MASTER OF SCIENCE
IN
AERONAUTICAL ENGINEERING

INVESTIGATION OF THE PRESSURE AND TEMPERATURE SENSITIVITIES OF A PRESSURE SENSITIVE PAINT

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In the development of a surface pressure measurement system for transonic compressor rotors, it has been shown that Pressure Sensitive Paint (PSP) is also temperature dependent. In the present study, the sensitivities to pressure and temperature were examined experimentally using an electronically-gated, intensified Charged-Coupled-Device (CCD) video camera, frame-grabber software and an eight-inch diameter calibration chamber. Using a signal generator, in a procedure that matched the requirements of the rotor application, multiple low-intensity-level camera exposures were integrated and captured to produce a single usable image. Ten captured images were averaged to increase the image's signal-to-noise ratio and the result was used to produce an image ratio with respect to a static (ambient pressure/temperature) reference condition. Calibration tests of constant temperature/variable pressure and constant pressure/variable temperature were completed. The results were then compared with data obtained using the same paint and an automated, single-exposure calibration procedure at NASA Ames Research Center. It was shown that the calibration data could be used to derive the static pressure field produced over a high-speed test rotor using PSP and the same image-capture system used in the calibration. In preparation for a bench test of the procedure, a uniform-stress, high-speed test rotor disk, fitted with a shock generator was driven at speeds in excess of 30,000 RPM. Recommendations are made toward the goal of obtaining quantitative pressure measurements on transonic compressor rotors.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pressure Sensitive Paint, PSP, Charged Couple Device Camera, CCD, Photoluminescence, Imaging, Luminescence, PTOEP, UV Illumination, Detection, Emission, Aerodynamics, Measurements, Temperature and Pressure Calibration

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MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

AN ANALYSIS OF LIMITATIONS IN ACTIVE CANCELLATION OF RADAR SIGNALS

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Acoustic noise suppression has been achieved by rebroadcasting a phase-inverted copy of an incident signal, such that the two signals cancel. The same effect applies in theory to electromagnetic signals, allowing the cancellation of radar signals. This effect would supplement existing "stealth" technologies. The electromagnetic equivalence theorem provides for a straightforward theoretical analysis, and several numerical analyses demonstrate cancellation on simple wire models. The limitations of the cancellation are covered with respect to bandwidth, canceler spacing, and two canceler unit failure (error) modes. Sucessful cancellation is demonstrated for two canceler densities up to approximately 50 MHz, and a significant reduction in canceler effectiveness results when the two failure modes are tested.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Sensors

KEYWORDS: Radar, Electromagnetic Field Cancellation, Radar Cancellation, Scattering Analysis

A SECOND LAW APPROACH TO AIRCRAFT CONCEPTUAL DESIGN

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With advancements in the fields of propulsion, aerodynamics, structures, materials and controls, the routine exploration of hypersonic, atmospheric flight has become a more feasible concept. Thus, there is a need for efficient and effective hypersonic configurations. Current studies in configuration efficiency and effectiveness seem to be concentrated in aircraft subsystem design, especially propulsion systems, rather than at the conceptual aircraft system design level. This thesis attempts to initiate the process of incorporating the Second Law of Thermodynamics into the conceptual aircraft design process. The methodology for this process involves the use of the thermodynamic variable exergy, also known as availability. The ultimate goal of the process introduced by this thesis is to be able to define an aircraft configuration design space based upon both the First and Second Laws of Thermodynamics.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Conceptual Design, Configuration, Second Law of Thermodynamics, Exergy, Availability

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

A LABVIEW© BASED WIND TUNNEL DATA ACQUISITION PROGRAM

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The Naval Postgraduate School (NPS) Aerolab® Low Speed Wind Tunnel located in Halligan Hall of the Naval Postgraduate School has been in operation since 1953. Although the tunnel is well maintained, its data acquisition system has not kept pace with modern technology. An effective but affordable solution for acquiring data was needed. It was determined that a software package known as LabVIEW© provides a low cost, data acquisition solution that will enhance the capabilities of the wind tunnel, while at the same time making it more user friendly to faculty and students. The focus of this thesis is the design of a VI that will collect and plot force and moment data from a six-component strain gauge balance and yield real time, non-dimensional, force and moment coefficients in six degrees of freedom. Wind tunnel tests consisting of α sweeps in the NPS Aerolab® low-speed wind tunnel were conducted to verify $(L/D)I_{sp}$ optimized, M_∞ = 6, conical-flow waverider data obtained in 1994 using a different data acquisition system. Results of current testing substantiate the validity of the 1994 test data. Analysis of the current data set resolved pitching moment concerns related to the 1994 data.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles, Battlespace Environments, Computing and Software, Conventional Weapons, Human Systems Interface, Sensors, Modeling and Simulation

KEYWORDS: Strain Gauge Balance, LabVIEW©, VI, Data Acquisition, Wind Tunnel, Waverider, Lift, Drag, Aeromoments

ALUMINUM 7075-T6 FATIGUE DATA GENERATION AND PROBABILISTIC LIFE PREDICTION FORMULATION

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The life extension of aging fleet aircraft requires an assessment of the safe-life remaining after refurbishment. Risk can be estimated by conventional deterministic fatigue analysis coupled with a subjective factor of safety. Alternatively, risk can be quantitatively and objectively predicted by probabilistic analysis. In this investigation, a general probabilistic life formulation is specialized for constant amplitude, fully reversed fatigue loading utilizing conventional breakdown laws applied to the general probability damage function. Experimental data was collected both as a benchmark database, as well as an example of the implementation of probabilistic fatigue life prediction. Fully reversed, sinusoidal fatigue testing under load control was carried out at load levels giving high cycle fatigue lives from 1×10^4 to 5×10^6 cycles. The life range is longer than currently available in the literature, thereby increasing the confidence of predictions in the long-life domain, as well as the number of replications at each load level thereby extending the statistics. The load level data sets are interpreted by the probabilistic damage function for life location as well as life shape parameters using maximum likelihood analysis. Homologous life ranking and the minimum entropy hypothesis are investigated as well.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Processes, and Structures

KEYWORDS: Aluminum 7075-T6, Fatigue Life Prediction, Fatigue Database, Probability, Reliability, Damage Accumulation, Maximum Likelihood Analysis

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF COLD-FLOWTHROUGH THE TURBINE OF THE SPACE-SHUTTLE MAIN ENGINE HIGH-PRESSURE FUEL TURBOPUMP

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Computational predictions and experimental measurements were made on the Naval Postgraduate School's cold-flow turbine test rig. The test turbine was the Space-Shuttle Main Engine, high-pressure Fuel Turbopump, Alternate Development Model, designed and manufactured by Pratt & Whitney. The flow-field around the first-stage rotor end-wall region was measured using a laser-Doppler velocimetry (LDV) system. Measurements were taken at two axial locations over the rotor blade tip and at three radial locations from the end-wall casing. Three circumferential velocity profile measurements were taken downstream of the first-stage using a three-hole pressure probe. All measurements were taken at a referred rotational speed between 4781 and 4904 rpm. A computational fluid dynamics model of the combined first-stage stator and rotor was developed. Predicted velocity data from this model were extracted for comparison to the rotor exit plane probe measurements.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Computational Fluid Dynamics, Laser-Doppler Velocimetry, High-Pressure Fuel Turbopump Turbine, Space-Shuttle Main Engine

ANALYSIS AND AUTOMATION OF AN AIRCRAFT TAIL-SIZING DESIGN TOOL

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The numerical input/output behavior of a previously developed tail-sizing design tool for the High Speed Civil Transport (HSCT) aircraft is described and analyzed. HSCT, under development by NASA with industry partners, is an engineering design model of a future supersonic transport aircraft intended for the commercial passenger aviation market. Tail sizing, in the context of HSCT design, constitutes determining the maximum aft center-of-gravity that the aircraft can accept, given fixed limits on horizontal tail volume, maximum horizontal tail actuator deflection, and maximum actuator deflection rate, while remaining controllable in response to disturbances. Considerations regarding application of the tail-sizing design tool to the problem of FAR gust recovery for this longitudinally unstable aircraft, and limitations thereof are identified and discussed. An algorithm to automate the tool to produce specified outputs is developed and is implemented in MATLABä. The automated tool is then applied to the problem of recovery from a series of gust profiles. A set of tests is conducted to verify and validate the features of the tool. The tool is shown to be valid and accurate over a limited range of flight conditions and gust inputs. The limitations of the tool are identified and methods for extending its capabilities in the future, if necessary, are proposed.

Features of previously developed graphical user interface (GUI) and data analysis software are extended, and new GUI and analysis software is developed.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: High Speed Civil Transport (HSCT), Automatic Flight Control, Linear Matrix Inequalities (LMI)

IDENTIFICATION OF CRITICAL COMPONENTS AND COMBAT KILL MODES OF NOTIONAL JOINT STRIKE FIGHTER AIRCRAFT DESIGNS

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The U.S. Navy is a partner with the U.S. Air Force in the new Joint Strike (JSF) program. In the JSF program, two conventional fixed wing versions, one land-based and one carrier-based, and a Short Take-Off and Vertical Landing (STOVL) version are being developed. Of interest to the Navy is the difference in the vulnerability of the carrier-based version and the STOVL version. An aircraft's vulnerability is the inability of the aircraft to withstand the damage caused by hits by enemy weapons. The first step in a vulnerability study of an aircraft is the identification of the critical components on the aircraft and the ways these components can be killed. The critical components on an aircraft are those components whose kill either individually or jointly, result in an aircraft kill. This thesis examines a notional design of a typical fighter/attack CV aircraft and two notional designs of a STOVL aircraft and identifies the critical components and their kill modes for each design. Comparing the set of critical components for each of the three designs reveals the potential differences in the vulnerability of the designs.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Other (Aircraft Survivability)

KEYWORDS: Vulnerability, Survivability, Kill Modes, Vulnerability Reduction, Vulnerability Reduction Technology, Joint Strike Fighter