLINGS, JR., inventor (to NASA) and FLOYD J. WILCOX, JR., inventor (to NASA) 28 May 1991 11 p Filed 28 Sep. 1988
(NASA-CASE-LAR-13875-1; US-PATENT-5,018,688; US-PATENT-APPL-SN-250468; US-PATENT-CLASS-244-137.4; US-PATENT-CLASS-244-118.1; US-PATENT-CLASS-244-130; INT-PATENT-CLASS-B64C-7/00; INT-PATENT-CLASS-B64D-1/02) Avail: US Patent and Trademark Office CSCL 01/3

A device is disclosed for reducing drag and store separation difficulties caused by shallow cavities on aircraft in supersonic flight consisting of a slab of porous material cut to fit precisely inside the cavity. This slab is mounted inside the cavity such that a plenum chamber is formed between the slab and the floor of the cavity. This device allows air to flow through the chamber opposite to the direction of flow outside the chamber. This results in reduced drag and improved store separation characteristics. Official Gazette of the U.S. Patent and Trademark Office

N91-28150# Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.
LANDING GEAR DESIGN LOADS
1990 283 p In FRENCH and ENGLISH Meeting held in *Povoa de Varzim, Portugal, 8-12 Oct. 1990*
(AGARD-CP-484; ISBN-92-835-0611-1) Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Papers presented to a Specialists Meeting organized by the Structures and Materials Panel are reported. The meeting provided a forum for the exchange of experiences between the NATA nations with the aim of advancing landing gear design criteria and methods of landing gear analysis. The meeting reviewed existing design practices and specifications, considered the various methods for load measurement and data analysis, and formulated guidelines for future design procedures.

N91-28151# National Defence Headquarters, Ottawa (Ontario). Directorate Aerospace Support Engineering.
FAILURE ANALYSIS CASE HISTORIES OF CANADIAN FORCES AIRCRAFT LANDING GEAR COMPONENTS
P. BEAUDET and M. ROTH (Department of National Defence, Ottawa, Ontario) *In* AGARD, Landing Gear Design Loads 24 p 1990

Despite the extensive landing gear design analyses and tests carried out by the designers and manufacturers, and the large number of trouble-free landings accumulated by the users, the Canadian Forces, as well as others, have experienced a range of problems or failures with landing gear components. Different data banks were surveyed and over 200 cases histories on more than 20 aircraft types were reviewed in order to assess trends in failure mechanisms and their causes. Fatigue and corrosion were found to be the main mechanisms. Fatigue occurred mainly in steel components while corrosion occurred mainly with aluminum alloy components and wheels. Very few overload failures were noted. Different failure causes were identified. Design deficiencies and manufacturing defects led mainly to fatigue failures while poor material selection and improper field series of preventive measures was either recommended or re-emphasized. While fatigue can best be addressed by improving the quality of manufacturing and by better characterizing in-service and manufacturing stress, much work remains to be done on the time-dependent degradation processes. Their synergism with fatigue and corrosion has often been neglected in both the design and testing stages as well as in the maintenance domain. Author

N91-28152# Aeronautical Systems Div., Wright-Patterson AFB, OH.
APPLICATION OF THE AIR FORCE GUIDE SPECIFICATION 87221A TO GROUND LOADS
DAN SHEETS and ROBERT GERAMI *In* AGARD, Landing Gear Design Loads 6 p 1990

The U.S. Air Force has eliminated the use of rigid and mandatory structural design specifications. In their place a new approach has been instituted that requires that every system structural specification be rationally tailored to the actual anticipated aircraft usage. The Air Force Guide Specification (AFGS-87221A) produces total system performance requirements as opposed to the old approach of meeting selected, isolated criteria. This new approach entails the conversion of operational requirements into the associated and anticipated loading environments. Examples of how this new design approach is applied are given. Author

N91-28153# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.).
DEVELOPMENT OF UNDERCARRIAGE DESIGN LOADS
G. KEMPF and G. H. HAINES (Dowty Aerospace Gloucester, England) *In* AGARD, Landing Gear Design Loads 12 p 1990

During the different phases of development from feasibility studies to the final design, the landing gear designer applies increasingly refined methods of analysis to derive the loads to which the system is designed. Future design procedures should reflect such a staged approach leading to designs which are fully optimized with the aid of rational methods of analysis to meet the complete range of aircraft operating conditions. Here, the design process is described. Comparisons are made of design load cases obtained using current landing gear requirements and those derived by rational analysis. These comparisons are made for the critical phases of landing touchdown, derotation onto the nosegear, landing roll out, repaired runway operation, etc. The application of the rational method of analysis to determining aircraft operating envelopes under asymmetric landing conditions is also discussed. Finally areas of work are identified which need addressing further, in order that a staged approach can be adopted completely in the future military landing gear design procedures. Author

N91-28154# Wright Research Development Center, Wright-Patterson AFB, OH.
RECENT DEVELOPMENTS IN THE AREA OF AIRCRAFT ROUGH FIELD PERFORMANCE
DAVID MORRIS and TONY GERARDI *In* AGARD, Landing Gear Design Loads 10 p 1990

Under project Have Bounce (HB), the USAF successfully determined the level of surface roughness that could be tolerated by most aircraft in the inventory. The runway roughness capability of each aircraft was determined by developing a sophisticated computer model of each aircraft. In most cases these computer models were validated with aircraft tests on rapidly repaired runways. This multimillion dollar effort has resulted in the definition of surface roughness criteria (repair criteria) for each aircraft. The knowledge gained as a result of all the testing and computer modeling has led to a much more thorough understanding of the complex interaction between the flexible structure, landing gear, and rough pavement. Discussed here is the development, laboratory qualification testing, and taxi testing of an improved F-15 rough field landing gear which provides a significant improvement in rough field and sink rate performance over the existing F-15 landing gear. This landing gear design utilizes passive, internal strut modification to achieve this performance without any effect on reliability and maintainability. Also discussed are the advantages of an automated Personal Computer (PC) based process for selecting the minimum operating strip (MOS) and for determining the minimum level of runway repair required. As backup to this automated approach, a novel technique for quantifying the ability of a given aircraft to traverse rough surfaces is also discussed. This method assigns a Vulnerability Index (VI) to each aircraft. The VI is a reflection of the aircraft's ability to absorb the energy that is transmitted from the pavement to the struts and the airframe. This method will give the base commander a tool for making good intuitive decisions in the event that the automated process cannot be used. It can also be used as a validation technique for the automated method. Author

N91-28155# British Aerospace Public Ltd. Co., Kingston-upon-Thames (England). Aerodynamics Dept.
THE SPECIAL REQUIREMENTS OF A VSTOL AIRCRAFT
D. C. THORBY, J. JOHNSON, A. B. K. AULD, H. T. NEWMAN, and M. J. BROOKER *In* AGARD, Landing Gear Design Loads 24 p 1990

The special landing gear requirements of the Harrier family of aircraft are described. Only topics peculiar to the Vertical and Short Take Off and Landing (VSTOL) aspects of this aircraft are addressed. Of the four possible modes of take-off, ramp-assisted (the ski jump) presents unique landing gear problems. This is described, covering the design of ramp profiles and the procedures used to establish service operating limits for the landing gear, including the effects of ship motion. The particular problems associated with vertical landing are discussed. This mode of landing can produce landing gear side loads potentially much higher than are normally possible in a conventional landing with forward speed. Clearance procedures using a multivariate approach are described. The Harrier has also been cleared for operation on unprepared rough fields. The Monte Carlo method, applied to the results of numerical modeling using computer-generated surfaces, is described. Other topics discussed are runway directional stability, and the load and directional stability implications of converting to radial tires. Author

N91-28156# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Airplane Div.
CONSIDERATIONS ON OPTIMALITY OF LANDING GEAR ARRANGEMENT AND DESIGN

A. J. KRAUSS *In* AGARD, Landing Gear Design Loads 11 p 1990
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Much effort has been spent and is still being spent on development and improvement of optimization procedures and computer codes. The formal task of optimization is to quantify that set of design variables which both satisfies a set of constraints and yields the absolute maximum or minimum of an objective function. One of the intrinsic problems of optimization is that the objective must be expressed as a numerical quantity, which often leads to conversion problems (in which way can one convert a quality into a nonnegative real number?). An other even more serious problem is that formal optimization requires that the dependence of the objective on the design variables must be analytically defined. In relation to these problems it appears of secondary importance that in most cases the optimization process will stop at the local optimum which is closest to the starting design, albeit there might exist better optimum solutions across the surrounding ridges of the objective function. Before formal (automatic) optimization methods are called in, the design must therefore be developed to a starting point in reasonable vicinity to the real optimum. A retractable landing gear is complex, requires a lot of internal space on the airplane, features a variety of doors, spoils the cleanliness of the structure by large cutouts and local introduction of large loads, and adds weight. Unquestionably the landing gear impairs flight performance proper of an airplane. However, operational benefit from a landing gear apparently is big enough to outweigh said disadvantages. It appears that the primary objective of airplane design is operational usefulness. Now, having accepted the landing gear as a basically useful subsystem, the aircraft designer should proceed by integrating the landing gear into overall functional optimization of the system. Based on a functionally sound general arrangement of the landing gear, specialists for aircraft-integrating the landing gear loads evaluation teamed with landing gear design specialists should provide for optimum detail characteristics fulfilling a variety of design criteria. Author

N91-28157# Aeronautical Research Inst. of Sweden, Bromma. Structures Dept.
LONG TIME MEASUREMENTS OF LANDING GEAR LOADS ON SAAB SF-340 COMMUTER AIRCRAFT
A. I. GUSTAVSSON, A. F. BLOM, and L. HELMERSSON (Saab-Scania, Linkoping, Sweden) *In* AGARD, Landing Gear Design Loads 16 p 1990 Sponsored in part by the Swedish Board for Technical Development; the Swedish Civil Aviation Admin.; and SAAB-SCANIA AB
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Strain gauge measurements of forces acting on the nose gear and main gears of the commuter aircraft SAAB SF-340 are discussed. During initial flight tests, forces in the longitudinal, transversal and vertical directions were measured for various maneuvers such as take-off, landing, taxiing and towing. The investigation revealed high transversal loads at the main gears at touch-down. The nose gear is most severely strained when steering during taxiing run and when the aircraft is towed connected to a tractor with a tow-bar. The results from such initial measurements formed the basis for a subsequent investigation with on line data acquisition of landing gear loads on a commuter aircraft in service at Swedair AB. The data acquisition system and the data analysis methods are described in some detail. The data acquisition was continuously carried out during nearly six months, and included various parameters such as different aircraft weight and static landing gear loads. Results from these measurements are presented as cumulative exceedances of longitudinal, transversal and vertical loads obtained from the rain-flow count analysis performed on-line during the measurements. Author

N91-28158# Deutsche Airbus G.m.b.H., Bremen (Germany, F.R.).
OPERATIONAL LOADS ON LANDING GEAR
V. LADDA and H. STRUCK *In* AGARD, Landing Gear Design Loads 16 p 1990
Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Prior statistics of airworthiness authorities indicate that landing gear (safe life design) often fail during scheduled aircraft service. Therefore investigations have been carried out during the last two decades in Germany with the aim of determining operational loads acting on the landing gear during service and defining the load cases which have to be taken into consideration for fatigue investigations related to landing gear and airframe. Statistics about failures on landing gear for civil and military aircraft and relevant load cases as well as information about essential fatigue requirements are presented. Some results of different landing gear load measurements are compared and discussed. These results, presented in form of cumulative frequency distributions for the taxiing and landing impact load cases, originate from the following measurements: Airbus A320; Airbus A310; Airbus A300; VFW 614; F-104 G. The impact of towing and push back operations on the nose landing gear using conventional and advanced towing methods is discussed. The primary results of the landing gear loads measurements are accentuated. Examples for the disposition of landing gear fatigue tests are considered, and essential future actions concerning load monitoring activities including hard- and overweight landing detection are reviewed. Author

N91-28159# Wright Research Development Center, Wright-Patterson AFB, OH.
LANDING GEAR IMPROVEMENTS FOR TRANSPORT AIRCRAFT
J. GREER MCCLAIN and B. M. CRENSHAW (Lockheed Aeronautical Systems Co., Marietta, GA.) *In* AGARD, Landing Gear Design Loads 17 p 1990
Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Discussed here are development, testing, and analysis of retrofit nose and main landing gears designed for improvement in C-130 transport aircraft rough field capabilities, concentrating primarily upon analytical model prediction aspects which might be applicable to other gear designs. Two levels of improvement are examined, with the second level resulting in a new longer stroke strut designed to retract into existing stowage volume. All improved gears are qualified by laboratory drop tests and also are compared with test results. Model improvements are developed where necessary, with particular attention to representing strut friction, predicting strut rebound damping, and modeling transition from isothermal toward adiabatic conditions in the strut inflation gas. Rough field capability estimates for the C-130 equipped with these gears are made. Recommendations for further analytical model improvements are included. Author

N91-28160# Messier-Hispano-Bugatti S.A., Montrouge (France).
NUMERICAL SIMULATION OF THE DYNAMIC BEHAVIOR OF LANDING GEARS [SIMULATION NUMERIQUE DU COMPORTEMENT DYNAMIQUE DES ATTERRISSEURS]
JEAN LUC ENGERAND *In* AGARD, Landing Gear Design Loads 28 p 1990 In FRENCH; ENGLISH summary
Copyright Avail: NTIS HC/MF A13; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The aim here is to describe the Messier-Bugatti analysis and numerical simulation system used for solving landing gear dynamics problems. The system is designed around a finite elements software package for the analysis of mechanisms and flexible bodies. The following examples of applications are examined: simulation of landing, simulation of taxiing on rough fields or repaired runways, simulation of extension and retracting, simulation of catapulting, and analysis of shimmy stability. Author

N91-28161# Dassault (E. M.) Co., Saint Cloud (France).
CALCULATION OF INTERACTIONS BETWEEN AIR AND GROUND OF LANDING
YVES MARTIN-SIEGFRIED *In* AGARD, Landing Gear Design

Loads 23 p 1990 In FRENCH; ENGLISH summary

The author presents the present state-of-the-art for the calculation of the ground dynamic response of the aircraft. The analysis tool described here forms a special branch of the CATINA-ELFINI system, the general purpose program for computer aided design (CAD) and structural analysis of DASSAULT. The system handles a large set of problems for ground dynamic response: landing impact, rough runway rolling and take off, catapulting and landing on carrier, etc. In these calculations, the structure is represented by a finite element model of the whole aircraft coupled with models of landing gears, aerodynamics, and other special systems (e.g., catapult). The time integration is performed via implicit finite differences scheme. The method handles nonlinearities with three levels of condensation: one time before integration; at each time step linearization of smooth nonlinearities (e.g., large rotations) and condensation of the problem for only nonlinearizable D.O.F. (as lamination); and resolution at each time step of these few hard nonlinear equations by a special B.F.G.S. method. The author presents some significant types of simulation stemming from analyses of Mirage III, Super-Etendard, Mirage 2000 and Rafale. Author

N91-28162# Fokker B.V., Schipol-Oost (Netherlands).
THE USE OF MONTE CARLO SIMULATION IN DETERMINING LANDING GEAR LOADS DURING LANDING
R. VANDERVALK *In* AGARD, Landing Gear Design Loads 12 p 1990

It is perceived by the airworthiness authorities that certification of automatic landing systems can only be done by applying statistical methods. However, if these particular statistical requirements are satisfied, there is no guarantee for the aircraft manufacturer that local limit and ultimate loads (stresses), developed during landing, occur at acceptable risk levels. Here, another approach is proposed, which is based on direct calculation of local loads by means of Monte Carlo simulation. In this context, the concept of load cases is superfluous (apart from preliminary design). Limited and ultimate loads are obtained by reading probability of exceedance distributions at desired risk levels. Maxima and minima are used for calculation of limit and ultimate loads. The whole time histories are used for the calculation of fatigue loads. Author

N91-28163# Politecnico di Milano (Italy). Dipt. di Ingegneria Aerospaziale.
DESIGN LANDING LOADS EVALUATION BY DYNAMIC SIMULATION OF FLEXIBLE AIRCRAFT
G. L. GHIRINGHELLI and M. BOSCHETTO (Aeronautica Macchi S.p.A., Varese, Italy) *In* AGARD, Landing Gear Design Loads 12 p 1990

Some significant applications of the integrated system GRAALL (Ground Roll Air And Landing Loads) to the analytical prediction of aircraft landing loads carried out at Aermacchi are presented. The capabilities of the system, able to treat both rigid and flexible models, make it a tool that can be profitably used during different phases of the design process. The results reported here describe the whole development of an actual design application; comparisons between analytical and experimental data are also provided. Author

N91-28164*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
F-106B AIRPLANE ACTIVE CONTROL LANDING GEAR DROP TEST PERFORMANCE
WILLIAM E. HOWELL, JOHN R. MCCEHEE, ROBERT H. DAUGHERTY, and WILLIAM A. VOGLER *In* AGARD, Landing Gear Design Loads 8 p 1990

Aircraft dynamic loads and vibrations resulting from landing impact and from runway and taxiway unevenness are recognized as significant factors in causing fatigue damage, dynamic stress on the airframe, crew and passenger discomfort, and reduction of the pilot's ability to control the aircraft during ground operations. One potential method for improving operational characteristics of aircraft on the ground is the application of active-control technology to the landing gears to reduce ground loads applied to the airframe. An experimental investigation was conducted on series-hydraulic active control nose gear. The experiments involved testing the gear in both passive and active control modes. Results of this investigation show that a series-hydraulic active-control gear is feasible and that such a gear is effective in reducing the loads transmitted by the gear to the airframe during ground operations. Author

N91-28165# BMW-A.G., Munich (Germany, F. R.). Structural Dynamics and Acoustics.
ACTIVELY DAMPED LANDING GEAR SYSTEM
RAYMOND FREYMANN *In* AGARD, Landing Gear Design Loads 18 p 1990

An active control undercarriage for the alleviation of aircraft landing gear and structural loads during operation on rough runway surfaces is described. For quantitative determination of the improvements obtained with an active control undercarriage compared with conventional landing gear systems, aircraft taxiing is realistically simulated by means of a laboratory test set-up especially designed for this kind of testing. Author

N91-28166# SAC Technology Ltd., Walton-on-Thames (England).
ASSESSMENT OF THE APPLICATION OF THE WORKING GROUP 22 STANDARD BUMP CONCEPT TO A CURRENT MILITARY AIRCRAFT
E. F. WILD, B. R. MORRIS, and A. E. DUDMAN (British Aerospace Public Ltd. Co., Bristol, England) *In* AGARD, Landing Gear Design Loads 19 p 1990

The application of standardized runway repair obstacles (SRO) for design purposes and post-design capability determinations was a basic outcome of SMP Working Group 22 deliberations. The WG 22 standardized shapes have been the basics of clearance work for a current military aircraft. To verify the adequacy of the SRO profile for this work the response to real repair profiles, obtained from practice repairs, has been related to the response to the SRO. Some comments on the SRO as a representation of real repairs and on some undesirable features of real repair profiles are presented. Author

N91-28168*# Sikorsky Aircraft, Stratford, CT.
TECHNOLOGY NEEDS FOR HIGH SPEED ROTORCRAFT (2)
MARK W. SCOTT Aug. 1991 253 p
(Contract NAS2-13058)
(NASA-CR-177590; A-91215; NAS 1.26:177590) Avail: NTIS HC/MF A12 CSCL 01/3

An analytical study was conducted to identify rotorcraft concepts best capable of combining a cruise speed of 350 to 450 knots with helicopter-like low speed attributes, and to define the technology advancements needed to make them viable by the year 2000. A systematic approach was used to compare the relative attributes and mission gross weights for a wide range of concepts, resulting in a downselect to the most promising concept/mission pairs. For transport missions, tilt-wing and variable diameter tilt-rotor (VDTR) concepts were found to be superior. For a military scout/attack role, the VDTR was best, although a shrouded rotor concept could provide a highly agile, low observable alternative if its weight empty fraction could be reduced. A design

speed of 375 to 425 knots was found to be the maximum desirable for transport missions, with higher speed producing rapidly diminishing benefits in productivity. The key technologies that require advancement to make the tilt-wing and VDTR concepts viable are in the areas of wing and proprotor aerodynamics, efficient structural design, flight controls, refinement of the geared flap pitch control system, expansion of the speed/descent envelope, and the structural and aerodynamic tradeoffs of wing thickness and forward sweep. For the shrouded rotor, weight reduction is essential, particularly with respect to the mechanism for covering the rotor in cruise. Author

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A91-45366#
FIBRE OPTIC DATA TRANSMISSION SYSTEMS FOR HELICOPTERS
MICHAEL J. KENNETT (Westland Helicopters, Ltd., Yeovil, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 11 p. Research supported by Royal Aerospace Establishment.

Research programs aimed at developing fiber optics for avionic applications are briefly reviewed. The main benefits offered by fiber optics to data transmission include improvements in the EMC-related aspects of intersystem signaling, improved safety through elimination of spark hazard, and the capability for vastly increased signal data rates due to higher bandwidth and potential cost and weight savings. Topics discussed are optical implementation of MIL-STD-1553B, multiple channel data networks, and application areas which include general avionics data busing, flight control systems, audio intercomms, and video and sensor data distribution. O.G.

A91-45407#
THE DEVELOPMENT OF AN ADVANCED INTEGRATED AVIONICS SYSTEM
D. ROUGHTON (Westland Helicopters, Ltd., Yeovil, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 12 p.

The development of highly integrated digital systems is reviewed, and three major stages of the development cycle - definition, system design, and development phases are discussed in detail. Key areas vital to the successful development of an advanced avionics system, including requirement specification, dealing with subcontractors, software development, design validation, and equipment reliability are outlined. It is pointed out that successful system integration is a complex process requiring a fusion of subsystems, aircraft, and crew in order to meet the operational requirements while obtaining an optimum balance of capability, operability, supportability, and affordability. V.T.

A91-46595#
THE 747-400 AIRCRAFT MONITORING SYSTEM
MASAAKI SAIGA and TOSHIRO ITO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 437, 1990, p. 284-290. In Japanese.

The paper presents the characteristics of various systems, including the Aircraft Condition Monitoring System (ACMS), the Central Maintenance Computer System (CMCS), the Aircraft Communications and Reporting System (ACARS), and SATCOM. The application of ACMS, ACARS, and CMCS to the monitoring of the 747-400 is dicsussed. B.J.

A91-46596#
COMPUTER TECHNOLOGY OF THE A320-200 AIRCRAFT
TAKETOSHI HIRAYAMA, HIDEKI HANEISHI, and MASASHI UEDA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 437, 1990, p. 290-300. In Japanese.

The computer technology of the A320-200 aircraft is described in some detail, with particular emphasis on the automatic flight control system (AFCS), the flight management guidance system, the primary flight display and the navigation display, and the pitch/roll/yaw control law. The characteristics of the onboard replaceable module are also examined. B.J.

A91-47166#
TAKE-OFF PERFORMANCE MONITORING SYSTEM ALGORITHM AND DISPLAY DEVELOPMENT
SJACK VERSPAY (National Aerospace Laboratory, Amsterdam, Netherlands) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 150-157. Research supported by Netherlands Agency for Aerospace Programs. refs
(AIAA PAPER 91-2863) Copyright

As part of a study into the potential safety benefit of a Take-Off Performance Monitoring (TOPM) system the development of the algorithms and displays needed for such a system are presented. The predictive algorithms make use of a first order correction polynome which is shown to be capable of predicting performance better than a zero-order correction. Three displays are presented for three different Types of TOPM, which represent different levels of sophistication. Author

A91-47807#
PARALLEL PROCESSORS OF THE VISTA/F-16 IN-FLIGHT SIMULATOR
THOMAS F. LANDERS (Arvin/Calspan Corp., Buffalo, NY) and LYNNE T. HAMILTON-JONES (USAF, Wright Laboratory, Wright-Patterson AFB, OH) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 56-64. refs
(AIAA PAPER 91-2917)

This paper discusses the implementation of a multiple processor computer architecture in the Variable Stability In-flight Simulator Test Aircraft (VISTA). The key to this aircraft's simulation capabilities is a sophisticated Variable Stability System (VSS) comprised of ten central processing units (CPUs), nine of which are programmed mostly in Ada. Efficiency is achieved in the nine Central Processing Units by the use of Direct Memory Access (DMA) interfaces. DMA allows one computer (or interface board) to directly access the memory of another, without involving the CPU in either computer. This feature allows data to be transferred between computers in the system while other computer tasks are being performed. In addition, by using interrupts to control scheduling, a minimum of overhead is needed to implement the simple real-time scheduling needed for this application. Author

A91-47813#
APPLICATION OF EXISTING SIMULATION AND FLIGHT TEST RESULTS TO DEFINING 21ST CENTURY AIRCRAFT VERTICAL SITUATION DISPLAYS
MOSES ARONSON (Aronson Industries, Orlando, FL) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 116-123. refs
(AIAA PAPER 91-2925) Copyright

The kinds of displays that a pilot should have to maneuver the future super or hypersonic aircraft where the pilot will be submerged inside the fuselage without direct or with limited direct view of the outside are examined. Previous studies on pilot control/display performance in simulators and aircraft with minimal time delay are investigated to define adequate subtended angle and resolution requirements. Recommendations for aircraft designers are offered and, where the existing data are inadequate, additional research is identified. Some hardware technologies are

examined that can provide the defined subtended angle of resolution and view. R.E.P.

N91-27157*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NASA LEWIS INTEGRATED PROPULSION AND FLIGHT CONTROL SIMULATOR
MICHELLE M. BRIGHT and DONALD L. SIMON 1991 13 p Presented at the Flight Simulation Technologies Conference, New Orleans, LA, 12-14 Aug. 1991; spons ored by AIAA
(NASA-TM-105147; E-6423; NAS 1.15:105147; AVSCOM-TR-91-C-037) Avail: NTIS HC/MF A03 CSCL 14/2

A new flight simulation facility was developed at NASA-Lewis. The purpose of this flight simulator is to allow integrated propulsion control and flight control algorithm development and evaluation in real time. As a preliminary check of the simulator facility capabilities and correct integration of its components, the control design and physics models for a short take-off and vertical landing fighter aircraft model were shown, with their associated system integration and architecture, pilot vehicle interfaces, and display symbology. The initial testing and evaluation results show that this fixed based flight simulator can provide real time feedback and display of both airframe and propulsion variables for validation of integrated flight and propulsion control systems. Additionally, through the use of this flight simulator, various control design methodologies and cockpit mechanizations can be tested and evaluated in a real time environment. Author

N91-28170# EG and G Energy Measurements, Inc., Las Vegas, NV.
THE IN-FLIGHT CALIBRATION OF A HELICOPTER-MOUNTED DAEDALUS MULTISPECTRAL SCANNER
L. K. BALICK, C. J. GOLANICS, J. E. SHINES, S. F. BIGGAR, and P. N. SLATER (Arizona Univ., Tucson.) 1991 10 p Presented at the SPIE International Symposium on Optical Engineering and Photonics in Aerospace Sensing, Orlando, 1-5 Apr. 1991
(Contract DE-AC08-88NV-10617)
(DE91-013054; EGG-10617-1127; CONF-910450-12) Avail: NTIS HC/MF A02

A convenient way that was used to calibrate, in-flight, a helicopter mounted Daedalus multispectral scanner is described. It used four large canvas panels laid out in a square with a Spectralon panel as a reference. A calibrated Barnes modular multispectral radiometer, carried on a 2.2 m boom was rotated around a 2.5 m high tripod at the center of the square. The radiometer sampled the four large panels and the Spectralon panel once every two minutes. Atmospheric spectral transmittance measurements were made using a filter radiometer on an autotracking mount during the morning of the flight. The reflectance and optical depth data were used in an atmospheric radiative transfer code to predict the spectral radiances at the scanner. The calibration was completed by comparing the image digital counts to the predicted spectral radiances. DOE

07

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.

A91-44525#
CHEMICAL COMPOSITION OF EXHAUST FROM AIRCRAFT TURBINE ENGINES
CHESTER W. SPICER, MICHAEL W. HOLDREN, DEBORAH L. SMITH (Battelle Memorial Institute, Columbus, OH), DAVID P. HUGHES (USAF, Tinker AFB, OK), and MARK D. SMITH (USAF, Environics Div., Tyndall AFB, FL) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-34)

This paper reports measurements of the chemical composition of exhaust from two aircraft turbine engines. The two engines are the F101, used on the B-1B aircraft, and the F110, used on the F-16C and F-16D aircraft. Samples were collected from each engine using a probe positioned just behind the exhaust nozzle. The measurements reported here were made at four power settings from Idle to Intermediate power. Exhaust composition measurements included carbon monoxide, carbon dioxide, nitrogen oxides, total hydrocarbons, and individual organic species. The principle focus of this paper is on the detailed organic species results. Author

A91-44528#
HEAT TRANSFER AND AERODYNAMICS OF A HIGH RIM SPEED TURBINE NOZZLE GUIDE VANE TESTED IN THE RAE ISENTROPIC LIGHT PISTON CASCADE (ILPC)
S. P. HARASGAMA and E. T. WEDLAKE (Royal Aerospace Establishment, Farnborough, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-41)

Detailed heat transfer and aerodynamic measurements have been made on an annular cascade of highly loaded nozzle guide vanes. The tests were carried out in an isentropic light piston test facility at engine representative Reynolds number, Mach number and gas-to-wall temperature ratio. The aerodynamics indicate that the vane has a weak shock at 65-70 percent axial chord (midspan) with a peak Mach number of 1.14. The influence of Reynolds number and Mach number on the Nusselt number distributions on the vane and endwall surfaces are shown to be significant. Computational techniques are used for the interpretation of test data. Author

A91-44537#
A METHOD FOR THE DESIGN OF OPTIMUM ANNULAR DIFFUSERS OF CANTED CONFIGURATION
R. C. ADKINS and M. H. WARDLE (Cranfield Institute of Technology, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-52)

A simple method is presented for the design of annular diffusers which takes into account the effects of compressibility and canted configurations by use of the area bisector line. The method is based on a one-dimensional approach and avoids boundary layer calculations by the introduction of the nondimensional parameter, defined as the ratio of local pressure gradients, the streamwise adverse gradient of static pressure, and the transverse gradient of dynamic pressure. It is concluded that the proposed method is useful for initial and intermediate stages of design. Full three-dimensional computational flow analysis should be used as a final stage, particularly in cases where curvature is severe. O.G.

A91-44558#
FURTHER DEVELOPMENT OF AN IMPROVED PULSE, PRESSURE GAIN, GAS-TURBINE COMBUSTOR
J. A. C. KENTFIELD and L. C. V. FERNANDES (Calgary, University, Canada) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(Contract NSERC-A-7928)
(ASME PAPER 90-GT-84)

Development work including both theoretical analysis and experimental testing is presented for an improved valveless, pulse-pressure-gain combustor for gas turbines. The analytical work involved the application to the nonsteady flow in the combustor secondary flow duct of the method of characteristics, as used for 1D time-dependent compressible flows. Gas temperatures in the secondary flow duct were measured experimentally, as were the

pressure gain, due to the pulse combustor, and the overall efficiencies of the gas turbine with both the conventional steady flow combustor and the alternative pressure-gain combustor. The analytical work confirmed earlier experimental findings showing the benefits of restricting the secondary flow-duct exit area. It was also concluded that the use of the pulse combustor resulted in a maximum improvement of 27 percent in the thermal efficiency of the small, low pressure-ratio gas generator turbomachine used. Author

A91-44570#
BASIC ANALYSIS OF COUNTER-ROTATING TURBINES
R. CAI, W. WU, and G. FANG (Chinese Academy of Sciences, Institute of Engineering Thermophysics, Beijing, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. NNSFC-supported research. refs
(ASME PAPER 90-GT-108)

A comprehensive basic analysis for various counter-rotating turbines is given with the blade element stage assumption. Similar to the classical analysis of common turbine stages, the appropriate independent variables and evaluation criteria of the counter-rotating turbine stages are first presented and then three typical kinds of rotating blade rows are defined and all possible typical schemes of counter-rotating turbine stages are enumerated. Their performances of specific work, load factor distribution between two counter-rotating shafts and efficiency are analyzed and discussed for different shaft rotating speed ratios. This information is useful for the selection and preliminary design of a counter-rotating turbine. From the analysis results, it is concluded that the load capacity per unit engine length of counter-rotating turbines can be much higher than that of common turbines (approximately twice) without efficiency penalty or even with higher efficiency. Some triple counter-rotating turbines suitable for three shaft gas turbine power plants are proposed and analyzed briefly too. Author

A91-44575#
DYNAMIC CONTROL OF CENTRIFUGAL COMPRESSOR SURGE USING TAILORED STRUCTURES
D. L. GYSLING, J. DUGUNDJI, E. M. GREITZER, and A. H. EPSTEIN (MIT, Cambridge, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 13 p. refs
(Contract AF-AFOSR-85-0288)
(ASME PAPER 90-GT-122)

A new method for dynamic control of centrifugal compressor surge is presented. The approach taken is to suppress surge by modifying the compression system dynamic behavior using structural feedback. One wall of a downstream volume, or plenum, is constructed so to move in response to small perturbations in pressure. This structural motion provides a means for absorbing the unsteady energy perturbations produced by the compressor, thus extending the stable operating range of the compression system. A lumped parameter analysis is carried out to define the coupled aerodynamic and structural system behavior and the potential for stabilization. A movable plenum wall lowered the mass flow at which surge occurred in a centrifugal compression system by roughly 25 percent for a large range of operating conditions. Author

A91-44576#
ACTIVE STABILIZATION OF CENTRIFUGAL COMPRESSOR SURGE
J. E. PINSLEY, G. R. GUENETTE, A. H. EPSTEIN, and E. M. GREITZER (MIT, Cambridge, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. U.S. Army-supported research. refs
(ASME PAPER 90-GT-123)

Active suppression of centrifugal compressor surge has been demonstrated on a centrifugal compressor equipped with a servo-actuated plenum exit throttle controller. The control scheme is fundamentally different from conventional surge control techniques in that it addresses directly the dynamic behavior of the compression system to displace the surge line to lower mass flows. The method used is to feed back perturbations in plenum pressure rise, in real time, to a fast acting control valve. The increased aerodynamic damping of incipient oscillations due to the resulting valve motion allows stable operation past the normal surge line. For the compressor used, a 25 percent reduction in the surge point mass flow was achieved, over a range of speeds and pressure rations. Time-resolved measurements during controlled operation revealed that the throttle required relatively little power to suppress the surge oscillations, because the disturbances are attacked in their initial stages. Although designed for operation with small disturbances, the controller was also able to eliminate existing, large amplitude, surge oscillations. Author

A91-44577#
ANALYTICAL AND EXPERIMENTAL SIMULATION OF FAN BLADE BEHAVIOUR AND DAMAGE UNDER BIRD IMPACT
H. C. TEICHMAN and R. N. TADROS (Pratt and Whitney Canada, Mississauga) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 15 p. Research supported by Canadian Department of Regional and Industrial Expansion. refs
(ASME PAPER 90-GT-126)

An extensive analytical and experimental program has been undertaken to investigate the Foreign Object Damage resistance capabilities of external components for small gas turbofan engines. A transient nonlinear impact analysis has been used to predict the structural response of fan blades under bird ingestion conditions. This analysis is based on finite elements, a 3D bird load model and an interactive structure-to-bird contact algorithm. Experiments were designed and carried out to record large blade deformations during bird impact, and were used to validate and calibrate the analytical models. The analytical models and testing program are described, and dominant fan blade response and failure modes are presented. Predicted results demonstrate good correlation with test. Analysis application to fan blade design and other engine components is recommended. Author

A91-44592#
TURBINE PRELIMINARY DESIGN USING ARTIFICIAL INTELLIGENCE AND NUMERICAL OPTIMIZATION TECHNIQUES
SIU SHING TONG (General Electric Co., Schenectady, NY) and BRENT A. GREGORY (GE Aircraft Engines, Cincinnati, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. General Electric Co.-supported research. refs
(ASME PAPER 90-GT-148)

This paper describes a new software approach to the preliminary design of aircraft engine turbines. A hybrid artificial intelligence and numerical-optimization-based design shell called Engineous was used to capture some basic turbine preliminary design knowledge, manipulate turbine design parameters, execute a turbine performance prediction program and its preprocessors, and analyze results. Engineous automatically supplements incomplete human design knowledge with symbolic and numerical search techniques when needed. This approach produced designs with higher predicted performance gains than the existing manual design process in a tenth of the turnaround time and has yielded new insights into turbine design. A comparison of turbine designs obtained by designers and by Engineous is presented here along with an overview of Engineous system architecture. Author

A91-44596#
CENTRIFUGAL COMPRESSOR INLET GUIDE VANES FOR INCREASED SURGE MARGIN
COLIN RODGERS (Sundstrand Power Systems, San Diego, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-158)

This paper describes the results of compressor rig testing with

a moderately high specific speed, high inducer Mach number, single-stage centrifugal compressor, with a vaned diffuser, and adjustable inlet guide vanes (IGVs). The results showed that the high speed surge margin was considerably extended by the regulation of the IGVs, even though the vaned diffuser was apparently operating stalled. Simplified one-dimensional analysis of the impeller and diffuser performances indicated that at inducer tip Mach numbers approaching and exceeding unity, the high speed surge line was triggered by inducer stall. Also, IGV regulation increased impeller stability. This permitted the diffuser to operate stalled, providing the net compression system stability remained on a negative slope. Author

A91-44602#
THE F109-GA-100 ENGINE DESIGNED SPECIFICALLY FOR TRAINER USE
HANS F. W. MAERTINS and THOMAS W. BRUCE (Allied-Signal Aerospace Co., Garrett Engine Div., Phoenix, AZ) ASME, *International Gas Turbine and Aeroengine Congress and Exposition*, 35th, Brussels, Belgium, June 11-14, 1990. 6 p.
(ASME PAPER 90-GT-167)

The present study describes the development history and the design features of the F109-GA-100 (F109) engine. Originally developed for the USAF, the F109 is a state-of-the-art powerplant designed specifically for trainer use. It has been designed to be fully aerobatic capable, without limitations throughout the training envelope. To minimize student pilot workload, the engine features a full-authority digital electronic fuel control with automatic start and restart, automatic overspeed-temperature-limiting, simple power management with no restrictions in operation, and automatic thrust trim. Maintenance features include extensive built-in test and data logging to support effective life management. Designed for an 18,000-hour life to a duty cycle with a mission severity comparable to that of a fighter, the F109 has demonstrated exceptional durability and high reliability which, coupled with excellent fuel efficiency, resulted in extremely low life-cycle-cost as demonstrated in accelerated mission testing. P.D.

A91-44610#
TRANSIENT PERFORMANCE AND BEHAVIOUR OF GAS TURBINE ENGINES
G. TORELLA (Accademia Aeronautica, Pozzuoli, Italy) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-188)

The paper deals with some activities carried out for setting up and using numerical computer codes for simulating the behavior of gas turbine engines during transient operations. Calculations for studying the influence on the performance of component characteristics decays have been performed. The flexibility of the codes have allowed for the evaluation of fuel flow laws suitable for obtaining assigned values of Turbine Inlet Temperature or engine thrust. The paper shows how it is possible to apply the codes for other similar calculations. Lastly, the so called secondary transient effects have been studied. The first results for taking into account the variation of component efficiencies due to heat transfer are presented. Author

A91-44611#
FLIGHT DEVELOPMENT OF THE RTM 322 ENGINE
PETER SEWELL and PAUL E. SCEARS (Rolls-Royce, PLC, Leavesden, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p.
(ASME PAPER 90-GT-189)

The design of the RTM 322 engine and its development status are described. The installation and flight testing in the S-70C are summarized. Ground and flight test results in the S-70C are discussed and data and photographs presented. The RTM 322 is a 2000-hp class turboshaft engine with a growth potential to approximately 3000 hp. The engine's core is designed to be adaptable to both turboprop and turbofan requirements to meet the primary objectives of competitive performance, good reliability, built-in growth potential, and low ownership cost. In a helicopter, the engine is mechanically attached to the aircraft transmission and rotor systems. Commonality was accomplished between the RTM 322 and the T700 for all major engine-to-aircraft interfaces, namely, overall length, forward and aft mountings, output drive spline, aircraft air intake, and exhaust duct. Vibration and air-temperature measurements show that all components will be within their appropriate design limitations. P.D.

A91-44614#
VATEMP - THE VARIABLE AREA TURBINE ENGINE MATCHING PROGRAM
J. R. PALMER (Cranfield Institute of Technology, England) and J. E. A. ROY-AIKINS ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-192)

Variable geometry in key gas turbine components offers the advantage of either improving the internal performance of a component or of re-matching the engine cycle to alter the flow-temperature-pressure relationships. Future gas turbines are expected to use variable geometry components extensively if they are to overcome some of the problems encountered by present day engines at off-design conditions in order to give much more advanced performance. Greater attention is also being paid to the impact of installation losses on the performance of aircraft engines. A computer program called VATEMP, herein described, has been developed capable of simulating the steady-state performance of arbitrary gas turbines with or without variable geometry in almost any gas path component. Results obtained from the program led to the conclusion that variable geometry components have the potential to improve significantly the off-design performance of gas turbines. Author

A91-44615#
NEW GENERATION OF THE SMALL TURBOSHAFT AND TURBOPROP ENGINES IN THE U.S.S.R
BORIS A. PONOMAREV (Tsentral'nyi Nauchno-Issledovatel'skii Institut Aviatsionnogo Motorostroeniia, Moscow, USSR) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p.
(ASME PAPER 90-GT-195)

Consideration is given to the main requirements for a new generation of small turboshaft and turboprop engines under development in the USSR. They are: (1) to improve engine fuel efficiency by 15 to 20 percent; (2) to increase dependability and service life by a factor of 2; (3) to improve performance substantially; (4) to provide high maintainability and decrease maintenance costs by a factor of 2 to 2.5; (5) to guarantee the possibility of further growth in power by 20 to 40 percent without significantly changing engine structure and size; (6) to reduce the life cycle cost by 20 to 30 percent. The performance of new small engines developed in the USSR is evaluated and their features are discussed. The features include: a low-stage, axial/centrifugal compressor, a short reverse flow annular combustion chamber, a cooled single-stage or two-stage gas generator, modular structure, integrated high-speed gearbox, and reduced number of supports and total components. P.D.

A91-44616#
A SMALL GAS TURBINE FOR DRONE AIRCRAFT - DESIGN PHILOSOPHY
J. R. BARBOSA, A. S. TAKEDA, J. F. C. MONTEIRO, M. T. MENDONCA (Centro Tecnico Aeroespacial, Sao Jose dos Campos, Brazil), and K. W. RAMSDEN (Cranfield Institute of Technology, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p.
(ASME PAPER 90-GT-196)

The present study describes two small gas turbine engines of 320 and 1000 newtons, respectively, for use as powerplant for RPV/Drone aircraft that were designed by the Aerospace Technical Center in Brazil. The design rationale and methodology are

presented for each of its components, namely, single-sided centrifugal compressor, vaned diffuser, reverse flow combustor, single-stage axial uncooled turbine, and electronic fuel/control systems. The design criteria were that the powerplant should be of low cost, low weight and small size. The performance characteristics for the powerplant are shown. The smaller engine's performance closely matched design targets. Comparisons with a range of existing small turbojet engines are favorable in terms of diameter, weight, and specific fuel consumption. For the larger engine, the design concept for each component is outlined. A comparison of the predicted figures for size, weight, and SFC with other small engines is presented. In all cases, it compares favorably with a selection of other engines of similar dimensions. P.D.

A91-44617#
GAS TURBINE WITH INTERMEDIATE HEAT EXCHANGER FOR FLIGHT APPLICATION
J. SHAPIRO and A. LEVY (Bet-Shemesh Engines, Ltd., Israel) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 4 p. refs
(ASME PAPER 90-GT-197)

Low specific fuel consumption (SFC) and high power/weight values are obtainable in gas turbines for helicopter applications through the incorporation of an intermediate regenerative heat exchanger, in conjunction with a 'double-decked' axial compressor/turbine-stage design. Heat transfer can in this way take place at higher gas/air temperature differences and higher absolute gas pressures than in conventional regenerative cycles. SFC is minimal at 70 percent of maximum power output. The additional weight represented by the heat exchanger is compensated for by fuel saved over the course of a 1-hr flight, in the case of a 926 kW cruise-power engine of this configuration. The cycle may be optimized for powerplant outputs in the range of 500 to 3000 shp, and is of course applicable to ground vehicles. O.C.

A91-44620#
INNOVATIONS IN REFURBISHING GAS TURBINE COMPONENTS
COLIN WALKER and JOSEPH COSART (Hickham Industries, LaPorte, TX) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 4 p.
(ASME PAPER 90-GT-202)

The continuing development of repair methods for turbine hot gas path components is considered, with emphasis on the salvaging of scrap components of gas turbines by cutting out areas of high damage and inserting a 'coupon' of new material. Standard coupons are cast to original vane profiles with allowances included for finishing after weld insertion. The parts go through penetrant welding and a series of heat treatments. A comparison analysis of the coupon material with the original cast vane segment and a carbon analysis showed that the coupon and segment compositions were virtually the same. Tungsten readings were high compared to nominal compositions of ECY768 and MAR-M 509. Hardness values were also comparable with readings between 28 and 32 Rockwell C-scale hardness. Microstructural comparison of the coupon versus the vane segment showed the typical carbides in script and eutectic/precipitate form. Incoming analysis of the vane segments showed a heavily overaged structure with sigma formation and strings of grain boundary carbides. P.D.

A91-44621#
GARRETT'S TURBOSHAFT ENGINES AND TECHNOLOGIES FOR THE 1990S
TERRY PYLE and DAN ALDRICH (Allied-Signal Aerospace Co., Garrett Engine Div., Phoenix, AZ) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-204)

The evolution of the T800 turboshaft engine (1300-shp, 1000-kW class) is traced, and new technologies incorporated in it and emerging technological concepts applicable to future turboshafts are discussed. Consideration is given to baseline engine characteristics, the inlet particle separator module, accessory gear box module, gas generator core module, and controls and lubrication systems. Performance and physical specifications are presented, and projected technology advancements and growth steps are described, with emphasis on a plan for up to 50 percent growth for the T800. Advances discussed include increased pressure ratio with a reduction in efficiency due solely to the envelope constraint, increased efficiencies, reduction in chargeable flow, and increased temperature capability. P.D.

A91-44626#
THE INTERACTION BETWEEN THE AXIAL COMPRESSOR AND THE DOWNSTREAM DISTORTING COMPONENT
GUO-CAI TANG (Nanjing Aeronautical Institute, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-209)

The interaction between a compressor and a downstream distorting component has been studied using a time-marching method for compressible flow with large perturbation. The results show that the flow field of a compressor is modified by the interaction between the compressor and the downstream distorting component. The flow field with downstream distortion is characterized by nonuniformity in the exit static pressure and maximum distortion at the last blade row, implying a possible critical source for instability. The whole flow process is described by a matching map, which clarifies the influence of various factors on the propagation of the downstream distortion. It is shown that the spacing between the compressor and the downstream distorting component has an influence of exponential type on the distortion at every axial position. The variation of the distortion with distortion coefficient is basically linear. O.G.

A91-44627#
AN INVESTIGATION OF THE DYNAMIC CHARACTERISTIC OF AXIAL FLOW COMPRESSORS
GUO-CAI TANG, BING HU, and HUI-MING ZHANG (Nanjing Aeronautical Institute, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-210)

The dynamic behavior of an axial flow compressor has been investigated when the flow rate is forced to vary quickly. It is found that there is a deviation of the dynamic characteristic from the steady-state one, depending upon the algebraic sum of the inertial effect and the lag effect. For the lightly loaded axial flow compressor, the dynamic characteristic exceeds the steady-state one when the valve is closed and falls below the steady-state one when the valve is opened. It is shown that the rapid closing of the valve results in an operating point end dynamic breaking into the instability limit, and the rapid opening of the valve may cause an initial transient decrease in flow rate. O.G.

A91-44639#
AN ENGINE DEMONSTRATION OF ACTIVE SURGE CONTROL
J. E. F. WILLIAMS and W. R. GRAHAM (Topexpress, Ltd., Cambridge, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 13 p. refs
(Contract N00014-87-J-1214)
(ASME PAPER 90-GT-224)

The unsteady behavior of a gas turbine engine has been investigated and the implementation on it of an active surge suppressor according to the strategy proposed by Epstein et al. (1986) has been tested. The results of the feedback control on unsteady pressure levels in the engine during steady operation indicate that the optimal controller must be broadband at least to the extent that it has a neutral effect on the engine. Transient fueling experiments show that violent surge activity in a gas turbine

can be suppressed by the action of an active controller. A theoretical model points to eventual extension of the safe operating range. O.G.

A91-44640#
ANALYSIS OF EXPERIMENTAL TIME-DEPENDENT BLADE SURFACE PRESSURES FROM AN OSCILLATING TURBINE CASCADE WITH THE INFLUENCE-COEFFICIENT TECHNIQUE
T. H. FRANSSON (Lausanne, Ecole Polytechnique Federale, Switzerland) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. Research sponsored by Ansaldo Componenti S.p.A. and Franco Tosi Industriale S.p.A. refs
(ASME PAPER 90-GT-225)

A 2-D section of the last stage of a steam turbine has been investigated experimentally in an annular nonrotating cascade facility as regards its time-dependent and steady-state aerodynamic characteristics at design and off-design conditions. The unsteady experimental data obtained with the blades vibrating in the 'travelling wave' mode suggest that one of the main reasons for the flutter susceptibility of the cascade are in the high expansion and subsequent shock wave close to the blade suction surface leading edge and the corresponding high unsteady loading. The decomposition of the experimental data into unsteady aerodynamic influence coefficients validates this conclusion. Another reason for the flutter susceptibility is that the cascade is overlapped for a part of the blade surface where the local flow velocities are nearly sonic. R.E.P.

A91-44652#
CT7-6 - THE MOST RECENT T700 GROWTH DERIVATIVE ENGINE
P. L. KASTRINELIS and W. E. LIGHTFOOT (GE Aircraft Engines, Lynn, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-241)

The evolution of the CT7-6 engine is traced and the technological enhancements which were incorporated to make it the most powerful member of the T700/CT7 family are discussed. A description is provided of the synergism in the design and test phase of the CT7-6, which resulted from the derivative approach in combination with an integrated development program that simultaneously qualified and certified four T700/CT7 engine models. The initial operator experience with the CT7-6 in a unique new European aircraft, the EH 101 helicopter, is reviewed. Innovations incorporated into the T700 include: a flared inlet to the stage 1 compressor, which increased airflow by 3 percent; an increase in turbine operating temperature by approximately 50 F; improved stage-1 turbine blade cooling through the addition of turbulators to the leading edge cooling hole; improved material for the stage 1 shroud, from the Bradelloy filled honeycomb to solid NiCrAlY. P.D.

A91-44653#
T407/GLC38 - 'A MODERN TECHNOLOGY POWERPLANT'
MICHAEL J. ZOCCOLI (Textron Lycoming, Stratford, CT) and DAVID D. KLASSEN (GE Aircraft Engines, Lynn, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-242)

The key features of the T407/GLC38 engine design, performance, and development program are described. Design modifications were made to increase low-cycle-fatigue calculated service life to 30,000 cycles, and verification demonstration accelerated simulated mission engine testing equivalent to 3000 hours of field operation was added to the development program. The engine's modularity features include module replacement capability with a minimum of tools, without any required adjusting or rigging and without disturbing or exposing oil-wetted areas. Design durability efforts resulted in elimination of titanium from all flowpaths and other potential fire areas, increased resistance to ingestion problems involving ice, birds, and water, and increased hardening to flameout. New features include hot start prevention, power management, and automatic flameout relight. The engine power unit is sized to deliver a minimum of 5160 shp input to the propeller gearbox, at a nominal output speed of 15,000 rpm for ambient temperatures up to 84 F. P.D.

A91-44654#
DERIVATIVE T406 BASED TURBOFANS FOR ADVANCED TRAINERS
R. E. RIFFEL and T. F. MCKAIN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 5 p.
(ASME PAPER 90-GT-243)

The potential trainer-applicable turbofan/turbojet derivatives of the T406-AD-400 turboshaft engine being developed for the V-22 Osprey are examined. An overview and the current status of the engine development program are followed by an evaluation of potential turbofan/turbojet derivatives of the T406 core as applicable to advanced trainer needs. The core size is shown to be desirable for the full range of anticipated trainer needs. Alternative applications, both military and commercial, of the T406 core are included to highlight its large potential production and operational base which would greatly enhance its desirability for trainer application. The benefits derived by a large production and operational base are increased maturity, improved durability, reduced risk, and lower production cost. P.D.

A91-44656#
T406 ENGINE DEVELOPMENT PROGRAM
JOHN R. ARVIN and MARK E. BOWMAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p.
(ASME PAPER 90-GT-245)

The present study discusses the T406 engine, a 6000-hp class turboshaft front-drive free-turbine engine being developed under U.S. Navy contract to power the V-22 Osprey V/STOL aircraft. A comprehensive engine description is given, with emphasis on the engine rating and design, compressor, diffuser combustor, gas generator turbine, power turbine, main power shafting, and lube and vent system. Produced under the T406 full-scale development program, the engine was found to provide the performance and durability necessary to conduct the V-22 flight test program. The engine is halfway through the development program and, based on results to date, is ready for the production of V-22 aircraft. The engine has substantial margin for future growth beyond the first production configuration now under development, as is shown by the high power/weight ratio which was demonstrated. P.D.

A91-44658#
DESIGN OF SHROUD INTERFACE-ANGLE TO MINIMIZE THE FORCED VIBRATION OF BLADES
J. H. WANG (National Tsing Hua University, Hsinchu, Republic of China) and H. L. YAU ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-247)

The blades with integral shrouds have been used widely in industry. The blades are brought together via the contact of shroud interfaces. Because the angle of shroud interface can alter the damping of the interfaces and the coupling effect among the blades, knowing how to design the shroud angle is important. In this work, the theoretical shroud model was first verified experimentally, and then used to investigate the effect of shroud angle on the resonant responses excited by wake flow. The results show that a small shroud angle is superior than large shroud angle to minimize the resonant vibration. However, a critical static interface preload should be selected to avoid the weak coupling effect. Author

A91-44672#
GENERALIZED HIGH SPEED SIMULATION OF GAS TURBINE ENGINES

NANAHISA SUGIYAMA (National Aerospace Laboratory, Chofu, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-270)

This paper describes a real-time or faster-than-real-time simulation of gas turbine engines, using an ultra high speed, multiprocessor digital computer, designated the AD100. It is shown that the frame time is reduced significantly without any loss of fidelity of a simulation. The simulation program is aimed at a high degree of flexibility to allow changes in engine configuration. This makes it possible to simulate various types of gas turbine engines, including jet engines, gas turbine for vehicles and power plants, in real-time. Some simulation results for an intercooled-reheat type industrial gas turbine are shown. Author

A91-44673#
CONSIDERATIONS FOR THE USE OF VARIABLE GEOMETRY IN GAS TURBINES
J. E. A. ROY-AIKINS (Cranfield, Institute of Technology, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-271)

Future gains in gas turbine performance will depend in part on novel control methods which can influence the position of the engine operating point. Among such methods is the use of variable geometry in one or more gas path components, in order to improve the internal matching of a component or to rematch the engine cycle so that either the component operating point and/or the primary cycle performance variables are reoptimized with changing operating conditions. The performance improvement obtained may take the form of reduced fuel comsumption, higher thrust, superior controllability over a given aircraft envelope, or a combination of these. O.C.

A91-44678#
EFFECTS OF GAS TURBINE COMBUSTOR GEOMETRY VARIATION ON POLLUTANT EMISSION USING A MULTI-ANNULAR, TELESCOPIC, SWIRL COMBUSTOR
VAHID MOTEVALLI (Worcester Polytechnic Institute, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(ASME PAPER 90-GT-280)

A variable geometry swirl combustor, consisting of four concentric annuli was used to examine the effect of combustor geometry variation on pollutant emission. All annuli, except the central one, were equipped with vane-type swirl generators. Natural gas was used as the fuel. Air and fuel were introduced alternatively into the combustor annuli with the central annulus carrying the fuel. Species concentration measurements using gas chromatography, temperature measurements and NO(x) gas analysis were conducted to evaluate the combustor performance. Detailed species and temperature measurements were obtained over a radial distance of 1.5 times the combustor exit radius and up to 2.5 diameters downstream of the combustor. A total swirl number for the combustor was determined from a theoretical formulation. It is shown here that finer control of the local equivalence ratio and air/fuel mixing may be achieved, yielding optimal combustion efficiencies and low pollutant emission, via variation of the combustor geometry. Author

A91-44681#
THE ROLLS-ROYCE/TURBOMECA ADOUR - THE OPTIMUM TRAINER ENGINE
MICHAEL FERGUSON (Rolls-Royce, Inc., Washington, DC) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p.
(ASME PAPER 90-GT-295)

The evolution and current status of the Rolls-Royce/Turbomeca Adour turbofan engine are reviewed, and the immediate future of the Adour family is examined. The Adour engine cycle was chosen to meet the requirements of ground attack and advanced training. A low bypass ratio or 0.75 to 1 was selected to combine a small frontal area with the good fuel economy of the turbofan, and to provide the capability for substantial thrust increases through afterburning. The traditional turbofan thrust lapse rate with altitude is minimized at this bypass ratio, providing good climb performance. Adour's two-stage low-pressure (LP) compressor is driven by a single-stage LP turbine, and the five-stage high-pressure (HP) compressor is driven by a single-stage HP turbine with air-cooled blades. There are no inlet guide vanes or variable stator vanes. The characteristics of the nonafterburning Adour for the BAe Hawk are presented as well. P.D.

A91-44682#
WHY AN ENGINE AIR PARTICLE SEPARATOR (EAPS)?
JOE T. POTTS, JR. (U.S. Army, Aviation Div., Alexandria, VA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-297)

The way in which an engine air particle separator (EAPS) removes contaminant particles before they enter the gas turbine engine is described. Contaminated air entering an EAPS is sent through a swirling motion induced by the vortex generator. This motion causes the heavier dirt particles and water droplets to be thrown radially outward by centrifugal force so that they may be scavenged from the engine air intake. The EAPS eliminates compressor erosion and reduces dust ingestion to the turbine to a level at which it no longer causes problems. It also works in an icing and snow environment without the aid of antiicing devices such as hot air or electricity. Test results are reported of helicopters with and without EAPS, and the steps necessary to design an EAPS for various air vehicles and engines are described. P.D.

A91-44690#
CERAMIC SMALL GAS TURBINE TECHNOLOGY DEMONSTRATOR
TIBOR BORNEMISZA (Sundstrand Power Systems, San Diego, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-306)

The present study discusses the design approach to, and the preliminary tests with, the T-20G10 Gemini gas turbine with metallic turbine components. The ceramic engine was designed to operate at a rated turbine inlet temperature of 2200 F, which is 400 F higher than the maximum operating temperature of the metallic engine. The radial inflow turbine wheel with 13 integrally cast blades had a tip diameter of 4.4 inches resulting in a moderate (1800 ft/s) tip speed. The thermal shock capability of the ceramic hardware enabled extremely fast engine starts using the standard Gemini electric starter. The fast starts were achieved by modifications to the existing fuel control system which allowed for the injection of the fuel at very low speed during engine starts. Fluorescent penetrant inspection and microscopic survey of the ceramic components revealed no cracks or surface damage to the ceramic hardware, and dimensional inspection revealed no discrepancies. P.D.

A91-44700#
ACCELERATED MISSION TESTS AND RELIABILITY IMPROVEMENT OF F3-30 ENGINE
HIDEAKI YANAGIHARA (Air Self-Defence Force, Tokyo, Japan) and AKIRA TATENO (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-322)

F3-30 is the low-bypass-ratio turbofan engine which has been developed to power the T-4 intermediate trainer for the Japan Air Self Defence Force (JASDF). The qualification tests of the engine were successfully completed in March, 1986, and the actual field service was started in September, 1988. Before the start of the actual use, accelerated mission tests (AMTs) were conducted for the purpose of finding deficiencies which would occur in the actual mission usage, and verifying the time between overhaul (TBO) of

the initial service. This paper describes the test method, the results, and the evaluation for them. Also it presents current status and basic ideas for the future reliability improvement of the F3-30 engine. Author

A91-44702#
ACTIVE CONTROL APPLICATION TO A MODEL GAS TURBINE COMBUSTOR
J. BROUWER, B. A. AULT, J. E. BOBROW, and G. S. SAMUELSEN (California, University, Irvine) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-326)

Closed-loop feedback control, developed in a axisymmetric can combustor, is demonstrated in a model can combustor with discrete wall jets. The study represents the initial steps toward the application of feedback control technology to practical gas turbine combustion systems. For the present application, the radiative flux from soot particulate is used as an indication of combustor performance, and nozzle atomizing air is selected as the input parameter. A measurement of radiative flux at the exit plane of the combustor is conveyed to a control computer which invokes an optimization algorithm to determine changes in the dome region necessary to minimize the radiative flux from soot. The results demonstrate the utility and potential of active control for maintaining optimal performance in real-time. Author

A91-44714#
AERO-THERMAL PERFORMANCE OF A TWO DIMENSIONAL HIGHLY LOADED TRANSONIC TURBINE NOZZLE GUIDE VANE - A TEST CASE FOR INVISCID AND VISCOUS FLOW COMPUTATIONS
TONY ARTS and MURIEL LAMBERT DE ROUVROIT (von Karman Institute for Fluid Dynamics, Rhode-Saint-Genese, Belgium) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-358)

This contribution deals with an experimental aero-thermal investigation around a highly loaded transonic turbine nozzle guide vane mounted in a linear cascade arrangement. The measurements were performed in the von Karman Institute short duration Isentropic Light Piston Compression Tube facility allowing a correct simulation of Mach and Reynolds numbers as well as of the gas to wall temperature ratio compared to the values currently observed in modern aero engines. The experimental program consisted of flow periodicity checks by means of wall static pressure measurements and Schlieren flow visualizations, blade velocity distribution measurements by means of static pressure tappings, blade convective heat transfer measurements by means of platinum thin films, downstream loss coefficient and exit flow angle determinations by using a new fast traversing mechanism and freestream turbulence intensity and spectrum measurements. These different measurements were performed for several combinations of the freestream flow parameters looking at the relative effects on the aerodynamic blade performance and blade convective heat transfer of Mach number, Reynolds number and freestream turbulence intensity. Author

A91-44717#
COMPARISON OF INVISCID COMPUTATIONS WITH THEORY AND EXPERIMENT IN VIBRATING TRANSONIC COMPRESSOR CASCADES
G. A. GEROLYMOS (Paris VI, Universite, France), H. QUINIOU (SNECMA, Centre de Villaroche, Moissy-Cramayel, France), and E. BLIN ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 16 p. refs
(ASME PAPER 90-GT-373)

The prediction of unsteady flow in vibrating transonic cascades is essential in assessing the aeroelastic stability of fans and compressors. In the present work an existing computational code, based on the numerical integration of the unsteady Euler equations, in blade-to-blade surface formulation, is validated by comparison with available theoretical and experimental results. Comparison with the flat plate theory of Verdon is, globally, satisfactory. Nevertheless, the computational results do not exhibit any particular behavior at acoustic resonance. The use of a 1D nonreflecting boundary condition does not significantly alter the results. Comparison of the computational method with experimental data from started and unstarted supersonic flows, with strong shock waves, reveals that, notwithstanding the globally satisfactory performance of the method, viscous effects are prominent at the shock wave/boundary layer interaction regions, where boundary layer separation introduces a pressure harmonic phase shift, which is not predicted by inviscid methods. Author

A91-44718#
THE ROLE FOR EXPERT SYSTEMS IN COMMERCIAL GAS TURBINE ENGINE MONITORING
DAVID L. DOEL (GE Aircraft Engines, Evendale, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-374)

A review is presented of current progress in commercial gas turbine engine condition monitoring and areas where AI and other advanced techniques could produce substantive gains are discussed. Attention is given to commercial engine condition monitoring software, on-the-wing modular performance analysis and trim balance, exhaust gas temperature margin trending, and vibration trending. Consideration is given to several features that contribute to a computer aided monitoring and maintenance system, e.g., data base and plot software, trend recognition and alerts, fleet average function, and integrating expert systems with jet engine health monitoring. R.E.P.

A91-44719#
GAS TURBINE COMPONENT FAULT IDENTIFICATION BY MEANS OF ADAPTIVE PERFORMANCE MODELING
A. STAMATIS, K. MATHIOUDAKIS, K. PAPAILIOU (Athens, National Technical University, Greece), and M. SMITH (Ruston Gas Turbines, Ltd., Lincoln, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. Research supported by Hellenic General Secretariat for Research and Technology and EEC. refs
(ASME PAPER 90-GT-376)

The method of adaptive modeling of gas turbine performance, proposed previously by the authors, is finding a new application in component fault detection. An appropriate choice of component characteristic parameters gives the possibility of characterizing their 'health condition', by appropriate processing of selected measured quantities according to the principles of adaptive modeling. Both a general deterioration of components and identification (kind, location) of component faults can be achieved. The proposed methodology is presented together with an experimental investigation of gas turbine faults. A commercial Gas Turbine has been used as a test vehicle and various kinds of faults have been implanted. An analysis of the results of the investigation provides information about the influence of the occurrence of such faults on engine performance. On the other hand, these data provide a basis for demonstrating the capabilities of the above mentioned methodology, as a powerful tool for diagnostic applications. Author

A91-44721#
TFE1042 - A NEW LOW BYPASS RATIO ENGINE
A. R. FINKELSTEIN (International Turbine Engine Corp., Phoenix, AZ) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 4 p.
(ASME PAPER 90-GT-385)

The paper describes the design and the development program of TFE1042, a new low-bypass-ratio afterburning engine for light-weight fighters and high-performance trainers of 1990s and beyond. The engine is rugged, compact, durable, and easily maintained. The development testing reached 5000 hrs during 1987, and the initial flight-release official tests were successfully

completed in 1988. The TFE1042 was selected to power the Republic of China Indigenous Defensive Fighter (IDF). Flight testing of the IDF aircraft started in 1989. I.S.

A91-44722#
PROBLEMS AND USE OF THE SCALING FACTORS IN THE NUMERICAL SIMULATION OF JET ENGINES
G. TORELLA (Accademia Aeronautica, Pozzuoli, Italy) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-386)

The use of scaling factors in the numerical simulation of jet engines is considered, demonstrating that the scaling factors technique is a powerful and flexible tool for many design and maintenance activities of gas turbine engines. It is shown that, by using the scaling factors technique, trend analyses may be successfully simulated, the matrices of influence can be calculated, and the component map shifting during the operational life of the engine can be evaluated. Results are presented on the effect of the use of scaling factors on the compressor maps. I.S.

A91-44727#
ADAPTATION OF A SMALL COMMERCIAL FAN JET TRAINER FOR MILITARY APPLICATIONS
D. I. BOYD (Pratt and Whitney Canada, Longueuil) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p.
(ASME PAPER 90-GT-391)

The paper examines the characteristics of the design features of a small commercial fan jet trainer JT15D-4 that made it possible to convert the conversion of this commercial trainer to the military combat trainer role, and discusses the associated development program. Particular attention is given to the specially designed test facility constructed to simulate aerobatic flight conditions. Results of field tests of a single-engine trainer application are described. I.S.

A91-45326*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TRANSIENT FLOW THRUST PREDICTION FOR AN EJECTOR PROPULSION CONCEPT
COLIN K. DRUMMOND (NASA, Lewis Research Center, Cleveland, OH) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 465, 466. Abridged. Previously cited in issue 21, p. 3272, Accession no. A89-49688. refs

A91-45343#
OPTIMUM GEOMETRIES FOR SCARFED PERFECT NOZZLES
JAY S. LILLEY (U.S. Army, Missile Command, Redstone Arsenal, AL) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 586-592. refs

The results of an investigation to determine the optimum geometry for length constrained scarfed nozzles employing perfect expansion contours is presented. A scarfed perfect nozzle performance analysis, based on an axisymmetric flowfield model and utilizing the method of characteristics solution technique, was developed. The performance model was utilized in an optimization procedure to determine, for a range of nozzle projected lengths, the optimum set of scarfed perfect nozzle geometries. For each projected length, the respective optimum nozzle geometry was selected to maximize motor axial thrust coefficient. The set of optimum scarfed nozzle geometries was compared against optimum length constrained scarfed nozzles employing conical expansion contours. The optimum scarfed perfect nozzle geometries generated by this investigation were specifically produced for utilization in a design methodology developed to minimize the length of tactical solid propellant propulsion systems. Used in conjunction with the design methodology, the results of the present investigation provide the designer with a means of further reducing propulsion system length. Author

A91-45344*# Rockwell International Corp., Canoga Park, CA.
PANEL METHOD FOR COUNTER-ROTATING PROPFANS
SHIH H. CHEN (Rockwell International Corp., Canoga Park, CA) and MARC H. WILLIAMS (Purdue University, West Lafayette, IN) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 593-601. Previously cited in issue 20, p. 3156, Accession no. A87-45279. refs
(Contract NAG3-499)

A91-45392#
ENGINE POWER INFLUENCED BY VERTICAL TIP WINGS AT ROTOR BLADES
P. PSAROUDAKIS (Pisa, Universita, Italy) and L. F. J. DE GROOT European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 14 p. refs

Vertical wings placed at each tip of the main-rotor blades are proposed in order to reduce helicopter-engine power requirements. The relationship between the aerodynamic characteristics of such vertical tip wings (VTW) and the ratio of the peripheral velocity at the rotor tip to the free flight velocity, peripheral position, and ratio of the rotor-blade radius to a VTW chord are investigated theoretically and numerically. It is noted that the use of the wings is beneficial for rotors with more than two blades and only during the flight. Further investigation into the shape of the wings, interference between them and rotor blades, flow transonic effect, and unsteady phenomena is suggested. V.T.

A91-45409#
COMPUTATIONAL FLUID DYNAMICS 3-D ANALYSIS FOR ADVANCED TRANSONIC TURBINE DESIGN
S. COLANTUONI, A. COLELLA, and G. SANTORIELLO (Alfa Romeo Avio S.p.A., Naples, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 28 p. Previously announced in STAR as N90-26291. refs

An overview of the most significant applications of the computational fluid dynamics three-dimensional inviscid method to the analysis of an existing transonic turbine stage is presented. The comparison between numerical results and the first experimental detailed measurements are discussed. The flowfield in the exit plane, obtained by a laser anemometry system on a cold air turbine rig, is analyzed. Author

A91-45410#
THE PW200 ENGINE DESIGN FOCUS ON RELIABILITY AND MAINTAINABILITY
G. J. BROWN and G. M. HOGG (Pratt and Whitney Canada, Longueuil) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p.

The PW200 is a small free turbine, turboshaft engine in the 600 SHP class. This paper begins by describing the engine, then traces the design philosophies employed to ensure it meets high reliability targets coupled with competitive performance and cost effective maintainability. Lessons learned from experience and operator feedback are discussed, followed by a more detailed review of the maintenance aspects, accessibility features and operational procedures. A brief review of the first engine installation, the PW205B, in the MBB 105 LS helicopter is also provided.
Author

A91-45411#
MTR390 - A NEW GENERATION TURBOSHAFT ENGINE
K. TRAPPMANN (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany), J. S. DUCOS (Turbomeca, Bordes, France), and A. R. SANDERSON (Rolls-Royce, PLC, Leavesden, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. refs

A turboshaft engine in the 1000 kW range designed for an antitank and support helicopter is presented. The functional and economic requirements the engine has to meet are outlined, and the engine design including its thermodynamic cycle, architecture, engine control and monitoring system, maintainability, component

design and technology, and gear system is described. Attention is focused on the combustion chamber, compressor turbine, and power turbine. It is pointed out that the engine configuration chosen is particularly suitable for nap-of-the-earth maneuverability and survivability in hostile battlefield environments. The program status is reviewed, and it is noted that a flying test-bed program will commence in late 1990 to confirm handling and performance characteristics. V.T.

A91-45462#
FLOW AND TEMPERATURE FIELD COMPUTATIONS IN COOLING LINERS OF AIRCRAFT ENGINE EXHAUST NOZZLES
ANIL K. TOLPADI (GE Research and Development Center, Schenectady, NY) ASME 1991 National Heat Transfer Conference, Minneapolis, MN, July 28-31, 1991. 6 p. GE Aircraft Engines-sponsored research. refs
(AIAA PAPER 91-4008) Copyright

Calculations are performed for the flow and temperature field in the linear cavity of an exhaust nozzle by utilizing a viscous two-dimensional fully elliptic body-fitted CFD code based on a pressure correction technique and modified to have an extended capability of performing depth-averaged calculations. Linear configurations including film holes through which the coolant enters the main hot gas path, blockages in the cavity such as struts, and partial blockages such as turbulators, fins, and hangars are considered. The velocity and temperature distributions obtained are shown to indicate that the coolant temperature is lowered when there is a film-cooling hole and increased behind the blockage. V.T.

A91-45780*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A LINEAR CONTROL DESIGN STRUCTURE TO MAINTAIN LOOP PROPERTIES DURING LIMIT OPERATION IN A MULTI-NOZZLE TURBOFAN ENGINE
DUANE MATTERN (NASA; Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Brook Park, OH) and PETER OUZTS (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 10 p. refs
(AIAA PAPER 91-1997) Copyright

The implementation of multi-variable control systems on turbofan engines requires the use of limit protection to maintain safe engine operation. Since a turbofan engine typically encounters limits during transient operation, the use of a limit protection scheme that modifies the feedback loop may void the desired 'guarantees' associated with linear multi-variable control design methods, necessitating considerable simulation to validate the control with limit protection. An alternative control design structure is proposed that maintains the desired linear feedback properties when certain safety limits are encountered by moving the limit protection scheme outside of the feedback loop. This proposed structure is compared to a structure with a limit protection scheme that modifies the feedback loop properties. The two design structures are compared using both linear and nonlinear simulations. The evaluation emphasizes responses where the fan surge margin limit is encountered. Author

A91-45782*# Maine Univ., Orono.
THREE-DIMENSIONAL CALCULATION OF THE MIXING OF RADIAL JETS FROM SLANTED SLOTS WITH A REACTIVE CYLINDRICAL CROSSFLOW
N. S. WINOWICH (Maine, University, Orono), H. L. NGUYEN (NASA, Lewis Research Center, Cleveland, OH), and S. A. MOEYKENS AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 12 p. refs
(Contract NAG3-1115)
(AIAA PAPER 91-2081) Copyright

A numerical model that calculates the 3D chemically reacting flowfield in an experimental low emission combustor is described. The ICEd-ALE finite volume computational methodology is employed in this study. Radial jets issuing from slanted slots interact with a cylindrical axially flowing mainstream to produce a bulk swirl velocity downstream of the slot region. The swirl pattern at a given axial station is composed of a clockwise rotating region near the wall and a counterclockwise rotating region extending from the combustor centerline. The jet radial penetration and downstream swirl velocity axial development are shown to depend principally on the jet-to-mainstream momentum flux ratio. R.E.P.

A91-45788*# Pratt and Whitney Aircraft Group, West Palm Beach, FL.
DESIGN AND EXPERIMENTAL EVALUATION OF COMPACT RADIAL-INFLOW TURBINES
A. J. FREDMONSKI, F. W. HUBER (Pratt and Whitney Group, West Palm Beach, FL), R. J. ROELKE (NASA, Lewis Research Center, Cleveland, OH), and S. SIMONYI (Sverdrup Technology, Inc., Brook Park, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 12 p. refs
(AIAA PAPER 91-2127) Copyright

The application of a multistage 3D Euler solver to the aerodynamic design of two compact radial-inflow turbines is presented, along with experimental results evaluating and validating the designs. The objectives of the program were to design, fabricate, and rig test compact radial-inflow turbines with equal or better efficiency relative to conventional designs, while having 40 percent less rotor length than current traditionally-sized radial turbines. The approach to achieving these objectives was to apply a calibrated 3D multistage Euler code to accurately predict and control the high rotor flow passage velocities and high aerodynamic loadings resulting from the reduction in rotor length. A comparison of the advanced compact designs to current state-of-the-art configurations is presented. Author

A91-45789*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARISON OF A QUASI-3D ANALYSIS AND EXPERIMENTAL PERFORMANCE FOR THREE COMPACT RADIAL TURBINES
P. S. SIMONYI (NASA, Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Brook Park, OH) and R. J. BOYLE (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 14 p. refs
(Contract NAS3-25266)
(AIAA PAPER 91-2128)

An experimental aerodynamic evaluation of three compact radial turbine builds was performed. Two rotors which were 40-50 percent shorter in axial length than conventional state-of-the-art radial rotors were tested. A single nozzle design was used. One rotor was tested with the nozzle at two stagger angle settings. A second rotor was tested with the nozzle in only the closed down setting. Experimental results were compared to predicted results from a quasi-3D inviscid and boundary layer analysis, called MTSB (Meridl/Tsonic/Blayer). This analysis was used to predict turbine performance. It has previously been calibrated only for axial, not radial, turbomachinery. The predicted and measured efficiencies were compared at the design point for the three turbines. At the design points the analysis overpredicted the efficiency by less than 1.7 points. Comparisons were also made at off-design operating points. The results of these comparisons showed the importance of an accurate clearance model for efficiency predictions and also that there are deficiencies in the incidence loss model used. Author

A91-45791*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL AND ANALYTICAL STUDIES OF FLOW THROUGH A VENTRAL AND AXIAL EXHAUST NOZZLE SYSTEM FOR STOVL AIRCRAFT
BARBARA S. ESKER (NASA, Lewis Research Center, Cleveland, OH) and JAMES R. DEBONIS (NASA, Lewis Research Center, Cleveland; Sverdrup Technology, Inc., Brook Park, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th,

Sacramento, CA, June 24-26, 1991. 20 p. Previously announced in STAR as N91-25175. refs
(AIAA PAPER 91-2135) Copyright

Flow through a combined ventral and axial exhaust nozzle system was studied experimentally and analytically. The work is part of an ongoing propulsion technology effort at NASA Lewis Research Center for short takeoff, vertical landing (STOVL) aircraft. The experimental investigation was done on the NASA Lewis Powered Lift Facility. The experiment consisted of performance testing over a range of tailpipe pressure ratios from 1 to 3.2 and flow visualization. The analytical investigation consisted of modeling the same configuration and solving for the flow using the PARC3D computational fluid dynamics program. The comparison of experimental and analytical results was very good. The ventral nozzle performance coefficients obtained from both the experimental and analytical studies agreed within 1.2 percent. The net horizontal thrust of the nozzle system contained a significant reverse thrust component created by the flow overturning in the ventral duct. This component resulted in a low net horizontal thrust coefficient. The experimental and analytical studies showed very good agreement in the internal flow patterns. Author

A91-45799*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ANALYTICAL COMBUSTION/EMISSIONS RESEARCH RELATED TO THE NASA HIGH-SPEED RESEARCH PROGRAM
H. L. NGUYEN (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 18 p. refs
(AIAA PAPER 91-2252) Copyright

A combustion analysis program aimed at upgrading and applying advanced computer programs for gas turbine applications is discussed. 2D and 3D codes, KIVA-II and LeRC-3D, have been used to provide insight into the combustion process and combustor design. The computations performed through these codes show their capability to produce reasonable results, despite such deficiencies in the current models as accurate chemical kinetics modeling of hydrocarbon combustion and turbulence and turbulence combustion interaction modeling. O.G.

A91-45800*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROGRESS TOWARD SYNERGISTIC HYPERMIXING NOZZLES
D. O. DAVIS and W. R. HINGST (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 10 p. refs
(AIAA PAPER 91-2264) Copyright

Mean flow measurements have been obtained for air-to-air mixing downstream of swept and unswept ramp wall-mounted hypermixing nozzle configurations. Aside from the sweep of the ramps, the two nozzle configurations investigated are identical. The nozzles inject three parallel supersonic jets at a 15-deg angle (relative to the wind tunnel wall) into a supersonic freestream. Mach number and volume fraction distributions in a transverse plane 11.1 nozzle heights downstream from the nozzle exit plane were measured. Data are presented for a freestream Mach number of three at a matched static pressure condition and also at an underexpanded static pressure condition (pressure ratio equal to 5). Surface oil flow visualization was used to investigate the near-wall flow behavior. The results indicate that the swept ramp injectors produce stronger and larger vortex pairs than the unswept ramp injectors. The increased interaction between the swept ramp model's larger vortex pairs yields better mixing characteristics for this model. Author

A91-46070
DEPOSIT FORMATION IN FLIGHT ENGINES. III - BEGINNING OF FORMATION [ABLAGERUNGEN IN FLUGTRIEBWERKEN. III - BEGINN DER BILDUNG]
E. JANTZEN, B. KOCH (DLR, Stuttgart, Federal Republic of Germany), and K. MAIER (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 15, June 1991, p. 165-170. In German. refs
Copyright

Research on the beginning of deposit formation in flight engines is discussed. Findings concerning the effect of temperature oil film thickness, oxygen concentration in the air, oil type, and changes in the oil on the initiation of deposit formation are reviewed. The effects of oil volatilization and variations in oil viscosity, additives, and composition on deposit formation are considered. C.D.

A91-46153#
APPLICATION OF TANDEM BLADES TO AN AEROENGINE
HOUWU MIAO, JINMAN GAO, and JIE GUO (Shenyang Aeronautical Research Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 203-206. In Chinese. refs

An aeroengine was modified by developing a set of tandem blades with a BC-6 profile, and the advantages of the tandem blades were demonstrated in tests conducted in a cascade wind tunnel at a compressor test stand and on an engine bed. The cascade-test data showed that the total pressure loss coefficient for tandem blades was less than for a single row of blades (0.0305 vs 0.0348, respectively) at the same design conditions, the range of the efficient incidence angle for tandem blades was 31.2 percent larger than for single-row blades, and the adiabatic efficiency was higher by 1.3 percent. The paper discusses the selection of the tandem blade parameters and the way of obtaining the optimum axial and tangential distances between the two rows of the tandem cascade from test data. The feasibility of using tandem blades in an aeroengine to expand its range of stable operation is discussed. I.S.

A91-46156#
EXPERIMENTAL INVESTIGATION OF A SMALL TWO-STAGE TRANSONIC AXIAL COMPRESSOR
LIANGMING LI (Nanhua Power Plant Research Institute, Zhuzhou, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 216-218. In Chinese. refs

A small-dimension two-stage transonic axial compressor has been designed with blade tip velocity 436 m/s and design revolution 45,000 r/min. Its tests have been carried out to investigate the performance of this compressor. It is shown that its performance attains or exceeds its design specifications. This paper also considers the effects of radial and axial clearances, probe blockage, step matching, and measuring techniques on the performance of the compressor. Author

A91-46165#
DIGITAL REAL-TIME SIMULATION OF A TWIN-SPOOL TURBOJET
SHANGMING LIU, XUEYU WANG, and XINGJIAN ZHU (Beijing University of Aeronautics and Astronautics, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 254-258. In Chinese. refs

A digital real-time simulation by means of single microcomputer has been developed for an actual two-spool afterburning turbojet engine. In order to overcome the contradiction between the computation precision and the speed necessary to digital real-time simulation technique, the characteristics of engine components have been reasonably simplified and modified and 80286 macroassembly, 80287 float arithmetic parallel processing method, and some programming techniques have been adopted. A nonlinear, large-deviation digital real-time simulation has been obtained. The results of this simulation are compared with the measured data. It is shown that its calculation accuracy and speed are suitable for the real-time simulation. Author

A91-46166#
DESIGN AND EXPERIMENTAL STUDY OF A COMBINED PILOT FLAMEHOLDER
QIUFANG CHENG (Shenyang Aeroengine Research Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 259-262. In Chinese. refs

The design and experimental study of a combined pilot flameholder is presented for a turbofan engine afterburner with an annular mixer. The combined pilot flameholder is composed of a main ingestion gutter ring with corrugated slots and radial finger gutters with ingestion holes. The 2D and double-stream flow visualization tests of its reduced-scale model demonstrate the flow pattern behind the flameholder, and also reveal the reason why the annular pilot burner can ignite and support the bypass flow flame. Its sector rig tests and engine bed tests show that the afterburners with this kind of flameholder possess enhanced combustion efficiency, improved combustion stability, and reduced pressure loss at both normal and low pressures. Author

A91-46168#
AN EXPERIMENTAL INVESTIGATION OF HYDROGEN-AIR SUPERSONIC COMBUSTION
LING LIU, ZHENG ZHANG, MING TANG (Northwestern Polytechnical University, Xian, People's Republic of China), JINGHUA LIU, LIXING YANG (31st Research Institute, People's Republic of China) et al. Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 267-270. In Chinese. refs

Results are presented on tests on a hydrogen-fueled supersonic combustor, conducted with arc-heated air at inlet Mach number 2.1, total temperature 2100 K, and total pressure 700,000 Pa. The axisymmetric combustor with a 4.6-cm inner diameter inlet was tested with hydrogen injected either normally or in parallel to the air stream, from a ring of equally spaced holes in the wall. The total pressure profiles were measured by a pressure probe rake just downstream of the combustor exit. The results of flow analysis showed that the combustion efficiency of the transverse injection ahead of a rearward facing step was higher than it was behind it, and that the combustion efficiency of transverse injection was higher than that of the downstream injection. The total pressure flow was maximal in the case of transverse injection ahead of a rearward facing step and was minimal in the case of parallel injection. I.S.

A91-46598#
THE DEVELOPMENT OF THE FJR710 TURBOFAN ENGINE AND ITS OPERATION WITH THE STOL RESEARCH AIRCRAFT ASUKA
HIROYUKI NOUSE, MITSUO MORITA, and MAKOTO SASAKI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 438, 1990, p. 333-341. In Japanese. refs

A91-46621#
STUDY ON AFTERBURNER OF AIRCRAFT ENGINE
TAKESHI KASHIWAGI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 31, March 1991, p. 109-114. In Japanese. refs

Studies of afterburners have been performed which reveal that mixing spray fuel injection type with injection of a small amount of fuel into the flameholder wake results in broadening of the combustible region. Use of a flameholder with scoop and double gutters causes high combustion efficiency. A prototype afterburner for an F3 turbofan engine was designed and its performance was tested. C.D.

N91-27159*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECT OF TABS ON THE EVOLUTION OF AN AXISYMMETRIC JET
K. B. M. Q. ZAMAN, M. SAMIMY, and M. F. REEDER (Ohio State Univ., Columbus.) 1991 14 p Presented at the Eighth Symposium on Turbulent Shear Flows, Munich, Fed. Republic of Germany, 9-11 Sep. 1991; sponsored by the Technical Univ. of Munich
(NASA-TM-104472; E-6125; NAS 1.15:104472) Avail: NTIS HC/MF A03 CSCL 21/5

The effect of vortex generators, in the form of small tabs at the nozzle exit, on the evolution of an axisymmetric jet was investigated experimentally over a jet Mach number range of 0.34 to 1.81. The effects of one, two, and four tabs were studied in comparison with the corresponding case without a tab. Each tab introduced an indentation in the shear layer, apparently through the action of streamwise vortices which appeared to be of the trailing vortex type originating from the tips of the tab rather that of the necklace vortex type originating from the base of the tab. The resultant effect of two tabs, placed at diametrically opposite locations, was to essentially bifurcate the jet. The influence of the tabs was essentially the same at subsonic and supersonic conditions indicating that compressibility has little to do with the effect. Author

N91-27160*# Cleveland State Univ., OH. Dept. of Mechanical Engineering.
TESTING, ANALYSIS, AND CODE VERIFICATION OF AERODYNAMICS AND HEAT TRANSFER RELATED TO TURBOMACHINERY Final Report
PAUL I. KING 15 Jul. 1991 18 p
(Contract NCC3-195)
(NASA-CR-188640; NAS 1.26:188640; ORS-KGG-R1) Avail: NTIS HC/MF A03 CSCL 21/5

Discussed here are the writing of a data acquisition code and the installation and testing of new pressure and temperature instrumentation to be used in the testing and evaluation of miniature heat flux sensors. A brief summary of the problem which led to the need for these tests is presented as well as a proposed data acquisition program and the results of investigations of two measurement systems, the Omega OM-900 temperature sensing system and the Scani-Valve Hyscan pressure measurement system. Author

N91-27161# Textile Technologies, Inc., Hatboro, PA.
ANGULAR WEAVING FOR TURBINE ENGINE COMPOSITE COMPONENTS Final Report, 1 Aug. 1987 - 29 Apr. 1988
STEPHEN P. ZAWISLAK May 1991 38 p
(Contract F33615-87-C-2793)
(AD-A236288; WL-TR-91-2045) Avail: NTIS HC/MF A03 CSCL 11/5

Two dimensional fabrics of woven graphite tows represent the structural backbone of present aerospace composite parts. These fabrics are comprised of 0 and 90 degree systems of yarns, X and Y respectively. They are flat planar structures produced on conventional weaving looms. As advanced composite materials find use in more critical aircraft components, more stringent requirements are placed on reinforcing yarns and fabrics. Textile loom design has not kept pace with the use of composite materials. There has never been a loom designed specifically for weaving high modulus (graphite, ceramics, etc.) yarns into fabrics. The overall objective of this program was to advance the level of materials and processing techniques for high temperature polymeric, metal matrix composites and ceramic matrix composites. The major emphasis of this work was directed towards developing a composite reinforcement fabrication system, specifically, a machine design study focused on designing a loom or loom adaptation capable of integrally weaving four or more directions of yarn (multi-angular weaving). GRA

N91-27162# Washington Univ., Seattle.
RESONANT JETS FOR TURBINE COOLING Final Report, Jan. 1989 - Feb. 1991
M. KUROSAKA 25 Apr. 1991 24 p
(Contract F49620-88-C-0041)
(AD-A236755; AFOSR-91-0512TR) Avail: NTIS HC/MF A03 CSCL 21/5

The objective of this investigation is to enhance the effectiveness of jet-impingement cooling, used in the hot turbine sections of jet aircraft engines, by exploiting the recently recognized capacity of the large-scale structures to alter the total temperature of jets. In this report, the results obtained from a newly constructed air-jet facility and from a water-jet test rig built separately for flow visualization study are described. In each, a jet discharged from a circular nozzle impinges on a plate. The results appear to substantiate the following speculations previously advanced: The

secondary vortices, which are induced by the bombardment of the primary vortices formed initially by the nozzle exhaust, are responsible for the cooling on the impingement surface. The degree of cooling is, however, significantly affected by the competition between the primary and secondary vortices and the occurrence of acoustic resonance. The effect of the curvature of the impingement plate and the jet Mach number is also described.
GRA

N91-27163*# ISTAR, Inc., Santa Monica, CA.
DETONATION DUCT GAS GENERATOR DEMONSTRATION PROGRAM Final Report
ANDREW WORTMAN, GAYL A. BRINLEE, PETER OTHMER, and MICHAEL A. WHELAN Jun. 1991 168 p
(Contract NAS3-25453)
(NASA-CR-187137; NAS 1.26:187137) Avail: NTIS HC/MF A08 CSCL 21/5

The feasibility of the generation of detonation waves moving periodically across high speed channel flow is experimentally demonstrated. Such waves are essential to the concept of compressing requirements and increasing the engine pressure compressor with the objective of reducing conventional compressor requirements and increasing the engine thermodynamic efficiency through isochoric energy addition. By generating transient transverse waves, rather than standing waves, shock wave losses are reduced by an order of magnitude. The ultimate objective is to use such detonation ducts downstream of a low pressure gas turbine compressor to produce a high overall pressure ratio thermodynamic cycle. A 4 foot long, 1 inch x 12 inch cross-section, detonation duct was operated in a blow-down mode using compressed air reservoirs. Liquid or vapor propane was injected through injectors or solenoid valves located in the plenum or the duct itself. Detonation waves were generated when the mixture was ignited by a row of spark plugs in the duct wall. Problems with fuel injection and mixing limited the air speeds to about Mach 0.5, frequencies to below 10 Hz, and measured pressure ratios of about 5 to 6. The feasibility of the gas dynamic compression was demonstrated and the critical problem areas were identified.
Author

N91-27165*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ANALYTICAL COMBUSTION/EMISSIONS RESEARCH RELATED TO THE NASA HIGH-SPEED RESEARCH PROGRAM
H. LEE NGUYEN 1991 12 p Presented at the 27th Joint Propulsion Conference, Sacramento, CA, 24-27 Jun. 1991; sponsored by AIAA, SAE, ASME, and ASEE
(NASA-TM-104521; E-6392; NAS 1.15:104521; AIAA-91-2252)
Avail: NTIS HC/MF A03 CSCL 21/5

Increasing the pressure and temperature of the engines of new generation supersonic airliners increases the emissions of nitrogen oxides to a level that would have an adverse impact on the Earth's protective ozone layer. In the process of implementing low emissions combustor technologies, NASA Lewis Research Center has pursued a combustion analysis program to guide combustor design processes, to identify potential concepts of greatest promise, and to optimize them at low cost, with short turn-around time. The approach is to upgrade and apply advanced computer programs for gas turbine applications. Efforts have been made to improve the code capabilities of modeling the physics. Test cases and experiments are used for code validation. To provide insight into the combustion process and combustor design, two-dimensional and three-dimensional codes such as KIVA-II and LeRC 3D have been used. These codes are operational and calculations have been performed to guide low emissions combustion experiments. Author

08

AIRCRAFT STABILITY AND CONTROL

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

A91-45139*# Georgia Inst. of Tech., Atlanta.
OPTIMAL TRAJECTORY SYNTHESIS FOR TERRAIN-FOLLOWING FLIGHT
P. K. A. MENON (Georgia Institute of Technology, Atlanta), V. H. L. CHENG (NASA, Ames Research Center, Moffett Field, CA), and E. KIM (1988 American Control Conference, 7th, Atlanta, GA, June 15-17, 1988, Proceedings. Volume 2, p. 1440-1447) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 807-813. Previously cited in issue 24, p. 3909, Accession no. A88-54571. refs
(Contract NAG2-463)
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A91-45141*# General Dynamics Corp., Fort Worth, TX.
ONBOARD AUTOMATIC AID AND ADVISORY FOR PILOTS OF CONTROL-IMPAIRED AIRCRAFT
ELAINE A. WAGNER (General Dynamics Corp., Fort Worth, TX) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 823-833. Previously cited in issue 23, p. 3618, Accession no. A89-52558. refs
(Contract N00014-82-K-0582; NAG2-297)
Copyright

A91-45319#
TOTAL INCIDENCE PLANE AERODYNAMICS - THE KEY TO UNDERSTANDING HIGH INCIDENCE FLIGHT DYNAMICS?
PETER J. LAMONT and ANDREW KENNAUGH (Manchester, Victoria University, England) Journal of Aircraft (ISSN 0021-8669), vol. 28, July 1991, p. 431-435. Previously cited in issue 09, p. 1294, Accession no. A89-25510. refs
Copyright

A91-45367#
AUTOMATIC FLIGHT SYSTEM FOR HELICOPTERS
TAKASHI KOBAYASHI (Mitsubishi Heavy Industries, Ltd., Helicopter Engineer Dept., Nagoya, Japan) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 12 p.

The primary functions and system architecture of the automated flight management system (AFMS) is described. AFMS is an integrated digital avionics system developed for advanced helicopters with the objective of reducing crew work load and insuring flight safety especially during low-altitude night flying. A distinctive feature is the automatic flight modes where flight can be accomplished without any steering actions by the pilots hovering at one location or moving to a remote location to hover. Other features discussed include flight monitoring, voice warning/announcement, integrated display of flight data, and integrated control of NAVCOM equipment. Consideration is given to the automatic flight control system (AFCS), management subsystem, and electronic horizontal situation indicator subsystem. Diagrams and tables illustrate the AFMS, the AFCS subsystem architecture, the flight pattern of the hover-to-hover mode, AFCS functions, and the flight management subsystem architecture.
P.D.

A91-45368#
A129 - AUTOMATIC FLIGHT CONTROL SYSTEM: DESIGN AND OPTIMIZATION OF A FULL DIGITAL FOUR AXIS AUTOPILOT
EMILIO MAJORI (Agusta S.p.A., Tradate, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 13 p.

The present study examines the automatic flight control system (AFCS) of the A129 Agusta antitank helicopter. The activities carried

out to optimize the design and adjustment of several autopilot modes are described. The steps followed, starting from helicopter model identification and simulation through AFCS parameters selection to flight test and data recording, reduction, and analysis, are traced. The principal aspects for optimization of different autopilot modes are analyzed, with emphasis on digital implementation, signal characterization, filtering, and frequency requirements for control algorithms. The integration of a strapdown platform is described, showing how the experience accumulated allowed the specification of better requirements and the successful coupling of a new attitude and heading reference system with the AFCS. P.D.

A91-45369#
THE FLY-BY-WIRE CONCEPT AND ITS APPLICATION TO THE NH90 HELICOPTER
J. GALLOT, G. MILLON, and C. CLERC (Aerospatiale, Division Helicopteres, Marignane, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 20 p. refs

Analysis of the NH90 fly-by-wire system was initiated during the Project Definition Phase. It helped define the NH90 specific architecture, functional requirements and major Flight Control System (FCS) components more accurately. The fully electrical quadruplex concept was selected, after a comparative analysis of conventional mechanical, hybrid and fully electrical solutions was completed. This result offers a satisfactory technical and commercial compromise. It meets the user's requirements and can be developed with a low level of risk on helicopters. The fly-by-wire system's definition also includes a Higher Harmonic Control (HHC) as the vibration reduction concept. V.I.

A91-45370#
EH101 - AUTOMATIC FLIGHT CONTROL SYSTEM: AUTOPILOT CABLE HOVER MODE COMPUTER AIDED DESIGN AND ASSESSMENT
GIAN P. BENEDETTI (Agusta S.p.A. Tradate, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p.

The design of the cable hover autopilot mode of the automatic flight control system of the EH-101 helicopter is addressed. The cable mode provides control of the cable angle of a submersible sonar. Two models developed to simulate an aircraft winch cable sonar system are considered: discrete and lumped. Assumptions made in developing the models are discussed, and the overall system configuration of the cable hover control law is outlined. A program simulating a mixed continuous/discrete system and producing the trends in such parameters as helicopter attitude, ground speed, and cable angles is reviewed along with simulations performed on a fligh dynamic simulator. Benefits of a CAD technique employed in the project are discussed. V.T.

A91-45371#
BK 117 SINGLE PILOT IFR CERTIFIED WITH HONEYWELL INC. DAFCS
BERNHART STAHUBER, MICHAEL VON GERSDORFF (MBB GmbH, Munich, Federal Republic of Germany), and TERRY KUNTZ (Honeywell, Inc., Phoenix, AZ) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 21 p.

A Digital Automatic Flight Control System (DAFCS) certified for dual- and single-pilot IFR operation is considered. Different components of DAFCS and their intended functions are described with focus on their weight, volume, and necessary power supply. DAFCS includes a computer architecture capable of handling requirements for functionality and safety; to meet these requirements, a complete duplex pitch axis, simplex pitch axis, simplex roll axis, and a yaw axis with duplex computation supplying a single actuator are developed. Ground- and flight-test results are discussed, and attention is focused on dynamic-stabilization and attitude modes. Emphasis is placed on the optimization of all control-law parameters and the harmonization of the monitoring of the flight envelope. V.T.

A91-45379#
NEW ASPECTS OF HIGHER HARMONIC CONTROL AT A FOUR BLADED HINGELESS MODEL ROTOR
R. KUBE (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. refs

Wind tunnel test results are presented which demonstrate that a 3/rev blade pitch angle is capable of simultaneously reducing all dynamic rotor components. Simulations were carried out with different rotor and downwash models to better understand this phenomenon. It is found that the 3- and 4/rev part of the first and second flapping mode are the major reason for the vibrations in the fixed system. K.K.

A91-45380*# Georgia Inst. of Tech., Atlanta.
USE OF AN OPTIMIZED CONTROLLER AND A FINITE-STATE STALL MODEL TO FIND TRIMMED HELICOPTER FLIGHT CONTROLS
DAVID A. PETERS, MNAOUAR CHOUCHANE, and MARK FULTON (Georgia Institute of Technology, Atlanta) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 21 p. U.S. Army-supported research. refs
(Contract NAG1-710)

An auto-pilot is applied to helicopter rotor flap-lag-torsion equations in order to obtain the control settings for a trimmed flight condition. The rotor aerodynamic description includes a state-space dynamic stall model for lift and for pitching moments. Thus, an attempt is made to trim the rotor for flight conditions in which significant stall and torsional deformations are present. The auto-pilot is extended to Q-bladed rotors by a series of time-delay terms. As a result, the optimum gains and time constants depend upon the number of blades as well as upon the torsional stiffness. Author

A91-45387#
OPTIMAL TAKEOFF AND LANDING OF HELICOPTERS FOR ONE-ENGINE-INOPERATIVE OPERATION
KEIJI KAWACHI (Tokyo, University, Japan), SHIRERU SAITO (National Aerospace Laboratory, Tokyo, Japan), AKIRA AZUMA (Tokyo Metropolitan Institute of Technology, Japan), and YOSHINORI OKUNO European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 12 p. refs

The case of engine failure is examined theoretically with respect to the takeoff and landing of helicopters. The rigid body dynamic performance model described by nonlinear optimal control is extended to predict the height-velocity (H-V) diagram and the maximum performance of category A operation. Specific optimization issues examined include the minimization of touchdown speed and the minimization of height loss during the one-engine-inoperative (OEI) transition. The minimization of the restricted region in the H-V diagram and the maximization of the takeoff weight for category A VTOL operation are also studied. Comparisons of the predicted H-V diagrams and operational limits with test-flight data demonstrate good correlation for a range of operating conditions. The model shows that the rejected takeoff distance decreases, and the height of the critical decision point increases, as the speed at the critical decision point decreases. C.C.S.

A91-45388#
SIMPLIFIED INVERSE SIMULATION FOR PRELIMINARY DESIGN PURPOSES
FABIO NANNONI and ALESSANDRO STABELLINI (Costruzioni Aeronautiche Giovanni Agusta S.p.A., Samarate, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 29 p. refs

A code is described which permits the evaluation of the power and control inputs required to accomplish a helicopter's flight path trajectory when the longitudinal plane information is given. Collective and longitudinal cyclic pitch, fuselage attitude, rotor RPM, and longitudinal flapping angle are considered in the model. Aerodynamic forces and rotor dynamic behavior are appraised by means of simplified formulations with integration steps of up to

0.25 second. The mathematical model is compared with other models as well as flight test data, and is found to be an effective preliminary design tool. A comparison with the HELINV code for a quick-hop maneuver show that the values for collective pitch, pitch attitude, and pitch attitude velocity are in good agreement. Because the integration code is modular, it can be expanded and applied to more complex models. C.C.S.

A91-45389*# Advanced Rotorcraft Technology, Inc., Mountain View, CA.
A REAL-TIME BLADE ELEMENT HELICOPTER SIMULATION FOR HANDLING QUALITIES ANALYSIS
RONALD W. DU VAL (Advanced Rotorcraft Technology, Inc., Mountain View, CA) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p. Research supported by U.S. Army and NASA. refs

A simulation model which utilizes parallel processing platforms is described in terms of its contributions to improved real-time helicopter simulation. The FLIGHTLAB parallel processing environment is explained, and the relative advantages of the blade element and rotor map models for rigid and elastic articulated blades are discussed. A UH-60 simulation is conducted by means of a rigid model with 14 degrees of freedom, as well as an elastic model with 26 degrees of freedom, to compare trim conditions, longitudinal static margins, and longitudinal and lateral frequency responses. The FLIGHTLAB system is shown to facilitate restructuring for parallel processing as well as the systematic comparison of a variety of models. The system can facilitate the comparison of rigid and elastic blade element rotor models at NASA-Ames and other research facilities. C.C.S.

A91-45390#
AN IN-FLIGHT INVESTIGATION INTO THE RELATIONSHIPS AMONG CONTROL SENSITIVITY, CONTROL BANDWIDTH AND DISTURBANCE REJECTION BANDWIDTH USING A VARIABLE STABILITY HELICOPTER
STEWART W. BAILLIE and J. M. MORGAN (National Aeronautical Establishment, Flight Research Laboratory, Ottawa, Canada) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p. DND-supported research. refs

A series of in-flight evaluations studying the effects of the variation in control bandwidth, control sensitivity and disturbance rejection capability on the handling qualities of rotorcraft was carried out using the NAE Bell 205 Airborne Simulator. The experiment comprised two major phases. In the first of these, the evaluated configurations differed in roll axis characteristics with pitch, yaw and collective axes characteristics kept constant, while in the second phase the pitch axis characteristics were the ones that varied. The results of the evaluations, in terms of subjective handling qualities ratings and pilot comments, validate the currently recognized boundaries on control bandwidth for Level 1 handling qualities (when measured using control position rather than control force) and provide guidance on the desirable level of control sensitivity for highly damped or rate command systems in pitch and roll. The results from the disturbance rejection portion of the program point out that handling qualities for precision tasks are not strongly affected by the level of disturbance present but there is a threshold disturbance level for both pitch and roll axes which, upon exceeding, does degrade handling qualities. Author

A91-45396*# Princeton Univ., NJ.
THE INFLUENCE OF THE ROTOR WAKE ON ROTORCRAFT STABILITY AND CONTROL
H. C. CURTISS, JR. (Princeton University, NJ) and T. R. QUACKENBUSH (Continuum Dynamics, Inc., Princeton, NJ) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 25 p. U.S. Army-supported research. refs
(Contract NAG2-561)

The effect of the time-averaged rotor wake flowfield on the aerodynamic behavior of the tail rotor and fixed tail surfaces is discussed. The flowfield at the location of these surfaces is predicted by two wake models, a simplified flat wake model and an accurate free wake model. Both models are shown to give similar predictions of the flowfield in the vicinity of the empennage that are generally in agreement with experiment. The contributions of these aerodynamic interactions to the helicopter stability derivatives are described and control responses using different wake models are compared with flight test. Author

A91-45406#
STABILITY ROBUSTNESS CRITERIA AND REDUNDANCY MANAGEMENT OF AN ACTIVE VIBRATION ISOLATION SYSTEM
G. E. PASSALIDIS (Greek Army Aviation, Greece) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 14 p. Royal Aerospace Establishment of England-supported research. refs

An active vibration-isolation system for helicopters, incorporating three planes of fault detection is presented. The first plane is at the sensor level and identifies the validity of sensor data. The detection and isolation at this level are accomplished through a generalized likelihood ratio test utilizing parity equations which are the linear combinations of sensors. The second plane detects and isolates inaccurate implementations of the control law and employs majority-voting algorithms, while the third plane includes a triplex electrohydraulic actuator in a mid-value redundant configuration. It is observed that such a redundancy management configuration provides better reliability and fault tolerance and minimizes problems related to stringent airworthiness issues. V.T.

A91-46455
A REVERSED-FRAME NORMALIZATION DESIGN OF ROBUST FLIGHT CONTROL SYSTEM
CHANGSHENG JIANG, CHUNLIN SHEN, and ZHONGHAN HU (Nanjing Aeronautical Institute, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 4, Feb. 1991, p. 35-45. NNSFC-supported research. refs
(Contract NSF INT-88-21843)
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The theory and method of the reversed-frame normalization design of robust flight-control system is discussed. The robust stability theory of the normal transfer-function matrix with the same characteristic gain loci is proved. An example of flight-control-system design shows the application and advantage of this method. Author

A91-47074
RECONFIGURABLE FLIGHT CONTROL VIA MULTIPLE MODEL ADAPTIVE CONTROL METHODS
PETER S. MAYBECK and RICHARD D. STEVENS (USAF, Institute of Technology, Wright-Patterson AFB, OH) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 27, May 1991, p. 470-480. refs
Copyright

An aircraft flight control system with reconfigurable capabilities is considered. A multiple model adaptive controller (MMAC) is shown to provide effective reconfigurability when subjected to single and double failures of sensors and/or actuators. A command generator tracker/proprotional-plus-integral/Kalman filter (CGT/PI/-KF) form of controller was chosen for each of the elemental controllers within the MMAC algorithm and each was designed via LQG synthesis to provide desirable vehicle behavior for a particular failure status of sensors and actuators. The MMAC performance is enhanced by an alternate computation of the MMAC hypothesis probabilities, use of maximum a posteriori probability (MAP) versus Bayesian form of the MAC (or a modified combination of both), and reduction of identification ambiguities through scalar residual monitoring for the case of sensor failures. I.E.

A91-47151
AIAA ATMOSPHERIC FLIGHT MECHANICS CONFERENCE, NEW ORLEANS, LA, AUG. 12-14, 1991, TECHNICAL PAPERS
Washington, DC, American Institute of Aeronautics and Astronautics, 1991, 552 p. For individual items see A91-47152 to

A91-47200.
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The present conference discusses topics in aircraft aerodynamics, parameter estimation, data preparation/analysis, computation of missile aerodynamics, aircraft trajectories and performance, unsteady and high angle-of attack aerodynamics, aerocapture techniques for manned Mars missions, aircraft agility, aircraft dynamics, parameter estimation modeling and identification, aircraft handling qualities, and hypersonic vehicle technologies. Attention is given to flutter suppression by feedback control, the dynamics of a towed sailplane, the effects of forebody strakes on asymmetric vortices of a vertically launched missile, earth aerobraking strategies for a manned return from Mars, control design for future agile fighters, aircraft wing rock due to inertial coupling, X-31A flying qualities, and reentry guidance and control of a space transporter. O.C.

A91-47153#
AERODYNAMIC POTENTIAL FLOW PANEL METHOD COUPLED WITH DYNAMICS AND CONTROLS
CURTIS P. MRACEK (USAF, Institute of Technology, Wright-Patterson AFB, OH) and DEAN T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 17-25. refs
(Contract AF-AFOSR-85-0158)
(AIAA PAPER 91-2846)

A numerical method for coupling a time-accurate aerodynamic model, dynamic equations of motion, and control inputs has been developed. This method provides a means of evaluating feedback control laws of an aircraft in a general unsteady nonlinear environment. The aerodynamic model is an unsteady 3D panel method. The dynamic equations of motion are for three angular degrees of freedom. The aerodynamics, dynamic equations and the control inputs are coupled through a fourth-order predictor-corrector algorithm, which integrates the dynamic equations while simultaneously solving the aerodynamic and the control surface positioning problems. A low aspect-ratio thin delta wing free to roll is presented as an example of the coupling of the dynamics and the aerodynamic model. Two examples of coupling the dynamic equations of motion, the aerodynamic model, and the control surface positioning are presented. Author

A91-47154#
FLUTTER SUPPRESSION BY FEEDBACK CONTROL
D. T. MOOK (Virginia Polytechnic Institute and State University, Blacksburg) and B. DONG IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 26-39. refs
(Contract AF-AFOSR-90-0032)
(AIAA PAPER 91-2847) Copyright

A numerical procedure for simulating the response of an airfoil mounted on an elastic support in a freestream to the deflections of a trailing-edge flap is described. The airfoil, flowing air, and a feedback control system are treated as a single dynamic system. The general unsteady aerodynamic model describes attached flows. To validate this model, some computed vorticity distributions in the wakes are shown to agree closely with observations. It is also shown that the present simulation accurately predicts the flutter speed of a flat plate at zero angle of attack. Next it is shown that the flutter speed for a NACA 0012 airfoil is not as clearly defined as the critical speed for the flat plate. It is shown that the motion in heave extracts energy from the airflow, and the motion in pitch transfers energy to the flow. The total energy extracted from the flow is: (1) negative when the motion decays; (2) positive when the motion grows; and (3) zero when a limit cycle develops. The present results demonstrate the feasibility of developing simulations of complete-aircraft systems. Author

A91-47155*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MAXIMIZED GUST LOADS FOR A NONLINEAR AIRPLANE USING MATCHED FILTER THEORY AND CONSTRAINED OPTIMIZATION
ROBERT C. SCOTT, BOYD PERRY, III (NASA, Langley Research Center, Hampton, VA), and ANTHONY S. POTOTZKY (Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 40-48. refs
(AIAA PAPER 91-2848)

This paper describes and illustrates two matched-filter-theory based schemes for obtaining maximized and time-correlated gust-loads for a nonlinear airplane. The first scheme is computationally fast because it uses a simple one-dimensional search procedure to obtain its answers. The second scheme is computationally slow because it uses a more complex multidimensional search procedure to obtain its answers, but it consistently provides slightly higher maximum loads than the first scheme. Both schemes are illustrated with numerical examples involving a nonlinear control system. Author

A91-47156#
STABILITY SENSITIVITY STUDIES OF A HELICOPTER ROTOR
YI LU and V. R. MURTHY (Syracuse University, NY) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 49-59. refs
(AIAA PAPER 91-2849) Copyright

The stability sensitivity of a hingeless rotor blade in forward flight with respect to system parameters is examined. The system parameters include extensive structural, aerodynamic, and geometrical design variables, as well as the quantities relating to nonlinear effects. The combined flap-lag-torsion degrees of freedom of the blade motion are considered. The aeroelastic stability characteristics about trim states is obtained by Floquet's stability theory. A direct analytically derived derivative formulation is developed and used for sensitivity analysis of the stability. The useful conclusions of effects of system parameter variation on the rotor aeroelastic stability are drawn from the derivatives. The significant reduction of CPU time required for calculation of the derivatives is achieved by using the present analytical approach, compared with the finite difference method. Author

A91-47157*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPTIMAL INPUT DESIGN FOR AIRCRAFT INSTRUMENTATION SYSTEMATIC ERROR ESTIMATION
EUGENE A. MORELLI (NASA, Langley Research Center; Lockheed Engineering and Sciences Co., Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 60-70. refs
(Contract NAS1-19000)
(AIAA PAPER 91-2850)

A new technique for designing optimal flight test inputs for accurate estimation of instrumentation systematic errors was developed and demonstrated. A simulation model of the F-18 High Angle of Attack Research Vehicle (HARV) aircraft was used to evaluate the effectiveness of the optimal input compared to input recorded during flight test. Instrumentation systematic error parameter estimates and their standard errors were compared. It was found that the optimal input design improved error parameter estimates and their accuracies for a fixed time input design. Pilot acceptability of the optimal input design was demonstrated using a six degree-of-freedom fixed base piloted simulation of the F-18 HARV. The technique described in this work provides a practical, optimal procedure for designing inputs for data compatibility experiments. Author

A91-47164#
NONLINEAR 2-D OPTIMAL EVASIVE AIRCRAFT MANEUVERS AGAINST A PROPORTIONAL NAVIGATION MISSILE
SHAW Y. ONG and BION L. PIERSON (Iowa State University of Science and Technology, Ames) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 131-139. refs
(AIAA PAPER 91-2860) Copyright

A comparative study of evasive strategies of an evader against two different missile models with fixed, g-limited, proportional navigation is conducted. The first missile model assumes kinematics with constant speed, while the second includes missile dynamics. No linearization about a nominal pursuit triangle is employed in the analysis. For simplicity, only motion in the horizontal plane is considered. The optimal control problem is treated as a constrained parameter optimization problem. Numerical results are presented for an early representation of the F-4 fighter aircraft. Author

A91-47165#
AN INVERSE SIMULATION METHOD APPLIED TO LARGE AMPLITUDE MANEUVERING FLIGHT
R. A. HESS (California, University, Davis) and C. GAO IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 140-149. refs
(AIAA PAPER 91-2861) Copyright

Inverse simulation techniques are computational methods which determine the control inputs to a dynamic system that will produce desired system outputs. Such techniques can be useful tools for the analysis and evaluation of problems associated with maneuvering flight. As opposed to current inverse simulation methods which require numerical time differentiation in their implementation, the proposed technique is essentially an integration algorithm. It is applicable to cases where the number of inputs equals or exceeds the number of constrained outputs. The algorithm is exercised in determining the trim conditions and then the control inputs which force a highly nonlinear model of an F-16 fighter to complete large amplitude maneuvers. Author

A91-47175#
'MODIFIED' LISSAJOUS ANALYSIS FOR FLIGHT TEST DATA
MARTINUS M. S. KLIJN (U.S. Navy, Naval Aviation Depot, Alameda, CA), NESRIN SARIGUL-KLIJN (California, University, Davis), and RAMESH KOLAR (U.S. Naval Postgraduate School, Monterey, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 250-263. refs
(AIAA PAPER 91-2876)

'Modified' Lissajous analysis based on Lissajous figures graphically combines a forcing function with its response in the same figure. Some of the benefits of this procedure include identification of the commensurateness of two signals, good operation with extremely short time data records, clear display of relative phase between two signals, and easy determination of the best signal to use in a feedback control system, in the case of many available feedback signals. It is concluded that, in general, an immediate benefit derived from this method is the physical insight which it provides for certain types of flight test data analysis. O.G.

A91-47178#
EXPERIMENTAL IDENTIFICATION OF GROUND EFFECT DURING AIRCRAFT LANDING
GRESELDA I. STRY, D. J. MOOK, and WILLIAM J. RAE (New York, State University, Buffalo) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 306-314. refs
(AIAA PAPER 91-2879) Copyright

The Minimum Model Error (MME) nonlinear identification algorithm is used to determine the ground-effect nonlinear analytical forms of two digital simulations of aircraft landing. One test contained a nonlinear term representing ground-effect, and the other contained the ground-effect plus another nonlinear term representing a pilot response. It is concluded that, in both cases, the nonlinearities were accurately identified in complete ignorance of the actual nonlinear model form and with approximate model of the linear process. The MME nonlinear identification algorithm is considered to be a valuable tool in finding an exact analytical discription of the ground effect from data of an actual aircraft landing approach. O.G.

A91-47179*# Kansas Univ., Lawrence.
THE MEASUREMENT AND IMPROVEMENT OF THE LATERAL AGILITY OF THE F-18
DAVID P. EGGOLD, JOHN VALASEK, and DAVID R. DOWNING (Kansas, University, Lawrence) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 315-322. refs
(Contract NCC2-588)
(AIAA PAPER 91-2880) Copyright

The effect of vehicle configuration and flight control system performance on the roll agility of a modern fighter aircraft has been investigated. A batch simulation of a generic F-18 Hornet was used to study the roll agility as measured by the time to roll through 90 deg metric. Problems discussed include definition of agility, factors affecting the agility of a vehicle, the development of the time to roll through 90 deg agility metric, and a simulation experiment. It is concluded that the integral of stability or wind axis roll rate should be used as a measure of the roll measure traversed. The time through roll angle 90 deg metric is considered to be a good metric for measuring the transient performance aspect of agility. Roll agility of the F-18, as measured by 90 deg metric, can be improved by 10 to 30 percent. Compatible roll and rudder actuator rates can significantly affect 90 deg agility metric. O.G.

A91-47180#
ON SPEED-TURN AGILITY
BERNT JARMARK (Saab-Scania, AB, Linkoping, Sweden) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 323-330. refs
(AIAA PAPER 91-2881) Copyright

The paper discusses an alternative measure of agility. It considers a horizontal turn for aircraft with realistic models. The agility is in respect to turning and speed variations performances. The solution is on a numerical form by numerical maximizing the Hamiltonian without any derivatives involved. The result can be used for on line generation of controls as well as comparing aircraft in this particular metric. Author

A91-47181*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROL DESIGN FOR FUTURE AGILE FIGHTERS
PATRICK C. MURPHY and JOHN B. DAVIDSON (NASA, Langley Research Center, Hampton, VA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 331-341. refs
(AIAA PAPER 91-2882)

The CRAFT control design methodology is presented. CRAFT stands for the design objectives addressed, namely, Control power, Robustness, Agility, and Flying Qualities Tradeoffs. The approach combines eigenspace assignment, which allows for direct specification of eigenvalues and eigenvectors, and a graphical approach for representing control design metrics that captures numerous design goals in one composite illustration. The methodology makes use of control design metrics from four design objective areas, namely, control power, robustness, agility, and flying qualities. An example of the CRAFT methodology as well as associated design issues are presented. Author

A91-47182*# Kansas Univ., Lawrence.
A STUDY OF A PROPOSED MODIFIED TORSIONAL AGILITY METRIC
JOHN VALASEK, DAVID P. EGGOLD, and DAVID R. DOWNING (Kansas, University, Lawrence) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 342-352. refs
(Contract NCC2-588)
(AIAA PAPER 91-2883)

A new candidate lateral agility metric, the modified torsional agility parameter, is proposed and tested through generic, nonlinear, non-real-time flight simulation programs of the F-18 and F-5A. The metric is aimed at quantifying high subsonic loaded roll capabilities which might be useful in modern air combat. The metric is considered to be straightforward for testing and measuring based on nonreal-time unmanned flight simulation. The metric is found to be sensitive to pilot input errors of less than full lateral stick to capture bank angle, when tested using unmanned flight simulations. It is suggested that, for redesigned configurations of both aircraft with improved lateral agility, the major benefit would be provided by fast and highly effective rudders, and a high level of pitch, roll, and yaw damping at moderate to high normal load factor levels. O.G.

A91-47183#
FLYING QUALITIES AS A ROLL AXIS AGILITY METRIC
DAVID R. RILEY and MARK H. DRAJESKE (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 353-366. refs
(AIAA PAPER 91-2884) Copyright

Recent agility research at McDonnell Aircraft has focused on determining which proposed agility measures of merit, called metrics, provide the pilot with a significant tactical advantage. Various agility metrics have been studied to determine if they do a better job of defining and measuring agility than traditional performance measures. A manned air combat simulation was conducted to determine if variations in lateral gross acquisition flying qualities provide a significant tactical advantage and can be used as a roll axis agility metric. The simulation results showed that variations in lateral flying qualities levels provided the pilot with a significant increase in tactical effectiveness for several tactical scenarios. The largest increase in tactical effectiveness was between flying qualities Levels 3 and 2. This result indicates the need for minimum agility guidelines rather than maximum agility specifications for fighter aircraft. Author

A91-47184#
AIRCRAFT WING ROCK BY INERTIAL COUPLING
L. V. SCHMIDT (U.S. Naval Postgraduate School, Monterey, CA) and S. R. WRIGHT (Naval Test Pilot School, Patuxent River, MD) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 367-372. refs
(AIAA PAPER 91-2885) Copyright

A wing-rock limit cycle oscillation is numerically demonstrated for a high performance aircraft operating at low speed. Particular attention is given to the features in aircraft dynamics that can contribute to the limit-cycle oscillation known as wing rock. It is concluded that an unstable lateral-directional motion takes place in conjunction with a stable longitudinal motion. The nonlinear coupling is found to be near optimum when the longitudinal characteristic frequency is twice that of the lateral-directional characteristic frequency. The prime influence of a loss in aircraft roll damping appeared to be the development of a spiral motion divergence superimposed upon the wing-rock oscillation. O.G.

A91-47185#
CONTROL OF WING-ROCK MOTION OF SLENDER DELTA WINGS
JIA LUO and C. E. LAN (Kansas, University, Lawrence) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 373-384. Research supported by University of Kansas. refs
(AIAA PAPER 91-2886) Copyright

Control of wing-rock motion of slender delta wings is investigated through a Hamiltonian formulation. The optimality equations are analyzed through Beecham-Titchener's averaging technique and numerically integrated by a backward-differentiation formulas method developed for implicit differential equations. The weighting factors in the cost function are shown to be related explicitly to the system output damping and frequency. A numerical model constructed for an 80-deg delta wing is solved to illustrate the results. It is shown that Beecham-Titchener's technique is accurate in determining the necessary control function to suppress wing rock. From the numerical results, it is also shown that an effective way to suppress wing rock is to control the roll rate. System sensitivity is investigated by determining variations in system output damping and frequency with aerodynamic model coefficients. The results show that higher sensitivity corresponds to lower system damping. Author

A91-47186#
AIRCRAFT DEEP STALL ANALYSIS AND RECOVERY
K. G. GOUSMAN, R. C. LOSCHKE, R. H. ROONEY (Lockheed Aeronautical Systems Co., Burbank, CA), and J. C. JUANG (American GNC Corp., Chatsworth, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 385-394. refs
(AIAA PAPER 91-2888) Copyright

In this paper simplified equations of motion, together with nonlinear aerodynamics, are utilized for aircraft deep stall analysis. The simplified equations of motion are compatible with existing knowledge of deep stall entry due to pitch ups, inertia coupling and zoom climbs. The analysis results in the construction of deep stall regions of convergence (ROCs) which define operational boundaries, lead to the design of less conservative command limiting/scheduling schemes and provide clues for methods of deep stall recovery. A nonlinear switching (bang-bang) control law for deep stall recovery, which is robust against measurement errors and command timing, is described. Application of this analysis method and control design are illustrated using an F-16A model. Author

A91-47190#
MODIFICATION OF THE NEAL-SMITH CRITERION FOR THE LATERAL AXIS OF AIRCRAFT
DOUGLAS A. DEMATTHEW (USAF, Mather AFB, CA) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 428-431. refs
(AIAA PAPER 91-2894) Copyright

The purpose of this research was to expand the knowledge base of flying qualities of the roll axis. Existing longitudinal flying qualities criteria were studied to learn if they could be adapted for use in the roll axis. The Neal-Smith longitudinal criterion was then chosen and investigated to learn if it could be modified for use in the lateral axis. It appears that the Neal-Smith Criteria does have some potential to be used as a predictor of the lateral axis lying qualities criteria. Author

A91-47256#
A SYNTHESIS OF REDUCED-ORDER COMPENSATORS FOR ACTIVE FLUTTER SUPPRESSION SYSTEMS BASED ON THE OPTIMAL PROJECTION METHOD
ATSUSHI FUJIMORI (Shizuoka University, Hamamatsu, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 34, May 1991, p. 12-26. refs

A synthesis of reduced-order compensators for the active flutter suppression of a two-dimensional airfoil is presented using the optimal projection method. The condition which minimizes a quadratic performance cost is taken into consideration for a

compensator whose order is less than that of the controlled plant. A reduced-order compensator is then constructed satisfying this condition. In this paper, two modified Riccati and two modified Lyapunov equations are derived for the conditions stated. Since these equations are coupled, iterative calculation methods are employed to solve them and an algorithm which overcomes some of the defects of the conventional method is proposed. Numerical simulations, carried out using a thirteenth-order active flutter suppression system for a two-dimensional airfoil, show that the optimal projection method can yield the second-order compensators in all cases. Compensators whose order is six or more display approximately the same control performance as that using the optimal observer, that is, a Kalman filter. Author

A91-47453
SYNTHESIS OF A CLASS OF NONLINEAR MULTICONNECTED AUTOMATIC SYSTEMS BY THE FREQUENCY METHOD [SINTEZ KLASSA NELINEINYKH MNOGOSVIAZNYKH AVTOMATICHESKIKH SISTEM CHASTOTNYM METODOM]
E. V. KARSLIAN (Erevanskii Politekhnicheskii Institut, Yerevan, Armenian SSR) and S. E. CHIMISHKIAN (Nauchno-Issledovatel'skii Institut Elektromashinostroeniia, Yerevan, Armenian SSR) Avtomatika i Telemekhanika (ISSN 0005-2310), March 1991, p. 35-46. In Russian. refs
Copyright

The paper describes a decomposition procedure for the automated synthesis of multiconnected systems with m inputs and m outputs, which are equivalently reducible to the synthesis of certain m single-input single-output abstract systems on the basis of the frequenty method. This approach guarantees the basic properties of linear systems (stability, and the high quality of processes in the dynamic and static modes) as well as stability taking into account the nonlinear characteristics of the sensors or actuators. A system for controlling the turn of an aircraft is considered as an example. L.M.

A91-47822*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MODEL ORDER REDUCTION APPLIED TO A HOT-BENCH SIMULATION OF AN AEROELASTIC WIND-TUNNEL MODEL
GAREY S. BUTTRILL and BARTON BACON, J. (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 185-195. refs
(AIAA PAPER 91-2935) Copyright

Simulations of an aeroelastically scaled wind-tunnel model were developed for hot-bench testing of a digital controller. The digital controller provided active flutter-suppression, rolling-maneuver-load alleviation, and plant estimation. To achieve an acceptable time scale for the hot-bench application, the mathematical model of the wind-tunnel model was reduced from 220 states to approximately 130 states while assuring that the required accuracy was preserved for all combinations of 10 inputs and 56 outputs. The reduction was achieved by focussing on a linear, aeroelastic submodel of the full mathematical model and by applying a method based on the internally balanced realization of a dynamic system. The error-bound properties of the internally balanced realization significantly contribute to its utility in the model reduction process. The reduction method and the results achieved are described. Author

A91-47823#
SIMULATED LEADSHIP AERODYNAMIC INTERFERENCE AS APPLIED IN THE B-2 AIRCREW TRAINING DEVICE
JEROME M. WEISS (CAE-Link Corp., Binghampton, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 196-209. refs
(AIAA PAPER 91-2936) Copyright

The modeling of the effects of vortices and engine exhaust from a lead aircraft on a lag aircraft during B-2 aircrew training is discussed. The interaction of the lead ship with the lag ship's bow wave is also taken into consideration. A detailed examination is made of the vortex geometry, delta velocity, transfer velocity component from the lead ship to the lag ship body reference system, dynamic pressure losses ratio, and delta aerodynamic effects. C.D.

A91-47826#
UTILIZING A BLADE ELEMENT MODEL FOR HELICOPTER PILOT TRAINING
MARTIN T. JAKUB, LEONARD RICHMOND, and ALLEN TRACY (Eyring, Inc., Salt Lake City, UT) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 232-238. refs
(AIAA PAPER 91-2939) Copyright

It has recently become possible to integrate the lift and drag along a rotary wing in real time using a so-called blade element model. Here, a method for describing the velocity field in the vicinity of the rotor is shown. The method is suitable for communication to dedicated blade element computer systems. C.D.

A91-47827#
COMPUTATIONAL REQUIREMENTS AND MODEL REFINEMENT CONSIDERATIONS FOR MODERN BLADE-ELEMENT ROTOR MODELS WITHIN HELICOPTER FLIGHT TRAINING SIMULATORS
STANLEY J. BRICZINSKI (CAE-Link Corp., Binghampton, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 239-251. refs
(AIAA PAPER 91-2940) Copyright

A blade-element rotor model was subjected to sensitivity analysis and optimization process for training simulator applications, and the results are discussed. The examination of the rotor power spectrum, the defining benchmark characteristics, and the evaluation criteria are examined. Sensitivity analysis results are reported for the number of blades and segments, azimuth advanced interval, rotor filter, rotor-fuselage solution ratio, fanned segments, and yawed flow models. Recommended controllability-type test criteria for evaluating the impact of model input parameter values and modeling considerations on solution accuracy are given. C.D.

A91-47831*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ESCAPE STRATEGIES FOR TURBOPROP AIRCRAFT IN MICROBURST WINDSHEAR
RICHARD B. BOBBITT (NASA, Ames Research Center; U.S. Navy, Moffett Field, CA) and RICHARD M. HOWARD (U.S. Naval Postgraduate School, Monterey, CA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 277-285. refs
(AIAA PAPER 91-2945)

The dynamic reponse of a P-3 aircraft and a light twin-engine turboprop to a low-level microburst encounter is modeled. The response to the microburst is depicted for various escape maneuvers. Plots of altitude, velocity, and specific energy are shown for all cases. Takeoff escape strategies are discussed. The optimal escape procedure is found to be flying a constant value of pitch angle. Constant angle of attack maneuvers sometimes result in superior performance. C.D.

A91-47837*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
USE OF PILOTED SIMULATION FOR HIGH-ANGLE-OF-ATTACK AGILITY RESEARCH AND DESIGN CRITERIA DEVELOPMENT
MARILYN E. OGBURN, JOHN V. FOSTER (NASA, Langley Research Center, Hampton, VA), and KEITH D. HOFFLER (Vigyan, Inc., Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers.

Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 337-357. refs
(AIAA PAPER 91-2954) Copyright

The application of piloted simulations in the development of advanced fighter aircraft is reviewed in the context of the NASA High-Angle-of-Attack Technology Program (HATP). The HATP combines wind-tunnel experiments, computational aerodynamics, piloted simulations, and flight tests on a modified F-18 testbed aircraft and utilizes the experience and facilities of several NASA centers. Consideration is given to the role of simulation in the overall research process, simulation capabilities and software requirements, simulation flexibility and fidelity, evaluation maneuvers, the role of simulator pilots in evaluations, the analysis of simulation results, flight validation of maneuvers and rating approaches, and the use of simulations to define design criteria. Extensive diagrams, graphs, and flow charts are included. D.G.

A91-47839#
MODELING AN AUTOPILOT AND THRUST COMPENSATOR IN AN AUTOMATIC CARRIER LANDING SYSTEM
JOHN L. CRASSIDIS and D. J. MOOK (New York, State University, Buffalo) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 368-377. refs
(AIAA PAPER 91-2956) Copyright

A detailed computer simulation which includes the aircraft flight dynamics, pitch attitude autopilot, and automatic thrust compensator is presented for an F-4 aircraft under automatic carrier landing system control. The aircraft simulation is first derived by utilizing a full six degree-of-freedom rigid-body model. This model is then increased to include the pitch autopilot and automatic thrust compensator. The control variables for these systems are the elevator, which generally controls pitch angle, and the thrust, which generally controls angle of attack. A detailed digital computer simulation, verified with frequency domain techniques and test data, allows the replacement of simplified transfer function models for use in an automatic carrier landing simulation. Therefore, internal states and dynamics associated with the aircraft subsystems can be evaluated. Author

A91-47842#
A NUMERICAL TECHNIQUE FOR SOLVING THE COUPLED-EQUATIONS OF MOTION OF AN AIRPLANE
MUHAMMAD A. GHAZI (King Abdulaziz University, Jeddah, Saudi Arabia) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 394-403. refs
(AIAA PAPER 91-2962) Copyright

A simple numerical technique is developed analytically to solve the coupled equations of motion of a symmetric aircraft in straight or maneuvering flight subjected to small disturbances. The formulation of the equations and the solution algorithm are outlined, and results for aircraft 'F' studied by Roskam (1982) are presented in extensive graphs. The responses and stability criteria calculated using the present first-order linearized formulation are found to be in good agreement with previous analytical results. D.G.

A91-48046
ABORT LANDING IN THE PRESENCE OF WINDSHEAR AS A MINIMAX OPTIMAL CONTROL PROBLEM. I - NECESSARY CONDITIONS
R. BULIRSCH, F. MONTRONE, and H. J. PESCH (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) Journal of Optimization Theory and Applications (ISSN 0022-3239), vol. 70, July 1991, p. 1-23. refs
Copyright

The landing of a passenger aircraft in the presence of wind shear is a threat to aviation safety. The present paper is concerned with the abort landing of an aircraft in such a series situation. Mathematically, the flight maneuver can be described by a minimax optimal control problem. In transforming this minimax problem into an optimal control problem of standard form, a state constraint of order three, a first-order state constraint, and a control variable constraint are imposed on the model. This optimal control problem is solved by means of the multiple shooting method in connection with an appropriate homotopy strategy. The solution obtained here satisfies all the sharp necessary conditions including those depending on the sign of certain multipliers. The trajectory consists of bang-bang and singular subarcs, as well as boundary subarcs induced by the two state constraints. Author

A91-48047
AIRCRAFT CONTROL FOR FLIGHT IN AN UNCERTAIN ENVIRONMENT - TAKEOFF IN WINDSHEAR
G. LEITMANN (California, University, Berkeley) and S. PANDEY Journal of Optimization Theory and Applications (ISSN 0022-3239), vol. 70, July 1991, p. 25-55. refs
Copyright

The design of the control of an aircraft encountering wind-shear after takeoff is treated as a problem of stabilizing the climb rate about a desired value of the climb rate. The resulting controller is a feedback one utilizing only climb rate information. Its robustness vis-a-vis windshear structure and intensity is illustrated via simulations employing four different windshear models. Author

A91-48076
PILOT'S ASSOCIATE - A COOPERATIVE, KNOWLEDGE-BASED SYSTEM APPLICATION
SHEILA B. BANKS and CARL S. LIZZA (USAF, Wright-Patterson AFB, OH) IEEE Expert (ISSN 0885-9000), vol. 6, June 1991, p. 18-29. refs
Copyright

The Pilot's Associate program, a joint effort of the DARPA and the USAF to build a cooperative, knowledge-based system to help pilots make decisions is described, and the lessons learned are examined. The Pilot's Associate concept developed as a set of cooperating, knowledge-based subsystems: two assessor and two planning subsystems, and a pilot interface. The two assessors, situation assessment and system status, determine the state of the outside world and the aircraft systems, respectively. The two planners, tactics planner and mission planner, react to the dynamic environment by responding to immediate threats and their effects on the prebriefed mission plan. The pilot-vehicle interface subsystem provides the critical connection between the pilot and the rest of the system. The focus in on the air-to-air subsystems. I.E.

N91-27166 Salford Univ. (England).
ACTIVE CONTROL OF V/STOL AIRCRAFT Ph.D. Thesis
DAVID JOHN FREDERICK HOPPER 1990 475 p
Avail: Univ. Microfilms Order No. BRD-91382

A controller design method is developed which alleviates pilot workload during transitions from jet-borne to fully wing-borne flight (and vice versa) for a V/STOL aircraft. The method is based upon a singular perturbation analysis which is used to expose the underlying dynamics of a closed-loop state-space system. New developments are described which allow high-order, dynamically complex parasitics, such as actuators, to be included in the design. Furthermore, the method gives the designer insight into the problem allowing tuning and engineering trade-offs to be performed intelligently with a two-way flow of design information. The end result is a robust high-gain multivariate controller. The method is applied to a representative non-linear time-varying aircraft simulation model. The necessary state-space matrices are obtained by linearizing the model at several different flight cases. This occurs over a wide flight envelope, from hover to 300 Kts, and consequently the multivariable control laws are implemented using gain scheduling. Finally, task tailored control and handling qualities requirements are derived for a V/STOL aircraft in the form of a design brief and subsequent controller design is presented. Dissert. Abstr.

N91-27167*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NEURAL NETWORK APPLICATION TO AIRCRAFT CONTROL SYSTEM DESIGN
TERRY TROUDET (Sverdrup Technology, Inc., Brook Park, OH.), SANJAY GARG, and WALTER C. MERRILL 1991 20 p Presented at the Guidance, Navigation and Control Conference, New Orleans, LA, 12-14 Aug. 1991; sponsored by AIAA
(NASA-TM-105151; E-6435; NAS 1.15:105151) Avail: NTIS HC/MF A03 CSCL 01/3

The feasibility of using artificial neural networks as control systems for modern, complex aerospace vehicles is investigated via an example aircraft control design study. The problem considered is that of designing a controller for an integrated airframe/propulsion longitudinal dynamics model of a modern fighter aircraft to provide independent control of pitch rate and airspeed responses to pilot command inputs. An explicit model following controller using H infinity control design techniques is first designed to gain insight into the control problem as well as to provide a baseline for evaluation of the neurocontroller. Using the model of the desired dynamics as a command generator, a multilayer feedforward neural network is trained to control the vehicle model within the physical limitations of the actuator dynamics. This is achieved by minimizing an objective function which is a weighted sum of tracking errors and control input commands and rates. To gain insight in the neurocontrol, linearized representations of the nonlinear neurocontroller are analyzed along a commanded trajectory. Linear robustness analysis tools are then applied to the linearized neurocontroller models and to the baseline H infinity based controller. Future areas of research are identified to enhance the practical applicability of neural networks to flight control design. Author

N91-27168*# Purdue Univ., West Lafayette, IN.
***THE INTEGRATED MANUAL AND AUTOMATIC CONTROL OF COMPLEX FLIGHT SYSTEMS* Final Technical Report, 1 Jan. 1980 - 30 Apr. 1989**
DAVID K. SCHMIDT (Arizona State Univ., Tempe.) 1 Aug. 1991 8 p
(Contract NAG4-1)
(NASA-CR-188664; NAS 1.26:188664) Avail: NTIS HC/MF A02 CSCL 01/3

Research dealt with the general area of optimal flight control synthesis for manned flight vehicles. The work was generic; no specific vehicle was the focus of study. However, the class of vehicles generally considered were those for which high authority, multivariable control systems might be considered, for the purpose of stabilization and the achievement of optimal handling characteristics. Within this scope, the topics of study included several optimal control synthesis techniques, control-theoretic modeling of the human operator in flight control tasks, and the development of possible handling qualities metrics and/or measures of merit. Basic contributions were made in all these topics, including human operator (pilot) models for multi-loop tasks, optimal output feedback flight control synthesis techniques; experimental validations of the methods developed, and fundamental modeling studies of the air-to-air tracking and flared landing tasks. Author

N91-28171 Illinois Univ., Urbana-Champaign.
ROBUST BIFURCATION BEHAVIOR IN THE PRESENCE OF EXTERNAL RANDOM EXCITATION Ph.D. Thesis
GERARD SIEW BING LENG 1990 186 p
Avail: Univ. Microfilms Order No. DA9114312

The effects of random external excitation on systems with marginally stable/unstable (critical) modes undergoing a soft loss of stability is examined within the context of bifurcation theory. Physically the problem is motivated by the flight dynamics of aircraft at large angles of attack and sideslip in a turbulent atmosphere. A qualitative criterion for robust bifurcation behavior is suggested. It is also found that the bifurcation behavior of systems with one critical mode is robust in the sense that the deterministic characteristics carry over to the steady state probability density function for the system in the presence of random external excitation. For systems with two critical modes, the bifurcation behavior is robust under special conditions on the relative degree of mode interaction and excitation intensities. Dissert. Abstr.

09

RESEARCH AND SUPPORT FACILITIES (AIR)

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

A91-44590#
DESIGN AND DEVELOPMENT OF A RESEARCH COMBUSTOR FOR LEAN BLOWOUT STUDIES
G. J. STURGESS, D. G. SLOAN (Pratt and Whitney Group, East Hartford, CT), A. L. LESMERISES (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH), S. P. HENEGHAN, and D. R. BALLAL (Dayton, University, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(Contract F33615-87-C-2822; F33615-87-C-2767)
(ASME PAPER 90-GT-143)

A research combustor that simulates the 'inside-out' recirculation pattern and lean blowout (LBO) processes of a modern annular aircraft gas turbine combustor is presented. The problems discussed include the combustor design constraints, aero-thermochemical design, choice of combustor configurations, sizing, mechanical design, combustor light-off, and acoustic considerations. It is found that the existing test facility, optics capabilities, and limit on fuel flowrate imposed dimensional constraints on combustor length and shape. The final preferred configuration is characterized by an axisymmetric arrangement of fuel and air jets, 27 mm and 40 mm diameter, respectively, and dumping unmixed reactants at a 55 mm wide step. The combustor is 735 mm long, has 150 mm square cross section with rounded corner fillets of 84 mm radius, and is fitted with an Inconel extension chimney with an orifice plate at its exit. O.G.

A91-44655#
GAS TURBINE ENGINE TEST CELL MODELING
D. SALINAS (U.S. Naval Postgraduate School, Monterey, CA) and E. E. COOPER (U.S. Navy, Naval Civil Engineering Laboratory, Port Hueneme, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(ASME PAPER 90-GT-244)

A numerical simulation of the aerothermal characteristics of a gas turbine engine test cell is presented. The three-dimensional system is modeled using the PHOENICS computational fluid dynamics code. Results predict the velocity field, temperatures, pressures, kinetic energy of turbulence, and dissipation rates of turbulent kinetic energy. Numerical results from two versions, a Cartesian coordinate model and a body fitted coordinate model, are compared to experimental data. The comparison shows good quantitative and very good qualitative agreement, suggesting that numerical modeling would be useful in the preliminary design of gas turbine test facilities. Author

A91-44711#
THE AERODYNAMIC AND MECHANICAL PERFORMANCE OF A HIGH PRESSURE TURBINE STAGE IN A TRANSIENT WIND TUNNEL
A. G. SHEARD (Rotadata, Ltd., Derby, England) and R. W. AINSWORTH (Oxford, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. Rolls-Royce, PLC-supported research. refs

(Contract SERC-GR/D/21189; SERC-GR/E/28062)
(ASME PAPER 90-GT-353)

In this paper the outline concept and mode of operation of the turbine test facility are given, and the key aerodynamic and mechanical aspects of the facility's performance are presented in detail. The variation of those parameters used to define the turbine operating point during facility operation are examined, and the accuracy with which the turbine's design point was achieved calculated. Aspects of the mechanical performance which are presented include the results of a finite element stress analysis of the loads in the turbine under operating conditions, and the performance of the rotor bearing system under these arduous load conditions. Both of these aspects present more information than has been available hitherto. Author

A91-44760#
A STUDY AND ANALYSIS OF LAUNCHING APPARATUS FOR CK1-M MODEL OF PILOTLESS AIRCRAFT

CHENGRONG WU (Institute of Pilotless Aircraft, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 19-25. In Chinese. refs

Some problems relevant to the design, experimental testing, and analysis of the launching apparatus of the CK1-M model pilotless aircraft. Included is the determination of the length of the skid rails in single and double-rocket takeoff configurations, selection of the release force, study of transient movement of the aircraft relative to the skid rails, and the design of skid rail structures. The results of a series of launch takeoff tests are in agreement with calculation results, indicating that the design concept can be used as a basis for an actual apparatus. C.D.

A91-44826
EXPERIMENTAL INVESTIGATION OF RAM ACCELERATOR PROPULSION MODES

A. HERTZBERG, A. P. BRUCKNER, and C. KNOWLEN (Washington, University, Seattle) Shock Waves (ISSN 0938-1287), vol. 1, March 1991, p. 17-25. Research supported by Orlin Corp. refs
(Contract F08635-89-C-0196)
Copyright

Several operational modes are possible in a ram accelerator; these are distinguished by their operating velocity range and by the way in which their combustion process is initiated and stabilized. Propulsive cycles employing subsonic, thermally-choked combustion theoretically allow projectiles to be accelerated to the Chapman-Jouguet (C-J) detonation speed of a gaseous propellant mixture. In the superdetonative velocity range, the projectile is accelerated while always traveling faster than the C-J speed. In the transdetonative regime lying at 85-115 percent of C-J speed, the projectile makes a smooth transition from sub- to superdetonative propulsive mode. Attention is given to the three regimes for the case of methane- and ethylene-based propellant mixtures. O.C.

A91-45628#
HYPERSONIC TEST FACILITIES [LES MOYENS D'ESSAIS EN HYPERSONIQUE]

JACKY LEYNAERT (ONERA, Chatillon, France) (Entretiens 'Science et Defense 91', Paris, France, May 14, 15, 1991) ONERA, TP no. 1991-47, 1991, 23 p. In French. refs
(ONERA, TP NO. 1991-47)

A review is presented of general hypersonic flight conditions as well as the aerothermodynamic parameters used to simulate these conditions in various test facilities. The principal French industrial test facilities and a complementary one in Germany are described. Various test parameters available at these facilities including high air temperatures, aerodynamic parameters, thermostructural parameters, cryogenic environments, and plasma generators are also described. R.E.P.

A91-46315#
FACTORS AFFECTING THE DESIGN OF A NEW TRANSONIC WIND TUNNEL FOR AUSTRALIA

NEIL POLLOCK (Defence Science and Technology Organisation, Aeronautical Research Laboratory, Melbourne, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 7.33-7.36. refs

Considerations leading to the specifications of a proposed transonic wind tunnel are discussed. The main test requirements for the tunnel are covered, and emphasis is placed on computational fluid dynamics as an alternative to wind tunnels. Basic simulation requirements including Mach numbers, Reynolds numbers, and the ratio of specific heats are outlined, and attention is focused on the test section size, type of tunnel, operating pressure, and drive power. It is noted that the power selected is such that the Reynolds-number values falling into the desirable range are available at all Mach numbers up to 1.0. Flow quality and equipment for mounting an aircraft model are reviewed, and the specifications derived from the considerations discussed are presented, including the test section configuration, main-model support, sidewall-model support, and flow quality and performance parameters. V.T.

A91-47804*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
THE ROLE OF THE REMOTELY AUGMENTED VEHICLE (RAV) LABORATORY IN FLIGHT RESEARCH

DOROTHEA COHEN and JEANETTE H. LE (NASA, Flight Research Center, Edwards, CA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 24-36. refs
(AIAA PAPER 91-2977) Copyright

This paper presents on overview of the unique capabilities and historical significance of the Remotely Augmented Vehicle (RAV) Laboratory at the NASA Dryden Flight Research Facility. The report reviews the role of the RAV Laboratory in enhancing flight test programs and efficient testing of new aircraft control laws. The history of the RAV Laboratory is discussed with a sample of its application using the X-29 aircraft. The RAV Laboratory allows for closed- or open-loop augmentation of the research aircraft while in flight using ground-based, high performance real-time computers. Telemetry systems transfer sensor and control data between the ground and the aircraft. The RAV capability provides for enhanced computational power, improved flight data quality, and alternate methods for the testing of control system concepts. The Laboratory is easily reconfigured to reflect changes within a flight program and can be adapted to new flight programs. Author

A91-47808#
THE COMPROMISE BETWEEN ACCURACY AND REALISM IN FLIGHT SIMULATION

A. G. BARNES IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 65-71. refs
(AIAA PAPER 91-2920) Copyright

An alternative way of classifying simulators, based on the interactions between the pilot or crew and the device, is discussed. A distinction is first made between simulators that are utilized to teach and to educate, and those that are employed to train motor skills and coordination. The approach described can be utilized to shed light on many issues relating to technology, such as the value of simulators for research on flying qualities, the likely effectiveness of networked simulators, the likelihood of a simulator inducing sickness, and the features needed to achieve virtual reality. R.E.P.

A91-47811#
MULTI-AIRCRAFT SIMULATION FOR THE TRAINING OF FLIGHT AIRCREW AND AIR TRAFFIC CONTROL PERSONNEL

G. D. GIBB, J. W. BLANCHARD, and A. J. KORNECKI (Embry-Riddle Aeronautical University, Daytona Beach, FL) IN: AIAA Flight Simulation Technologies Conference, New Orleans,

LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 87-92.
(AIAA PAPER 91-2924) Copyright

The networking of flight simulators and air traffic control stations to emulate the major components of an airspace environment is discussed. Air traffic functions, flight operations, and meteorological factors are accurately integrated to form the basis of the simulation system. A 3D real-time airspace is generated by engineering air traffic control stations and networking software to commercially available meteorological computers and flight simulators. Attention is given to the engineering design specifications, associated hardware, and technological problems experienced. R.E.P.

A91-47829#
REAL-TIME INTEGRATION OF MAN-IN-THE-LOOP HYBRID SIMULATORS
LISA F. GIRARDI, CHARLES E. HAGEN, and JAMES E. HATEM (Calspan Advanced Technology Center, Buffalo, NY) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 262-270.
(AIAA PAPER 91-2942) Copyright

Real-time integration of the Redcap facility with other electric combat simulators, including ACETEF, EMTE, and AFEWES is discussed. The simulation capabilities of these facilities are reviewed. The improved capabilities of the integrated facilities are addressed. C.D.

A91-47847*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NASA LEWIS INTEGRATED PROPULSION AND FLIGHT CONTROL SIMULATOR
MICHELLE M. BRIGHT (NASA, Lewis Research Center, Cleveland, OH) and DONALD L. SIMON (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 448-458. refs
(AIAA PAPER 91-2969) Copyright

A new flight simulation facility has been developed at NASA Lewis to allow integrated propulsion-control and flight-control algorithm development and evaluation in real time. As a preliminary check of the simulator facility and the correct integration of its components, the control design and physics models for an STOVL fighter aircraft model have been demonstrated, with their associated system integration and architecture, pilot vehicle interfaces, and display symbology. The results show that this fixed-based flight simulator can provide real-time feedback and display of both airframe and propulsion variables for validation of integrated systems and testing of control design methodologies and cockpit mechanizations. Author

N91-27169*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OVERVIEW OF THE APPLIED AERODYNAMICS DIVISION
Washington Jun. 1991 39 p
(NASA-TM-102698; NAS 1.15:102698) Avail: NTIS HC/MF A03 CSCL 14/2

A major reorganization of the Aeronautics Directorate of the Langley Research Center occurred in early 1989. As a result of this reorganization, the scope of research in the Applied Aeronautics Division is now quite different than that in the past. An overview of the current organization, mission, and facilities of this division is presented. A summary of current research programs and sample highlights of recent research are also presented. This is intended to provide a general view of the scope and capabilities of the division. Author

N91-28173# Los Alamos National Lab., NM.
AIR COMBAT ENVIRONMENT TEST AND EVALUATION FACILITY AND THE DEVELOPMENT OF THE OFFENSIVE SENSORS LABORATORY
K. LEE, K. HANNON, and D. MACONE (Naval Air Test Center, Patuxent River, MD.) Apr. 1991 13 p Presented at the 4th Joint Service Test Technology Symposium (TTS), Laurel, 8-11 Apr. 1991
(Contract W-7405-ENG-36)
(DE91-011398; LA-UR-91-1117; CONF-9104232-1) Avail: NTIS HC/MF A03

Recent combat experience has brought to light a critical need to assess the mission effectiveness of Naval aviation weapons systems and vehicles against a myriad of new threats. Flight testing is the primary source of data on the effectiveness of our aircraft and weapons, but flight testing is costly and limited to only a few of the most crucial questions. Flight testing is also inherently a public event; it can be observed with impunity. Hence, flight testing is patently unsatisfactory for dealing with many issues related to national security interests. Senior decision-makers in the DoD require objective, quantitative assessments of the effectiveness of our weapons and people against literally thousands of possible combinations of threat and contingency planning conditions. A revolutionary approach is needed to obtain the requisite data. The Naval Air Test Center (NATC) has begun to develop an innovative system, known as the Air Combat Environment Test and Evaluation Facility (ACETEF), to meet this need. ACETEF is a fully integrated ground test facility that will use state-of-the-art simulation and stimulation techniques to provide test scenarios, which will reproduce the conditions of actual combat. This is being accomplished by integration of existing laboratories and development of new laboratories such as the Communications, Navigation and Identification (CNI) Laboratory and the Offensive Sensors Laboratory (OSL). This paper will describe ACETEF and the OSL development effort. DOE

N91-28175*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IMPROVED METHOD AND APPARATUS FOR MACH NUMBER CHANGE IN WIND TUNNEL Patent Application
RICHARD L. PUSTER, inventor (to NASA) 26 Jun. 1991 15 p
(NASA-CASE-LAR-13548-1; NAS 1.71:LAR-13548-1; US-PATENT-APPL-SN-721039) Avail: NTIS HC/MF A03 CSCL 14/2

A description of an insert in a wind tunnel nozzle is presented. The insert has a variable sized passageway that helps create two pressure regions which, in turn, create a diffusion shock wave system and a compression wave system with each system having a plurality of waves. The diffusion shock wave system compresses a flow while the compression wave system turns the flow and is attenuated by the flow itself. NASA

N91-28176# Federal Aviation Administration, Atlantic City, NJ.
RUNWAY VISUAL RANGE (RVR) OPERATIONAL TEST AND EVALUATION (OT AND E)/INTEGRATION TEST PLAN
JOSEPH GOSLIN, FRANCES A. MACKUSE, BRUCE E. WARE, and ALANNA RANDAZZO Aug. 1991 44 p
(DOT/FAA/CT-TN91/4) Avail: NTIS HC/MF A03

The Runway Visual Range (RVR) System consists of a group of sensors with associated software/firmwave, displays, and data distribution links. The data provided by this array of sensors provides runway visual range at various points of a precision approach runway. These RVR products are automatically processed and distributed to air traffic controllers. The data is then presented to the pilot by the controller in a numerical format equating to the number of feet forward along the runway that a pilot may be expected to see. 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.

A91-44550#
SOLAR DYNAMIC CBC POWER FOR SPACE STATION FREEDOM
WILLIAM B. HARPER, JR., ROBERT V. BOYLE (Allied-Signal Aerospace Co., Garrett Fluid Systems Div., Tempe, AZ), and CHARLES T. KUDIJA (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-70)

NASA has selected a closed-Brayton-cycle (CBC) solar-dynamic-power-conversion system to provide electric power for the growth phase of Space Station Freedom. This selction was based in part on the comparative reduction in solar radiation collection made possible by the high efficiency closed-Brayton-cycle system when compared to the efficiency of static conversion systems. The smaller required collector area results in a significant reduction in drag in the low earth orbit which is planned for the Space Station. Recently under development is the Solar Dynamic Power Generating Subsystem (PGS), which consists of a solar receiver, which accepts sunlight from the multifaceted collector mirror (the concentrator), and a CBC heat engine that converts the solar heat into electricity. This paper reviews the design requirements for the Space Station Solar Dynamic Power Module and presents results of the PGS cycle analysis and preliminary design. Author

A91-45138# Princeton Univ., NJ.
OPTIMAL PLANE CHANGE DURING CONSTANT ALTITUDE HYPERSONIC FLIGHT
K. D. MEASE (Princeton University, NJ), N. X. VINH (Michigan, University, Ann Arbor), and S. H. KUO Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 797-806. Previously cited in issue 21, p. 3502, Accession no. A88-50587. refs
(Contract JPL-956416; NAG1-907)
Copyright

A91-45297#
METALLIC THERMAL PROTECTION CONCEPT FOR HYPERSONIC VEHICLES
H. GRALLERT (MBB GmbH, Munich, Federal Republic of Germany) and K. KELLER (ESTEC, Noordwijk, Netherlands) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 1, p. 416-423) Journal of Aircraft (ISSN 0021-8669), vol. 28, June 1991, p. 410-416. Previously cited in issue 03, p. 274, Accession no. A89-13543. refs
Copyright

A91-47838*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UTILIZATION OF SIMULATION TOOLS IN THE HL-20 CONCEPTUAL DESIGN PROCESS
E. B. JACKSON, RICHARD W. POWELL (NASA, Langley Research Center, Hampton, VA), and W. A. RAGSDALE (Unisys Corp., Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 358-367. refs
(AIAA PAPER 91-2955) Copyright

The role of simulations in the design of the HL-20, the crew-carrying unpowered lifting-body component of the NASA Personnel Launch System, is reviewed and illustrated with drawings and diagrams. Detailed consideration is given to the overall implementation of a real-time simulation of the HL-20 approach and landing phase, the baseline and experimental control laws used in the flight-control system, autoland guidance and control laws (vertical and lateral steering), the control-surface mixer and actuator model, and simulation results. The simulations allowed identification and correction of design problems with respect to the position of the landing gear and the original maximum L/D ratio of 3.2. D.G.

N91-28219*# Pennsylvania State Univ., University Park.
A REVIEW OF LIQUID ROCKET PROPULSION PROGRAMS IN JAPAN
CHARLES L. MERKLE *In* NASA, Washington, Space Transportation Propulsion Technology Symposium. Volume 2: Symposium Proceedings p 523-547 May 1991
Avail: NTIS HC/MF A99 CSCL 21/8

An assessment of Japan's current capabilities in the areas of space and transatmospheric propulsion is presented. The primary focus is upon Japan's programs in liquid rocket propulsion and in space plane and related transatmospheric areas. Brief reference is also made to their solid rocket programs, as well as to their supersonic air breathing propulsion efforts that are just getting underway. Author

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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.

A91-44524#
A COMPUTATIONAL FLUID DYNAMICS AND CHEMISTRY MODEL FOR JET FUEL THERMAL STABILITY
J. L. KRAZINSKI (Argonne National Laboratory, IL), S. P. VANKA (Illinois, University, Urbana), J. A. PEARCE, and W. M. ROQUEMORE (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. Research supported by DOE and USAF. refs
(ASME PAPER 90-GT-33)

The development of a second-generation computational fluid-dynamics and chemistry thermal decomposition and deposition model is described. The preexponential constant and activation energy for the wall reaction, the preexponential constant and activation energy for the bulk autoxidation reaction, and preexponential constant and activation energy for the precursor decomposition reaction required for calibration of the model are estimated using experimental data from published heated-tube experiments. It is shown that the current model can characterize trends in fuel deposition rates and can be useful in demonstrating the coupling between chemistry, fluid-mechanics, and heat-transfer processes taking place during fuel decomposition. V.T.

A91-44556#
THE LCF BEHAVIOR OF SEVERAL SOLID SOLUTION STRENGTHENED ALLOYS USED IN GAS TURBINE ENGINES
S. K. SRIVASTAVA and D. L. KLARSTROM (Haynes International, Inc., Kokomo, IN) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-80)

LCF tests were performed on production plate (16 mm thick) materials of HAYNES alloy No. 230, HASTELLOY alloy X and INCONEL alloy 617. The tests were conducted in air at 760, 871 and 982 C under the fully reversed strain controlled mode on

materials in the annealed condition. The results showed that 230 alloy possesses the best low cycle fatigue characteristics followed by alloy X and alloy 617 under all test conditions. The paper presents total strain range-life data, cyclic hardening/softening, and metallographic observations on selected failed samples. It is shown that oxidation plays a key role in fatigue-crack initiation in alloy 617. Author

A91-44623#
HIGH TEMPERATURE CORROSION RESISTANCE OF MECHANICALLY ALLOYED PRODUCTS IN GAS TURBINE ENVIRONMENTS
G. D. SMITH and J. J. FISCHER (Inco Alloys International, Inc., Huntington, WV) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-206)

The present study describes the high-temperature corrosion performance of the heat-resistant, mechanically alloyed, oxide-dispersion-strengthened alloys Incoloy alloy MA 956, Inconel alloy MA 754, Inconel alloy MA 760, and Inconel alloy MA 6000. Oxidation and oxidation-sulfidation data for a range of temperatures and environmental conditions are presented, along with comparative data on five wrought alloys. Scale types are related to performance. The performance of MA 956 was found to be exceptional in all test environments. MA 754 displayed satisfactory oxidation resistance to 1200 C and performed well in the burner rig environment, but exhibited breakaway oxidation-sulfidation corrosion under severe laboratory test conditions. MA 760 showed oxidation and burner rig test results similar to those of MA 956 but displayed breakaway corrosion behavior in the more severe laboratory oxidation-sulfidation tests. MA 6000 has adequate oxidation resistance to 1100 C but would be unsuited for service above that temperature without a coating. P.D.

A91-44675#
CORRELATED FUEL PROPERTY EFFECTS ON AN F402-RR-406A (PEGASUS) ENGINE COMBUSTOR
H. C. LOW, C. J. SCOTT (Rolls-Royce, PLC, Bristol, England), and A. VENINGER (Rolls-Royce, Inc., Atlanta, GA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 16 p. U.S. Navy-supported research. refs
(ASME PAPER 90-GT-276)

An F402-RR-406A (Pegasus) engine has been subjected to extensive sea-level and altitude operation on a wide range of viable emergency fuels. Sea-level main engine starting was successful for all six fuels and windmilling altitude relight tests were equally flawless, even outside the flight envelope. Cold soak sea-level starting was achieved with DFM of viscosities up to 12 centistokes. Clear inter-relationships between combustor metal temperatures, primary zone flame radiation and optically measured exhaust Smoke Numbers demonstrate a common dependence of these parameters upon the indeterminable primary zone soot concentration. Correlations against fuel properties illustrate the dominance of fuel chemistry over physical properties, even with respect to changes in carbon monoxide and unburned hydrocarbon emissions (and hence combustion inefficiency) at low power. The degrees of premixing and prevaporization within the Rolls-Royce 'vaporizer' fuel injector are considered responsible for the diminished significance of physical properties relative to influences upon conventional fuel atomizer behavior. Author

A91-44689*# Allied-Signal Aerospace Co., Phoenix, AZ.
ATTAP/AGT101 - YEAR 2 PROGRESS IN CERAMIC TECHNOLOGY DEVELOPMENT
J. R. KIDWELL, L. J. LINDBERG, and R. E. MOREY (Allied-Signal Aerospace Co., Garrett Auxiliary Power Div., Phoenix, AZ) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. DOE-supported research. refs
(Contract DEN3-335)
(ASME PAPER 90-GT-305)

The progress made by the Advanced Turbine Technology Applications Project (ATTAP) is summarized, with emphasis on the following areas: ceramic materials assessment and characterization, ceramic impact damage assessment, ceramic combustor evaluation, turbine inlet particle separator development, impact-tolerant turbine designs, and net-shape ceramic component fabrications. In the evolutionary ceramics development in the Automotive Gas Turbine (AGT101) and ATTAP programs initial designs were conceived to reduce stresses by using well-established criteria: bodies of revolution were preferred over nonaxisymmetric geometries, sharp corners were avoided, the contact area between components was kept as large as possible, and small parts were preferred over large when feasible. Projects discussed include: initial ceramic component fabrication by ceramic suppliers in 1990, engine test to 1371 C in 1991, 100-hr test bed engine durability test in 1991, and 300-hr test bed engine durability in 1992. P.D.

A91-44697#
FATIGUE STRENGTH ENHANCEMENT USING SHAPE MEMORY ALLOY BUSHINGS
EDWARD R. BUCHANAN (Holtgren, Inc., Union, NJ) and REGINA B. CELIN (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-316)

This paper presents the initial results of a program to evaluate a new process for the repair of fatigue-damaged aircraft engine components. In this process, the fatigue-damaged area is drilled out and replaced with a bushing manufactured from a new class of material called a 'shape memory' alloy. This material has the capability to expand in place following insertion, thus placing the surrounding material into compression. A significant improvement in low cycle fatigue life was observed at 288 C in Ti-6Al-4V specimens treated with the above technique. The degree of improvement is about twice that which was obtained with a mechanical cold expansion technique used commercially to extend fatigue life. The degree of improvement of the subject process is greater at high numbers of cycles than at low numbers of cycles. Author

A91-44716#
AN APPROACH TO DESCRIBING THE SIMULTANEOUS EROSION AND HIGH TEMPERATURE OXIDATION OF ALLOYS
I. G. WRIGHT, V. K. SETHI, and V. NAGARAJAN (Battelle, Columbus, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-361)

The rate of wastage of an alloy surface subjected to erosion under conditions where high-temperature oxidation can occur can be significantly greater than that arising from erosion alone. This is because the erosion conditions can act to accelerate the oxidation process by causing regular shedding of the otherwise protective oxide scale. It is suggested that an important parameter in determining the rate of erosion-oxidation is the erodent flux, since the time available for oxide growth (or regrowth) in a given area is determined by the interval between successive erodent impacts. Using this simple premise, an approach is suggested by which the rate of erosion-oxidation can be related to the factors that control the alloy oxidation process, and those that describe the erosive environment. The assumptions made are examined, and some of the implications of this approach are discussed. Author

A91-45331#
COMBUSTION BEHAVIOR OF BORON-BASED BAMO/NMMO FUEL-RICH SOLID PROPELLANTS
WEN-HSIN HSIEH, ARIE PERETZ, KENNETH K. KUO (Pennsylvania State University, University Park), and I.-T. HUANG Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 497-504. Previously cited in issue 20, p. 3142, Accession

no. A89-47149. refs
(Contract N00014-86-K-0468)
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A91-45397#
DEVELOPMENT OF THERMOPLASTIC PARTS FOR AEROSPATIALE HELICOPTERS
A. TURCHETTI, G. CURCIO, and J. SAPORITO (Aerospatiale, Division Helicopteres, Marignane, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 13 p.

Thermoplastic materials such as PA, PC, PMMA, and ABS resins with or without short-glass-fiber reinforcement are reviewed along with injection-molded thermoplastic and thermoformed parts and assemblies used in Aerospatiale helicopters. A Dauphin main-landing-gear wheel rim made of injection or compression-molded polyetheretherketone (PEEK) and short carbon fibers is covered in detail as well as a high-precision injection-molded PEEK/short-carbon-fiber fan motor and a two-piece Dauphin upper tail fin with a PEEK/carbon-fiber central section and Kevlar/polyamide sandwich tip fairing with a Nomex honeycomb core. Quality control procedures including material-acceptance, process-inspection, and product-examination steps are emphasized. V.T.

A91-45416#
STRUCTURAL WEIGHT SAVINGS ON THE EH101 USING ALUMINUM-LITHIUM ALLOYS
A. F. SMITH (Westland Helicopters, Ltd., Yeovil, England) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p. refs

The weight saving cost analysis associated with the planned introduction of aluminum-lithium alloys into the EH101 helicopter is summarized, and results of the studies carried out to assess their applicability and characteristics are presented. The use of such alloys in the form of sheet, extruded profiles, and die forgings is covered, and three types of commercial compositions (8090, 2091, and 2090) are considered. It is concluded that the 8090 composition is the preferred alloy for use in the helicopter, although 2091 can be considered as an alternative. Experiment show that these alloys exhibit satisfactory mechanical properties, with the fatigue behavior, in particular, generally being significantly better than current alloys. V.T.

A91-45624#
COMBUSTION BEHAVIOR OF BORON-BASED SOLID PROPELLANTS IN A DUCTED ROCKET
C. VIGOT, A. COCHET, and C. GUIN (ONERA, Chatillon, France) (International Symposium on Special Topics in Chemical Propulsion, 2nd, Lampoldshausen, Federal Republic of Germany, Mar. 4-6, 1991) ONERA, TP no. 1991-43, 1991, 19 p. Research supported by Ministere de la Defense. refs
(ONERA, TP NO. 1991-43)

The results of a study on a boron-propellant ducted rocket are presented. Tests were performed at reduced and full scales in a connected pipe system. The possibility that the propellant is self-throttling is investigated as well. K.K.

A91-45655#
FD-TD CALCULATION WITH COMPOSITE MATERIALS - APPLICATION TO C160 AIRCRAFT MEASUREMENTS
J. C. ALLIOT, J. GRANDO, F. ISSAC (ONERA, Chatillon, France), and X. FERRIERES (SLX Informatique, Courbevoie, France) (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-79, 1991, 10 p. refs
(ONERA, TP NO. 1991-79)

A formalism based on a sheet impedance concept is presented. Allowance is made for electromagnetic coupling through lossy materials and resistive joints. The penetration of electromagnetic fields through a carbon composite door located on the fuselage of an aircraft struck by lightning during an in-flight experiment is modeled. Good agreement with in-flight measurements is obtained if allowance is made for coupling through the joint surrounding the door. K.K.

A91-45658
STABILIZATION OF HYDROGEN-AIR FLAMES IN SUPERSONIC FLOW
G. WINTERFELD (DLR, Institut fuer Antriebstechnik, Cologne, Federal Republic of Germany) IN: Modern research topics in aerospace propulsion - In honor of Corrado Casci. New York, Springer-Verlag, 1991, p. 37-47. refs
Copyright

Experiments are presented demonstrating that flame stabilization in supersonic combustors using hydrogen as a fuel is possible if the flame holder dimensions are chosen appropriately. The Damkohler number for flame stabilization by recirculation zones, introducing the fuel characteristics via the laminar burning velocity, is derived and verified experimentally for hydrogen and hydrocarbon fuels. It has been applied to hydrogen-air diffusion flames stabilized by cylindrical flame holders in supersonic flows as high as Mach 2.1. Typical fluid mechanic times for hydrogen-air flames have been measured for a broad range of equivalence ratios. R.E.P.

A91-45730
HEAT RESISTANT CONCRETE FOR AIRFIELD PAVEMENTS - PRELIMINARY NUMERICAL STUDY
L. J. MALVAR (California, University, Davis) and M. C. HIRONAKA (U.S. Navy, Naval Civil Engineering Laboratory, Port Hueneme, CA) (Nonlinear finite element analysis and ADINA; Proceedings of the 8th ADINA Conference, Cambridge, MA, July 17-19, 1991. A91-45726 19-39) Computers and Structures (ISSN 0045-7949), vol. 40, no. 2, 1991, p. 303-311. U.S. Navy-supported research. refs
Copyright

Concrete airfield pavements subjected to the exhaust gas of the F/A-18 aircraft auxiliary power unit experience cracking and spalling. A two-step finite element simulation of the airfield pavement yields the temperature distribution and the consequent stress field. It is shown that normal weight concrete pavements will deteriorate. A parameter study is then carried out to assess the influence of each concrete property on the thermal stress field. From this study, the adequacy of any type of concrete can be determined. In particular, the properties of all-lightweight structural concrete are considered. It is shown that all-lightweight structural concrete may provide a satisfactory solution, even when the pavement is initially frozen. Author

A91-45777*# University of South Florida, Tampa.
NUMERICAL SIMULATION OF JET-A COMBUSTION APPROXIMATED BY IMPROVED PROPANE CHEMICAL KINETICS
SHUH-JING YING (South Florida, University, Tampa, FL) and HUNG LEE NGUYEN (NASA, Lewis Research Center, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 6 p. refs
(Contract NAG3-1112)
(AIAA PAPER 91-1859) Copyright

Through the effort devoted to the chemical kinetics for propane air combustion, three mechanisms are developed. The full mechanism consists of 131 reactions. This mechanism is used as a guide for the evaluation of other mechanisms, but because of the long expected cpu time, it is not to be incorporated into the computer code KIVA-II for actual simulation. Through the sensitivity analysis, a reduced mechanism of 45 reactions is produced. But the calculated results from the 45 reaction mechanism are always low in temperature. Some efforts are devoted to correct this situation and details are included in this report. A simplified mechanism of reactions is successfully improved and computed results are compared with experimental data. Contour plots of physical parameters and species concentrations and results for emission indices of CO and NOx are presented. Author

A91-45810*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
JET-A REACTION MECHANISM STUDY FOR COMBUSTION APPLICATION
CHI-MING LEE, KRISHNA KUNDU (NASA, Lewis Research Center, Cleveland, OH), and WALDO ACOSTA (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 12 p. refs
(AIAA PAPER 91-2355) Copyright

Simplified chemical kinetic reaction mechanisms for the combustion of Jet A fuel are studied. Initially 40 reacting species and 118 elementary chemical reactions were chosen based on the literature review of previous works. Through a sensitivity analysis with the use of LSENS General Kinetics and Sensitivity Analysis Code, 16 species and 21 elementary chemical reactions were determined from this study. This mechanism is first justified by comparison of calculated ignition delay time with available shock tube data, then it is validated by comparison of calculated emissions from plug flow reactor code with in-house flame tube data.
Author

A91-46169#
COMBUSTION PROCESSES OF HYDROGEN IN A SUPERSONIC AIR FLOW
AIKUO YANG (Computing Technical Research Institute, People's Republic of China), LING LIU, and HONGJI WANG (Northwestern Polytechnical University, Xian, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 271, 272. In Chinese. refs

According to the implicit numerical integration method proposed by Tyson, an improved computer program for pseudo-1D flow of combustion kinetics is developed with the aid of a chemical kinetic model with 12-species and 31 reactions. Variations of temperature, pressure, Mach number, and mass fraction of chemical species in a supersonic combustion model are studied in detail. The results of scramjet combustor conditions corresponding to flight Mach numbers 6, 10, and 15 show that chemical reaction rates decrease at rather low temperature and pressure at a combustor inlet and there is not enough time to ignite the mixture-gas in the combustor at very high Mach number; as a result the performance limits of scramjet kinetic combustion occur. Author

N91-27285*# Virginia Univ., Charlottesville. Dept. of Materials Science.
NASA-UVA LIGHT AEROSPACE ALLOY AND STRUCTURES TECHNOLOGY PROGRAM (LA2ST) Progress Report, 1 Jan. - 30 Jun. 1991
RICHARD P. GANGLOFF 30 Jun. 1991 347 p
(Contract NAG1-745)
(NASA-CR-188626; NAS 1.26:188626; UVA/528266/MS91/108)
Avail: NTIS HC/MF A15 CSCL 11/6

The general objective of the Light Aerospace Alloy and Structures Technology (LA2ST) Program is to conduct interdisciplinary graduate student research on the performance of next generation, light weight aerospace alloys, composites, and associated thermal gradient structures in close collaboration with Langley researchers. Specific technical objectives are established for each research project. Relevant data and basic understanding of material behavior and microstructure, new monolithic and composite alloys, advanced processing methods, new solid and fluid mechanic analyses, measurement advances, and a pool of educated graduate students are sought.

N91-28108*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EVALUATION OF ON-BOARD HYDROGEN STORAGE METHODS FOR HYPERSONIC VEHICLES
ATES AKYURTLU, J. F. AKYURTLU, A. A. ADEYIGA, SAMARA PERDUE (Hampton Univ., VA.), and G. B. NORTHAM *In* Alabama A & M Univ., NASA-HBCU Space Science and Engineering Research Forum Proceedings p 329-335 1989
Avail: NTIS HC/MF A23 CSCL 21/4

Hydrogen is the foremost candidate as a fuel for use in high speed transport. Since any aircraft moving at hypersonic speeds must have a very slender body, means of decreasing the storage volume requirements below that for liquid hydrogen are needed. The total performance of the hypersonic plane needs to be considered for the evaluation of candidate fuel and storage systems. To accomplish this, a simple model for the performance of a hypersonic plane is presented. To allow for the use of different engines and fuels during different phases of flight, the total trajectory is divided into three phases: subsonic-supersonic, hypersonic and rocket propulsion phase. The fuel fraction for the first phase is found be a simple energy balance using an average thrust to drag ratio for this phase. The hypersonic flight phase is investigated in more detail by taking small altitude increments. This approach allowed the use of flight profiles other than the constant dynamic pressure flight. The effect of fuel volume on drag, structural mass and tankage mass was introduced through simplified equations involving the characteristic dimension of the plane. The propellant requirement for the last phase is found by employing the basic rocket equations. The candidate fuel systems such as the cryogenic fuel combinations and solid and liquid endothermic hydrogen generators are first screened thermodynamically with respect to their energy densities and cooling capacities and then evaluated using the above model.
Author

N91-28343# Naval Air Development Center, Warminster, PA. Air Vehicle and Crew Systems Technology Dept.
RAPID SOLIDIFICATION PROCESSING OF AL3TI AND AL3TI PLUS COPPER Progress Report, Oct. 1989 - Oct. 1990
WILLIAM F. FRAZIER, JOHN BENCI, JOSEPH ZANTER, and HARRY TYNDALL 1 Dec. 1990 41 p
(Contract NADC PROJ. RS-3-4-A50)
(AD-A236600; NADC-91002-60) Avail: NTIS HC/MF A03
CSCL 07/2

The development of advanced airframes and propulsion systems has generated significant research and development activity in the area of light weight, high temperature intermetallic alloys, e.g., alpha-two and gamma titanium aluminides. However, Al3Ti, an intermetallic which has a low density (3.35 g/cu cm) and a high melting point (1350 C) has received little scientific scrutiny, principally because of its intrinsically low ductility. X ray diffraction, and optical and electron microscopy were used to interrogate the microstructure of Al3Ti and Al3Ti plus copper in their as-cast and melt spun conditions. Rapid solidification enhanced chemical uniformity and the addition of copper transformed the structure of Al3Ti from tetragonal DO22 into cubic Li2, a structure with a higher crystallographic symmetry. GRA

N91-28373*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TEST OF SUPERPLASTICALLY FORMED CORRUGATED ALUMINUM COMPRESSION SPECIMENS WITH BEADED WEBS
RANDALL C. DAVIS, DICK M. ROYSTER, THOMAS T. BALES, WILLIAM F. JAMES (Lockheed Engineering and Sciences Co., Hampton, VA.), and JOSEPH M. SHINN, JR. Jun. 1991 33 p
(NASA-TM-104119; NAS 1.15:104119) Avail: NTIS HC/MF A03
CSCL 11/6

Corrugated wall sections provide a highly efficient structure for carrying compressive loads in aircraft and spacecraft fuselages. The superplastic forming (SPF) process offers a means to produce complex shells and panels with corrugated wall shapes. A study was made to investigate the feasibility of superplastically forming 7475-T6 aluminum sheet into a corrugated wall configuration and to demonstrate the structural integrity of the construction by testing. The corrugated configuration selected has beaded web segments separating curved-cap segments. Eight test specimens were fabricated. Two specimens were simply a single sheet of aluminum superplastically formed to a beaded-web, curved-cap corrugation configuration. Six specimens were single-sheet corrugations modified by adhesive bonding additional sheet material to

selectively reinforce the curved-cap portion of the corrugation. The specimens were tested to failure by crippling in end compression at room temperature. Author

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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.

A91-44507#
THE INFLUENCE OF CURVATURE ON FILM COOLING PERFORMANCE
S. G. SCHWARZ (Louisiana, Tulane University, New Orleans), R. J. GOLDSTEIN, and E. R. G. ECKERT (Minnesota, University, Minneapolis) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(Contract F49620-85-C-0049)
(ASME PAPER 90-GT-10)

The effects of injection rate and strength of curvature on film cooling performance of gas injected through a row of holes on a convex surface is studied. Comparisons are made to film cooling of concave and flat surfaces. Three different relative strengths of curvature (ratio of radius of curvature to radius of injection hole), two density ratios (0.95 and 2.0), and a wide range of blowing rates (0.3 to 2.7) are considered. A foreign gas injection technique (mass transfer analogy) is used. The strength of curvature was controlled by varying the injection hole diameter. At low blowing rates, film cooling is more effective on the convex surface than on a flat or a concave surface. The cross stream pressure gradient present in curved flows tends to push the jet into the convex wall. As the injection rate is increased, normal and tangential jet momentum promote lift-off from the convex surface, thereby lowering performance. In contrast, previous studies show that a concave surface, tangential jet momentum, flow instabilities, and blockage improve performance on a concave surface as blowing rate is increased. Author

A91-44513#
ROTATING CAVITY WITH AXIAL THROUGHFLOW OF COOLING AIR - HEAT TRANSFER
P. R. FARTHING, C. A. LONG, J. M. OWEN, and J. R. PINCOMBE (Sussex, University, Brighton, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Research supported by SERC, Rolls-Royce, PLC, and Ruston Gas Turbines, PLC. refs
(ASME PAPER 90-GT-16)

Results are presented of heat transfer measurements in two rotating cavity rigs with axial throughflow of cooling air, for a wide range of flow rates, rotational speeds, and temperature distributions. It was found that the magnitudes, the distributions, and the behavior of the local Nusselt numbers depended on whether or not the rotating cavities were heated symmetrically (i.e., both disks had the same distribution of temperature) or asymmetrically and whether or not the temperature distribution was increasing or decreasing. For the increasing temperature case (where the temperature on the disks increases radially), a simple correlation was obtained between the local Nusselt numbers and the local Grashof numbers and the axial Reynolds number. I.S.

A91-44516#
THE CALCULATION OF THREE DIMENSIONAL VISCOUS FLOW THROUGH MULTISTAGE TURBOMACHINES
J. D. DENTON (Cambridge, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. refs
(ASME PAPER 90-GT-19)

A well established 3D flow calculation method using the basic Euler solver described by Denton (1982, 1985) is extended to calculate the flow through multiple turbomachinery blade rows. The method, which incorporates a range of options for the inclusion of viscous effects, is applied to several multistage turbines and compressors. It is shown that the main attraction of the method is its ability to reduce the amount of human intervention needed to obtain solutions by eliminating the need to iterate between throughflow solutions and blade-to-blade solutions. At the same time, the method removes most of the limitations implicit in the quasi-3D approach, especially the neglect of stream surface twist and the need to assume a distribution of stream surface thickness within the blade rows. I.S.

A91-44520#
LOCAL HEAT TRANSFER IN TURBINE DISK-CAVITIES. II - ROTOR COOLING WITH RADIAL LOCATION INJECTION OF COOLANT
R. S. BUNKER, D. E. METZGER, and S. WITTIG (Karlsruhe, Universitaet, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. refs
(ASME PAPER 90-GT-26)

The detailed radial distributions of rotor heat-transfer coefficients for three basic disk-cavity geometries applicable to gas turbines are presented. The coefficients are obtained over a range of parameters including disk rotational Reynolds numbers of 200,000 to 50,000, rotor/stator spacing-to-disk ratios of 0.025 to 0.15, and jet mass flow rates between 0.10 and 0.40 times the turbulent pumped flow rate of a free disk. The effects of a parallel rotor are analyzed, and strong variations in local Nusselt numbers for all but the rotational speed are pointed out and compared with the associated hub-injection data from a previous study. It is demonstrated that the overall rotor heat transfer is optimized by either the hub injection or radial location injection of a coolant, dependent on the configuration. V.T.

A91-44529*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NAVIER-STOKES ANALYSIS OF TURBINE BLADE HEAT TRANSFER
R. J. BOYLE (NASA, Lewis Research Center, Cleveland, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 16 p. Previously announced in STAR as N90-21300. refs
(ASME PAPER 90-GT-42)

Comparisons with experimental heat transfer and surface pressures were made for seven turbine vane and blade geometries using a quasi-three-dimensional thin-layer Navier-Stokes analysis. Comparisons are made for cases with both separated and unseparated flow over a range of Reynolds numbers and freestream turbulence intensities. The analysis used a modified Baldwin-Lomax turbulent eddy viscosity mode. Modifications were made to account for the effects of: (1) freestream turbulence on both transition and leading edge heat transfer; (2) strong favorable pressure gradients on relaminarization; and (3) variable turbulent Prandtl number heat transfer. In addition, the effect of heat transfer on the near wall model of Deissler is compared with the Van Driest model. Author

A91-44531#
GAS TURBINE FILM COOLING - FLOWFIELD DUE TO A SECOND ROW OF HOLES
A. K. SINHA, D. G. BOGARD, and M. E. CRAWFORD (Texas, University, Austin) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Allied-Signal Aerospace Co.-supported research. refs
(ASME PAPER 90-GT-44)

Flowfield measurements with relevance to gas turbine film

cooling were carried out behind a second row of holes located 40 hole diameters downstream of a first row and staggered with respect to it. The effects of the thicker boundary layer and that of injection from the first row were examined. Experiments were carried out for jet-to-mainstream density ratios of 1 and 2 and results compared to those obtained by Pietrzyk et al. (1989a,b) behind the first row. Results show that the dominant structures identified in the flowfield downstream of the first row were also present behind the second row. Due to the thicker boundary layer, though, the mean flowfield and the turbulence and shear stress fields were altered. One of the significant results was that the thicker boundary layer enables the jets to penetrate deeper into the mainstream. Author

A91-44534#
FABRICATION AND DEVELOPMENT OF AXIAL SILICON NITRIDE GAS TURBINE ROTORS
G. BANDYOPADHYAY, K. W. FRENCH, D. J. SORDELET (GTE Laboratories, Inc., Waltham, MA), and K. D. MOERGENTHALER (Daimler-Benz AG, Stuttgart, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-47)

Since 1984, GTE Laboratories Incorporated has performed research to develop net shape fabrication technology for axial silicon nitride rotors for the Daimler-Benz research gas turbine engine. The initial effort was focused on the fabrication of injection-molded profile disks. Subsequently, efforts were shifted to develop injection molding and slip casting technology for the bladed gasifier rotors. This joint activity has demonstrated that the ceramics technology has improved significantly over the last five years, as is evidenced by major improvement in properties and performance of silicon nitride components. The evolution of the ceramics fabrication technology at GTE and the role of improved process and NDE methods on components fabricated in recent years are described in this paper. Author

A91-44535#
DESIGN OF CERAMIC GAS TURBINE COMPONENTS
G. STUERMER, M. FUNDUS, A. SCHULZ, and S. WITTIG (Karlsruhe, Universitaet, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-48)

The numerical code CERITS, which has been developed for FEM calculation reliability analysis of ceramic gas turbine components, determines the failure probability of such components with reference to volumetric flaws. CERITS is coupled with the FEM code ADINA, which facilitates the requisite temperature and stress distribution predictions. The present demonstration of this procedure concerns gas turbine combustor components fabricated from either siliconized SiC or sintered SiC. Results are presented from both FEM and reliability analyses of these combustors. O.C.

A91-44542#
FULL COVERAGE DISCRETE HOLE FILM COOLING - THE INFLUENCE OF THE NUMBER OF HOLES AND PRESSURE LOSS
G. E. ANDREWS, A. A. ASERE, M. L. GUPTA, M. C. MKPADI, and A. TIRMAHI (Leeds, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(Contract SERC-GR/D/53029)
(ASME PAPER 90-GT-61)

Experimental measurements of the overall cooling effectiveness for full coverage discrete hole effusion cooling are presented for a wide range of practical geometries and for a density ratio between the coolant and combustion gases of 2.5. The influence of the number of holes per unit surface area was investigated at two fixed total hole areas or design pressure losses of 3 percent and 0.1 percent, at a relatively low coolant flow rate per unit of surface area. Hole configurations suitable for both combustor and turbine blade cooling were investigated with hole sizes from 1.4 to 0.6 mm at 3-percent design pressure loss and 1.3 to 3.3 mm at 0.1-percent design presure loss. The diameter change at a fixed pressure loss was for a constant total hole area with more holes as the size was reduced. This was shown to increase the cooling effectiveness through improved film cooling. Enlarging the hole size for a fixed number of holes and hence reducing the pressure loss for a fixed coolant mass flow was also shown to improve the cooling effectiveness through better film cooling. Author

A91-44555#
GAS TURBINE ROTOR BLADE FILM COOLING WITH AND WITHOUT SIMULATED NGV SHOCK WAVES AND WAKES
M. J. RIGBY (Rolls-Royce, PLC, Derby, England), A. B. JOHNSON (Schlumberger Cambridge Research, England), and M. L. G. OLDFIELD (Oxford, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Rolls-Royce, PLC-supported research. refs
(Contract F33615-84-C-2475)
(ASME PAPER 90-GT-78)

Detailed heat transfer measurements have been made around a film-cooled transonic gas turbine rotor blade in the Oxford Isentropic Light Piston Tunnel. Film cooling behavior for four film cooling configurations have been analyzed for a range of blowing rates both without and with simulated nozzle guide vane (NGV) shock wave and wake passing. The superposition model of film cooling has been employed in analysis of time-mean heat transfer data, while time resolved unsteady heat transfer measurements have been analyzed to determine interaction between film-cooling and unsteady shock wave and wake passing. It is found that there is a significant change of film-cooling behavior on the suction surface when simulated NGV unsteady effects are introduced. Author

A91-44563#
MEASURING ROTOR AND BLADE DYNAMICS USING AN OPTICAL BLADE TIP SENSOR
HAROLD R. SIMMONS, DOUGLAS L. MICHALSKY, KENNETH E. BREWER, and ANTHONY J. SMALLEY (Southwest Research Institute, San Antonio, TX) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. Research supported by Southwest Research Institute. refs
(ASME PAPER 90-GT-91)

Attention is given to the physical probe, light transmission, electronics, and initial performance evaluation of a measurement system for monitoring combustion turbine blade tips. The distance to a blade tip is measured through a sensor using triangulation of reflected laser light. Triangulation is accomplished through an optical position sensing device and high-speed data acquisition. Static calibration data for the measurement system show its degree of linearity and range. Also discussed are data obtained on a dynamic blade test rig, with tip passing speeds and blade widths comparable to those encountered in high-performance industrial combustion turbines. These data characterize rotor vibration, shift in shaft average position, blade-to-blade tip clearance variation, and variation with speed of minimum blade tip clearance. O.G.

A91-44565#
MODEL ADJUSTMENT OF SMALL ROTORS FOR HIGH SPEED GAS TURBINES
ALAIN DELBEZ, CHRISTIAN BETH (Microturbo, Toulouse, France), and DANIEL GAY (Toulouse III, Universite, France) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-93)

Studies aimed at improving prediction of the behavior of rotor-bearing systems mounted in small high-speed gas turbines are reported. The development of an adequate model of a free-free nonrotating shaft using an optimization procedure is described. The resulting model is used to study the influence of angular velocities, bearings, and housing on critical speeds. C.D.

A91-44568#
DEVELOPMENT AND TESTING OF AN AXIAL SILICON NITRIDE GAS TURBINE ROTOR
K. D. MOERGENTHALER, H. HEMPEL, L. JUNGBAUER, M. STUTE, H. WIEST (Daimler-Benz AG, Stuttgart, Federal Republic of Germany) et al. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. BMFT-sponsored research. refs
(ASME PAPER 90-GT-96)

A ceramic gasifier turbine wheel has been developed for an automative gas turbine with turbine inlet temperatures up to 1350 C, using processes suitable for volume production. The development work included designing a new turbine rotor made from sintered or HIPed silicon nitride suitable for production by slip casting or injection molding. Beside proof tests and thermal shock tests, some rotors were tested in a hot gas test rig and in the research gas turbine PWT 110. Author

A91-44571#
EXPERIMENTAL AND COMPUTED PERFORMANCE CHARACTERISTICS OF HIGH SPEED SILICON NITRIDE HYBRID BALL BEARINGS
GEORGE W. HOSANG (Sundstrand Power Systems, San Diego, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 12 p. refs
(ASME PAPER 90-GT-110)

Development testing of hybrid bearings with M-50 rings and HIP'ed silicon nitride balls in small high speed turbojet engines was carried out for several minutes at speeds up to 110,000 rpm. After each test phase the bearings were removed for examination and re-used or replaced. Four of the bearings were submitted to inspection with special equipment to measure operating contact angles, as evidenced by the visible ball tracks, and any wear present. Contact angles and other operating characteristics estimated with the Jones, SHABERTH, and ADORE computer codes are compared with the experimental data. Author

A91-44574#
THE EFFECT OF INCIDENT WAKE CONDITIONS ON THE MEAN HEAT TRANSFER OF AN AIRFOIL
K. DULLENKOPF, A. SCHULZ, and S. WITTIG (Karlsruhe, Universitaet, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. Research supported by BMFT and Turbo AG. refs
(ASME PAPER 90-GT-121)

Measurements of unsteady wake flow obtained by a fixed hot-wire anemometer using the ensemble average technique are presented and compared to results from the literature for the wake width of a cylinder in cross-flow. Experimentally evaluated mean heat transfer coefficients obtained under different unsteady initial conditions are reported. The results show the strong effect of unsteady wakes to the suction side boundary layer and heat transfer. Temporary laminar and turbulent conditions in the boundary layer lead to an elongated transitional zone where the wake frequency is a dominant factor for the mean heat transfer. C.D.

A91-44581#
RIM SEAL EXPERIMENTS AND ANALYSIS FOR TURBINE APPLICATIONS
W. A. DANIELS, B. V. JOHNSON (United Technologies Research Center, East Hartford, CT), D. J. GRABER (Pratt and Whitney Group, West Palm Beach, FL), and R. J. MARTIN (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Research supported by United Technologies Corp. refs
(Contract F33615-83-C-2331)
(ASME PAPER 90-GT-131)

An experimental investigation was conducted to determine the sealing effectiveness and the aerodynamic characteristics of four rim seal models for a number of flow conditions. The experiments were conducted to obtain an extended data base for advanced turbine rim seal design. The class of rim seals investigated are those found on the downstream side of the rotor where the boundary layer on the disk is pumped directly into the seal gap. The results of this investigation indicate that decreasing the radial gap of the seal produces a better improvement in seal effectiveness than increasing the axial overlap of the seal, that seal effectiveness increases only modestly as the swirl across the top of the seal decreases, and that the trace gas technique employed to determine seal effectiveness is an accurate alternative to pressure measurement or flow visualization techniques used by other investigators. Author

A91-44586#
MORE ON THE TURBULENT-STRIP THEORY FOR WAKE-INDUCED TRANSITION
R. E. MAYLE (Rensselaer Polytechnic Institute, Troy, NY) and K. DULLENKOPF (Karlsruhe, Universitaet, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 5 p. refs
(ASME PAPER 90-GT-137)

A theory for transition from laminar to turbulent flow with an unsteady, periodic passing of turbulent wakes in the free stream has recently been presented by the authors. The theory considers a time-averaged transitional flow caused by the formation and propagation of turbulent strips along the surface. To apply the theory, however, both the origin and a quantity related to the production rate of these turbulent strips must be known. In this paper, after a brief review of the theory, a dimensional analysis of the problem is presented and data from experiments re-examined in light of the result. From this, an expression for the time-averaged intermittency is obtained which may be used to calculate the time-averaged distributions of various boundary layer quantities for wake-induced transitional flow. Author

A91-44587#
HEAT TRANSFER MEASUREMENTS IN RECTANGULAR CHANNELS WITH ORTHOGONAL MODE ROTATION
W. D. MORRIS (Swansea, University College, Wales) and G. GHAVAMI-NASR (British Steel, PLC, Welsh Research Laboratories, Port Talbot, Wales) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 11 p. Research supported by Ministry of Defence of England, Rolls-Royce, PLC, and SERC. refs
(ASME PAPER 90-GT-138)

The influence of rotation on local heat transfer in a rectangular-sectioned duct is investigated for the case where the duct rotates about an axis orthogonal to its own central axis. The results demonstrate that orthogonal mode rotation produces an enhancement of local and mean heat transfer on the trailing surface of the duct and that this effect is caused by a Coriolis-induced cross stream secondary flow. On the leading surface of the duct, local and mean heat transfer can be significantly impaired in relation to the corresponding nonrotating flow situation. In the practical situation of rotor blade cooling, this can give rise to local overheating. It is shown that rotational buoyancy affects both leading and trailing surfaces with a tendency for the local and mean heat transfer to increase with increases in the wall to fluid temperature difference. O.G.

A91-44593#
ASSESSMENT OF UNSTEADY FLOWS IN TURBINES
O. P. SHARMA, G. F. PICKETT, and R. H. NI (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 18 p. refs
(ASME PAPER 90-GT-150)

The impact of unsteady flow research activities on flow simulation methods used in the turbine design process are assessed. Results from experimental investigations, which identify the impact of periodic unsteadiness on the time-averaged flows in

turbines, and results from numerical simulations obtained by using three-dimensional unsteady computational fluid dynamics (CFD) codes indicate that some of the unsteady flow features can be fairly accurately predicted. Flow parameters that can be modeled with existing steady CFD codes are distinguished from those that require unsteady codes. Author

A91-44604#
A SIMPLE AND RELIABLE COMBUSTION CONTROL SYSTEM
B. BECKER, F. BONSEN, and G. SIMON (Siemens AG, Muelheim an der Ruhr, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-173)

The basis of a simple and reliable control system is a low number of components to be controlled. In order not to bend the outer casing of the turbomachinery components during transients a symmetric arrangement of the combustors is required. Two combustors are then the lowest possible number. For modern dry-low-Nox burner systems with different modes of operation in the load range, more than one fuel nozzle system and the air flow distribution in the combustors have to be controlled. A low number of combustors therefore leads to a low number of such control devices. Author

A91-44605#
COMBUSTOR EXIT TEMPERATURE DISTORTION EFFECTS ON HEAT TRANSFER AND AERODYNAMICS WITHIN A ROTATING TURBINE BLADE PASSAGE
S. P. HARASGAMA (Royal Aerospace Establishment, Propulsion Dept., Farnborough, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-174)

A numerical simulation of temperature distortion at inlet to a rotating turbine rotor has been performed. A 3D Navier-Stokes code and the 2D boundary layer code STAN5 have been used. The results show that the hot gas is transported to the pressure surface of the blade and that hot gas also migrates to the blade pressure side tip. At locations greater than 50-60 percent axial chord, the hot gas enters the tip gap and emerges over the suction side. These computations are in agreement with previous experimental results. The secondary flows within the turbine rotor are enhanced by the introduction of inlet radial temperature distortion, and this is in accord with previous analytical work. It is shown that the heat flux near the tip region on the pressure side of the blade can be increased by up to 76 percent due to the redistribution of the inlet temperature distortion. Author

A91-44606#
UNSTEADY HEAT TRANSFER MEASUREMENTS ON A ROTATING GAS TURBINE BLADE
M. A. HILDITCH (National Power Technology and Environmental Centre, Leatherhead, England) and R. W. AINSWORTH (Oxford, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 16 p. Research supported by SERC and Rolls-Royce, PLC. refs
(ASME PAPER 90-GT-175)

This paper presents heat transfer measurements made on the rotor blade of a full-stage model turbine operating at engine representative conditions. The measurement technique of mounting thin film heat transfer gauges on enamel-coated turbine blades enables the heat transfer rate to be measured across a frequency range of dc to 100 KHz. A calibration experiment in which the gauge is pulsed with a laser beam is described in detail. The results are compared with data from a previous 2D simulation of wake-passing flow in the midheight section of the same blade. The mean heat transfer rate recorded in the two experiments shows reasonable agreement. Fluctuations in the unsteady heat transfer signal at nozzle-guide-vane passing frequency are seen at the same locations in data from both experiments. The magnitude of the fluctuations seen on the rotor are much smaller than those recorded in the 2D simulation. Frequency spectra and correlation analysis of heat transfer traces recorded on the rotor are also presented. P.D.

A91-44607*# Norton Co., Northboro, MA.
A COMPARISON OF FORMING TECHNOLOGIES FOR CERAMIC GAS-TURBINE ENGINE COMPONENTS
R. R. HENGST, D. N. HEICHEL, J. E. HOLOWCZAK, A. P. TAGLIALAVORE, and B. J. MCENTIRE (Norton/TRW Ceramics, Northboro, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. Research supported by DOE, NASA, and Allied-Signal Aerospace Co. refs
(ASME PAPER 90-GT-184)

For over ten years, injection molding and slip casting have been actively developed as forming techniques for ceramic gas turbine components. Co-development of these two processes has continued within the U.S. DOE-sponsored Advanced Turbine Technology Application Project (ATTAP). Progress within ATTAP with respect to these two techniques is summarized. A critique and comparison of the two processes are given. Critical aspects of both processes with respect to size, dimensional control, material properties, quality, cost, and potential for manufacturing scale-up are discussed. Author

A91-44609#
DEVELOPMENT IN INJECTION MOLDING SILICON NITRIDE TURBINE COMPONENTS
J. NEIL, G. BANDYOPADHYAY, D. SORDELET, and M. MAHONEY (GTE Laboratories, Inc., Waltham, MA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 6 p. refs
(ASME PAPER 90-GT-186)

The use of injection molding technology for the fabrication of near-net-shape silicon nitride turbine components has been demonstrated in a number of rotor and blade configurations. The current emphasis at GTE Laboratories is to refine the process, bringing it to a level of durability and reproducibility sufficient for production needs. Progress in injection molding technology development will be described with emphasis on the flow and mechanical property requirements for forming flaw-free green components. Application of the findings to the fabrication of AGT-5 axial turbine rotors and vanes under the DOE sponsored Advanced Turbine Technology Applications Project will be reviewed. Author

A91-44645#
UNSTEADY VELOCITY AND TURBULENCE MEASUREMENTS WITH A FAST RESPONSE PRESSURE PROBE
G. RUCK and H. STETTER (Stuttgart, Universitaet, Federal Republic of Germany) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(ASME PAPER 90-GT-232)

To investigate the 3D unsteady flow and the turbulence intensities behind rotating blade rows of turbomachines, a procedure using a fast-response pressure probe has been developed. The integration of the cylindrical miniature pressure transducers into the probe head minimizes the risk of mechanical damage. The dynamic behavior of the probe was analyzed. The application of the probe to the rotor exit flow of an axial compressor is described and results are presented. Author

A91-44659*# Allied-Signal Aerospace Co., Torrance, CA.
DEVELOPMENT OF SILICON NITRIDE ENGINE COMPONENTS FOR ADVANCED GAS TURBINE APPLICATIONS
B. J. BUSOVNE, JR. and J. P. POLLINGER (Allied-Signal Aerospace Co., Torrance, CA) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. Research sponsored by Allied-Signal Aerospace Co. and DOE. refs
(Contract DEN3-335; DEN3-336)
(ASME PAPER 90-GT-248)

The development and fabrication of reliable high temperature-high strength silicon nitride rotors is discussed. The current status of rotor net-shape forming capability, achievable mechanical properties, NDE development/implementation, and statistical process control results are presented. Author

A91-44661#
HEAT TRANSFER CHARACTERISTICS OF TURBULENT FLOW IN A SQUARE CHANNEL WITH ANGLED DISCRETE RIBS
S. C. LAU, R. D. MCMILLIN, and J. C. HAN (Texas A & M University, College Station) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(Contract NSF CBT-87-13833)
(ASME PAPER 90-GT-254)

Experiments have been conducted to study the turbulent heat transfer and friction for fully developed flow of air in a square channel in which two opposite walls are roughened with 90-deg full ribs, parallel and crossed full ribs with angles-of-attack (alpha) of 60 deg and 45 deg, 90-deg discrete ribs, and parallel and crossed discrete ribs with = 60, 45, and 30 deg. Results are obtained for a rib height-to-channel hydraulic diameter ratio of 0.0625, a rib pitch-to-height ratio of 10, and Reynolds numbers between 10,000 and 80,000. Parallel angled discrete ribs are superior to 90 deg discrete ribs and parallel angled full ribs. For alpha = 60 deg and 45 deg, parallel discrete ribs have higher ribbed wall heat transfer, lower smooth wall heat transfer, and lower channel pressure drop than parallel full ribs. Author

A91-44664#
DEVELOPMENT OF AN EFFICIENT OIL FILM DAMPER FOR IMPROVING THE CONTROL OF ROTOR VIBRATION
SHIPING ZHANG and LITANG YAN (Beijing University of Aeronautics and Astronautics, People's Republic of China) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. NNSFC-supported research. refs
(ASME PAPER 90-GT-257)

An efficient oil film damper known as porous squeeze film damper (PSFD) was developed for more effective and reliable vibration control of high speed rotors based on the conventional squeeze film damper (SFD). The outer race of the PSFD is made of permeable sintered porous metal materials. The permeability allows some of the oil to permeate into and seep out the porous matrix, with remarkebly improvement of the squeeze film damping properties. The characteristics of PSFD oil film stiffness and damping coefficients and permeability, also, the steady state unbalance response of a simple rigid rotor and flexible Jeffcott's rotor supported on PSFD and SFD are investigated. A typical experiment is presented. Investigations show that the nonlinear vibration characteristics of the unpressurized SFD system such as bistable jump phenomena and 'lockup' at rotor pin-pin critical speeds could be avoided and virtually disappear under much greater unbalance level with properly designed PSFD system. PSFD has the potential advantages to operate effectively under relative large unbalance conditions. Author

A91-44674#
AERO/AERODERIVATIVE ENGINES - INTERNAL TRANSDUCERS OFFER POTENTIAL FOR ENHANCED CONDITION MONITORING AND VIBRATION DIAGNOSTICS
MALCOLM J. WERNER (Bently Nevada Corp., Minden) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-273)

Gas turbine aero engines and their ground based derivatives can benefit greatly from the enhanced condition and diagnostic data available from internal vibration transducers. This paper discusses transducer selection, illustrates typical transducer locations and mounting, and describes some of the rotor malfunctions that can be diagnosed from the vibrations data. Author

A91-44676#
AIR BLAST ATOMIZATION AS A FUNCTION OF PRESSURE LOSS FOR LARGE AIR FLOW RATES
U. S. ABDUL HUSSAIN and G. E. ANDREWS (Leeds, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. refs
(ASME PAPER 90-GT-277)

Combined air blast atomization and fuel and air mixing was studied in an interacting shear layer jet mixing flame stabilizer, termed Jet Mix, at gas turbine primary zone design conditions. Air blast atomization improves if large proportions of the combustion air flow are used and the maximum possible airflows were used in this study, as all the primary zone air flow was used for atomization. A Malvern spray analyzer was used with a simulated gas-oil fuel. The atomization was investigated at 37 and 76 mm from the sprayer and there was a significant improvement in the atomization at the furthest downstream position. At gas turbine primary zone air flow pressure loss conditions, values of SMD below 20 microns were demonstrated and the results were lower than any other published air blast atomizer SMD for the same pressure loss. The results were correlated in terms of the atomizer air flow pressure loss and the pressure loss exponent varied from 0.9 to 0.6 as the blockage was increased. A general correlation for three different blockages was achieved with the constants a function of the blockage. Author

A91-44685#
MEASUREMENT AND CALCULATION OF END WALL HEAT TRANSFER AND AERODYNAMICS ON A NOZZLE GUIDE VANE IN ANNULAR CASCADE
N. W. HARVEY (Rolls-Royce, PLC, Turbine Technology Dept., Derby, England) and T. V. JONES (Oxford, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 10 p. Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC. refs
(ASME PAPER 90-GT-301)

Detailed measurements of surface static pressures and heat transfer rates on the aerofoil and hub end wall of an annular nozzle guide vane (in the absence of a downstream rotor) are presented. Heat transfer rates have been measured using thin film gages in an annular cascade in the Pyestock Isentropic Light Piston Casccade. Test Mach numbers, Reynolds numbers and cascade geometry are fully representative of engine conditions. The results of 3D calculations of surface Mach number and 2D calculations of aerofoil heat transfer are presented and compared with the measurements. A new method of calculating end wall heat transfer using the axisymmetric analogue for three-dimensional boundary layers is described in detail. The method uses a 3D Euler solver to calculate the inviscid surface streamlines along which heat transfer coefficients are calculated. The metric coefficient which describes the lateral convergence or divergence of the streamlines is used to include three-dimensional effects in the calculation. The calculated heat transfer rates compare well with the measured values. Reference is made to surface flow visualization in the interpretation of the results. Author

A91-44696#
THE ASSUMED MODE METHOD IN STRUCTURAL DYNAMICS OF BLADED-DISK-SHAFT SYSTEMS
NAIM KHADER (Jordan University of Science and Technology, Irbid) and SAMER MASOUD ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 9 p. Research sponsored by Jordan University of Science and Technology. refs
(ASME PAPER 90-GT-315)

Analytical investigation into the effect of transverse bending of continuous flexible shafts is presented. While the blades are allowed both in-plane and out-of-plane deformations, the considered disk is rigid, and the shaft is allowed to bend in two planes. The assumed mode method is used to express flexible blade and shaft deformations, and the Lagrangian approach is

used to derive the governing equations of motion for the considered structure. Stiffness and inertia properties of an actual experimental rotor, typical of a fan stage, are used in the analysis. Calculations are performed for three different disk-shaft configurations, and results are presented for different shaft stiffness and inertia parameters, as well as for a wide range of rotational speed.
Author

A91-44698#
CHEMICAL STRIPPING OF HONEYCOMB AIRSEALS - OVERVIEW AND UPDATE
ZEV GALEL (United Airlines, San Francisco, CA), FRANK BRINDISI (Enthone, Inc., West Haven, CT), and DONALD NORDSTROM (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p.
(ASME PAPER 90-GT-318)

Chemical stripping of the braze joint on honeycomb airseals is discussed as an improvement over mechanical methods, which reduce part wall thickness below acceptable limits. Chemical stripping has been successfully tested for a range of parts with different braze alloy/base metal combinations. Advantages and disadvantages of this approach are discussed, along with optional methods that enhance the replenishment of the chemical solution within the honeycomb cell. Author

A91-44705#
AN INVESTIGATION OF CONVECTIVE HEAT TRANSFER IN A ROTATING COOLANT CHANNEL
J. O. MEDWELL, W. D. MORRIS, J. Y. XIA, and C. TAYLOR (Swansea, University College, Wales) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. Rolls-Royce, PLC-supported research. refs
(ASME PAPER 90-GT-329)

A numerical method is presented for the determination of heat transfer rates in a cylindrical cooling duct within turbine blades which rotate about an axis orthogonal to its own axis of symmetry. The equations of motion and energy are solved in conjunction with the k-epsilon model of turbulence using the finite element method. The predicted results are compared with experimental data and it is clearly demonstrated that conduction in the solid boundary must be taken into account if satisfactory agreement is to be achieved. Excluding these effects can lead to an overestimation of the maximum wall temperature by approximately 50 percent. Author

A91-44712#
ENDWALL LOSSES AND FLOW UNSTEADINESS IN A TURBINE BLADE CASCADE
L. ADJLOUT and S. L. DIXON (Liverpool, University, England) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p. refs
(ASME PAPER 90-GT-355)

An experimental investigation of the flowfield downstream of a low-speed linear cascade of turbine blades utilizing a Kiel probe transducer, hot wire, and flow visualization is presented. Flow visualization was employed to obtain detailed photographs of the flow patterns on the endwall and to exhibit the trailing edge vortices. Hot-wire anemometry together with a spectrum analyzer program was employed to determine the frequencies of the flow oscillations. It is shown that the pressure distribution on the blade with the lower turbulence intensity of the free-stream has the larger lift in the aft half of the suction side of the blade. R.E.P.

A91-44725#
NON-INTRUSIVE SENSING TECHNIQUES FOR ADVANCED TURBINE ENGINE STRUCTURES
WILLIAM A. STANGE (USAF, Aero Propulsion and Power Laboratory, Wright-Patterson AFB, OH) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 5 p. refs
(ASME PAPER 90-GT-389)

This paper presents an overview of current research efforts aimed at improving turbine engine structural instrumentation capabilities. Emphasis is placed on non-intrusive concepts which will be applicable to the advanced engines currently being designed for initial operational testing around the turn of the century. Technologies to be described include: blade tip deflection sensors to determine dynamic stress, thermographic phosphors to measure metal temperature, fiber optics to measure both temperature and steady-state strain while embedded in composites, and neutron diagnostic techniques. Advantages of the various systems, potential problems and limitations, as well as, an assessment as to when the various technologies are likely to be ready for actual engine test usage are discussed. Author

A91-44726#
DEVELOPMENT OF ADVANCED DIAGNOSTICS FOR TURBINE DISKS
J. R. DUNPHY (United Technologies Research Center, East Hartford, CT) and W. H. ATKINSON (Pratt and Whitney Group, East Hartford, CT) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 7 p.
(ASME PAPER 90-GT-390)

Quantitative diagnostics are essential for use during design optimization studies of turbine engine components to insure that performance goals and lifetime requirements are met. This paper addresses development and testing of sensors for diagnostic application in turbine hot sections. Technologies tested during this investigation included optical fiber static strain sensors, thin metallic film static strain sensors, advanced wire static strain sensors, thermographic phosphor temperature sensors and heat flux sensors. Reference measurements for the strain sensors were provided by speckle photogrammetry and conventional strain gages, while reference measurements for temperature sensor were provided by optical pyrometry and conventional thermocouples. Simulated engine conditions typical of a high pressure turbine disk were provided by operating a disk in a high speed spin-rig which ran to 13,200 revolutions per minute and 950 K. Representative results and application issues will be provided for each sensor type. Author

A91-44728#
THE EFFECT OF AMBIENT PRESSURE ON THE SPRAY CHARACTERISTICS OF A TWIN-FLUID ATOMIZER
S. A. DRENNAN, W. A. SOWA, and G. S. SAMUELSEN (California, University, Irvine) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 8 p. refs
(Contract F08635-86-C-0309)
(ASME PAPER 90-GT-393)

A combined simplex/air-assist atomizer with swirl is characterized in an isothermal high-pressure spray-characterization chamber, with optical access, under various ambient pressures. A single-component, phase Doppler laser interferometer is used to obtain spatially resolved droplet size and velocity information. Data are obtained at atmospheric pressure as well as 3 and 6 atmospheres for conditions of constant fuel and atomizing air flow rates. Two different nozzle air flow rates and, hence, two different air-to-liquid ratios are considered. Increasing ambient pressure decreases the air-to-liquid momentum ratio and thereby decreases droplet mean axial velocity and increases the droplet size. The response of a spray to increasing ambient pressure is sensitive to the parameters which are held constant while increasing ambient pressure. Author

A91-44762#
THE OPTIMAL DESIGN WITH LOCAL INSTABILITY
NAIXIAN MO and XIN QIAO (Nanjing Aeronautical Institute, People's Republic of China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956), vol. 23, March 1991, p. 35-45. In Chinese. refs

The optimal design of a constant-section, thin-walled skin acting as the fuel tank of an aircraft wing with local instability under

compression is examined. The finite strip method is used to perform the critical stress analysis of the local instability. The results meet engineering requirements, so the method has a remarkable advantage over the FEM. The same results are obtained using direct method of nonlinear programming. The results meet design requirements and pass the aircraft static test. C.D.

A91-44810* Minnesota Univ., Minneapolis.
WAKE INTERFERENCE BEHIND TWO FLAT PLATES NORMAL TO THE FLOW - A FINITE-ELEMENT STUDY
M. BEHR, T. E. TEZDUYAR (Minnesota, University, Minneapolis), and H. HIGUCHI (Syracuse University, NY) Theoretical and Computational Fluid Dynamics (ISSN 0935-4964), vol. 2, June 1991, p. 223-250. refs
(Contract NAG9-449; NSF MSM-87-96352; DAAL03-89-C-0038)
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A finite-element model of the Navier-Stokes equations is used for numerical simulation of flow past two normal flat plates arranged side by side at Reynolds number 80 and 160. The results from this simulation indicate that when the gap between the plates is twice the width of a single plate, the individual wakes of the plates behave independently, with the antiphase vortex shedding being dominant. At smaller gap sizes, the in-phase vortex shedding, with strong wake interaction, is favored. The gap flow in those cases becomes biased, with one of the wakes engulfing the other. The direction of the biased flow was found to be switching at irregular intervals, with the time histories of the indicative flow parameters and their power spectra resembling those of a chaotic system. Author

A91-44831
OVER FORTY YEARS OF CONTINUOUS RESEARCH AT UTIAS ON NONSTATIONARY FLOWS AND SHOCK WAVES
I. I. GLASS (Toronto, University, Downsview, Canada) Shock Waves (ISSN 0938-1287), vol. 1, March 1991, p. 75-86. NSERC-supported research. refs
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Unique facilities have been created at the University of Toronto Institute for Aerospace Studies to investigate the properties of planar, cylindrical, and spherical shock waves, as well as their interactions, shock-wave structures, boundary layers, vapor condensation in rarefaction waves, magnetogasdynamic flows, and oblique shock waves' Mach reflections. The effects of sonic-shock booms on humans, animals, and structures have also been studied. Recent interest has focused on shock waves in dusty gases, the viscous and vibrational structure of weak spherical blast waves, and oblique shock-wave reflections. Attention is given to the development of experimental instrumentation and CFD methods throughout these efforts. O.C.

A91-44953
RADIO-ELECTRONIC EQUIPMENT [RADIOELEKTRONNOE OBORUDOVANIE]
VIKTOR A. BOLDIN, GENNADII I. GORGONOV, VIKTOR D. KONOVALOV, N. N. KURILOV, V. V. LEVONCHUK et al. Moscow, Voennoe Izdatel'stvo, 1990, 289 p. In Russian. refs
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The fundamentals of radio electronics are first elaborated, with attention given to the principles of circuits and signals, semiconductor devices, computing techniques, radio transmitters and receivers, and wave propagation. The principles of operation of onboard radio-electronic devices are then described, with emphasis on radio communication systems, radar systems, radio navigation systems, radio control systems, and electronic countermeasures. The maintenance of radio-electronic devices is also discussed. L.M.

A91-44967
ESTIMATION OF THE ALGORITHMIC ERROR OF DIGITAL FILTERS WITH A RANDOM DISCRETIZATION INTERVAL [OTSENKA ALGORITMICHESKOI POGRESHNOSTI TSIFROVYKH FIL'TROV SO SLUCHAINYM INTERVALOM DISKRETIZATSII]
V. IU. KIRILLOV and E. I. PEKAR' (Moskovskii Aviatsionnyi Institut, Moscow, USSR) Priborostroenie (ISSN 0021-3454), vol. 34, no. 1, 1991, p. 31-35. In Russian. refs
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The problem of estimating the error of digital filtering due to stochastic external perturbations is formulated. A solution to the problem is then presented for a digital filter synthesized by the transition characteristic invariance method. The resulting formulas make it possible to optimize the discretization period of digital filters exposed to random external perturbations. V.L.

A91-45134#
CRITICAL MODE INTERACTION IN THE PRESENCE OF EXTERNAL RANDOM EXCITATION
G. LENG and N. SRI NAMACHCHIVAYA (Illinois, University, Urbana) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 770-777. refs
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The effects of random external excitation on nonlinear systems with marginally stable/unstable modes is studied within the context of stochastic bifurcation theory. Using the method of stochastic averaging, a Markov approximation is derived and a perturbation technique is developed to solve the resulting Fokker-Planck equation. It is found that, due to mode interaction through system nonlinearities, deterministic bifurcation characteristics are not preserved in the presence of external random excitation. In general, one critical mode can experience a stabilizing effect at the expense of the other. The theory is then applied to a flight dynamics problem at large angles of attack and sideslip. Author

A91-45177*# North Carolina State Univ., Raleigh.
COMPUTATION OF WEAKLY IONIZED HYPERSONIC FLOWS IN THERMOCHEMICAL NONEQUILIBRIUM
GRAHAM V. CANDLER (North Carolina State University, Raleigh) and ROBERT W. MACCORMACK (Stanford University, CA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 5, July-Sept. 1991, p. 266-273. SDIO-supported research. Previously cited in issue 07, p. 1007, Accession no. A88-22377. refs
(Contract DAAL03-86-K-0139; NAGW-965; F33615-86-C-3015)
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A91-45192#
EXPERIMENTAL STUDY ON CONFINED TWO-PHASE JETS
Y. LEVY (Technion - Israel Institute of Technology, Haifa) and D. ALBAGLI Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 5, July-Sept. 1991, p. 387-393. refs
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The basic mixing phenomena in confined, coaxial, particle-laden turbulent flows are studied within the scope of ram combustor research activities. Cold-flow experiments in a relatively simple configuration of confined, coaxial two-phase jets provided both qualitative and quantitative insight on the multiphase mixing process. Pressure, tracer gas concentration, and two-phase velocity measurements revealed that unacceptably long ram combustors are needed for complete confined jet mixing. Comparison of the experimental results with a previous numerical simulation displayed a very good agreement, indicating the potential of the experimental facility for validation of computational parametric studies. Author

A91-45329#
SPRAY PATTERNATION AT HIGH PRESSURE
J. M. COHEN and T. J. ROSFJORD (United Technologies Research Center, East Hartford, CT) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 481-487. Research supported by Pratt and Whitney Group. Previously cited in issue 20, p. 3150, Accession no. A89-46750. refs
(Contract F33615-85-C-2515)
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A91-45345#
FINITE-ELEMENT ANALYSIS OF RING GEAR/CASING SPLINE CONTACT

S. SUNDARARAJAN and S. AMIN (Pratt and Whitney Canada, Longueuil) Journal of Propulsion and Power (ISSN 0748-4658), vol. 7, July-Aug. 1991, p. 602-606. Previously cited in issue 18, p. 3078, Accession no. A88-44715. refs
Copyright

A91-45373#
NEW TRANSMISSION COMPONENTS FOR HELICOPTER APPLICATIONS
E. HERMENS (DAF Special Products, Eindhoven, Netherlands) and N. VERSCHUREN (UCN Aerospace, Almelo, Netherlands) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 16 p.

The paper deals with the potential for production of major transmission components for existing and future helicopters in the Netherlands. Attention is focused on the components that have been proposed for the application in the drive systems for new helicopter programs. A flat crownwheel-pinion drive is considered, and the specific geometry of a crownwheel tooth, the characteristics of this gearset, and the results of static and dynamic tests are described. The application of such technologies as flow-turning and wet-filament winding for the production of ultra-high-speed rotors to the production of high-quality metal and composite drive shafts is discussed. V.T.

A91-45378#
FINITE DIFFERENCE TECHNIQUES AND ROTOR BLADE AEROELASTIC PARTIAL DIFFERENTIAL EQUATIONS - AN EXPLICIT TIME-SPACE FINITE ELEMENT APPROACH FOR P.D.E
Y. K. YILLIKCI and S. HANAGUD (Georgia Institute of Technology, Atlanta) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 22 p. refs

A conditionally stable explicit finite difference scheme is used to numerically integrate the nonlinear partial differential equations of motion in space and time to obtain the aeroelastic steady-state and transient responses of a hingeless rotor blade. Numerical stability analysis is performed for soft and stiff inplane blades. The effect of different spatial discretizations on blade responses and the convergence of the finite difference scheme are also analyzed. Rotor blade responses are calculated for different blade configurations and results are compared with the results of previous analysis. Author

A91-45398#
ADVANCES IN COMPOSITE MANUFACTURING OF HELI COMPONENTS - IMPACTS ON FACTORY INSTALLATIONS AND METHODS
DIERK MINKE (MBB Helicopter and Military Aircraft Group, Ottobrunn, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p.

Evolutionary steps in helicopter-airframe design and manufacturing are outlined, and the health aspects of composite manufacturing are reviewed. Thermoplastic composites such as polyetheretherketone (PEEK) yarns and fabrics, commingled yarns and fabrics, and powder prepregs are discussed, and the production cost calculations of identical structures both in aluminum alloy and carbon-fiber reinforced plastic are compared. Attention is focused on fiber placement in series production and a production line for sandwich structures, allowing a better division of labor and sufficient flexibility in a case of frequently changing batches. Modular techniques in composite manufacturing are considered, and procedures used in manufacturing the carbon-fiber structure of the Airbus vertical stabilizer is illustrated. V.T.

A91-45415#
EMC CHARACTERISTICS OF COMPOSITE STRUCTURE - ELECTRIC/ELECTROMAGNETIC SHIELDING ATTENUATION
P. WEGERTSEDER and R. BREITSAMETER (MBB GmbH, Munich, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 13 p.

The paper reports electric/electromagnetic shielding-attenuation experiments performed on different test boxes built with the same materials and processes as those to be used for the construction of a helicopter. The measurements are performed in the frequency range of 14 to 18 GHz, and the effects of different composite materials, jointing and bonding of structure parts of the boxes, application and bonding of the mesh, the construction of access panels, and conductive seals on these panels are assessed. It is demonstrated that moderate electric/eletromagnetic shielding-attenuation values can be achieved by composite structures made from carbon, and materials and procedures required for high shielding attenuation are discussed. V.T.

A91-45418#
S-61N FREE WHEEL UNIT MALFUNCTIONING
F. LOUWERS and F. SCHAPER (KLM Helikopters, Schiphol, Netherlands) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 11 p.

The free-wheel unit (FWU) of the Sykorsky S-61 helicopter is described, and the study concentrates on the failures of the unit due to the introduction of a cage retention spring in 1987. It is noted that the FWU malfunctions appeared to be related to excessive wear of the unit components. Inspections involving the extensive measurements of the camshaft, gear housing, rollers, and roller cage are outlined, and the increase in the roller contact angle due to wear and imperfections is analyzed. A modified FWU incorporating a redesign of a roller cage support on one side, so it becomes almost identical to that on the other side, is discussed. A lead-the-fleet program being carried out in order to eliminate the present midlife inspection and to extend the life of FWU from 2500 to 3000 hours is considered. V.T.

A91-45547*# Sverdrup Technology, Inc., Brook Park, OH.
COMPUTATION OF A CIRCULAR-TO-RECTANGULAR TRANSITION DUCT FLOW FIELD
J. R. SIRBAUGH (Sverdrup Technology, Inc, Brook Park, OH) and B. A. REICHERT (NASA, Lewis Research Center, Cleveland, OH) AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 22nd, Honolulu, HI, June 24-26, 1991. 13 p. refs
(AIAA PAPER 91-1741) Copyright

This paper presents the results of a Computational Fluid Dynamics (CFD) calibration study of flow through a circular-to-rectangular transition duct. The design of these ducts is critical to the optimum performance of aircraft with rectangular exhaust nozzles, since these ducts transfer the flow from the gas turbine engine to the exhaust nozzle. Two duct inflow conditions are considered, the first with straight inflow and the second with swirling inflow. Both flows contain realistic wall boundary layers. The first case permits examination of the effects of the geometric transition on the flowfield, while the second case adds in the rotational flow effect that can be present from the gas turbine engine. The flowfields associated with the two cases have been shown, both with CFD and experiment, to have significant differences. The Navier-Stokes CFD code PARC with the Baldwin and Lomax turbulence model was used in this study. The turbulence model had to be modified for both cases in order to achieve accurate determination of the edge of the wall bounded vorticity layers and thus turbulent viscosity. The results of this calibration study will be valuable to aircraft designers who rely on CFD to assist in the design and evaluation of propulsion systems.
Author

A91-45603#
THE SURFACE IMPEDANCE - A PERTINENT PARAMETER TO DESCRIBE FINITE CONDUCTIVITY MATERIALS IN NUMERICAL CODES
V. GOBIN, J. P. APARICIO, J. GRANDO, and J. C. ALLIOT (ONERA, Chatillon, France) (International Symposium on Electromagnetic Compatibility, Zurich, Switzerland, Mar. 12-14, 1991) ONERA, TP no. 1991-20, 1991, 6 p. refs
(ONERA, TP NO. 1991-20)

This paper deals with the description of finite conductivity materials in numerical codes solving Maxwell's equations. It is shown that the surface impedance concept leads to a good

representation in many practical cases, and numerical results are validated by comparison with analytical formulas. The applicability limits of the surface impedance modeling is finally discussed. Author

A91-45604#
ELECTROMAGNETIC TOPOLOGY - COUPLING OF TWO WIRES THROUGH AN APERTURE
J. P. PARMANTIER (Dassault Aviation, Saint-Cloud, France) and J. P. APARICIO (ONERA, Chatillon, France) (International Symposium on Electromagnetic Compatibility, Zurich, Switzerland, Mar. 12-14, 1991) ONERA, TP no. 1991-21, 1991, 7 p.
(ONERA, TP NO. 1991-21)

The scattering parameters of a junction are analyzed by studying the electromagnetic coupling of two wires located on both sides of an aperture. The present concepts are tested on a 1/10 scale model of a C160 Transall aircraft. A comparison is made between measurements and the high-frequency modeling of the S(0)-parameters of the wing. K.K.

A91-45617#
THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE LARGE DEFLECTIONS OF BEAMS
A. LAULUSA (ONERA, Chatillon, France) ONERA, TP no. 1991-35, 1991, 20 p. refs
(ONERA, TP NO. 1991-35)

As part of the research on the aeroelasticity stability of helicopter blades, a kinematic nonlinear model including structural couplings has been investigated for an orthotropic, pretwisted, rotating beam element. A beam-type finite element method has been implemented to evaluate static large deflections and to predict natural frequencies for small vibrations of a beam that can be rotated at uniform speed about a fixed axis. In the numerical model, the nonlinearities are limited to the third degree involving displacements for elastic terms and to the second degree for inertial and external load terms. A series of static experiments has been performed on aluminium cantilevered beams. Author

A91-45632#
HEAT TRANSFER MEASUREMENTS IN ONERA SUPERSONIC AND HYPERSONIC WIND TUNNELS USING PASSIVE AND ACTIVE INFRARED THERMOGRAPHY
D. BALAGEAS, D. BOSCHER, A. DEOM, and G. GARDETTE (ONERA, Division de Thermophysique, Chatillon, France) (ESA, European Symposium on Aerothermodynamics for Space Vehicles, 1st, Noordwijk, Netherlands, May 28-30, 1991) ONERA, TP no. 1991-51, 1991, 7 p. Research supported by DRET, CEA, and Cryospace Co. refs
(ONERA, TP NO. 1991-51)

Over the past few years, a major intellectual and technical investment has been made at ONERA to use data acquisition systems and data reduction procedures using an infrared camera as a detector under routine wind tunnel conditions. This allows a really quantitative mapping of heat transfer rate distributions on models in supersonic and hypersonic flows. Sufficient experience has now been acquired to allow us to give an overview of: (1) the systems and data reduction procedures developed for both passive and active methods; (2) typical results obtained on various configurations such as supersonic axisymmetrical flow around an ogival body (passive and active thermography), heat flux modulation in the reattachment zone of a flap in hypersonic regime, transitional heating on very slightly blunted spheroconical bodies in hypersonic flows, and materials testing in high-enthalpy hypersonic flow (passive thermography). Author

A91-45635#
COMPUTATION TECHNIQUES FOR THE SIMULATION OF TURBOMACHINERY COMPRESSIBLE FLOWS
J. P. VEUILLOT and L. CAMBIER (ONERA, Chatillon, France) (International Conference on Numerical Methods in Fluid Dynamics, 12th, Oxford, England, July 9-13, 1990) ONERA, TP no. 1991-54, 1991, 13 p. refs
(ONERA, TP NO. 1991-54)

Computation techniques for the simulation of turbomachinery compressible flows via the numerical solution of Euler and Navier-Stokes equations are described. In a discussion of the Euler and Navier-Stokes equations for turbomachinery flow calculations, attention is given to equations for a rotating system, quasi-three-dimensional formulation, and turbulence modeling. Examples of Navier-Stokes calculations are presented. K.K.

A91-45653#
A FINITE ELEMENT INVERSE METHOD FOR THE DESIGN OF TURBOMACHINERY BLADES
DIDIER NICOUD, CATHERINE LE BLOA (SNECMA, Moissy-Cramayel, France), and OLIVIER-PIERRE JACQUOTTE (ONERA, Chatillon, France) ONERA, TP no. 1991-77, 1991, 11 p. refs
(ASME PAPER 91-GT-80; ONERA, TP NO. 1991-77)

A quasi-three-dimensional inverse method for the design of turbomachinery blades corresponding to an arbitrarily-given velocity distribution is presented. Consideration is given to the theoretical aspect of the problem as well as to equations governing the quasi-three-dimensional potential model. It is noted that the present method can be used to define sub- or transonic profiles with allowance for streamtube thickness and radius variation. K.K.

A91-45654#
AN OVERVIEW OF THE ELECTROMAGNETIC TOPOLOGY
J. P. PARMANTIER (Dassault Aviation, Saint-Cloud, France), X. FERRIERES (SLX Informatique, Courbevoie, France), J. P. APARICIO (ONERA, Chatillon, France), and J. C. ALLIOT (ESA, Workshop on Electromagnetic Compatibility, 2nd, Noordwijk, Netherlands, Dec. 4, 5, 1990) ONERA, TP no. 1991-78, 1991, 11 p. refs
(ONERA, TP NO. 1991-78)

A general description of the electromagnetic topology method is presented with emphasis on the topological diagram and interaction graph. Quantitative treatment of electromagnetic interactions is considered, and for a general case, a model physically representing the propagation channels of electromagnetic signals and their scattering in topological volumes is derived. A multiconductor transmission line network is analyzed, and simplifications and approximations in the resolution of the Baum-Liu-Tesche equation are discussed. V.T.

A91-45656
MODERN RESEARCH TOPICS IN AEROSPACE PROPULSION - IN HONOR OF CORRADO CASCI
GIANFRANCO ANGELINO, ED., L. DE LUCA, ED. (Milano, Politecnico, Milan, Italy), and W. A. SIRIGNANO, ED. (California, University, Irvine) New York, Springer-Verlag, 1991, 399 p. For individual items see A91-45657 to A91-45673.
Copyright

Topics presented include the mechanics of turbulent flow in combustors for premixed gases, the thermodynamics of refractory material formation by combustion techniques, catalytic combustion processes, and combustion modeling and stability of double-base solid rocket propellants. Also presented are a review of the anisotropy of drop and particle velocity fluctuations in two-phase round gas jets, an efficient solution of compressible internal flows, unsteady flow in axial flow compressors, and some perspectives on wind shear flight. R.E.P.

A91-45669
CONVECTIVE HEAT TRANSFER WITH FILM COOLING AROUND A ROTOR BLADE
T. ARTS (von Karman Institute for Fluid Dynamics, Rhode-Saint-Genese, Belgium) IN: Modern research topics in aerospace propulsion - In honor of Corrado Casci. New York, Springer-Verlag, 1991, p. 253-274. refs
Copyright

This paper deals with an experimental convective heat transfer investigation around a high pressure gas turbine film cooled rotor blade. The measurements were performed in the von Karman Institute short duration isentropic light piston compression tube

facility allowing a correct simulation of Mach and Reynolds number as well as free stream to wall and free stream to coolant temperature ratios. The airfoil was mounted in a linear stationary cascade environment and heat transfer measurements were obtained by using platinum thin film gages painted on a blade made of machinable glass ceramic. The coolant flow was ejected simultaneously through the leading edge (3 rows of holes), the suction side (2 rows of holes), and the pressure side (1 row of holes). The coolant hydrodynamic behavior is described and the effects of overall coolant to free stream mass weight ratio, coolant to free stream temperature ratio, and free stream turbulence intensity on the convective heat transfer distribution are successively described. Author

A91-45820*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SOME PRELIMINARY RESULTS OF BRUSH SEAL/ROTOR INTERFERENCE EFFECTS ON LEAKAGE AT ZERO AND LOW RPM USING A TAPERED-PLUG ROTOR
R. C. HENDRICKS, M. P. PROCTOR, J. A. SCHLUMBERGER (NASA, Lewis Research Center, Cleveland, OH), M. J. BRAUN (Akron, University, OH), and R. L. MULLEN (Case Western Reserve University, Cleveland, OH) AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference, 27th, Sacramento, CA, June 24-26, 1991. 15 p. refs
(AIAA PAPER 91-3390) Copyright

Some preliminary brush seal leakage results for ambient-temperature air are presented. Data for four nominal brush-rotor radial clearances of -0.09, -0.048, -0.008, and 0.035 mm were taken by using a tapered plug rotor at 0 and 400 rpm with rotor runout of 0.127 mm peak to peak. The brush seal nominal bore diameter was 38 mm with 0.05-mm bristles at 200 bristles/mm of circumference and a 0.61-mm fence height. Leakages were greater than predicted, but agreement was reasonable. Leakage rates were not significantly altered by hysteresis or inlet flow variations. Visualization studies showed that the bristles followed the 400-rpm excitation, and loading studies indicated that bristles slid relative to one another. Author

A91-46163#
CALCULATION OF MODAL CHARACTERISTICS FOR A PROPELLER-GEAR BOX-ENGINE COUPLE SYSTEM
ZHONGQUAN GU and YUANDA WANG (Nanjing Aeronautical Institute, People's Republic of China) Journal of Aerospace Power (ISSN 1000-8055), vol. 6, July 1991, p. 244-248. In Chinese.

In this paper the calculation problems of modal characteristics are studied for a propeller-gear box-engine system by considering the flapwise and lagwise flexibilities, the pitch angle of the blade, and the coupling of torsional vibration with longitudinal vibration. The expressions suitable for computer are deduced for the calculation of the modal characteristics. A numerical example for a propeller-gear box-engine system demonstrates that the method is reasonable and feasible. Author

A91-46186#
NONIMPULSIVELY STARTED STEADY FLOW ABOUT A CIRCULAR CYLINDER
TURGUT SARPKAYA (U.S. Naval Postgraduate School, Monterey, CA) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1283-1289. NSF-supported research. Previously cited in issue 06, p. 816, Accession no. A90-19928. refs

A91-46336#
THE EXCITATION OF ACOUSTIC RESONANCES BY FLOW AROUND TWO CIRCULAR CYLINDERS IN TANDEM IN A DUCT
M. C. WELSH, K. HOURIGAN, M. C. THOMPSON, J. SORIA (CSIRO, Div. of Building, Construction and Engineering, Highett, Australia), and A. N. STOKES (CSIRO, Div. of Mathematics and Statistics, Clayton, Australia) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 10.43-10.46. refs

The excitation of acoustic resonances by the flow around two cylinders located in tandem in a hard walled duct is described. It is hypothesized that the excitation is due to discrete vortices in the shear layers separating from the surface of the upstream cylinder. This hypothesis is supported by flow visualization studies, numerical simulation of the flows with an acoustic field superimposed, and measured high coherence between the resonant acoustic pressure field and the oscillating flow velocity field in the shear layer between the cylinders. It is anticipated that these studies explain one possible mechanism responsible for exciting acoustic resonances in in-line cross-flow tubular heat exchangers. Author

A91-46352#
ON THE ROLE OF MEAN-FLOW THREE-DIMENSIONALITY IN TURBULENCE MODELLING
G. ROMBERG (DLR, Goettingen, Federal Republic of Germany) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 12.9-12.12. refs

A new modeling concept is developed as a tool to take into account the role of mean-flow three-dimensionality in turbulence modeling. This concept is based on a thermodynamic analogy. Application of the concept to the turbulent boundary layer on an infinite swept wing leads to identifying two effects of mean-flow three-dimensionality that cause the normalized magnitude of the shear-stress vector to deviate from its value at the start of the pressure gradient. Comparison of calculated and experimental results for the local skin-friction coefficient gives satisfactory agreement. Author

A91-46373*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL INVESTIGATION OF HYPERSONIC EXHAUST PLUME/AFTERBODY FLOW FIELDS
T. A. EDWARDS (NASA, Ames Research Center, Moffett Field, CA) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 2. Parkville, Australia, University of Melbourne, 1989, p. 15.29-15.32. refs

An upwind, implicit Navier-Stokes computer program has been applied to hypersonic exhaust plume/afterbody flowfields. The sensitivity of gross thrust to operating conditions has been assessed through parametric variations. Comparison of the numerical results with available experimental data shows good agreement in all cases investigated. Results show that, for moderately underexpanded jets, the afterbody force varies linearly with the nozzle exit pressure. Exhaust gases with low isentropic exponents (gamma) were found to contribute up to 25 percent more afterbody force than high-gamma exhaust gases. Modifying the nozzle geometry influenced the exhaust plume development, which had a significant effect on the afterbody force. Grid density, while important to resolving the initial plume/afterbody interaction, had only a minor impact on the resultant afterbody force. Author

A91-46454
NUMERICAL CALCULATIONS OF GASEOUS REACTING FLOWS IN A MODEL OF GAS TURBINE COMBUSTORS
CHUANJUN YAN, MING TANG, HUILING ZHU, and HUIXIAN SUN (Northwestern Polytechnical University, Xian, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 4, Feb. 1991, p. 26-34. refs
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The numerical calculations of gaseous reaction flows in a model of gas-turbine combustors are described. The profiles of hydrodynamic and thermodynamic patterns in a 3D combustor model are obtained by solving the governing differential transport equations. The well-established numerical prediction algorithm SIMPLE; a modified turbulence model, and a turbulent diffusion flame model are adopted in the computations. The beta-function is selected as the probability density function. The effect of the combustion process on flow patterns is investigated. The calculated

results are verified by experiments, and are in good agreement. Author

A91-46610
DESIGN OF GUIDE VANES FOR MINIMIZING THE PRESSURE LOSS IN SHARP BENDS
ALEXANDER SAHLIN and ARNE V. JOHANSSON (Royal Institute of Technology, Stockholm, Sweden) Physics of Fluids A (ISSN 0899-8213), vol. 3, Aug. 1991, p. 1934-1940. Research supported by STU. refs
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A guide-vane section was designed with the aim of minimizing the pressure drop for flow in a 90-deg corner. A central part of the design process was to use potential flow calculations in order to obtain a vane geometry such that the velocity distribution on the suction side replicates that of a chosen single airfoil at the angle of attack for maximum lift/drag in a straight free stream. The choice was based on proven good drag characteristics at low Reynolds numbers. For the design of the pressure-side velocity, distribution advantage of the expansion in the middle part of the cascade was taken to obtain a high pressure coefficient on the pressure side, as compared to the single airfoil case. Vanes were built and tested in a special-purpose wind tunnel. The 2D pressure-loss coefficient, as measured downstream of a five-vane corner, was found to be as low as 0.036, which is about one-fifth of that for traditional quarter-circle-shaped vanes. Author

A91-46618* Centre Europeen Recherche et de Formation Advance en Calcul Scientific, Toulouse (France).
THE ORIGIN OF A CHARACTERISTIC FREQUENCY IN HARD THERMAL TURBULENCE
ALAIN P. VINCENT (Centre Europeen de Recherche et de Formation Avancee en Calcul Scientifique, Toulouse, France), ULRICH HANSEN (Koeln, Universitaet, Cologne, Federal Republic of Germany), DAVID YUEN, ANDREI V. MALEVSKY, and SHERRI E. KROENING (Minnesota, University, Minneapolis) Physics of Fluids A (ISSN 0899-8213), vol. 3, Aug. 1991, p. 2003-2006. Research supported by NASA and DFG. refs
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The detection of characteristic frequencies in hard turbulent convection is facilitated by a technique in which the time series of heat flux is filtered. The solutions derived demonstrate bursts at high Rayleigh when the Nusselt number undergoes high-pass spectral filtering, and the bursts are associated with plumes in the thermal boundary layer. The bursts are characterized by even temporal spacing and a single characteristic frequency, and are theorized to be related to the pulsation mechanism in hard turbulent convection. C.C.S.

A91-46811
PREDICTIONS ON FATIGUE
JAAP SCHIJVE (Delft University of Technology, Netherlands) JSME International Journal, Series I (ISSN 0914-8809), vol. 34, July 1991, p. 269-280. refs
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Various aspects involved in fatigue predictions for practical purposes are outlined and some special considerations of aircraft fatigue predictions are discussed. Results are presented of recent investigations related to crack closure of part through cracks, fatigue crack growth prediction models for variable-amplitude loading, and the significance of fractographic observations for the verification of prediction models. The high fatigue crack growth resistance of new laminates built up from thin Al-alloy sheets and unidirectional fiber prepregs is described. R.E.P.

A91-46819#
FUNDAMENTAL PHILOSOPHY OF PAR-WIG DESIGN AT USA-DTNSRDC
SHIGENORI ANDO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 39, no. 448, 1991, p. 218-226. In Japanese. refs

Problems with the first-generation WIG (wing-in-ground) are discussed. The PAR (power augmented ram) technology is classified into three types: (1) wing PAR cushion; (2) fuselage PAR cushion; and (3) LEX/TEX PAR cushion. IGE (in-ground-effect) and OGE (off-ground-effect) improvements are addressed. Three types PAR-WIG designs are presented, and a PAR-WIG water impact design methodology is described. Y.P.Q.

A91-46820#
PRACTICAL APPLICATION OF THE WING-IN-GROUND (WIG) EFFECT VEHICLE
SYOZO KUBO, TETUYA KAWAMURA, TAKENORI MATSUBARA, and TOSHIO MATSUOKA Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 39, no. 448, 1991, p. 236-242. In Japanese. refs

Possible future applications of the WIG-effect vehicle are considered. The IGE (in-ground-effect) and OGE (off-ground-effect) techniques are examined, and the aerodynamic problems of the WIG.are discussed. Aspects of WIG technology development are examined, including wing efficiency, off-water and on-water problems, and the use of new materials. Environmental pollution concerns, including noise and exhaust emissions, are addressed. Y.P.Q.

A91-46821#
MANEUVER SIMULATION MODEL OF AN EXPERIMENTAL HOVERCRAFT FOR THE ANTARCTIC
RINICHI MURAO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 39, no. 448, 1991, p. 250-258. In Japanese. refs

Results of an investigation of a hovercraft model designed for Antarctic conditions are presented. The buoyancy characteristics, the propellant control system, and simulation model control are examined. An ACV (air cushion vehicle) model of the hovercraft is used to examine the flexibility and friction of the skirt. Simulation results are presented which show the performance of the hovercraft. Y.P.Q.

A91-47213*# Akron Univ., OH.
EFFECTS OF GEAR BOX VIBRATION AND MASS IMBALANCE ON THE DYNAMICS OF MULTISTAGE GEAR TRANSMISSION
F. K. CHOY, Y. K. TU (Akron, University, OH), J. J. ZAKRAJSEK, and D. P. TOWNSEND (NASA, Lewis Research Center, Cleveland, OH) ASME, Transactions, Journal of Vibration and Acoustics (ISSN 0739-3717), vol. 113, July 1991, p. 333-344. Previously announced in STAR as N91-21534. refs
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The dynamic behavior of multistage gear transmission system, with the effects of gear-box-induced vibrations and rotor mass-imbalances is analyzed. The model method, using undamped frequencies and planar mode shapes, is used to reduce the degree-of-freedom of the system. The various rotor-bearing stages as well as lateral and torsional vibrations of each individual stage are coupled through localized gear-mesh-tooth interactions. Gear-box vibrations are coupled to the gear stage dynamics through bearing support forces. Transient and steady state dynamics of lateral and torsional vibrations of the geared system are examined in both time and frequency domain. A typical three-staged geared system is used as an example. Effects of mass-imbalance and gear box vibrations on the system dynamic behavior are presented in terms of modal excitation functions for both lateral and torsional vibrations. Operational characteristics and conclusions are drawn from the results presented. Author

A91-47219#
STRESS INTENSITY FACTORS OF MULTIPLE CRACKED SHEET WITH RIVETED STIFFENERS
T. NISHIMURA (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan) ASME, Transactions, Journal of Engineering Materials and Technology (ISSN 0094-4289), vol. 113, July 1991, p. 280-284. refs
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A new method is proposed for analyzing the stress intensity factors of multiple cracks in a sheet reinforced with riveted stiffeners. Using the basic solution of a single crack and taking

unknown density of surface tractions and fastener forces, Fredholm integral equations and compatibility equations of displacements among the sheet, fasteners, and stiffeners are formulated. After solving the unknown density, the stress intensity factors of multiple cracks in the sheet are determined. Some numerical examples are analyzed. Author

A91-47600
FATIGUE STRENGTH OF STRUCTURAL ELEMENTS [SOPROTIVLENIE USTALOSTI ELEMENTOV KONSTRUKTSII]
ALEKSANDR Z. VOROB'EV, BORIS I. OL'KIN, VALERII N. STEBENEV, and TAISIIA S. RODCHENKO Moscow, Izdatel'stvo Mashinostroenie, 1990, 240 p. In Russian. refs
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The principal characteristics of the fatigue of elements aircraft structures are examined in relation to loading conditions typical of flight operations. An analysis is made of the effect of design and fabrication factors on the fatigue strength of structural elements, and it is shown how the fatigue strength should be taken into account in the design. Methods are also presented for evaluating the effect of a variety of factors on the fatigue strength. V.L.

A91-47603
METHODS AND MEANS OF MEASUREMENT IN THE STRENGTH EXPERIMENT [METODY I SREDSTVA IZMERENII V PROCHNOSTNOM EKSPERIMENTE]
ALEKSEI N. SER'EZNOV and ALEKSANDR K. SHASHURIN Moscow, Izdatel'stvo MAI, 1990, 200 p. In Russian. refs
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Methods and equipment used for measuring the structure and ambient medium parameters during the bench testing of engineering products (including aircraft components) are examined. In particular, attention is given to the measurement of the stress-strain parameters of aircraft structures; surface temperature measurements during the testing of aircraft structures; methods and instrumentation for measuring displacements; and analysis of the fatigue damage of structures. The discussion also covers nondestructive testing techniques, problem-oriented data processing systems in strength testing, and optimization of problem-oriented data acquisition and processing systems. V.L.

A91-47622
ITERATIVE SOLUTION OF NAVIER-STOKES DUAL VARIABLE DIFFERENCE EQUATIONS
GEORGE MESINA and CHARLES HALL (Pittsburgh, University, PA) Journal of Computational Physics (ISSN 0021-9991), vol. 96, Sept. 1991, p. 71-98. refs
(Contract AF-AFOSR-88-0262)
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Application of the dual transformation to implicit finite-difference approximations of the Navier-Stokes equations yields a factor-of-3 reduction in the number of unknowns while generating velocities that satisfy the discrete continuity equation exactly. It is demonstrated that novel iterative methods for unsymmetrical dual variable system solution converge for a large class of problems, taking advantage of the distinctive structure of the dual-variable coefficient matrix, and are more easily vectorized and parallelized than current alternatives. O.C.

A91-47825#
DYNAMICS OF AERO-DRIVEN BODIES WITH COLLISIONS AND SLIDING CONTACT
D. T. WANG, G. A. NYSTROM, and C. K. LOMBARD (PEDA Corp., Palo Alto, CA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 224-231. refs
(AIAA PAPER 91-2938) Copyright

The relations governing sabot-discarding motion with either collisions or sliding contact are obtained. Numerical solutions are presented to illustrate the two-dimensional behavior of sabot components under the influence of aerodynamic forces and contact with the nearby projectile. The number of collisions is found to be a strong function of initial conditions and the collision coefficients. Author

A91-47832#
OBSERVATION OF CHAOTIC DYNAMICS IN VIBRATING AIRFRAMES
JAMES GALASYN (Boeing Flight Systems Laboratory, Seattle, WA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 286-299. refs
(AIAA PAPER 91-2946) Copyright

Airframe responses to rudder frequency sweeps and dwells are examined using phase-space reconstruction. For airframe VK001, this method suggests the presence of double-well potentials similar to those encountered in the buckled elastic beam problem. Motion around these potentials appears chaotic. Fractal dimensions are estimated using a correlation integral method. Similar results are obtained for the dimension of the NA001 fin, but are not observed for the NA001 body. C.D.

A91-47882
DOUBLE LINEARIZATION THEORY OF THREE-DIMENSIONAL CASCADES WITH VIBRATING BLADES UNDER SPANWISE-NONUNIFORM MEAN LOADING. I - SUBSONIC FLOW. II - SUPERSONIC FLOW
M. NAMBA and K. TOSHIMITSU (Kyushu University, Fukuoka, Japan) Journal of Sound and Vibration (ISSN 0022-460X), vol. 148, July 8, 1991, p. 41-102. refs
Copyright

A91-48037
THE STABILITY OF TWO-DIMENSIONAL MEMBRANES IN STREAMING FLOW
B. G. NEWMAN and M. P. PAIDOUSSIS (McGill University, Montreal, Canada) Journal of Fluids and Structures (ISSN 0889-9746), vol. 5, July 1991, p. 443-454. Research supported by NSERC and Ministere de l'Education du Quebec. refs
Copyright

The paper is concerned with the stability of a two-dimensional membrane at small incidence in a fluid flow. When the incidence becomes slightly negative, the membrane begins to oscillate. The corresponding behavior for sails is known as luffing. The associated tension coefficient, C(r), can be predicted using the theory for either static or dynamic stability. It is found that the luffing incidence, alpha, depends mainly on the excess-length ratio, epsilon, but is not generally proportional to sq rt epsilon as inviscid theory for the static membrane would indicate. For epsilon less than 0.02 luffing occurs at C(r) = 1.3, and at C(r) about 0.6 for larger values of epsilon. The latter situation has complete separation on the underside of the membrane. Both values of C(r) are quite well predicted by the dynamic stability theory. The stability of an inflated aerofoil at zero incidence is also examined, and the predictions are very good. Author

A91-48192
A RELIABILITY SIMULATION APPROACH FOR USE IN THE DESIGN PROCESS
THOMAS L. LANDERS, HAMDY A. TAHA (Arkansas, University, Fayetteville), and CHARLES L. KING (Anderson Consulting, Dallas, TX) IEEE Transactions on Reliability (ISSN 0018-9529), vol. 40, June 1991, p. 177-181. refs
(Contract F49620-87-R-0004)
Copyright

A simulation model for use in the engineering design process is reported. The simulation model facilities reliability modeling by design engineers and reliability analysts early in the design process. The model applies to preliminary feasibility and design tradeoff studies. This model is described, with a focus on applications to mission reliability analysis, and a case study of the voice-communication system for the F-16 fighter aircraft presented. I.E.

A91-48269
ON THE DYNAMICS OF TURBULENT JET IMPINGEMENT IN A CROSS-FLOW
G. D. CATALANO, K. CHANG, and J. MATHIS (Louisiana State University, Baton Rouge) IN: Laser anemometry - Advances and applications; Proceedings of the 3rd International Conference, Swansea, Wales, Sept. 26-29, 1989. Oxford, England/Berlin and New York, BHRA (Information Services)/Springer-Verlag, 1990, p. 417-428. refs
(Contract FY1456-88-O-5065)
Copyright

Turbulent velocity measurements are reported for the flow of a turbulent jet into a confined crossflow for jet/cross flow mean velocity ratios equal to 2.0 and 4.0. Quantities measured in this investigation include mean velocities, turbulent intensities, Reynolds stresses, autocorrelations, autospectral densities, the Taylor micro and integral scales, and skewness and flatness of the velocity probability density functions. The velocity measurements are made with the use of a frequency tracker based, computer interfaced, single component, laser Doppler velocimeter. Author

N91-27389# Federal Aviation Administration, Atlantic City, NJ.
EVALUATION OF EXTERNAL FILTERS IN REDUCING TYPE B1 AND B2 FM BROADCAST INTERFERENCE TO VHF COMMUNICATIONS AVIONICS RECEIVERS
MARTIN BADINELLI and ARTHUR CUSHMAN Jul. 1991 23 p
(DOT/FAA/CT-TN91/16) Avail: NTIS HC/MF A03

Commercial FM broadcast stations radiate high power signals in commercial airspace that can produce type B1, third order intermodulation products, interference in the aviation very high frequency (VHF) communications band. It has been proposed that passive, external filters may be a possible solution to this problem. Tests performed on three passive, external filters at the Federal Aviation Administration (FAA) Technical Center are described. These tests compared avionics transceiver performance both with and without the filter installed and were performed in a controlled laboratory environment, using eight avionics transceivers. It was found that passive, external filters can reduce interference effects due to Type B1 intermodulation in some cases. However, this was only a technical investigation of the filters and as such did not consider other issues; e.g., (1) certification requirements, (2) cost versus benefit, and (3) environmental operating conditions. These issues must be fully evaluated prior to any installations. Author

N91-27404# Federal Aviation Administration, Atlantic City, NJ.
CONTROLLER EVALUATION OF INITIAL DATA LINK EN ROUTE AIR TRAFFIC CONTROL SERVICES: MINI STUDY 3 Final Report
HANK MAREK, EPHRAIM SHOCHET, EVAN DARBY, FRANK BUCK, DAVID SWEENEY, and PRESTON CRATCH (Mitre Corp., McLean, VA.) Jun. 1991 131 p
(Contract T2001G)
(DOT/FAA/CT-91/11) Avail: NTIS HC/MF A07

The results of Mini Study 3 conducted November 5-9, 1990 are presented. This Mini Study was conducted at the Federal Aviation Administration (FAA) Technical Center utilizing the Washington Air Route Traffic Control Center (ARTCC) airspace in the Data Link test bed. Initial Data Link en route services were evaluated in order to identify service delivery methods which optimize the human computer interface. Controllers from the Air Traffic Data Link Validation Team participated in this study. Author

N91-27413# Massachusetts Inst. of Tech., Lexington. Lincoln Lab.
TERMINAL DOPPLER WEATHER RADAR OPERATIONAL TEST AND EVALUATION, ORLANDO 1990
DAVID M. BERNELLA 9 Apr. 1991 107 p
(Contract F19628-90-C-0002; DTFA01-L-83-4-10579)
(AD-A236108; ATC-179) Avail: NTIS HC/MF A06 CSCL 17/9

Lincoln Laboratory conducted an evaluation of the Federal Aviation Administration (FAA) Terminal Doppler Weather Radar (TDWR) system in Orlando, Florida during the summer of 1990. In previous years, evaluations have been conducted at airports in Kansas City, MO (1989) and Denver, CO (1988). Since the testing at the Kansas City International Airport, the radar was modified to operate in C-band, which is the intended frequency band for the production TDWR systems. The objectives of the 1990 evaluation period were to evaluate TDWR system performance in detecting low-altitude wind shear, specifically microbursts and gust fronts, at the Orlando International Airport and in the surrounding area; to refine the system's wind shear detection capabilities; and to evaluate elements of the system developed by the contractor, which were new for the C-band system and therefore not available for evaluation in previous years. Some performance comparisons are made among results from the vastly different weather environments of Denver, Kansas City, and Orlando. Statistics are presented and discussed for the performance of the system in detecting and predicting microbursts and gust fronts. A significant use of the prediction capability is its potential use for air traffic control (ATC) personnel to plan airport operations when hazardous weather is predicted. Issues such as low velocity ground clutter (from tree leaves, road traffic, and dense urban areas) that affect prediction performance are discussed along with possible software modification to account for them. GRA

N91-27438# Scientech, Inc., Idaho Falls, ID.
S-76 ROTORCRAFT HIGH INTENSITY RADIATED FIELDS. TEST PLAN
JERRY T. BLAIR, STEVE M. BROOKS, and KEN A. BARNES Jul. 1991 71 p Sponsored by FAA
(Contract DE-AC07-90ID-12916)
(SCIE-FAA-001-91; DOT/FAA/CT-TN91/26) Avail: NTIS HC/MF A04

Concern over the effects of High Intensity Radiated Fields (HIRF) on civil and military aircraft has increased over the past 10 years. The increase is due to several factors which affect the safe flight of all fixed-wing and rotorcraft. Previous flight-critical mechanical controls are being replaced by electronic computer-driven controls; manufacturers are increasing the use of composite materials in the fabrication of new aircraft; and frequency ranges and output power levels of commercial and military transmitters have significantly increased. While much HIRF susceptibility information has been collected, the data are proprietary and have not been released. To address the HIRF concerns and begin development of a releasable HIRF data base, the FAA Technical Center, has implemented a HIRF research program. As part of that program, a HIRF test was performed on a Sikorsky S-76 Helicopter. The purpose, approach, and initial findings of the S-76 HIRF test are addressed. Author

N91-27460# Wright Research Development Center, Wright-Patterson AFB, OH.
PERCEPTUAL LIMITATIONS OF PERIPHERALLY DISPLAYED COLORS ON CRTS Final Report, Jan. 1990 - Jan. 1991
EILEEN G. ANCMAN Mar. 1991 44 p
(AD-A236289; WL-TM-91-309-FIGK) Avail: NTIS HC/MF A03 CSCL 09/5

Cathode ray tubes are currently used in aircraft cockpits to relay important color coded information necessary for mission completion and pilot survival. Color CRT's presently used are as large as 6 x 6 inch, but are projected to increase in size until the all glass cockpit is achieved. As the display gets larger, peripheral vision may be relied upon even more heavily. Peripheral vision is also important in present situations involving more than one CRT display used in a row, and especially when the pilot is in a head-up mode. The research in this report dealt with a subject's ability to recognize in their peripheral vision the three primary colors, blue, green, and red, on a cathode ray tube (CRT) with all three guns adjusted to achieve equal luminance. Data for various subject psychological states (normal, stressed, and relaxed) was collected. Percent error (e.g., how many times red was perceived as green or blue) was recorded for each state and color. A second performance measure, visual field dimension (e.g., degrees off of

fovea where the color of the circle was correctly perceived) along the x-axis, was also collected for each color and psychological state. GRA

N91-27472# Naval Air Development Center, Warminster, PA. Air Vehicle and Crew Systems Technology Dept.
THE 270 VOLT DIRECT CURRENT GENERATOR PERFORMANCE EVALUATION Final Report, Jun. - Aug. 1990
JENIFER M. SHANNON Dec. 1990 45 p
(Contract NR PROJ. W13-55)
(AD-A236946; NADC-91003-60) Avail: NTIS HC/MF A03 CSCL 10/2

This document presents the results of the testing of a 45 kW, 270 VDC generator. Parameters measured include line voltage, field current, peak-to-peak ripple voltage, distortion spectrum, and transients due to both load application and load removal. The purpose of this testing was to provide a baseline of 270 VDC generator performance. The baseline data will be used as an input of the revision of MIL-STD-704D, the aircraft power quality specification. The performance of the generator under test exceeded expectations. The conclusion of this testing is that no significant problems should be encountered by generator vendors in their efforts to meet the new 270 VDC requirements set forth in MIL-STD-704E. GRA

N91-27489*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
VISUALIZATION TECHNIQUES TO EXPERIMENTALLY MODEL FLOW AND HEAT TRANSFER IN TURBINE AND AIRCRAFT FLOW PASSAGES
LOUIS M. RUSSELL and STEVEN A. HIPPENSTEELE Washington Jun. 1991 19 p Original contains color illustrations
(NASA-TM-4272; E-5811; NAS 1.15:4272) Avail: NTIS HC/MF A03; 7 functional color pages CSCL 20/4

Increased attention to fuel economy and increased thrust requirements have increased the demand for higher aircraft gas turbine engine efficiency through the use of higher turbine inlet temperatures. These higher temperatures increase the importance of understanding the heat transfer patterns which occur throughout the turbine passages. It is often necessary to use a special coating or some form of cooling to maintain metal temperatures at a level which the metal can withstand for long periods of time. Effective cooling schemes can result in significant fuel savings through higher allowable turbine inlet temperatures and can increase engine life. Before proceeding with the development of any new turbine it is economically desirable to create both mathematical and experimental models to study and predict flow characteristics and temperature distributions. Some of the methods are described used to physically model heat transfer patterns, cooling schemes, and other complex flow patterns associated with turbine and aircraft passages. Author

N91-27490*# Institute for Computer Applications in Science and Engineering, Hampton, VA.
OPTIMAL CONTROL OF LIFT/DRAG RATIOS ON A ROTATING CYLINDER Final Report
YUH-ROUNG OU and JOHN A. BURNS (Virginia Polytechnic Inst. and State Univ., Blacksburg.) Jun. 1991 14 p Submitted for publication
(Contract NAS1-18605; AF-AFOSR-0079-89; AF-AFOSR-0001-89)
(NASA-CR-187586; NAS 1.26:187586; ICASE-91-49) Avail: NTIS HC/MF A03 CSCL 20/4

The numerical solution to a problem of maximizing the lift to drag ratio by rotating a circular cylinder in a two-dimensional viscous incompressible flow is presented. This problem is viewed as a test case for the newly developing theoretical and computational methods for control of fluid dynamic systems. The authors show that the time averaged lift to drag ratio for a fixed finite time interval achieves its maximum value at an optimal rotation rate that depends on the time interval. Author

N91-27493# Cincinnati Univ., OH.
DIRECT SOLUTION TECHNIQUES FOR VISCOUS FLOW AND THEIR CONTROL Final Report, Oct. 1986 - Apr. 1990
KIRTI N. GHIA and URMILA GHIA May 1991 63 p
(Contract AF-AFOSR-0074-87; AF PROJ. 2307)
(AD-A236201; AFL-91-5-75; AFOSR-91-0531TR) Avail: NTIS HC/MF A04 CSCL 20/4

Major objectives of this study of two- and three-dimensional low-speed viscous separated flow problems were to understand the effect of flow separation, unsteadiness, three-dimensionality and nonlinear dynamics in simple two- and three-dimensional flows and, subsequently, to examine the control of these flows. Significant effort was directed toward developing basic computational methods which were made available to interested researchers and organizations involved in computational fluid dynamics research. The several analyses developed include two-dimensional Navier-Stokes analyses for steady and unsteady bluff body separation and massively separated flow past generalized airfoils at high angle of attack; a passive flow-control analyses using a flap for a generalized airfoil; active flow control analyses using an oscillating flap modulated suction/injection and free-stream unsteadiness; nonlinear dynamical systems analysis for low-speed separated flows; and, finally, three-dimensional analysis using velocity and vorticity for internal flows. The finite-Re results obtained for steady bluff body separation revealed some anomalies in the existing theoretical models and should help in improving these models. The Navier-Stokes analysis for unsteady separation past a circular cylinder provided very accurate prediction of Reynolds stresses from the first principles. GRA

N91-27497# Army Military Personnel Center, Alexandria, VA.
NUMERICAL SIMULATION OF FLUID FLOW IN A SIMPLE ROTOR/STATOR PAIR M.S. Thesis Final Report, Jan. - Jun. 1991
JOSEPH J. MCVEIGH, JR. Jun. 1991 110 p
(AD-A236720) Avail: NTIS HC/MF A06 CSCL 20/4

A series of numerical experiments are described which deal with rotor/stator interactions in hydroturbines. The means of analysis was a nonconforming sliding spectral element method for the unsteady, incompressible Navier-Stokes equations in two-dimensional geometry. The variable parameter in the simulation was the rotor advance coefficient. A comparison of lifting forces, flow rate, dissipation and kinetic energy was conducted for the various test cases. Robustness of the numerical discretizations was demonstrated by the consistency of the computed results. The divergence, vorticity and streamlines generated during postprocessing were in strong agreement with hydrodynamic theory. A step-by-step procedure is presented for manipulating the working environment (the discrete spectral element control volume) around the rotor-stator pair. The selection criteria for the input parameters and boundary conditions is developed. GRA

N91-27500# City Coll. of the City Univ. of New York, NY. Dept. of Physics.
TURBULENT MOLECULAR PROCESSES AND STRUCTURES IN SUPERSONIC FREE SHEAR LAYERS Final Technical Report
JOSEPH A. JOHNSON, III 31 Dec. 1990 4 p
(Contract N00014-90-J-1239)
(AD-A236922) Avail: NTIS HC/MF A01 CSCL 20/4

We used our Ludwieg tube-wind-tunnel to determine Reynolds number and Mach number effects on the dynamics of coherent structures in a supersonic free shear layer. We proposed to implement fluorescence in NO2 as a local point density diagnostic and to develop a capacity of simultaneous three dimensional measurements of velocity and Reynolds number histories in the free shear layer and to determine as well the axial and transverse profiles for such a flow. Using a Mach number 2.5 nozzle, we have confirmed our previously published evidence of Reynolds number sensitivity in supersonic turbulent shocklets in compressible free shear layers. We have determined that shocklet-producing entities are low velocity systems in these flows and have impact on the local scales associated with turbulent effects. We have

determined a local evolution of coherence in the Reynolds stress data, using both phase coherence velocimetry and new techniques for direct velocity estimations, between the on-axis and off-axis regions of the free shear layer. We find that classical turbulent effects are in a long-wavelength range while effects accompanying chaos are at short wavelengths, -- with fractal dimensions which suggest that the observed chaotic behavior evolves from instabilities in flow which is topologically two dimensional. GRA

N91-27501*# Institute for Computer Applications in Science and Engineering, Hampton, VA.
STABILITY OF A NON-ORTHOGONAL STAGNATION FLOW TO THREE DIMENSIONAL DISTURBANCES Final Report
D. G. LASSEIGNE and T. L. JACKSON (Old Dominion Univ., Norfolk, VA.) Jun. 1991 29 p Submitted for publication
(Contract NAS1-18605)
(NASA-CR-187591; NAS 1.26:187591; ICASE-IR-91-51) Avail: NTIS HC/MF A03 CSCL 20/4

A similarity solution for a low Mach number nonorthogonal flow impinging on a hot or cold plate is presented. For the constant density case, it is known that the stagnation point shifts in the direction of the incoming flow and that this shift increases as the angle of attack decreases. When the effects of density variations are included, a critical plate temperature exists; above this temperature the stagnation point shifts away from the incoming stream as the angle is decreased. This flow field is believed to have application to the reattachment zone of certain separated flows or to a lifting body at a high angle of attack. Finally, the stability of this nonorthogonal flow to self similar, 3-D disturbances is examined. Stability properties of the flow are given as a function of the parameters of this study; ratio of the plate temperature to that of the outer potential flow and angle of attack. In particular, it is shown that the angle of attack can be scaled out by a suitable definition of an equivalent wavenumber and temporal growth rate, and the stability problem for the nonorthogonal case is identical to the stability problem for the orthogonal case. Author

N91-27507# Queensland Univ., Brisbane (Australia). Dept. of Civil Engineering.
MEASUREMENTS OF FLUCTUATING EFFECTS ON A CIRCULAR CYLINDER IN A UNIFORM FLOW AT SUBCRITICAL REYNOLDS NUMBER, PART 1
G. S. WEST and C. J. APELT Jul. 1990 53 p
(PB91-177865; RR-CE-109-PT-1; ISBN-0-86776-384-1) Avail: NTIS HC/MF A04 CSCL 20/4

Experiments were carried out on long, smooth, circular cylinders to establish data on the fluctuating pressure distributions and r.m.s. lift and drag forces in sub-critical flow (10,000 less than R less than 250,000) on an elemental slice of the cylinder. Parametric studies of the effects of variation of Reynolds number, aspect ratio, turbulence of the incident flow, and wind tunnel blockage were undertaken. The results are presented in graphical and tabular form. The work presented here provides a basis for a study of spanwise effects. Author

N91-27508# Queensland Univ., Brisbane (Australia). Dept. of Civil Engineering.
MEASUREMENTS OF FLUCTUATING EFFECTS ON A CIRCULAR CYLINDER IN A UNIFORM FLOW AT SUBCRITICAL REYNOLDS NUMBER, PART 2
G. S. WEST and C. J. APELT Jul. 1990 33 p
(PB91-177873-PT2; RR-CE-110-PT-2; ISBN-0-86776-385-X-PT-2)
Avail: NTIS HC/MF A03 CSCL 20/4

Spanwise correlations of the forces on two elements of a long, smooth cylinder with end plates were carried out for a range of Reynold numbers and turbulence intensities. The resulting correlation curves are presented. A theory is proposed to use these curves to calculate the lift and drag coefficients of cylinders of finite length. These coefficients have been evaluated, and are presented in graphical form. Spanwise pressure correlations have also been investigated, and their correlation curves are shown. The results apply to aspect ratios from 10 to 50, Reynolds numbers from 10,000 to 250,000, and turbulence intensities between 0.2 percent and 7.5 percent. Author

N91-27549# Wright Research Development Center, Wright-Patterson AFB, OH.
INVESTIGATION INTO THE FAILURE CAUSE OF A DOUBLE ACTING, LEADING EDGE GROOVE, TILTING PAD THRUST BEARING Final Report, Feb. - Aug. 1990
BRIAN K. PETERSON Oct. 1990 56 p
(Contract DA PROJ. 668A)
(AD-A235613; WRDC-TR-90-2120) Avail: NTIS HC/MF A04 CSCL 13/9

The results are described of bench tests simulating operation and failure of a thrust bearing used in a gas turbine engine compressor development test rig. The bearing was a double acting, tilting pad with offset pivot, leading edge groove configuration using an AMS 4928 titanium collar and C18200 copper-chrome alloy pads with a No. 2 babbitt face. The bench tests successfully simulated the bearing failure and demonstrated a materials incompatibility. This was supported by visual examination, scanning electron microscopy and X-ray energy spectroscopy. A comparison of the bench test results to the compressor rig bearing failure is provided to support the report conclusions. GRA

N91-27559*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SOME PRELIMINARY RESULTS OF BRUSH SEAL/ROTOR INTERFERENCE EFFECTS ON LEAKAGE AT ZERO AND LOW RPM USING A TAPERED-PLUG ROTOR
R. C. HENDRICKS, M. P. PROCTOR, J. A. SCHLUMBERGER, M. J. BRAUN, and R. L. MULLEN (Case Western Reserve Univ., Cleveland, OH.) 1991 16 p Presented at the 27th Joint Propulsion Conference, Sacramento, CA, 24-27 Jun. 1991; sponsored by AIAA, SAE, ASME and ASEE
(NASA-TM-104396; E-6212; NAS 1.15:104396; AIAA-91-3390)
Avail: NTIS HC/MF A03 CSCL 11/1

Some preliminary brush seal leakage results for ambient temperature air are presented. Data for four nominal brush rotor radial clearances of -0.09, -0.048, -0.008, and 0.035 mm were taken by using a tapered plug rotor at 0 and 400 rpm with rotor runout of 0.127 mm peak to peak. The brush seal nominal bore diameter was 38 mm with 0.05 mm bristles at 200 bristles/mm of circumference and a 0.61 mm fence height. Leakages were greater than predicted, but agreement was reasonable. Leakage rates were not significantly altered by hysteresis or inlet flow variations. Visualization studies showed that the bristles followed the 400 rpm excitation, and loading studies indicated that bristles slid relative to one another. Author

N91-27560* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH-TEMPERATURE, FLEXIBLE, THERMAL BARRIER SEAL Patent
PAUL J. SIROCKY, inventor (to NASA) and BRUCE M. STEINETZ, inventor (to NASA) 14 May 1991 13 p Filed 27 Nov. 1989
(NASA-CASE-LEW-14672-1; US-PATENT-5,014,917;
US-PATENT-APPL-SN-441672; US-PATENT-CLASS-239-265.11;
US-PATENT-CLASS-277-34; US-PATENT-CLASS-277-157;
US-PATENT-CLASS-277-226; US-PATENT-CLASS-277-229;
INT-PATENT-CLASS-B64D-33/04;
INT-PATENT-CLASS-F16J-15/46) Avail: US Patent and Trademark Office CSCL 13/9

This device seals the sliding interfaces between structural panels that are roughly perpendicular to each other or whose edges are butted against one another. The nonuniformity of the gap between the panels requires significant flexibility along the seal length. The seal is mounted in a rectangular groove in a movable structural panel. A plurality of particles or balls is densely packed in an outer sheathing. The balls are laterally preloaded to maintain sealing contact with the adjacent wall using a pressurized linear bellows. Distortions in the adjacent panel are accommodated by rearrangement of the particles within the outer sheathing.

Leakage through the seal is minimized by densely compacting the internal particles and by maintaining positive preload along the back side of the seal. The braid architecture of the outer sheathing is selected to minimize leakage through the seal and to resist mechanical abrasion.

Official Gazette of the U.S. Patent and Trademark Office

N91-27561* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

QUICK ACTION CLAMP Patent

FRANK S. CALCO, inventor (to NASA) 16 Jul. 1991 8 p Filed 30 Mar. 1990

(NASA-CASE-LEW-14887-1; US-PATENT-5,032,045; US-PATENT-APPL-SN-503418; US-PATENT-CLASS-410-80; US-PATENT-CLASS-410-84; US-PATENT-CLASS-292-60; US-PATENT-CLASS-292-61; INT-PATENT-CLASS-B60P-7/15; INT-PATENT-CLASS-E05C-5/04) Avail: US Patent and Trademark Office CSCL 13/11

A quick release toggle clamp that utilizes a spring that requires a deliberate positive action for disengagement is presented. The clamp has a sliding bolt that provides a latching mechanism. The bolt is moved by a handle that tends to remain in an engaged position while under tension.

Official Gazette of the U.S. Patent and Trademark Office

N91-27563# Southwest Research Inst., San Antonio, TX.

GAS ROTARY ENGINE TECHNOLOGY DEVELOPMENT Final Report, Apr. - Dec. 1990

T. A. KUCHNICKI, B. E. GOODRICH, and R. A. PAGE Dec. 1990 90 p

(Contract GRI-5083-242-0930)

(PB91-182402; SWRI-3458; GRI-91/0096) Avail: NTIS HC/MF A05 CSCL 13/9

The feasibility of developing a small natural gas oil cooled rotary engine for long life gas heat pump applications was explored. A literature search was conducted, rotary engine manufacturers were contacted and questionned, experts in engine materials and engine lubricants furnished reports, and discussions were held with engineering management and staff engineers to review rotary engine technology and discuss practical ideas for more durable engine designs. Author

N91-27591*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

AEROELASTIC MODAL CHARACTERISTICS OF MISTUNED BLADE ASSEMBLIES: MODE LOCALIZATION AND LOSS OF EIGENSTRUCTURE

CHRISTOPHE PIERRE and DURBHA V. MURTHY (Toledo Univ., OH.) Jul. 1991 38 p Previously announced as A91-32032

(Contract NAG3-1163; NAG3-742; NASA ORDER C-99066-G)

(NASA-TM-104519; E-6389; NAS 1.15:104519; ICOMP-91-12)

Avail: NTIS HC/MF A03 CSCL 20/11

An investigation of the effects of small mistuning on the aeroelastic modes of bladed disk assemblies with aerodynamic coupling between blades is presented. The cornerstone of the approach is the use and development of perturbation methods that exhibit the crucial role of the interblade coupling and yield general findings regarding mistuning effects. It is shown that blade assemblies with weak aerodynamic interblade coupling are highly sensitive to small blade mistuning, and that their dynamics is quantitatively altered in the following ways: the regular pattern that characterizes the root locus of the tuned aeroelastic eigenvalues in the complex plane is totally lost; the aeroelastic mode shapes becomes severely localized to only a few blades of the assembly and lose their constant interblade phase angle feature; and curve veering phenomena take place when the eigenvalues are plotted versus a mistuning parameter. Author

N91-28116*# Prairie View Agricultural and Mechanical Coll., TX. Dept. of Mechanical Engineering.

SUBCOOLED FREON-11 FLOW BOILING IN TOP-HEATED FINNED COOLANT CHANNELS WITH AND WITHOUT A TWISTED TAPE

ALVIN SMITH and RONALD D. BOYD, SR. *In* Alabama A & M Univ., NASA-HBCU Space Science and Engineering Research Forum Proceedings p 390-397 1989 Sponsored by NASA. Johnson Space Center and Sandia National Labs.

Avail: NTIS HC/MF A23 CSCL 20/5

An experimental study was conducted in top-heated finned horizontal tubes to study the effect of enhancement devices on flow boiling heat transfer in coolant channels. The objectives are to examine the variations in both the mean and local (axial and circumferential) heat transfer coefficients for circular coolant channels with spiral finned walls and/or spiral fins with a twisted tape, and improve the data reduction technique of a previous investigator. The working fluid is freon-11 with an inlet temperature of 22.2 C (approximately 21 C subcooling). The coolant channel's exit pressure and mass velocity are 0.19 M Pa (absolute) and 0.21 Mg/sq. ms, respectively. Two tube configurations were examined; i.e., tubes had either 6.52 (small pitch) or 4.0 (large pitch) fins/cm of the circumferential length (26 and 16 fins, respectively). The large pitch fins were also examined with a twisted tape insert. The inside nominal diameter of the copper channels at the root of the fins was 1.0 cm. The results show that by adding enhancement devices, boiling occurs almost simultaneously at all axial locations. The case of spiral fins with large pitch resulted in larger mean (circumferentially averaged) heat transfer coefficients, h sub m, at all axial locations. Finally, when twisted tape is added to the tube with large-pitched fins, the power required for the onset of boiling is reduced at all axial and circumferential locations. Author

N91-28231*# Pennsylvania State Univ., University Park. Dept. of Mechanical Engineering.

ANALYSIS OF FOIL BEARINGS FOR HIGH SPEED OPERATION IN CRYOGENIC APPLICATIONS

MARC CARPINO *In* NASA, Washington, Space Transportation Propulsion Technology Symposium. Volume 2: Symposium Proceedings p 709-715 May 1991

Avail: NTIS HC/MF A99 CSCL 13/11

The general objective of this project is to develop analysis tools which are required for the design of foil bearings to be used in cryogenic applications. During the second year of this project, a general analysis approach and code for journal bearings operating under steady state conditions will be completed. This will be followed by the initiation of an investigation into transient behavior of foil bearings to determine their performance in rotor systems. Foil bearings have been proposed as an alternative to rolling element bearings for use in cryogenic turbopumps in liquid propellant rocket engines. This type of bearing offers several advantages over rolling element bearings since they would use the cryogenic pump fluid for a lubricant and have structural flexibility. These bearings have the potential of high reliability and long life. The bearing surface is constructed of a 'foil' which resists deflection by a combination of bending, membrane, and elastic foundation effects. The relative motion between the rotating shaft and the foil causes pressure in the fluid film to develop. This pressure deflects the the foil surface away from the shaft. Once a full fluid film is established between the foil and the rotor shaft, contact no longer takes place and there is no subsequent wear of the surfaces. The flexible foil structure of the bearing allows it to compensate for minor tolerance and manufacturing defects. This same flexibility also has a significant effect on the dynamic performance of the rotor-bearing system. Author

N91-28455*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

METHOD AND APPARATUS FOR CLEANING RUBBER DEPOSITS FROM AIRPORT RUNWAYS AND ROADWAYS Patent Application

SANDY M. STUBBS, inventor (to NASA) 3 Apr. 1991 11 p

(NASA-CASE-LAR-14483-1; NAS 1.71:LAR-14483-1; US-PATENT-APPL-SN-682153) Avail: NTIS HC/MF A03 CSCL 13/8

A method and apparatus for cleaning rubber deposits from surfaces such as airport runways and roadways is disclosed. The

apparatus includes a large vehicle that has the capacity to be loaded so as to effectively add weight to rubber cleaning tires of the vehicle. In addition, the vehicle has a water tank and sprinkler system so that the surface may be wetted down in front of the tires as the vehicle proceeds across the surface. The cleaning tires of the apparatus are aligned so that they are at a yaw angle to the direction of travel, and the cleaning tire assembly is attached to the underside of the trailer of the vehicle and positioned between a forward and rear water tank. In addition, this tire assembly is equipped with a means of loading the tires onto the contaminated surface. The method comprises driving such a vehicle at low speeds down the surface as the road is being wet in front of the cleaning tires. The effect of the angled tires is to create a scrubbing action that not only heats the rubber deposits by friction but also causes it to be removed from the surface. The rubber that does not stick to the cleaning tires is then removed from the surface by sweeping. NASA

N91-28503*# MCAT Inst., San Jose, CA.
ALGORITHM AND CODE DEVELOPMENT FOR UNSTEADY THREE-DIMENSIONAL NAVIER-STOKES EQUATIONS Annual Report, 1 Apr. 1989 - 30 Mar. 1991
SHIGERU OBAYASHI Jun. 1991 130 p
(Contract NCC2-605)
(NASA-CR-188039; NAS 1.26:188039; MCAT-91-005) Avail: NTIS HC/MF A07 CSCL 20/4

A streamwise upwind algorithm for solving the unsteady 3-D Navier-Stokes equations was extended to handle the moving grid system. It is noted that the finite volume concept is essential to extend the algorithm. The resulting algorithm is conservative for any motion of the coordinate system. Two extensions to an implicit method were considered and the implicit extension that makes the algorithm computationally efficient is implemented into Ames's aeroelasticity code, ENSAERO. The new flow solver has been validated through the solution of test problems. Test cases include three-dimensional problems with fixed and moving grids. The first test case shown is an unsteady viscous flow over an F-5 wing, while the second test considers the motion of the leading edge vortex as well as the motion of the shock wave for a clipped delta wing. The resulting algorithm has been implemented into ENSAERO. The upwind version leads to higher accuracy in both steady and unsteady computations than the previously used central-difference method does, while the increase in the computational time is small. Author

N91-28504# Royal Aerospace Establishment, Farnborough (England).
THE APPLICATION OF PARTICLE IMAGE VELOCIMETRY (PIV) IN A SHORT DURATION TRANSONIC ANNULAR TURBINE CASCADE
S. P. HARASGAMA, P. J. BRYANSTON-CROSS, C. E. TOWERS, and S. T. HOPWOOD Mar. 1991 12 p
(AD-A236639; RAE-TM-P-1203; DRIC-BR-301039) Avail: NTIS HC/MF A03 CSCL 20/4

A series of experiments was performed to demonstrate the application of Particle Image Velocimetry to turbomachinery flows. The tests were performed at transonic speeds on a fully annular engine size turbine nozzle guide vane. The vane cascade was installed in a short duration Isentropic Light Piston Cascade (ILPC) test facility operating with high inlet turbulence levels. The technique was shown to map the whole flow field with a resolution of 0.5 mm. The quality of the results obtained are not greatly affected by local turbulence rates. The accuracy of the measurements is put at around 4 pct. of absolute velocity and is limited by the quality of the image on the film plane. The velocities derived from the PIV images were compared with predictions from a 3-D viscous numerical calculation. It is shown that the experimental and predicted results are in good agreement. It is considered that this technique has considerable potential in application to turbomachinery flow field diagnostics. GRA

N91-28505# Sandia National Labs., Albuquerque, NM.
A NUMERICAL APPROACH FOR MODELLING CAVITATING FLOWS
M. S. INGBER (New Mexico Univ., Albuquerque.) and C. E. HAILEY 1991 15 p Presented at the 1st International Conference on Computational Modeling of Free and Moving Boundary Problems, Southampton, England, 2-4 Aug. 1991
(Contract DE-AC04-76DP-00789)
(DE91-009178; SAND-90-2418C; CONF-910863-1) Avail: NTIS HC/MF A03

The flow about a submerged partially or supercavitating axisymmetric body is considered both at zero and non-zero angle of attack. The direct boundary element method is used to solve for the potential flow field and to determine the cavity shape. This is accomplished by performing a Newton-Raphson iteration in which the cavity shape is perturbed in an effort to satisfy the nonlinear dynamic boundary condition along the surface of the cavity. For problems with non-zero angle of attack, the flow field is 3-D and the cavity is not symmetric. In these cases, the convergence of the Newton-Raphson iteration is sensitive to the initial estimate of the cavity shape. Methods of generating these initial estimates are discussed which have been successful in leading to convergent solutions. Also efficient methods of parameterizing the cavity are developed to reduce the computational effort. DOE

N91-28513# Los Alamos National Lab., NM.
MOVING FINITE ELEMENTS: A CONTINUOUSLY ADAPTIVE METHOD FOR COMPUTATIONAL FLUID DYNAMICS
A. H. GLASSER, K. MILLER, and N. CARLSON (California Univ., Berkeley.) 1991 6 p Presented at the Power Supercomputer Users Meeting, Gaithersburg, 21-22 May 1991
(Contract W-7405-ENG-36)
(DE91-013391; LA-UR-91-1716; CONF-9105202-3) Avail: NTIS HC/MF A02

Moving Finite Elements (MFE), a recently developed method for computational fluid dynamics, promises major advances in the ability of computers to model the complex behavior of liquids, gases, and plasmas. Applications of computational fluid dynamics occur in a wide range of scientifically and technologically important fields. Examples include meteorology, oceanography, global climate modeling, magnetic and inertial fusion energy research, semiconductor fabrication, biophysics, automobile and aircraft design, industrial fluid processing, chemical engineering, and combustion research. The improvements made possible by the new method could thus have substantial economic impact. This paper describes the mathematical formulation and illustrates its use. DOE

N91-28530 Michigan Univ., Ann Arbor.
USE OF A ROTATED RIEMANN SOLVER FOR THE TWO-DIMENSIONAL EULER EQUATIONS Ph.D. Thesis
DAVID WILLIAM LEVY 1990 159 p
Avail: Univ. Microfilms Order No. DA9116236

A scheme for the 2-D Euler equations that uses flow parameters to determine the direction for upwind differencing is described. This approach exploits the multi-dimensional nature of the equations and reduces the grid dependence of conventional schemes. Several angles are tested as the dominant upwind direction, including the local flow, pressure gradient, and velocity magnitude gradient angles. Roe's approximate Riemann solver is used to calculate fluxes in the upwind direction, as well as for the flux component normal to the upwinding direction. The approach is first tested for 2-D scalar convection, where data used to calculate cell face fluxes are interpolated to lie along characteristic lines. The scheme is shown to have accuracy comparable to a high order MUSCL scheme. A method is also implemented to preserve monotonicity. Solutions of the Euler equations are calculated for a variety of test cases, including channel flows and flows about airfoils. Dissert. Abstr.

N91-28536 Council for National Academic Awards (England).
PREDICTION OF THE FLOW AND HEAT TRANSFER BETWEEN A ROTATING AND A STATIONARY CONE Ph.D. Thesis
NICHOLAS EDWARD MAY 1990 370 p
Avail: Univ. Microfilms Order No. BRDX92318

The development of a theoretical method for predicting the turbulent flow and heat transfer in the cavity between a rotating and a stationary cone is discussed. The developed method is the integral method, which reduces the governing partial differential equations to ordinary differential equations. A number of solution methods for these equations are described, and the optimum in terms of speed and accuracy is indicated. A computer program which solves the full Reynolds-averaged Navier-Stokes and energy equations in steady and axisymmetric form, using a finite difference method is modified for use in the conical geometry.
Dissert. Abstr.

N91-28578*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
IMPROVED SUPERCONDUCTING BEARINGS Patent Application
YURY FLOM, inventor (to NASA) and JAMES D. ROYSTON, inventor (to NASA) 17 Apr. 1991 24 p
(NASA-CASE-GSC-13346-1; NAS 1.71:GSC-13346-1; US-PATENT-APPL-SN-691609) Avail: NTIS HC/MF A03 CSCL 13/9

An improved superconducting bearing is presented. Rotor is confined within two superconducting circular bearing structures, each of which has a number of embedded heating elements, and will levitate rotor which has embedded magnets in its end. Heating elements are connected to a feedback control unit, as are rotor position sensors. The temperature profiles of each circular bearing structure is then adjusted according to the information on rotor position provided to control unit by position sensors. Novelty is believed to reside in providing a superconducting circular bearing structure allowing for a control of the levitating forces. NASA

N91-28627*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ASTROP2 USERS MANUAL: A PROGRAM FOR AEROELASTIC STABILITY ANALYSIS OF PROPFANS
G. V. NARAYANAN (Sverdrup Technology, Inc., Brook Park, OH.) and K. R. V. KAZA Washington Aug. 1991 75 p
(Contract NAS3-25266)
(NASA-TM-4304; E-5768; NAS 1.15:4304) Avail: NTIS HC/MF A04 CSCL 20/11

A user's manual is presented for the aeroelastic stability and response of propulsion systems computer program called ASTROP2. The ASTROP2 code preforms aeroelastic stability analysis of rotating propfan blades. This analysis uses a two-dimensional, unsteady cascade aerodynamics model and a three-dimensional, normal-mode structural model. Analytical stability results from this code are compared with published experimental results of a rotating composite advanced turboprop model and of nonrotating metallic wing model. Author

N91-28643*# Wayne State Univ., Detroit, MI. Dept. of Mathematics.
ACTIVE CONTROL OF PANEL VIBRATIONS INDUCED BY BOUNDARY-LAYER FLOW Annual Report, 10 Aug. 1990 - 9 Aug. 1991
PAO-LIU CHOW 24 Aug. 1991 13 p
(Contract NAG1-1175)
(NASA-CR-188733; NAS 1.26:188733) Avail: NTIS HC/MF A03 CSCL 20/11

Some problems in active control of panel vibration excited by a boundary layer flow over a flat plate are studied. In the first phase of the study, the optimal control problem of vibrating elastic panel induced by a fluid dynamical loading was studied. For a simply supported rectangular plate, the vibration control problem can be analyzed by a modal analysis. The control objective is to minimize the total cost functional, which is the sum of a vibrational energy and the control cost. By means of the modal expansion, the dynamical equation for the plate and the cost functional are reduced to a system of ordinary differential equations and the cost functions for the modes. For the linear elastic plate, the modes become uncoupled. The control of each modal amplitude reduces to the so-called linear regulator problem in control theory. Such problems can then be solved by the method of adjoint state. The optimality system of equations was solved numerically by a shooting method. The results are summarized. Author

N91-28644*# Applied Research Associates, Inc., Raleigh, NC.
PROBABILISTIC STRUCTURAL MECHANICS RESEARCH FOR PARALLEL PROCESSING COMPUTERS Final Report
ROBERT H. SUES, HEH-CHYUN CHEN, LAWRENCE A. TWISDALE, and WILLIAM R. MARTIN (Michigan Univ., Ann Arbor.) Aug. 1991 74 p
(Contract NAS3-25824)
(NASA-CR-187162; NAS 1.26:187162; ARA-5589) Avail: NTIS HC/MF A04 CSCL 20/11

Aerospace structures and spacecraft are a complex assemblage of structural components that are subjected to a variety of complex, cyclic, and transient loading conditions. Significant modeling uncertainties are present in these structures, in addition to the inherent randomness of material properties and loads. To properly account for these uncertainties in evaluating and assessing the reliability of these components and structures, probabilistic structural mechanics (PSM) procedures must be used. Much research has focused on basic theory development and the development of approximate analytic solution methods in random vibrations and structural reliability. Practical application of PSM methods was hampered by their computationally intense nature. Solution of PSM problems requires repeated analyses of structures that are often large, and exhibit nonlinear and/or dynamic response behavior. These methods are all inherently parallel and ideally suited to implementation on parallel processing computers. New hardware architectures and innovative control software and solution methodologies are needed to make solution of large scale PSM problems practical. Author

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

A91-45637#
VHF DISCHARGES IN STORM CELLS PRODUCING MICROBURSTS
P. LAROCHE, C. MALHERBE, A. BONDIOU (ONERA, Chatillon, France), M. WEBER, C. ENGHOLM (MIT, Lexington, MA) et al. (International Conference on Lightning and Static Electricity, Cocoa Beach, FL, Apr. 16-19, 1991) ONERA, TP no. 1991-57, 1991, 14 p. Research supported by DRET, Direction Generale de l'Aviation Civile, and FAA. refs
(ONERA, TP NO. 1991-57)

An experiment is carried out in which the three-dimensional mapping of VHF sources is compared to a three-dimensional description of the reflectivity and dynamics of associated cloud cells observed by a radar network. Data from 61 microbursts are analyzed and it is found that, in 93 percent of the cases, electrical activity precedes outflow development. The results confirm that the peak in intracloud activity precedes the maximum value of the outflow. K.K.

A91-47833*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASSESSMENT OF MICROBURST MODELS FOR DOWNDRAFT ESTIMATION

DAN D. VICROY (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 300-309. refs
(AIAA PAPER 91-2947) Copyright

The effectiveness of three microburst models in estimating the downdraft from horizontal velocity measurements is assessed. The development of the models and their characteristics are discussed. The simplest model, a linear one, works well for altitudes below 200 m and near the microburst core. A ring-vortex model and an empirical model give the best overall results. The former is the most complex, requiring four variables to define it. The empirical model uses three variables. C.D.

A91-48352
INCREASE IN THE PSC-FORMATION PROBABILITY CAUSED BY HIGH-FLYING AIRCRAFT
THOMAS PETER, CHRISTOPH BRUEHL, and PAUL J. CRUTZEN (Max-Planck-Institut fuer Chemie, Mainz, Federal Republic of Germany) Geophysical Research Letters (ISSN 0094-8276), vol. 18, Aug. 1991, p. 1465-1468. refs
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The saturation temperature T(sat) for the formation of polar stratospheric clouds (PSC) strongly depends on the local partial pressures of nitric acid and water vapor, and thus is sensitive to NOx and H2O-injection due to exhaust from aircraft in the stratosphere. The present paper investigates this effect, using daily stratospheric temperature data from the Northern Hemisphere compiled over the last 25 years. The analyses are compared of both a background atmosphere and one perturbed by a fleet of 600 stratospheric aircraft flying at about 22 km altitude. The result is that between December and March in the polar cap region there might be more than a doubling in the occurrence of Type-I PSCs and an even stronger increase of Type-II PSCs, and accordingly a substantial enhancement in the potential ozone destruction by chlorine radicals. Author

N91-27628# Rijksinstituut voor de Volksgezondheid, Bilthoven (Netherlands).
EFFECT OF AIRCRAFT EMISSIONS ON ATMOSPHERIC OZONE IN THE NORTHERN HEMISPHERE
J. P. BECK, C. E. REEVES, F. A. A. M. DELEEUW, and S. A. PENKETT Jun. 1990 100 p Prepared in cooperation with East Anglia Univ., Norwich (England) Sponsored in part by Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer
(PB91-172072; RIVM-222201001) Avail: NTIS HC/MF A05
CSCL 13/2

Since the 1960's there has been intensive research leading to increased understanding of the processes controlling the ozone budget in both the troposphere and stratosphere. Anthropogenic emissions of NO(x) and hydrocarbons, which play at low level most of the time. However, the exhaust gases of aircraft are injected directly into higher altitudes and therefore immediately affect the chemistry at these altitude levels. In the present work the effects of subsonic aircraft emissions in the chemical composition of the troposphere are studied in this particular part of the atmosphere in more detail. This is done by using a channel model, which describes the meteorology and chemistry of the atmosphere between 30 degrees and 60 degrees north. A literature overview of the effects of aircraft emissions and a description of the channel model are presented. The construction of the emission inventory is described. The results of several model runs plus interpretation and discussion of the results are presented, and conclusions are summarized. GRA

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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.

A91-44730
A HIGHLY PARALLEL ALGORITHM FOR MULTISTAGE OPTIMIZATION PROBLEMS AND SHORTEST PATH PROBLEMS
JOHN K. ANTONIO (Purdue University, West Lafayette, IN), WEI K. TSAI (California, University, Irvine), and G. M. HUANG (Texas A & M University, College Station) Journal of Parallel and Distributed Computing (ISSN 0743-7315), vol. 12, July 1991, p. 213-222. Research supported by Texas Advanced Research Program. refs
(Contract NSF ECS-89-00499)
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The present method for recursive division of an original multistage optimization problem into a set of smaller problems which are solvable in parallel, using a tightly-coupled parallel computer, has its basis in the recursive application of a simple aggregation procedure. While this algorithm can achieve a time complexity of O(log n) for a multistage process with n stages, competing algorithms based entirely on dynamic programming are capable only of Theta(n) time complexity. It is demonstrated that the algorithm can serve as a fast and efficient means of decoding convolutional codes, as well as of solving shortest-path problems and determining minimum-fuel flight trajectories. O.C.

A91-45140#
DYNAMIC INTERPOLATION AND APPLICATION TO FLIGHT CONTROL
JOSEPH W. JACKSON (Honeywell, Inc., Glendale, AZ) and PETER E. CROUCH (Arizona State University, Tempe) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 14, July-Aug. 1991, p. 814-822. refs
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It may be advantageous to designate a set of intercept points that the trajectory is required to pass through, to simplify the specification of a desired trajectroy for some subset of the variables of a dynamic control system. To meet these requirements for dynamic interpolation in terms of a spline function, the system controls can then be computed. The method of splines has been applied to the control of linearizable dynamical systems such that an affine invariant cost functional (total energy) is minimized subject to discrete path constraints. Computer-aided geometric design methods have been applied to derive a reference trajectory for comparison with the dynamic results, and to determine intercept times for the discrete points that the dynamic trajectory is required to intersect. An acceptable trajectory has been generated by the application of these methods to a difficult aircraft approach problem. To modify the intercept times and so improve the dynamic trajectory in relation to the reference trajectory, arclength and cost iteration schemes were applied. Neither of these methods yielded significant improvement in the dynamic trajectory, demonstrating the difficulty in enhancing the basic dynamic interpolation result. V.I.

A91-45219* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE MAMS QUICK VIEW SYSTEM-2 (QVS2) - A WORKSTATION FOR NASA AIRCRAFT SCANNER DATA EVALUATION
GARY J. JEDLOVEC, MARK W. JAMES (NASA, Marshall Space Flight Center, Huntsville, AL), MATTHEW R. SMITH (Universities Space Research Association, Huntsville, AL), and ROBERT J. ATKINSON (General Electric Co., Huntsville, AL) IN: International Conference on Interactive Information and Processing Systems

for Meteorology, Hydrology, and Oceanography, New Orleans, LA, Jan. 14-18, 1991, Preprints. Boston, MA, American Meteorological Society, 1991, p. 198-203. refs
Copyright

This paper describes a ground-based data-evaluation workstation named Quick View System-2 (QVS2) developed to support postflight evaluation of data supplied by the Multispectral Atmospheric Mapping Sensor (MAMS), one of the four spectrometers that can be used with the Daedalus scanner flown on the ER-2 aircraft. The QVS2 provides advanced analysis capabilities and can be applied to other airborne scanners used throughout NASA for earth-system-science investigations, because of the commonality in the data stream and in the generalized data structure. I.S.

A91-45391#
A NEW APPROACH IN HELICOPTER REAL-TIME SIMULATION
G. LEHMANN, C.-H. OERTEL, and B. GELHAAR (DLR, Institut fuer Flugmechanik, Brunswick, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 18 p. refs

It is shown that the consistent mapping of real world processes into a corresponding hardware-software system based on TRANSPUTER and OCCAM provides a clear and easily extendable data processing structure with real-time capabilities. Programming of the processes is carried out in a high level language, such as Pascal or C, which incorporates the constructs for parallel programming. The present real-time simulator shows advantages in terms of performance, modular design, and expense. K.K.

A91-45417#
COMPUTERIZED TEST ANALYSIS SYSTEM
R. DAHAN and P. GAULENE (Aerospatiale, Division Helicopteres, Marignane, France) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 19 p.

A computerized test-analysis system SEE developed in 1985 in conjuction with a series of tests involving a Puma helicopter is described. The principles underlying the design and architecture of the system are discussed. The initial concept is reviewed along with conventional measurement acquisition and analysis procedures used in the early 1980s. The programming principles, organization, and functions of the system are covered. The use of the system for analyzing flight test data is considered as well as its implementation by a design group. The system is developed in FORTRAN on an IBM 3090 under VM, but is portable to workstations utilizing UNIX. It accepts data represented in a tabular form: time-dependent measurements, means, spectrum analysis, etc. and provides such tools as data management, graphs, statistical analysis, sorting, conversions, and multilinear regression. V.T.

A91-46452
A UNIFIED APPROXIMATE FEEDBACK SOLUTION OF COPLANAR VARIABLE-SPEED INTERCEPTION GAMES
CHANGYOU LIU and SIYING ZHANG (Northeast University of Technology, Shenyang, People's Republic of China) Chinese Journal of Aeronautics (ISSN 1000-9361), vol. 4, Feb. 1991, p. 11-19. refs
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The problem of coplanar variable-speed interception between a tactical missile and an aircraft is analyzed by using the differential games theory. A unified approximate guidance law in feedback form is obtained by using the technique of forced singular perturbation. An illustrative example with realistic aerodynamic and propulsion data shows that this suboptimal guidance control law is available for practical applications. Author

A91-46594#
THE ROLE OF INTELLIGENCE FOR AIRCRAFT
KOHTARO MATSUMOTO and AKIRA WATANABE Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 437, 1990, p. 276-283. In Japanese. refs

The concept of the intelligent cockpit is described, and the use of expert systems and artificial intelligence in aviation is discussed. The general context of the discussion is the implementation of fly-by-wire systems. A table listing the characteristics of various intelligent and expert systems in aviation is provided, including such systems as EPES, the Expert Navigator, FLES, HEAT, the Pilot's Associate, SARA, and CAS. B.J.

A91-46597#
THE DATA PROCESSING SYSTEM FOR AIR TRAFFIC CONTROL - ITS PRESENT AND FUTURE
MUNEAKI MIYAMURA and NORIYASU TOFUKUJI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 38, no. 437, 1990, p. 301-308. In Japanese. refs

A91-47177#
PARAMETER IDENTIFICATION MODELING FOR SIMULATION AERODYNAMIC MODEL UPDATES
SCOTT W. STEVENSON (McDonnell Aircraft Co., Saint Louis, MO) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 298-305. refs
(AIAA PAPER 91-2878) Copyright

A method of aerodynamic modeling that combines the simulator and parameter identification models is discussed. A-priori values for the parameter identification model are computed from the simulator model. A method of computing correction terms for the simulator model by subtracting the a-priori parameter identification model from the estimated parameter identification model is discussed. The method requires that the a-priori parameter identification model provide a good match to the simulator, or that any mismatch between the two models be accounted for in the estimation. A method of accounting for mismatches is given and illustrated in an example. Author

A91-47189#
PILOT MODEL STRUCTURE IDENTIFICATION USING PRINCIPAL COMPONENTS REGRESSION
MARK R. ANDERSON (Systems Control Technology, Inc., Lexington Park, MD) IN: AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 420-427. refs
(AIAA PAPER 91-2893) Copyright

Continuous time-domain pilot model structure determination is addressed in this paper using a principal components regression algorithm. The principal components algorithm is used so that prior knowledge of the pilot model parameters can be blended with the extracted parameters when insufficient signal excitation exists. Thus, the engineer can select the appropriate model structure for study instead of relying completely on the given data. The continuous time-domain pilot model form is studied because previously published data using the continuous model form can be used to form 'prior' models. The method is demonstrated using a simple tracking experiment with a known pilot model structure. Author

A91-47451
ROBUST OPTIMAL CONTROL [ROBASTNOE OPTIMAL'NOE UPRAVLENIE]
V. N. BUKOV and I. A. KNIAZEV (Voenno-Vozdushnaia Inzhenernaia Akademiia, Moscow, USSR) Avtomatika i Telemekhanika (ISSN 0005-2310), March 1991, p. 15-22. In Russian. refs
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The paper examines the synthesis of optimal controls possessing low or even zero sensitivity to certain parameters of the plant that are indeterminate at the design stage. Three methods for transforming the initial problem are described, which lead to different mathematical formulations. One of the methods is illustrated by an example, i.e, the synthesis of robust motion control for a flight vehicle. L.M.

A91-47454
FILTERING AND SMOOTHING IN INDETERMINATELY STOCHASTIC SYSTEMS WITH PARTIALLY OBSERVABLE INPUTS [FIL'TRATSIIA I SGLAZHIVANIE V NEOPREDELENNO-STOKHASTICHESKIKH SISTEMAKH S CHASTICHNO NABLIUDAEMYMI VKHODNYMI *VOZDEISTVIIAMI*]
A. V. BORISOV, A. R. PANKOV, and N. M. SOTSKII (Moskovskii Aviatsionnyi Institut, Moscow, USSR) Avtomatika i Telemekhanika (ISSN 0005-2310), March 1991, p. 85-95. In Russian. refs
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A method is proposed for the optimal recursive estimation of the phase vector of a discrete-time linear indeterminately stochastic system according to nonsynchronized measurements of phase coordinates and inputs. A procedure of double-pass smoothing over a fixed observation interval is examined. The statistical properties of the estimates obtained are investigated, and results of numerical experiments are presented. The results are of interest in connection with estimating the motion parameters of a flight vehicle. L.M.

A91-47759
DESIGN AND INTEGRATION OF AIRBORNE SYSTEMS - EXPERIENCE OF AVIONICS SYSTEMS DEVELOPMENT AT DASSAULT AVIATION, SAINT-CLOUD, FRANCE
J. SASS and J. L. JARRIGE (Dassault Aviation, Saint-Cloud, France) IN: The management of large software projects in the space industry; Colloquium, Toulouse, France, Oct. 16-18, 1990, Proceedings. Toulouse, France, Cepadues-Editions, 1991, p. 111-120.
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The methodology and tools implemented at Dassault Aviation for avionics systems development are described. An original systems development methodology has been defined; a dedicated systems engineering environment has been designed and built; and a software engineering environment has been evaluated. The methodology precisely defines the development stages, with related activities, products, and means. L.M.

A91-47810#
A COMPUTER GENERATED HELICOPTER FOR AIR TO AIR COMBAT
AMNON KATZ, BRETT E. BUTLER, and DANIEL E. M. ALLEN (McDonnell Douglas Helicopter Co., Mesa, AZ) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 82-86. refs
(AIAA PAPER 91-2923) Copyright

The prototype of a computer generated helicopter named Intelligent Player, to be used for air to air combat, has been implemented in real-time, running against a high fidelity manned helicopter simulator. Implementation issues are addressed along with aspects of the control logic (override logic). The logic engine driving this prototype is based on chess type lookahead adapted to the air combat application. The four board lookahead architecture described is very effective for prototyping and low volume production, where software development and integration make up the bulk of the cost. R.E.P.

A91-47812#
IMPROVING THE PERFORMANCE OF FLIGHT SIMULATORS VIA SMART I/O INTERFACE SYSTEMS
W. H. DEISS, E. J. FADDEN, and R. M. HOWE (Applied Dynamics International, Ann Arbor, MI) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 93-115. refs
(AIAA PAPER 91-2983) Copyright

This paper shows how the dynamic performance of flight simulators can be improved significantly through the use of multirate I/O as well as reordering of the computational code. The code reordering permits generation of simulation outputs before they occur in real time. This in turn permits interpolation/extrapolation to be used to generate multirate drive signals for DACs, including compensation for the half-frame delay normally associated with DAC outputs. Alternatively, the multirate outputs can be used to drive other digital devices or simulations operating with different frame rates or even asychronously. Multirate sampling and averaging of real-time inputs can also be used to improve simulation *fidelity and eliminate aliasing. The Applied Dynamics SIMsystem* is ideally suited to implement the concept of multirate I/O. Its key hardware and software characteristics are described, and examples illustrating the implementation are included. Author

A91-47840#
A COMPARISON OF SEVERAL NUMERICAL INTEGRATION ALGORITHMS EMPLOYED IN REAL TIME FLIGHT SIMULATION - ESPECIALLY INCLUDING THEIR IMPACT ON EFFECTIVE DELAY AND SIMULATION ACCURACY
FRANK M. CARDULLO (New York, State University, Buffalo), MARK KACZMAREK, and BRIAN J. WOYCECHOWSKY IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 378-385. refs
(AIAA PAPER 91-2979) Copyright

Results are reported from a performance comparison of five algorithms used for integration in real-time man-in-the-loop flight simulations, including the second-order Adams-Bashford algorithm, an advanced Euler algorithm, a sinusoidal predictor, a sinusoidal corrector, and a Howe-modified Euler algorithm. The simulation is a 6-DOF full force and moment nonlinear formulation which yields aircraft accelerations in body axes to be integrated twice; the cases of (1) a slightly damped second-order system and (2) a high-performance aircraft responding to a step elevator input are considered, and the results are presented in graphs. All of the algorithms are found to be adequate and to give similar results at low Delta t, with some advantages of lead and computational simplicity for the Euler methods. D.G.

A91-47843*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A METHOD FOR DETERMINING TRANSPORT DELAYS IN THE FLIGHT SIMULATION ENVIRONMENT
R. M. SMITH (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 404-411. refs
(AIAA PAPER 91-2964) Copyright

This paper will describe the process of transport delay measurement along several points in the signal path for a piloted flight simulation. Several transport delay measurement techniques were compared to determine the accuracy and ease of use of each method. Measurements were made in both the frequency and time domain. The transport delays for individual pieces of equipment as well as the math model of the simulated vehicle are measured and broken out from the system's total transport delay. Author

A91-47848*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HIGH PERFORMANCE COMPUTING SYSTEM FOR FLIGHT SIMULATION AT NASA LANGLEY
JEFF I. CLEVELAND, II, STEVEN J. SUDIK, and RANDALL D. GROVE (NASA, Langley Research Center, Hampton, VA) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 459-467. refs
(AIAA PAPER 91-2971) Copyright

The computer architecture and components used in the NASA Langley Advanced Real-Time Simulation System (ARTSS) are briefly described and illustrated with diagrams and graphs. Particular attention is given to the advanced Convex C220 processing units, the UNIX-based operating system, the software interface to the fiber-optic-linked Computer Automated Measurement and Control system, configuration-management and real-time supervisor software, ARTSS hardware modifications, and the current

implementation status. Simulation applications considered include the Transport Systems Research Vehicle, the Differential Maneuvering Simulator, the General Aviation Simulator, and the Visual Motion Simulator. D.G.

A91-47849#
A NEW RADAR SIMULATOR ARCHITECTURE
RODERIC DEYO, KENNETH C. GEORGE, and JOHN T. MASON (Evans and Sutherland Computer Corp., Salt Lake City, UT) IN: AIAA Flight Simulation Technologies Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1991, p. 468-477.
(AIAA PAPER 91-2972) Copyright

The design principles and implementation of ESRIG, a novel real-time multimode radar-image generation system for flight simulators, are discussed. ESRIG is based on an object-oriented software approach, analytic feature primitives, a scalable pipeline/parallel multiprocessor architecture, and a standard data bus. Particular attention is given to the similarities and differences between radar and visual data bases and the need for correlation between them in simulators. Block diagrams of the architecture and sample radar images are provided. D.G.

N91-27777# Naval Postgraduate School, Monterey, CA.
AN AERONAUTICAL ENGINEERING USER'S MANUAL TO THE HP-28S HANDHELD CALCULATOR M.S. Thesis
HARRY F. MOLYNEUX Mar. 1991 68 p
(AD-A236618) Avail: NTIS HC/MF A04 CSCL 12/6

Handheld calculators are now powerful enough to have become indispensible tools for the engineer and scientist. With enhanced equation solving capability and extensive user memory, the HP-28S introduces exciting new possibilities. The entire set of tables for one-dimensional gas dynamics can be accessed with unequalled accuracy and speed. But this enhanced power cannot be properly tapped without a pre-planned user directory organization which takes advantage of the HP-28S internal structure. Experience has shown that many students buy expensive programmable calculators but underuse them, finding their powerfulness baffling and frustrating. They employ the same computational techniques with sophisticated $200 continuous memory programmable machines as could be accomplished with a simple $20 scientific calculator. This manual contains a compendium of useful formulae, programming, and computational techniques for the popular HP-28S Pocket Calculator. In addition to helpful instructions on units conversion, directory organization, and problem solving methodology which will benefit any HP-28S user, the Aeronautical Engineering student will find sections on Thermodynamics, Aerodynamics, and Controls which will prove useful in those fields of study. GRA

N91-27786*# Computational Logic, Inc., Austin, TX.
REPORT ON THE FORMAL SPECIFICATION AND PARTIAL VERIFICATION OF THE VIPER MICROPROCESSOR Technical Report No. 46
BISHOP BROCK and WARREN A. HUNT, JR. Jul. 1991 32 p
(Contract ARPA ORDER 58-4155; NASA ORDER L-39627C)
(NASA-CR-187540; NAS 1.26:187540) Avail: NTIS HC/MF A03 CSCL 09/2

The formal specification and partial verification of the VIPER microprocessor is reviewed. The VIPER microprocessor was designed by RSRE, Malvern, England, for safety critical computing applications (e.g., aircraft, reactor control, medical instruments, armaments). The VIPER was carefully specified and partially verified in an attempt to provide a microprocessor with completely predictable operating characteristics. The specification of VIPER is divided into several levels of abstraction, from a gate-level description up to an instruction execution model. Although the consistency between certain levels was demonstrated with mechanically-assisted mathematical proof, the formal verification of VIPER was never completed. Author

N91-27802# Carnegie-Mellon Univ., Pittsburgh, PA. Software Engineering Inst.
GENERIC AVIONICS SOFTWARE SPECIFICATION Final Report
C. D. LOCKE, D. R. VOGEL, LEE LUCAS, and JOHN B. GOODENOUGH Dec. 1990 35 p
(Contract F19628-90-C-0003)
(AD-A235752; CMU/SEI-90-TR-8; ESD-TR-90-209) Avail: NTIS HC/MF A03 CSCL 12/5

This report informally specifies the general functions, data interactions, and timing constraints for a hypothetical avionics mission control computer (MCC) system typical of those found in some existing U.S. Navy and Marine Corps aircraft. Avionics functions and equipment are described only to the extent needed to specify generic MCC behavior. The specification was developed primarily to exemplify timing requirements and functional interactions in a heavily loaded real time system. The devices, functions, and architecture presented here were prepared for illustrative purposes and are not those of any specific military aircraft. In particular, the quantitative timing information and discussion of functional interactions is hypothetical. The specification consists of an introductory description of the environment in which the mission computer operates followed by a functional description of the requirements imposed on the mission computer. The functional description is minimal and serves mainly to characterize computer workload and data interactions. An appendix contains a summary of the timing requirements together with an analysis of the expected CPU load for a possible attack scenario. GRA

N91-27868*# SRI International Corp., Menlo Park, CA.
FORMAL SPECIFICATION AND VERIFICATION OF A FAULT-MASKING AND TRANSIENT-RECOVERY MODEL FOR DIGITAL FLIGHT-CONTROL SYSTEMS Final Report
JOHN RUSHBY Washington Jul. 1991 129 p
(Contract NAS1-18969)
(NASA-CR-4384; NAS 1.26:4384) Avail: NTIS HC/MF A07 CSCL 09/2

The formal specification and mechanically checked verification for a model of fault-masking and transient-recovery among the replicated computers of digital flight-control systems are presented. The verification establishes, subject to certain carefully stated assumptions, that faults among the component computers are masked so that commands sent to the actuators are the same as those that would be sent by a single computer that suffers no failures. Author

N91-27877*# Washington Univ., Seattle. Dept. of Mechanical Engineering.
PROGRESS IN MULTIRATE DIGITAL CONTROL SYSTEM DESIGN Final Report
MARTIN C. BERG and GREGORY S. MASON Jun. 1991 102 p
(Contract NAG1-1055)
(NASA-CR-187561; NAS 1.26:187561) Avail: NTIS HC/MF A06 CSCL 09/2

A new methodology for multirate sampled-data control design based on a new generalized control law structure, two new parameter-optimization-based control law synthesis methods, and a new singular-value-based robustness analysis method are described. The control law structure can represent multirate sampled-data control laws of arbitrary structure and dynamic order, with arbitrarily prescribed sampling rates for all sensors and update rates for all processor states and actuators. The two control law synthesis methods employ numerical optimization to determine values for the control law parameters. The robustness analysis method is based on the multivariable Nyquist criterion applied to the loop transfer function for the sampling period equal to the period of repetition of the system's complete sampling/update schedule. The complete methodology is demonstrated by application to the design of a combination yaw damper and modal suppression system for a commercial aircraft. Author

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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.

A91-45103*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPERSONIC RECTANGULAR JET IMPINGEMENT NOISE EXPERIMENTS
THOMAS D. NORUM (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1051-1057. Previously cited in issue 17, p. 2685, Accession no. A89-40476. refs
Copyright

A91-45104#
RECENT ADVANCES IN ACTIVE NOISE CONTROL
K. K. AHUJA (Georgia Institute of Technology, Atlanta) and J. C. STEVENS AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1058-1067. Previously cited in issue 02, p. 227, Accession no. A91-12440. refs
Copyright

A91-45106*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONTROL OF LAMINAR SEPARATION OVER AIRFOILS BY ACOUSTIC EXCITATION
K. B. M. Q. ZAMAN and D. J. MCKINZIE (NASA, Lewis Research Center, Cleveland, OH) AIAA Journal (ISSN 0001-1452), vol. 29, July 1991, p. 1075-1083. Previously cited in issue 09, p. 1284, Accession no. A89-25454. refs
Copyright

A91-45353#
INITIAL RESULTS OF A MODEL ROTOR HIGHER HARMONIC CONTROL (HHC) WIND TUNNEL EXPERIMENT ON BVI IMPULSIVE NOISE REDUCTION
W. R. SPLETTSTOESSER, G. LEHMANN, and B. VAN DER WALL (DLR, Brunswick, Federal Republic of Germany) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 15 p. refs

Initial acoustic results are presented from a higher harmonic control (HHC) wind tunnel pilot experiment on helicopter rotor blade-vortex interaction (BVI) impulsive noise reduction, making use of the DFVLR 40-percent-scaled BO-105 research rotor in the DNW 6m by 8m closed test section. Considerable noise reduction (of several decibels) has been measured for particular HHC control settings, however, at the cost of increased vibration levels and vice versa. The apparently adverse results for noise and vibration reduction by HHC are explained. At optimum pitch control settings for BVI noise reduction, rotor simulation results demonstrate that blade loading at the outer tip region is decreased, vortex strength and blade vortex miss-distance are increased, resulting altogether in reduced BVI noise generation. At optimum pitch control settings for vibration reduction adverse effects on blade loading, vortex strength and blade vortex miss-distance are found. Author

A91-45438
MECHANISMS OF ACTIVE NOISE CONTROL BY VIBRATION SOURCES
S. D. SNYDER and C. H. HANSEN (Adelaide, University, Australia) Journal of Sound and Vibration (ISSN 0022-460X), vol. 147, June 22, 1991, p. 519-525. refs
Copyright

It is shown how vibration control sources can be effectively used in systems designed to actively control structural radiation. Two physical mechanisms are employed: a reduction in structural modal amplitude and/or an alteration in the relative amplitudes and phases of the structured modes. It is noted that the importance of these two mechanisms is a function of various structural/acoustic system parameters. K.K.

A91-45439
FINITE ELEMENT ANALYSIS OF NATURAL FREQUENCIES OF ACOUSTIC ENCLOSURES WITH PERIODIC PROPERTIES
G. SENGUPTA (Boeing Commercial Airplanes, Seattle, WA) Journal of Sound and Vibration (ISSN 0022-460X), vol. 147, June 22, 1991, p. 528-532.
Copyright

A method for determining acoustic natural frequencies is presented. The method is based on finite-element modeling of the basic periodic unit and the imposition of certain periodic boundary conditions to capture the coupling of the acoustic behavior of one section with that of the next section. It is noted that, since the proposed approach accounts for the periodicity of the system, it is more cost-effective than the conventional FEM. K.K.

A91-46176#
STRUCTURE-BORNE NOISE TRANSMISSION INTO CYLINDRICAL ENCLOSURES OF FINITE EXTENT
DIMITRI A. BOFILIOS (Integrated Aerospace Sciences Corp., Athens, Greece) and CONSTANTINOS S. LYRINTZIS (San Diego State University, CA) AIAA Journal (ISSN 0001-1452), vol. 29, Aug. 1991, p. 1193-1201. Research supported by San Diego State University. Previously cited in issue 11, p. 1758, Accession no. A90-29402. refs
Copyright

A91-46287#
NOISE RATING OF FANS ON THE BASIS OF THE SPECIFIC SOUND POWER LEVEL
W. NEISE (DLR, Berlin, Federal Republic of Germany) IN: Australasian Fluid Mechanics Conference, 10th, Melbourne, Australia, Dec. 11-15, 1989, Proceedings. Vol. 1. Parkville, Australia, University of Melbourne, 1989, p. 1.41-1.44. refs

The aerodynamic noise output of fans of different designs are compared on the basis of the specific sound power level, i.e., the sound power level normalized in a certain way by the aerodynamic power of the fan. Using this concept, it is possible to compare different fan types over the whole range of their aerodynamic performance characteristics. Author

A91-47883
DYNAMICS OF PERIODIC STRUCTURES INTERACTING WITH AN ENCLOSED FLUID MEDIUM
H. JAMSHIDIAT and G. SENGUPTA (Boeing Commercial Airplanes, Seattle, WA) Journal of Sound and Vibration (ISSN 0022-460X), vol. 148, July 8, 1991, p. 103-115. refs
Copyright

A method is developed for predicting the natural modes of periodic structures coupled with an enclosed fluid medium. In this method, the structure and the fluid medium of the basic periodic unit are first modeled using the Finite Element Method (FEM). Periodic Structures (PS) theory is then applied to the dynamic matrices obtained from the finite element program, to account for the periodicity of the structure. By using the combined FEM-PS method, natural modes of the entire coupled structure-fluid system can be computed from the resulting matrix difference equation. It is shown that significant cost saving can be achieved, both in terms of computer time and memory, by using the proposed FEM-PS method. This method can be particularly effective early in design, for identifying design parameters that are important for reducing the structure-fluid response. Author

N91-27909*# Florida Atlantic Univ., Boca Raton. Dept. of Ocean Engineering.
EXPERIMENTAL MEASUREMENT OF STRUCTURAL POWER FLOW ON AN AIRCRAFT FUSELAGE Progress Report No. 6, Jan. - Jun. 1989
J. M. CUSCHIERI Jun. 1991 25 p

(Contract NAG1-685)
(NASA-CR-187560; NAS 1.26:187560) Avail: NTIS HC/MF A03 CSCL 20/1

An experimental technique is used to measure structural intensity through an aircraft fuselage with an excitation load applied near one of the wing attachment locations. The fuselage is a relatively large structure, requiring a large number of measurement locations to analyze the whole of the structure. For the measurement of structural intensity, multiple point measurements are necessary at every location of interest. A tradeoff is therefore required between the number of measurement transducers, the mounting of these transducers, and the accuracy of the measurements. Using four transducers mounted on a bakelite platform, structural intensity vectors are measured at locations distributed throughout the fuselage. To minimize the errors associated with using the four transducer technique, the measurement locations are selected to be away from bulkheads and stiffeners. Furthermore, to eliminate phase errors between the four transducer measurements, two sets of data are collected for each position, with the orientation of the platform with the four transducers rotated by 180 degrees and an average taken between the two sets of data. The results of these measurements together with a discussion of the suitability of the approach for measuring structural intensity on a real structure are presented. Author

N91-28817 Southampton Univ. (England).
A RECIPROCITY TECHNIQUE FOR THE CHARACTERISATION OF SOUND TRANSMISSION INTO AIRCRAFT FUSELAGES
Ph.D. Thesis
JAMES MEREDITH MASON 1990 163 p
Avail: Univ. Microfilms Order No. BRDX92098

Experimental determination of the sound insulation of propfan aircraft fuselage structures is problematic. The use of full scale flight tests to study and optimize sidewall design is expensive, while the use of simplified excitation tests is questionable, due to the complicated nature of propeller sound fields and their interaction with the fuselage. The development and evaluation is described of a new experimental reciprocity technique for calibrating a fuselage as a transmitter of pressure acting on the external surface to the interior: it is based upon the use of a transducer which measures the volume velocity of the vibrating fuselage surface. The data generated may be combined with any impinging sound field to obtain a prediction of cabin sound pressure level. Interior noise predictions are obtained for plane wave excitation and a representation of propeller sound field excitation. The important features relating to correct representation of the excitation field and the fuselage structure are isolated, within the scope of the models evaluated. Also, a statistical perturbation technique is described which shows confidence in the predictions.
Dissert. Abstr.

N91-28818 California Univ., Los Angeles.
QUADRUPOLE PHENOMENA OF NOISE FROM A SUBSONIC JET IMPINGING ON A LARGE, RIGID, AND FLATE PLATE
Ph.D. Thesis
JIANPING SHEN 1990 151 p
Avail: Univ. Microfilms Order No. DA9115281

The aerodynamic sound generated by a subsonic jet impinging on a large, rigid, and flat plate were studied. Cross correlation techniques were used to discriminate against unwanted noise. Correlation between the signals from the surface transducers on the plate and from the far field microphone were measured at different jet speeds, nozzle sizes, nozzle-to-plate distances and impinging angles. For each case, the microphone was placed at different locations around the jet, so that the directivity pattern was obtained. Those obtained by using correlation were compared with the patterns by using the microphone alone. The comparison showed that the correlation approach resulted in obviously quadrupole-like directivity patterns, while the overall microphone measurements revealed little information on directivity of the acoustic field. The correlation was also measured between hot-wire and far field microphone, and similar directivity patterns were obtained. Based on the experimental results, an exploratory physical model based on the coherent structure of turbulent flow was proposed to explain the mechanism of the quadrupole radiation caused by a turbulent source. Dissert. Abstr.

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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.

A91-44677#
ECONOMIC CONSIDERATIONS OF AIRCRAFT TURBINES MANUFACTURING
JACINTO J. ALONSO (General Electric CGR Espana, S.A.; Madrid, Universidad Politecnica, Spain) ASME, International Gas Turbine and Aeroengine Congress and Exposition, 35th, Brussels, Belgium, June 11-14, 1990. 4 p. refs
(ASME PAPER 90-GT-278)

Because lead times for design and development of new systems have greatly increased with growing aircraft engine complexities in recent years, computer-based cost-estimation, program planning/control, and production control, are essential features of state-of-the-art aircraft gas turbine engine manufacturing. Detailed consideration must be given to the learning-curve approach in labor time and production-cost estimation. It is generally accepted that cost-control systems based on computer-acquired work data are required; such services are often an integral part of CAD/CAM and computer-integrated manufacturing systems. O.C.

A91-45375#
HELICOPTER CONFIGURATION SELECTION - A PROCUREMENT POINT OF VIEW
P. A. GIULIANI (Ministero della Difesa, Rome, Italy) European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989, Paper. 15 p.

The present study addresses the balancing of cost effectiveness against available resources as the prime consideration in choosing the composition of a helicopter fleet and the configuration of its element. Costs are considered in relation to the present tendency to overdesign in terms of complexity, redundancy, and sophistication. It is suggested that appropriate operational, technical and economic evaluations be iterated from the outset in order to verify and assess a system's technical feasibility, the optical cost-effectiveness trade-off, the overall life-cycle-costs affordability of possible solutions, and flexibility. It is concluded that the optimal decision process leading to the selection of new advanced complex systems should be based on accurate quantitative analysis of all relevant aspects. If integrated with cost-analysis algorithims, system 'test-beds', scenario simulators, and the like could potentially constitute a first step toward a 'standard' evaluation and selection methodology. P.D.

A91-45448
TAXATION IN THE FIELD OF INTERNATIONAL AIR TRANSPORT - LEGAL ASPECTS
R. I. R. ABEYRATNE (Air Lanka, Ltd., Colombo, Sri Lanka) Air Law (ISSN 0165-2079), vol. 16, June 1991, p. 106-117. refs
Copyright

The taxation policies of ICAO in the field of civil international air transport are reviewed. Attention is given to ICAO's legal role, academic views and judicial decisions, and legal measures to be taken. Two fundamental postulates that result from these discussions are that taxation is principally used to pay for public services and that there are coherent guidelines as introduced by ICAO Resolutions of November 14, 1966 relating to the taxation of international air transport. Consideration is given to certain legal

aspects of IATA, the London Convention of 1939, and the Chicago Convention of 1944. R.E.P.

A91-45449
BERMUDA BIAS - SUBSTANTIAL OWNERSHIP AND EFFECTIVE CONTROL 45 YEARS ON
MARC L. J. DIERIKX (Catholic University, Nijmegen, Netherlands) Air Law (ISSN 0165-2079), vol. 16, June 1991, p. 118-124. refs
Copyright

This review serves to illustrate that restrictions on ownership and control, both on an international (bilateral) and on a national level, originated as protective instruments with the primary objective of safeguarding national security. When compared to the granting of air transport rights by sovereign governments, the joint questions of ownership and control seem to hold real possibilities of being separated from the public law framework they are now tied in with. It is suggested that, if present civil air transport is accepted to be an ordinary economic activity offering services to the general public, there appears to be little reason for keeping international air transport in a singular position of governmental patronage. R.E.P.

A91-45450
TWO RECENT GERMAN CASES OF PRIVATIZATION - AIR TRAFFIC CONTROL AND THE SPACE AGENCY
STEFAN A. KAISER Air Law (ISSN 0165-2079), vol. 16, June 1991, p. 125-132. refs
Copyright

A comparison is presented that illustrates two approaches to privatization and obstacles to it associated with the German space agency (DARA) and Germany's air traffic services. Consideration is given to the reasons for privatization, the legislative procedure, and the position of the German federal President. The establishment of DARA under private law and the Act on the Transfer of Administrative Competences in the Field of Space Activities are also considered. R.E.P.

A91-48346
LEGAL ISSUES INVOLVED IN THE TRANSMISSION TO AN AIRPORT OF RADAR DATA VIA THE FEDERAL MINISTRY OF AVIATION SAFETY [RECHTSFRAGEN BEI DER UEBERMITTLUNG VON RADAR-DATEN DURCH DIE BUNDESANSTALT FUER FLUGSICHERUNG AN EINEN FLUGHAFEN-BETREIBER]
ELMAR VITT Zeitschrift fuer Luft- und Weltraumrecht (ISSN 0340-8329), vol. 40, June 1991, p. 123-131. In German. refs
Copyright

FANOMOS (Flight and Noise Monitoring System) uses radar data to connect aircraft with airports and reduce the noise level in the airport environs. This paper addresses legal questions which arise when private airports desire to attach themselves to this system in order to acquire radar data. C.D.

N91-28047# Committee on Science, Space and Technology (U.S. House).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MULTIYEAR AUTHORIZATION ACT OF 1991
GEORGE E. BROWN, JR. Washington GPO 25 Apr. 1991 72 p Report to accompany H.R. 1988 presented by the Committee on Science, Space and Technology, 101st Congress, 1st Session, 25 Apr. 1991
(H-REPT-102-41; GPO-49-006) Avail: Document Room, House of Representatives, Washington, DC, 20515 HC free

This report, submitted by the House Committee on Science, Space, and Technology, reviews the bill (H.R. 1988) to authorize appropriations to NASA for fiscal years 1992, 1993, and 1994, and to the Department of Transportation Office of Commercial Space Transportation, the Department of Commerce Office of Space Commerce, and the National Space Council within the Executive Office of the President. The bill authorizes appropriations to NASA for research and development; space flight, control, and data communications; construction of facilities; research and program management; and for other purposes. The bill also sets forth special policy provisions and authorities in order to carry out the activities of the civil space program. The report reflects favorably upon the bill with an amendment and recommends the bill as amended to pass. Author

N91-28048# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION ACT, FISCAL YEAR 1992
ERNEST F. HOLLINGS Washington GPO Jul. 1991 49 p Presented by the Committee on Commerce, Science, and Transportation, 102d Congress, 1st Session, H. R. 1988, 2 Jul. 1991
(S-REPT-102-97; GPO-49-010) Avail: Committee on Commerce, Science, and Transportation, Senate, Washington, DC 20510 HC free

The purpose of this bill is to authorize appropiations to the National Aeronautics and Space Administration for research and development; space flight, control, and data communications; construction of facilities; research and program management; and the Inspector General. B.G.

N91-28049# Federal Aviation Administration, Washington, DC.
FEDERAL AVIATION REGULATIONS. PART 1: DEFINITIONS AND ABBREVIATIONS, CHANGE 14
4 Feb. 1991 23 p
(PB91-176644) Avail: NTIS HC/MF A03 CSCL 05/4

The final rule upgrades the airworthiness standards for normal, utility, acrobatic, and commuter category airplanes. The amendment provides airworthiness standards for advancements in technology being incorporated in current designs, permits type certification of spin resistant airplanes, and reduces the regulatory burden in showing compliance with some of the requirements for the design and type certification of small airplanes. These new and amended airworthiness standards also result in the need for new definitions. As a result, new definitions are added. These amendments are necessary to ensure that the regulations reflect current industry practices. GRA

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GENERAL

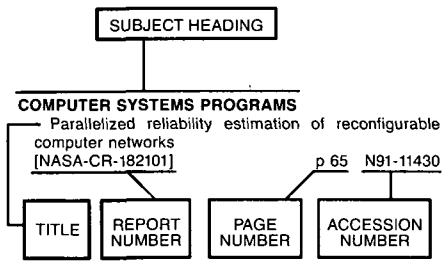
A91-45621#
EIGHTY YEARS OF AEROSPACE TECHNOLOGY THROUGH ATMA BULLETINS [80 ANS DE TECHNIQUE AEROSPATIALE A TRAVERS LES BULLETINS DE L'ATMA]
J.-P. MAREC (ONERA, Chatillon, France) ONERA, TP no. 1991-39, 1991, 123 p. In French. refs
(ONERA, TP NO. 1991-39)

The history of aerospace technology over the past 80 years is reviewed on the basis of the proceedings of ATMA (Association Technique Maritime et Aeronautique) sessions held during this period. The main topics discussed are aerodynamics and hydrodynamics, flight mechanics, structures and materials, equipment, navigation, different types of vehicles, engines, and aerospace programs. Some significant passages from the proceedings are cited, and the text is illustrated by figures taken from the papers given. Chronological and analytical indices of the proceedings are given. L.M.

A91-48031
DEMYSTIFYING THE HISTORY OF AERONAUTICS
JAMES R. HANSEN (Auburn University, AL) IN: A spacefaring nation - Perspectives on American space history and policy. Washington, DC, Smithsonian Institution Press, 1991, p. 153-166. refs
Copyright

The present study focuses on the infrastructural aspect of aeronautical engineering. It is contended that an aircraft's success depends on the designer's vision and talent less than on the extent to which those who write the requirements, plus those whose job it is to meet the requirements (the manufacturer who employs the designers) understand the state of the art. The need for greater attention to aerodynamic considerations in aircraft design is argued. P.D.

Typical Subject Index Listing



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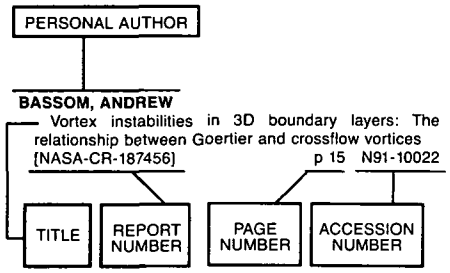

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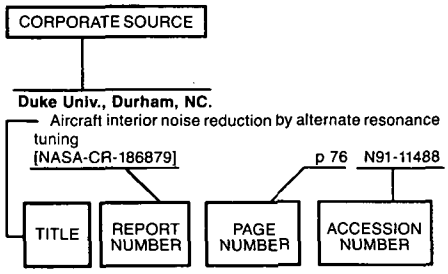

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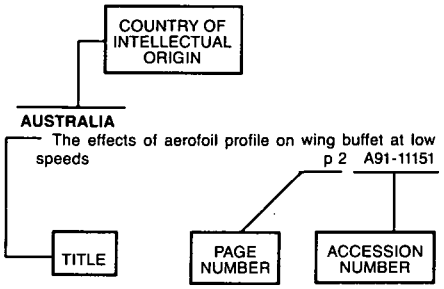

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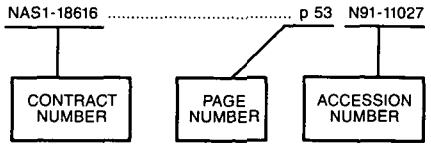

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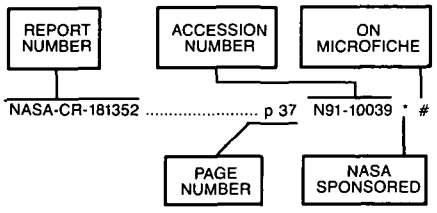

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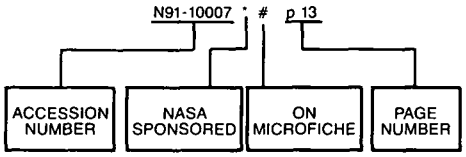

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