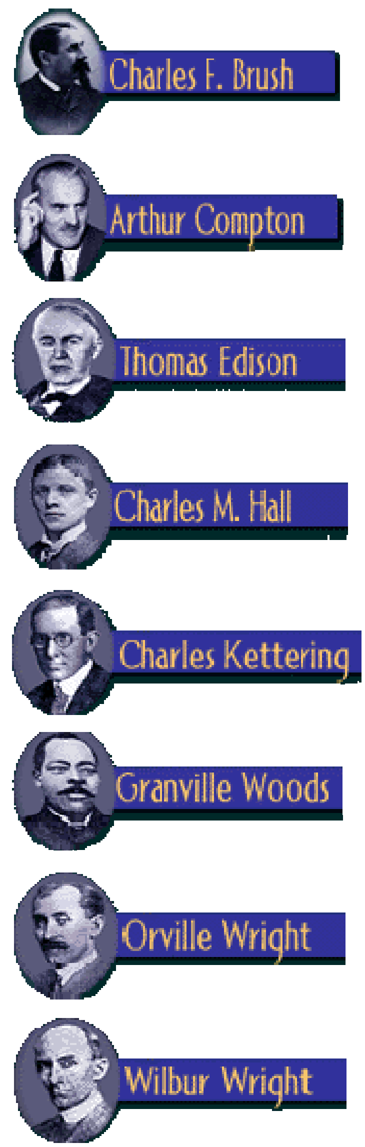
1st Dayton Engineering Sciences Symposium

October 31, 2005

WSU Student Union, Dayton, OH

ASME's 125TH ANNIVERSARY

Ohio Inventors



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OAI Ohio Aerospace Institute

WELCOME TO THE SYMPOSIUM

On behalf of the organizing committee, we welcome you to the 1st Dayton Engineering Sciences Symposium (DESS). This symposium is being held to celebrate Dayton region's strong tradition of engineering innovation, to help commemorate ASME's 125th anniversary in Dayton, to facilitate communication between members of the local technical community, and to provide a forum for sharpening technical presentation skills among students, engineers, and scientists. The event is organized and sponsored by the Executive Committee of the ASME Dayton Section, Wright State University, Ohio Aerospace Institute, and Innovative Scientific Solutions, Inc.

This year's symposium features 63 technical presentations, divided into 11 sessions covering broad areas of engineering pursued in the Dayton region. We are delighted to have Prof. John Heitmann, history professor at the University of Dayton, as our distinguished keynote speaker. We believe that his address on "19th Century Engineering in America and the Origins and Early History of the ASME" is an appropriate topic during this historical year of 125th anniversary of ASME.

We hope that this type of symposium will serve to encourage increased participation and cooperation within the Dayton region's professional and student communities. Its success would not have been possible without your participation, speakers, session chairs, the ASME Dayton Section Executive Board, symposium organizing committee, and corporate sponsors. We would like to express our deepest appreciation to all, especially to those listed below for their selfless dedication. Finally, we sincerely thank the AIAA Dayton-Cincinnati Section for allowing us to use its web-based tools and other timely needed resources.

We trust that you will benefit from participating in this historic symposium. Enjoy your day, and we hope to see you again next year.

Sivaram Gogineni and Ramana Grandhi
General Chair and Co-Chair

Organizing Committee

General Chair & Co-Chair	Dr. Sivaram P. Gogineni, Prof. Ramana Grandhi
Technical Program	Prof. George Doyle, Prof. Robert Chasnov
Communications	Ms. Alyson Turri, Dr. Terrence R. Meyer
Keynote	Dr. Roger Kimmel
Corporate Sponsorship	Dr. Sivaram P. Gogineni
Website	Dr. Richard Snyder, Mr. Stephen Balek
Venue	Prof. Nathan Klingbeil
Registrations	Mr. Vincent Miller, Dr. Jordi Estevadeordal
Publications	Dr. Terrence R. Meyer, Mr. Joseph Miller, Mr. Todd Benanzer

PROGRAM SCHEDULE

Morning: 9:00 – 11:00a.m.

Session I: Power & Propulsion	Room E156A	Chair: Ms. Cynthia Obringer
Session II: Design & Analysis	Room E156B	Chair: Prof. Robert Canfield
Session III: Fluid Dynamics I	Room E156C	Chair: Dr. Lance Chenault
Session IV: Materials Analysis	Room E163A	Chair: Prof. Robert Mott
Session V: Manufacturing	Room E163B	Chair: Dr. Ruth Sikorsky
Session VI: Turbomachinery	Room E157	Chair: Dr. Dave Car

Keynote Address and Lunch 11:15am. – 1:15p.m. Apollo Room

Afternoon: 1:30p.m. – 3:30p.m.

Session VII: Heat Transfer & Thermal Management	Room E156A	Chair: Dr. R. Ponnappan
Session VIII: Sensors & Instrumentation	Room E156B	Chair: Dr. James Gord
Session IX: Fluid Dynamics II	Room E156C	Chair: Dr. Datta Gaitonde
Session X: Materials Processing	Room E163A	Chair: Mr. Gerald Govin
Session XI: Human Factors	Room E163B	Chair: Dr. John Blanton

Session I: Power & Propulsion **Room E156A** **Chair: Ms. Cynthia Obringer**

1. 9:00 – 9:20 am
   Helfrich, Timothy, "Effects of Fuel Injection Temperatures on Selected Pulsed Detonation Engine Performance Parameters," Wright-Patterson AFB

2. 9:20 – 9:40 am
   Ogunjobi, Taiwo, "Computational Study of Optimal Configurations of Wall Magnets of an Ion Engine's Discharge Chamber," Wright State University

3. 9:40 – 10:00 am
   Hank, Joseph, "Operability and Performance Analysis of Two-Stage-to-Orbit Reusable Launch Vehicles using Airbreathing Propulsion for Military Applications," Wright-Patterson AFB

4. 10:00 – 10:20 am
   Brown, Michael, "Role of Soot in the Transient Grating Signal Observed in Liquid-Fueled Combustors,' Innovative Scientific Solution, Inc.

5. 10:20 – 10:40 am
   Lynch, Amy, "Laser Diagnostics for Particulate Mitigation Studies in Gas-Turbine Combustors,' Wright-Patterson AFB

6. 10:40 – 11:00 am
   Cory, Joshua, "Comparison of a Generic Engine Model with an Industrial Cycle Deck," University of Cincinnati

<u>Session II: Design & Analysis</u> **Room E156B** **Chair: <u>Prof. Robert Canfield</u>**

1. 9:00 – 9:20 am
   Eger, Carl, "University of Dayton – Engineers in Technical, Humanitarian Opportunities of Service-Learning Program," University of Dayton

2. 9:20 – 9:40 am
   Callaway, David, "Thermal-based Comparison between Rocket Boost-back and Jet Fly-back Booster Recovery Approaches," Wright-Patterson AFB

3. 9:40 – 10:00 am
   Strong, Richard, "Magic Dragon Aircar Project"

4. 10:00 – 10:20 am
   Kaloyanova, Valentina, "Stress Analysis of the Joint Region of Joined-Wing High Altitude Long-Endurance (HALE) Aircraft Using Submodeling Technique," University of Cincinnati

5. 10:20 – 10:40 am
   Mertz, George, "Conceptual Design of Net Zero Energy Campus Residence," University of Dayton

6. 10:40 – 11:00 am
   Benanzer, Todd, "An Optimization Approach for Future Combat Ground Vehicles," Wright State University

<u>Session III: Fluid Dynamics I</u> **Room E156C** **Chair: <u>Dr. Lance Chenault</u>**

1. 9:00 – 9:20 am
   Croker, Barry, "Overview of High-Speed Research in AFRL/VAAC," Wright- Patterson AFB

2. 9:20 – 9:40 am
   Zhang, Qian, "Computation of Oscillating Airfoil Unsteady Aerodynamics for Stalled and Unstalled Flow," University of Kentucky

3. 9:40 – 10:00 am
   Schmit, Ryan, "Control and Visualization of a Shear Layer over a Weapons Bay," Wright-Patterson AFB

4. 10:00 – 10:20 am
   Hong, YoungSun, "An Experimental Study on Lift Force Generation Resulting from Spanwise Flow in Flapping Wings," University of Dayton

5. 10:20 – 10:40 am
   Henderson, Sean, "Equilibrium Properties of High Temperature Air for a Range of Pressures," Wright State University

6. 10:40 – 11:00 am
   Miller, James, "Computational Aerothermodynamic Datasets for Heat Transfer on Reentry Vehicles,' Wright-Patterson AFB

Session IV: Materials Analysis **Room E163A** **Chair: Prof. Robert Mott**

1. 9:00 – 9:20 am
   Briggs, Joshua, "Thermo-Oxidative Degradation of Carbon Fibers and Carbon-Fiber Reinforced Composites," University of Dayton

2. 9:20 – 9:40 am
   Adduri, Phani, "System Reliability Bounds in the Presence of Uncertain Intervals," Wright State University

3. 9:40 – 10:00 am
   Paty, Spandana, "Damage Sensing in Carbon Fiber Reinforced Polymer Composites Using Electrical Resistivity Measurements," University of Dayton

4. 10:00 – 10:20 am
   Diggs, Darnell, "Molecular Binding and Enhanced Photoluminescence of Bromocresol Purple in Marine Derived DNA," Wright-Patterson AFB

5. 10:20 – 10:40 am
   Buryachenko, Valeriy, "Effective Elastic Properties of Nanocomposites with Random Orientation of Cylindrical Nanofibers," University of Dayton

6. 10:40 – 11:00 am
   Hilton, Harry, "Probabilistic Failures and Flutter in Panels Under Aerodynamic Noise Limited by Viscoelastic Functionally Graded Designer Materials," University of Illinois

Session V: Manufacturing **Room E163B** **Chair: Dr. Ruth Sikorsky**

1. 9:00 – 9:20 am
   Malik, Arif, "A New Rolling Mill Deflection Model Using Timoshenko Beam Finite Elements with Multiple Coupled Elastic Foundations," Wright State University

2. 9:20 – 9:40 am
   Ranatunga, Vipul, "The Application of UBET in Bulk Deformation Processes," Miami Univ.

3. 9:40 – 10:00 am
   Eger, Carl, "The University of Dayton Industrial Assessment Center Program," Univ. of Dayton

4. 10:00 – 10:20 am
   Repalle, Jalaja, "Hybrid Shape Sensitivity Analysis of Metal Forming Processes," Wright State University

5. 10:20 – 10:40 am
   Byrnes, John, "Pieces & Parts: A Simulation Investigation of Manufacturing Costs," Wright-Patterson AFB

6. 10:40 – 11:00 am
   Bontha, Srikanth, "The Effects of Laser Power Distribution and Melt Pool Behavior on Microstructure in Laser-Deposited Materials," Wright State University

Session VI: Turbomachinery **Room E157** **Chair: Dr. Dave Car**

1. 9:00 – 9:20 am
   Das, Kaushik, "Effect of Super-cooled Water Droplet Characteristics on Fan Rotor-Ice Accretion," University of Cincinnati

2. 9:20 – 9:40 am
   Perry, Jason, "Verification of a Fluid Structure Interaction Model for the Prediction of the Forced Response of a Stator Vane Due to Gust Loading," University of Kentucky

3. 9:40 – 10:00 am
   Manna, Rudranil, "Modeling of Surface Roughness on Rotating Turbomachinery Fan Component," University of Cincinnati

4. 10:00 – 10:20 am
   Whitlow, Darryl, "A Comparison of Turbulence/Transition Models for Solutions of a Turbomachine Cascade," University of Kentucky

5. 10:20 – 10:40 am
   Laing, Clinton, "A Comparison of Reduced Order Modeling Techniques for Mistuned Rotors," Wright-Patterson AFB

KEYNOTE PRESENTATION

"19th Century Engineering in America and the Origins and Early History of the ASME"
Prof. John Heitmann of University of Dayton

Time: 11:15AM - 12:15PM

LUNCH

Time: 12:15AM - 1:15PM

Session VII: Heat Transfer & Thermal Management **Room E156A**
Chair: Dr. Rengasamy Ponnappan

1. 1:30 – 1:50 pm
   McCarty, Robin, "Enhancing Thermoelectric Energy Recovery Via Modulations of Source Temperature for Cyclical Heat Loadings," University of Dayton

2. 1:50 – 2:10 pm
   Ashbrook, Kelli, "Electrochromics for Thermal Control of Spacecraft," Wright-Patterson AFB

3. 2:10 – 2:30 pm
   Mahalingam, Sudhakar, "Computational Model Tracking Primary Electrons, Secondary Electrons and Ions in the Discharge Chamber of an Ion Engine," Wright State University

4. 2:30 – 2:50 pm
   Shaikh, Shadab, "Effect of Multiple Phase Change Materials (PCMS) Slab Configurations," University of Dayton

5. 2:50 – 3:10 pm
   Prithivirajan, Muthumanikandan, "Topology Optimization of a Curved Thermal Protection System," Wright State University

Session VIII: Sensors & Instrumentation **Room E156B** **Chair: Dr. James Gord**

1. 1:30 – 1:50 pm
   Druffner, Carl, "Developing Optical Diagnostic Sensors for Monitoring Pulsed Laser Deposition of Long Lengths of YBA2CU307-X Wires," Air Force Institute of Technology

2. 1:50 – 2:10 pm
   McQuilling, Mark, "Pressure and Temperature Sensitive Paint – A Review and State of the Art," Wright State University

3. 2:10 – 2:30 pm
   Talbert, Michael, "Analyzing Area of Interest Coverage from Multi-Sensor UAV Swarms," Wright-Patterson AFB

4. 2:30 – 2:50 pm
   Gogineni, Sivaram, "Development of an A.C. Plasma Anemometer for Aerospace Applications," Innovative Scientific Solutions, Inc.

5. 2:50 – 3:10 pm
   Gord, James, "Picosecond Coherent Anti-Stokes Raman Scattering Thermometry in Fuel-Rich Hydrocarbon-Air Diffusion Flames," Wright-Patterson AFB

6. 3:10 – 3:30 pm
   Miller, Joseph, "Tunable Diode-Laser Absorption Spectroscopy for High-Speed Combustion Monitoring," Innovative Scientific Solutions, Inc.

<u>Session IX: Fluid Dynamics II</u> **Room E156C** **Chair: <u>Dr. Datta Gaitonde</u>**

1. 1:30 – 1:50 pm
   Thompson, Ernest, "Using Trailing Edge Deflection to Minimize Induced Drag: A Verification Study," University of Dayton

2. 1:50 – 2:10 pm
   Meyer, Terrence, "Advances in Dense-Spray Imaging Using Ultrafast Lasers," Innovative Scientific Solutions, Inc.

3. 2:10 – 2:30 pm
   Kimmel, Roger, "Application of Plasma Discharge Arrays to High-Speed Flow Control," Wright-Patterson AFB

4. 2:30 – 2:50 pm
   Basu, Debashis, "Numerical Investigations of Transonic Cavity Flow Control Using Steady and Pulsed Fluidic Injection," University of Cincinnati

5. 2:50 – 3:10 pm
   Jung, Tim, "High Speed Wind Tunnel Testing Relating to Aft Release of a Store," Air Force Institute of Technology

6. 3:10 – 3:30pm
   Leggiero, Stephen, "Simulation with Metamodeling to optimize Cessna A-37 Weapon Loading," Air Force Institute of Technology

<u>Session X: Materials Processing</u> **Room E163A** **Chair: <u>Mr. Gerald Govin</u>**

1. 1:30 – 1:50 pm
   Cherukuri, Balakrishna, "Severe Plastic Deformation of AA6061," Wright State University

2. 1:50 – 2:10 pm
   Hamilton, Carter, "Alloy Development and Friction Stir Welding," Miami University

3. 2:10 – 2:30 pm
   Bennett, Mats, "Rolling of AS-Cast Boron Modified TI-6AL-4V," Wright State University

4. 2:30 – 2:50 pm
   Daily, Jeremy, "Plastic Dissipation Energy from Cyclic Loading of Bimaterial Interface Cracks," Universal Technologies Corporation

5. 2:50 – 3:10 pm
   Gaddam, Deepika, "Three-Dimensional Modeling of Meltpool Geometry and Solidification Microstructure in Laser Deposited TI-6AL-4V," Wright State University

6. 3:10 – 3:30 pm
   Kuhlman, Sarah, "Navy Aircraft Arrestment Shank: A Material Selection and Cost Benefit Case Study," University of Dayton

Session XI: Human Factors **Room E163B** **Chair: Dr. John Blanton**

1. 1:30 – 1:50 pm
   Caldwell, Erin, "The Characterization of Spinal Compression in Various-Sized Human and Manikin Subjects during +GZ Impact," Wright-Patterson AFB

2. 1:50 – 2:10 pm
   Parakkat, Julia, "Quantitative Method for Determining Cushion Comfort," Wright-Patterson AFB

3. 2:10 – 2:30 pm
   Albery, William, "Human Factors Research in Multisensory Integration for the Cockpit," Wright-Patterson AFB

4. 2:30 – 2:50 pm
   McKinley, Richard, " Integrating the Effects of Acceleration on Human Cognition and Performance into Flight Simulation," Wright-Patterson AFB

5. 2:50 – 3:10 pm
   Albery, William, "Use of the Dynamic Environment Simulator for Human Factors Research," Wright-Patterson AFB

ABSTRACTS

Session I: Power & Propulsion — Room E156A

Chair: Ms. Cynthia Obringer

EFFECTS OF FUEL INJECTION TEMPERATURES ON SELECTED PULSED DETONATION ENGINE PERFORMANCE PARAMETERS

1LT Timothy M Helfrich†‡, Prof Paul I King, and Dr Frederick R Schauer

United States Air Force; Wright-Patterson AFB, OH

In recent research liquid fuel droplets were found to hinder the detonation process in a pulse detonation engine. Flash vaporization of liquid hydrocarbon fuels has successfully been demonstrated to decrease ignition times and increase fuel efficiency. The experiments performed for this effort were done using a counter-flow heat exchanger located on the thrust tube. Exact details of the heat exchanger design will be discussed. Recent research has also shown that as the fuel manifold temperatures reaches supercritical temperatures, the mass flow rate begins to decrease as the fuel density drops. This drop in mass flow rate reduces consistency of data due to variations in equivalence ratio. For this research a constant fuel flow system has been introduced to alleviate the inconsistencies. By increasing the fuel injection temperature to flash vaporization and supercritical temperatures the deflagration to detonation transition time, ignition time, and detonation distance are reduced. Due to the impact upon cycle time, these improvements in detonation initiation can enhance the performance of the pulse detonation engine. The effort included analysis of ignition time, DDT time, and detonation location as a function of fuel injection temperature for various fuels.

†Corresponding author ‡Presenting author

COMPUTATIONAL STUDY OF OPTIMAL CONFIGURATIONS OF WALL MAGNETS OF AN ION ENGINE'S DISCHARGE CHAMBER

Mr Taiwo A Ogunjobi‡ and Dr James Menart†

Wright State University; Dayton, Ohio

Ion propulsion is a form of rocket propulsion, which converts electrical energy to thrust via generation of a plasma, followed by an electrostatic acceleration of the generated ions through a pair of grids. The accelerated ions generated within the discharge chamber exits the chamber at high velocities to produce thrust. The efficiency of ion engines is related to the chambers ability to contain the primary electrons within the discharge chamber long enough to ionize neutral atoms. This ionization efficiency is improved by producing magnetic fields along the discharge chamber wall. The magnetic field stems the absorption of the primary electrons into the anode chamber wall, and thus improves its retention within the chamber. The shape of the 'constructed' magnetic field is a parameter that can be controlled by the magnetic circuit's configuration. The goal of the study behind this presentation is then to determine a generally applicable rule-of-thumb as to the optimal geometrical configuration of the permanent magnetic circuit for an axis-symmetrical discharge chamber. The first study of two permanent magnets rings situated on an axis-symmetrical cylinder chamber sidewalls requires a spacing of about 12 cm for optimum efficiency. A second configuration with one ring magnet on the sidewall and the other on the rear-wall of the chamber, approximately gives a 13 cm optimum spacing for optimum efficiency. While the optimum spacing does depend on the diameter of the discharge chamber, from the cases studied in this work, there is only a weak dependence. The results for different chamber diameters are generally identical.

†Corresponding author ‡Presenting author

OPERABILITY AND PERFORMANCE ANALYSIS OF TWO-STAGE-TO-ORBIT REUSABLE LAUNCH VEHICLES USING AIRBREATHING PROPULSION FOR MILITARY APPLICATIONS

Capt Joseph M Hank†‡ and Prof Milton E. Franke†
Air Force Institute of Technology; WPAFB, OH
Dr. Dean R. Eklund†
Air Force Research Laboratory; Wright-Patterson AFB, OH

The Department of Defense (DoD) has identified operationally responsive, low-cost access to space as vital to maintaining U.S. military supremacy. Reusable Launch Vehicles (RLVs) will allow the U.S. to keep the technological advantage over our adversaries, and many designs for RLVs have been proposed over the years. In addition, advances in airbreathing propulsion technology have made it feasible for use in space launch vehicles. Using airbreathing propulsion in RLVs has three distinct advantages: better launch, flight, and ground operability than rockets; lower sensitivity to weight growth than rockets; and the potential for large advancements in airbreathing technology when compared to the mature state of rocket technology. This study considers two-stage-to-orbit (TSTO) RLV configurations, each using combinations of propulsion including pure rocket, pure turbojet, rocket-based-combined-cycle (RBCC), and turbine-based-combined-cycle (TBCC) for the booster stage. Using vehicle empty weight as the primary figure of merit, preliminary results show that the all-rocket configuration has the lowest empty weight. The RLV using a TBCC booster with a rocket orbiter has a higher vehicle empty weight, but allows the RLV to gain the advantages of using airbreathing propulsion. The second part of this study will examine the operability aspects of using airbreathing propulsion. Rather than strictly look at vehicle empty weight, other possible advantages of airbreathing propulsion are explored, including multi-role mission capabilities, longer duration launch windows, more flexible launch locations and options, and increased safety due to abort options. This study will quantify the advantages of airbreathing propulsion in those key areas when compared to a baseline configuration. The requirements used for this comparison are: a payload requirement of 20,000 pounds; a 50x100 nautical mile low-earth-orbit (LEO); use of hydrocarbon fuels (RP-1 and/or JP-1); and use of liquid oxygen and/or air as oxidizers. ASTROX Corporation's Hypersonic System Integrated Design Environment (HySIDE) code is used as the design tool throughout the study. †Corresponding author ‡Presenting author

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ROLE OF SOOT IN THE TRANSIENT GRATING SIGNAL OBSERVED IN LIQUID-FUELED COMBUSTORS

Dr Michael S Brown†‡ and Dr Terrence R Meyer,
Innovative Scientific Solutions, Inc.; Dayton, OH
Mr Dale T Shouse and Dr James R Gord
Air Force Research Laboratory, Propulsion Directorate; Wright-Patterson AFB, OH

Transient-grating thermometry has been performed in the rich flame zone of a turbulent, pressurized, JP-8-fueled combustor. Measurements were executed at 100 psi under local equivalence ratios of ~1.1. The pump beams were derived from the 565-nm output of a Nd:YAG-pumped dye laser. The cw output of a vanadate laser (532 nm) provided the probe beam. A series of 1300 single-shot measurements was analyzed in the frequency domain using expressions from the literature for the power spectrum. The resulting single-shot histogram of derived temperatures exhibits a distribution with a peak near 1950 K and an average of 2260 K. Typical of turbulent flame environments, the histogram is quite broad with a half-width of ~1100 K. While the pump lasers were not tuned to a particular molecular resonance, the detected signals clearly showed signs of thermalization and the absence of nonresonant electrostriction. Soot is the most likely candidate for signal generation. The pump laser beams superheat the soot particles in the bright grating planes leading to rapid sublimation. Diffusion of the soot fragments from the bright to the dark fringes in the grating lead to

broadening of the half-width of the Brillouin feature in the power spectra. For transient-grating signals with extracted temperatures near the peak of the histogram, the half-widths range from 40-75 MHz. This is consistent with soot loading in the range of 4-8 10-7 g/cm3. Such soot densities are typically found in rich laminar laboratory flames. The observed soot loading is also consistent with the minimum pump-beam-absorption requirement for transient-grating signal generation based on previous laboratory work. †Corresponding author ‡Presenting author

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LASER DIAGNOSTICS FOR PARTICULATE MITIGATION STUDIES IN GAS-TURBINE COMBUSTORS

Ms Amy C Lynch‡, Dr James R Gord, Dr Vincent M Belovich, and Mr Edwin Corporan
Air Force Research Laboratory, Propulsion Directorate; Wright-Patterson AFB, OH
Dr Terrence R Meyer† and Dr Sukesh Roy
Innovative Scientific Solutions, Inc.; Dayton, OH
Dr Matthew J DeWitt
University of Dayton Research Institute; Dayton, OH

A study to characterize the production of particulate-matter (PM) emissions is performed in a liquid-fueled model gas-turbine combustor while varying fuel type and operating conditions. Laser-induced incandescence (LII), OH planar laser-induced fluorescence (PLIF), and laser Mie scattering are used to track soot volume fraction, measure local equivalence ratio, and visualize droplet scattering in the reaction zone, respectively. Studies are performed for fuel aromatic content that varies from 0-45% by volume as well as for paraffinic fuels low in aromatic and heteroatomic content. Consistent with results of previous studies, fuels containing aromatics, which have been shown to promote PM production, produce higher quantities of soot than straight-chain hydrocarbons. Laser-based measurements show a significant correlation among physical flame structure, fuel type, and particle number density. †Corresponding author ‡Presenting author

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COMPARISON OF A GENERIC ENGINE MODEL WITH AN INDUSTRIAL CYCLE DECK

Mr. Joshua Cory†‡
Air Force Research Laboratory, WPAFB, OH

Today, development of gas turbine engine systems and controls is a costly and lengthy process requiring collaboration among industry, government and academic parties. By using a dynamic generic turbine engine model that can be modified to specific engines to study, this cost can be reduced. A Matlab/Simulink model has been developed, that can represent the dynamic and transient behavior of a generic turbine engine. It has been modified to represent an existing commercial engine. The accuracy of the modified generic turbine engine model as compared to the steady state cycle deck of the existing commercial engine is discussed and results are presented. †Corresponding author ‡Presenting author

UNIVERSITY OF DAYTON - ENGINEERS IN TECHNICAL, HUMANITARIAN OPPORTUNITIES OF SERVICE-LEARNING PROGRAM

Mr Carl W Eger, III†‡ and Dr Margaret F Pinnell
University of Dayton; Dayton, Ohio

The Engineers in Technical, Humanitarian Opportunities of Service-learning (ETHOS) program at the University of Dayton (Dayton, Ohio) is founded on the belief that engineers are more apt and capable to serve our world when they have experienced opportunities that increase their understanding of technology's global linkage with values, culture, society, politics and economy. ETHOS seeks to provide these opportunities by means of curriculum integrated service-learning programming. Opportunities include classroom projects, student organization activities, collaborative research and international technical-immersion volunteer internships which support the facilitation of appropriate and sustainable technologies for the developing world, locally and globally. Such educational activities facilitate holistic learning, ethical engineering practices, perspectives of technology integration and appropriate technology transfer. Over the course of four years, thirty-nine engineering students have participated in semester long service-learning internships, working with development organizations and communities throughout Central, South America and Africa. Students live in the community which they volunteer and together, with the community, work to appropriately and creatively solve technical challenges. Such experiences expose students to alternative, non-traditional technologies that are based on fundamental science and engineering principles, thus allowing higher comprehension of curriculum material in a hands-on, practical and humanitarian manner. This presentation will discuss the ETHOS program's education pedagogy in relation to facilitation of student learning and provision of unique learning opportunities. Furthermore, various technical challenges, encountered by students living and working with development organizations in global communities, will be discussed to illustrate the various fundamental, yet complex problems students apply engineering knowledge and expertise.
†Corresponding author ‡Presenting author

THERMAL-BASED COMPARISON BETWEEN ROCKET BOOST-BACK AND JET FLY-BACK BOOSTER RECOVERY APPROACHES

Capt David W Callaway†‡, Mr Gregory E Moster, and Mr Amarshi A Bhungalia
USAF; Wright-Patterson AFB, OH

The Air Force Research Laboratory has been exploring approaches that may be considered for a quick turn-time booster research demonstrator for possible utilization on a full scale such as the Affordable Responsive Space (ARES) system. Part of this effort includes the evaluation and comparison of a wide variety of operating approaches that may yield significant variations in aerodynamic heating, material selection, design-space expansion, and maintenance approaches. One approach that has been under investigation by AFRL since 2001 is Rocket Boost-Back. This approach replaces the fly-back hardware (Thermal Protection System (TPS) and the jet engines) used to fly back to the launch site area (common in the most widely publicized systems) with additional rocket fuel and uses rocket motors to "boost" the system back within gliding range of the launch site. Eliminating the need for TPS opens up the design space and may allow a larger variety of wing and tail configurations than the limited Space Shuttle looking concepts. This paper will compare the relative size, weight, and thermal implications of the rocket boost-back and jet engine fly-back (AFRL baseline system) concepts at a high level in order to identify where additional effort may be desired. †Corresponding author ‡Presenting author

MAGIC DRAGON AIRCAR PROJECT

Mr. Richard Strong

The ‘Magic Dragon' Aircar Development Project Designing and building the 'Magic Dragon' aircar mock-up is a personal "labor of love" work in progress; the design was begun several decades ago. The design has been through the preliminary design process and scale model wind-tunnel testing and is now considered to be mature enough to proceed with prototype development. The high cost and inconvenience of flying their own airplanes discourages potential airplane owners and pilots who would prefer to use an attractive, reasonable, and practical aircar. The design is aimed mainly at a market of frequent regional business travelers; the cost avoidance in terms of personal time is expected to virtually pay for the Dragon expenses. The unique feature of the Magic Dragon is that it is a fully integrated automobile and airplane, so that conversion may be done with a push of a button, like magic. The design features: a. an automobile-style lifting body-fuselage with automotive chassis and road subsystem; b. a front-mounted ducted fan propulsor with exhaust throttles operated in the flight mode; c. a transaxle road drive; d. folding swing-wings stowed in the body-fuselage; and e. an automobile-style rear end and bumper that flip to form a streamlined tail. The production model is expected carry two persons and baggage on a 400-mile trip at about 160 miles per hour. Development and production of the "Magic Dragon" aircar is considered to be a viable enterprise that would satisfy a niche market and provide a profitable venture for an extensive period of time. The full-size mock-up was recently exhibited at AirVenture in Oshkosh and was well received by the thousands of visitors who viewed it. A full description is at www.strongware.com/dragon.
†Corresponding author ‡Presenting author

STRESS ANALYSIS OF JOINT REGION OF JOINED-WING HIGH-ALTITUDE LONG-ENDURANCE (HALE) AIRCRAFT USING SUBMODELING TECHNIQUE

Valentina B. Kaloyanova†‡, Dr Karman N. Ghia, and Dr Urmila Ghia

University of Cincinnati; Cincinnati, OH

A high-altitude long-endurance mission requires a light vehicle flying at low speed in the stratosphere at altitudes of 60,000-80,000 ft, with a continuous loiter time of up to several days. To provide high lift and low drag at these high altitudes, where the air density is low, the wing area should be increased, i.e., high-aspect-ratio wings are necessary. To reduce the structural deformation, and increase the total lift in a long-spanned wing, a sensorcraft model with a joined-wing configuration, proposed by AFRL, is employed. In the joined-wing design, the main wing is swept backwards, and the aft wing/tail is swept forwards to join the main wing at 70% of its span. Also, the main and aft wings are not in the same plane, to increase the stiffness and aerodynamic efficiency. However, the region of the joint has a very complicated geometry that has adverse effects in the flow and stress behavior. Nonlinear static analysis is performed using a detailed finite-element model of the joined wing. The von Mises stress in the joint region is found to increase towards the aft wing. To obtain more accurate results for the stress distribution in the joint, the submodeling finite-element technique is utilized. An independent, more finely meshed model (submodel) of the joint region is generated and analyzed. The cut-boundary displacement method is used to connect the joined-wing coarse model to the submodel of the joint. The maximum von Mises stress in the joint region obtained via the submodeling technique is 6% higher than that obtained with the coarse model. Also, a detailed discussion of the stress distribution obtained in the joint region via the submodeling technique will be included in the presentation. †Corresponding author ‡Presenting author

CONCEPTUAL DESIGN OF NET ZERO ENERGY CAMPUS RESIDENCE

Mr George Mertz‡, Mr Gregory Raffio†, Dr Kelly Kissock, Phd PE, and Dr Kevin Hallinan, Phd
University of Dayton; Dayton, OH

In response to both global and local challenges, the University of Dayton is committed to building a net-zero energy student residence, called the Eco-house. A unique aspect of the Eco-house is the degree of student involvement; in accordance with UD's mission, interdisciplinary student teams from mechanical engineering, civil engineering and the humanities are leading the design effort. This paper discusses the conceptual design of a net-zero energy use campus residence, and the analysis completed thus far. Energy use of current student houses is analyzed to provide a baseline and to identify energy saving opportunities. The use of the whole-system inside-out approach to guide the overall design is described. Using the inside-out method as a guide, the energy impacts of occupant behavior, appliances and lights, building envelope, energy distribution systems and primary energy conversion equipment are discussed. The design of solar thermal and solar photovoltaic systems to meet the hot water and electricity requirements of the house is described. Eco-house energy use is simulated and compared to the energy use of the existing houses. The analysis shows the total source energy requirements of the Eco-house could be reduced by about 340 mmBtu per year over older baseline houses, resulting in CO_2 emission reductions of about 54,000 lb per year and utility cost savings of about $3,000 per year. Detailed cost analysis and cost optimization have not been performed but are critical aspects of the UD Eco-house project, which will be performed in the future. †Corresponding author ‡Presenting author

AN OPTIMIZATION APPROACH FOR FUTURE COMBAT GROUND VEHICLES

Mr Todd W Benanzer‡ and Dr Ramana V Grandhi†
Wright State University; Dayton, OH

The United State Army has set the year of 2012 as the goal for the entire force to be converted to what they call Future Combat Systems. These systems are to be comprised of both manned and unmanned units that strategically work together on the battle field efficiently and effectively. The end goal creates a highly dispatchable, intelligent and lethal tactical unit. The vehicles involved in each of these systems are lightweight and highly maneuverable vehicles. The design demands of these vehicles include conflicting issues of weight, protection, and maneuverability. The aim of this research is to suggest a method for modeling each of these system parameters into an optimization algorithm. The method will incorporate system approximation due to the heavy computer demands of simulation of several design constraints as well as careful physical assumptions that will guide the algorithm to a designable and operational result. †Corresponding author ‡Presenting author

Session III: Fluid Dynamics I — Room E156C

Chair: Dr. Lance Chenault

OVERVIEW OF HIGH-SPEED RESEARCH IN AFRL/VAAC

Capt Barry A Croker†‡ and Dr Datta Gaitonde

AFRL/VAAC; WPAFB, OH

This presentation will provide an overview of the current high-speed research being done by Computational Sciences Center of Excellence at Wright-Patterson AFB (AFRL/VAAC), to include: - Plasma-Fluid Interactions - Shock/Turbulent Boundary Layer Interactions - High-Temperature Phenomena - DC Glow Discharge Modeling - High-Speed Transition †Corresponding author ‡Presenting author

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COMPUTATION OF OSCILLATING AIRFOIL UNSTEADY AERODYNAMICS FOR STALLED AND UNSTALLED FLOW

Qian Zhang‡

University of Kentucky; Lexington, KY

Dr Vincent R. Capece†

University of Kentucky; Paducah, KY

The design of fans and compressors for aircraft gas turbine engines is challenging due to part speed stall flutter. The high incidence angles and high subsonic or transonic Mach numbers at these operating conditions make viscous effects important. In this paper a two dimensional compressible viscous flow solver is used to compute the flow in the NASA Transonic Flutter Cascade, which has been used to simulate the operating conditions at part speed where stall flutter occurs. To model the influence of flow transition on the steady and unsteady aerodynamic flow characteristics, the Solomon, Walker, and Gostelow (SWG) transition model has been implemented in the flow solver. Predictions from the computational model using the Spalart-Allmaras and Baldwin-Lomax turbulence models along with the SWG transition model are correlated with the experimental data. The operating conditions considered are an inlet Mach number of 0.5 and chordal incidence angles of 0 and 10 deg. at a Reynolds number of 0.9 Million. For the oscillating airfoil cases a reduced frequency of 0.4 is considered with the airfoils oscillating in a pitching motion around mid-chord. †Corresponding author ‡Presenting author

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CONTROL AND VISUALIZATION OF A SHEAR LAYER OVER A WEAPONS BAY

Dr Ryan F Schmit†‡

AFRL/VAAI; Wright-Patterson AFB, OH

Prof Ganesh Raman

Illinois Institute of Technology; Chigaco, IL

Prof Luis Lourenco

Florida State University; Tallahasse, FL

Dr Valdis Kibens

The Boeing Company; St. Louis, MO

In July 2005, the AFRL program Flow Control Analysis Development (FlowCAD) tested the High Frequency Excitation Active Flow Control for Supersonic Weapons Release (HIFEX) generic weapons bay model in the Boeing's Polysonic windtunnel facility. The 10% scaled weapons bay with an L/D of 5 was tested at Mach 1.82. Several flow control devices were tested, including: the goalpost, a wedge and pin configuration, and the splash jet, to determine their effectiveness at reducing the sound pressure levels inside the weapons bay. The results show the wedge and splash jet are equally effective at reducing the peak Rossiter tone by 20 dB. The main objective of this test was to visualize the shear layer over the weapons bay cavity. By examining the cavity shear layer with a 10 kHz Focused Schlieren system the effects from the flow control devices can be understood to produce a more effective flow control device in the future. †Corresponding author ‡Presenting author

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AN EXPERIMENTAL STUDY ON LIFT FORCE GENERATION RESULTING FROM SPANWISE FLOW IN FLAPPING WINGS

Mr YoungSun Hong†‡ and Dr Aaron Altman

University of Dayton; Dayton, OH

It is difficult to explain how insects and most birds fly using existing aerodynamic theory. Therefore, previous research has attempted to show that insects use specific mechanisms or tricks to get more lift such as clap and fling, delayed stall, rotational circulation, wake capture, etc. However, it is proposed that the flowfield resulting from the flapping motion is dominated by flow in the spanwise direction due to several complementary forces. Even though the flowfield resulting from the flapping motion is believed to be dominated by flow in the spanwise direction, no one has tried to explain how spanwise flow directly affects the generation of lift force in insect and bird wings. In the case of a fixed wing, spanwise flow is a by-product of a pressure imbalance resulting from the existence of high pressure on the lower surface and low pressure on the upper surface. Most research has tried to explain aspects of aerodynamic force using the wingtip vortex as a by-product of spanwise flow at near the tip, not just spanwise flow effects, because lift induced drag is strongly influenced by the wingtip vortex. Previous research has also neglected to directly address the lift force generated by the wingtip vortex resulting from the flapping motion. However, even if flat plate wings are flapped with zero angle of attack and no relative wind, they have been shown to generate positive and negative lift forces due only to the flapping motion. Therefore, as chordwise effects have so commonly been used to investigate the lift distribution across an airfoil, spanwise flow due to rotational fluid dynamic mechanisms can be used to validate some component of the lift force from the flapping motion. In addition, the wingtip vortex will also be investigated to determine how to augment the lift force throughout flapping motion. These spanwise flow effects are being investigated using a combination of the DPIV (Digital Particle image Velocimetry) technique and a mechanical flapping mechanism. Total lift force was measured using a force transducer. The DPIV results were used to determine the aerodynamic forces due to spanwise flow and wingtip vortices in flapping wings, and to show the presence of strong, stable spanwise vortices and the effect of vortices to generate the lift forces. †Corresponding author ‡Presenting author

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EQUILIBRIUM PROPERTIES OF HIGH TEMPERATURE AIR FOR A RANGE OF PRESSURES

Sean J Henderson‡ and Dr James A. Menart†

Wright State University; Dayton, Ohio

This paper will present a number of thermodynamic properties for air in chemical equilibrium at high temperatures. Specifically the temperature range of interest will be from 300 to 30,000 K. The pressure range covered will be from 10 Pa to 101,325 Pa. The emphasis will be on the lower pressure range. The first properties presented in this paper will be the equilibrium composition presented in terms of the particle number densities and mole fractions. The thermodynamic properties determined will be the constant pressure specific heat, specific internal energy, specific enthalpy, and specific entropy, compressibility factor, and the speed of sound. To verify the results this work is compared to the chemical equilibrium results published in the literature.
†Corresponding author ‡Presenting author

COMPUTATIONAL AEROTHERMODYNAMIC DATASETS FOR HEAT TRANSFER ON REENTRY VEHICLES

James H Miller, Ph.D.†‡
Air Vehicles Directorate, AFRL; Wright-Patterson AFB, Ohio

In the present work, a collection of experimental and computational results is presented for computational heat transfer validation and code-to-code comparisons. Numerous experimental data sets that also include companion computational fluid dynamics (CFD) results are described. Additional verification solution sets are also included. The present collection of datasets includes nonablating flowfields within the Earth's atmosphere and with freestream Mach numbers equal to 6 and greater. Results from experimental ground tests are interpreted with flight data on a consistent basis. The datasets provide a high fidelity validation and verification collection for hypersonic heat transfer in reentry flows. The present work does not intend to be an exhaustive review of all experiments and computations performed for the flow regime of interest. Rather, the sets of experimental data (ground test and flight test) included in the present work have been grouped with at least one set of computational solutions that compare reasonably well with the data in the literature. By making this a constraint for the experimental data, many valuable datasets are not included. However as a result, the CFD community is more likely to have high confidence in the present datasets and not question the interpretation of the experimental data. In addition to the experimental and computational groups of datasets, other purely computational datasets are included to fill in validation gaps via code-to-code comparisons where flight test or ground test data do not exist. †Corresponding author ‡Presenting author

<u>Session IV: Materials Analysis</u> Room E163A

Chair: Prof. Robert Mott

THERMO-OXIDATIVE DEGRADATION OF CARBON FIBERS AND CARBON-FIBER REINFORCED COMPOSITES

Mr Joshua F. Briggs†‡ and Dr Gyaneshwar P. Tandon
University of Dayton Research Institute; Dayton, Ohio
Dr Gregory A. Schoeppner
Air Force Research Laboratory; WPAFB, OH

An understanding of the effects of thermo-oxidation in high temperature polymer matrix composites for structural components subjected to arbitrary service environment is critical to life performance predictions. Oxidative aging studies were conducted on carbon fibers and carbon-fiber reinforced composite specimens to characterize the physical and mechanical changes that occur in the material during the aging process. The extent of degradation of graphite fibers was determined through single-fiber mechanical testing and weight loss measurements. Fiber surface morphology changes were examined using scanning electron microscopy. The significant decrease in mechanical strength and weight measurements leads us to believe that the graphite fibers should not be treated as a static entity when composites containing these fibers are analyzed. Dark-field microscopy was utilized to monitor the oxidation propagation rates in both the axial direction (along the fiber) and the transverse direction (transverse to the fibers) of unidirectional carbon-fiber composites aged in air at elevated temperatures. It appears that the rate of oxidation growth in the axial direction is an order of magnitude greater than the rate of oxidation growth in the transverse direction and is attributed to the higher diffusivity in the fiber-matrix interphase region. †Corresponding author ‡Presenting author

SYSTEM RELIABILITY BOUNDS IN THE PRESENCE OF UNCERTAIN INTERVALS

Phani R Adduri†‡, Dr Ravi C Penmetsa, and Dr Ramana V Grandhi
Wright State University; Dayton, Ohio

The failure of a structural system is usually governed by multiple failure criteria, all of which are to be taken into consideration for the reliability estimation. If all the uncertain parameters are defined as random variables, then the reliability of a structural system can be estimated accurately by using the existing techniques. But when the knowledge about some of the variables is limited to lower and upper bounds, the entire range of these bounds should be explored while estimating the bounds on the reliability. The computational cost involved in estimating these bounds increases tremendously because a single reliability analysis, which is a computationally expensive procedure, is performed multiple times for each configuration of the interval variables. To reduce the computational cost involved, high quality function approximations for each of the limit states and the joint failure surface are considered in this research work. The proposed technique will be demonstrated with numerical examples. †Corresponding author ‡Presenting author

DAMAGE SENSING IN CARBON FIBER REINFORCED POLYMER COMPOSITES USING ELECTRICAL RESISTIVITY MEASUREMENTS

Ms. Spandana Paty†‡
University of Dayton, Dayton, OH

Self-diagnostic structural health monitoring using nondestructive techniques is a revolutionary opportunity area critical to both safety and cost-effective application of composites in aerospace applications. Development of non-destructive techniques, such as the ones utilizing electrical resistivity measurements to explore the coupled electro-mechanical response of damage, therefore hold considerable potential for guiding the development of carbon fiber reinforced polymers (CFRP) for damage sensors in structural components. Success in the applications of damage sensing by the electric resistance technique requires a quantitative understanding of the relationship between the actual mechanical damage and the electrical response. In this work, we will establish quantitative relationships between specific damage type, size and location with the electrical resistivity measurements. This will be achieved by introducing damage in carbon fiber-reinforced polymer laminates and correlating the damage with the measured response. An electrode grid pattern will be designed for taking measurements. We will study the role of the electrode lead geometries and sensing array geometries so that the measured electrical response can be appropriately related to known internal damage. Design curves establishing the zones of influence for known damage type will be constructed for isolating and classifying damage. †Corresponding author ‡Presenting author

MOLECULAR BINDING AND ENHANCED PHOTOLUMINESCENCE OF BROMOCRESOL PURPLE IN MARINE DERIVED DNA

Mr. Darnell Diggs†‡

Deoxyribonucleic Acid (DNA) extracted and purified from salmon sperm was studied for binding and photoluminescence effects using bromocresol purple (BCP). BCP is both water and alcohol soluble, so it could be investigated for binding efficiency in a DNA/Water solution as well as a modified DNA-CTMA/Butanol solution. It was proven through Circular Dichroism studies that there was a maximum binding loading of BCP in the DNA/Water solution at ~5% by weight of BCP:DNA. The DNA-CTMA/Butanol solution however did not show this same quenching effect, with increased loading up through 10% by weight BCP:DNA-CTMA. This binding effect also shows an enhancement of photoluminescence over 6 times when compared to a PMMA:BCP thin film of equal loading. Keywords: molecular binding, intercalation, DNA, photoluminescence, bromocresol purple †Corresponding author ‡Presenting author

EFFECTIVE ELASTIC PROPERTIES OF NANOCOMPOSITES WITH RANDOM ORIENTATION OF CYLINDRICAL NANOFIBERS

Dr Valeriy A. Buryachenko†‡
University of Dayton Research Institute; Dayton, OH
Dr Ajit Roy
Air Force Research Laboratory, AFRL/MLBC, WPAFB, OH
Dr Vladimir I. Kushch and Dr Vasil A. Dutka
Institute for Superhard Materials of the National Academy of Sciences; Kiev, Ukraine

A nanocomposite is modeled as a linearly elastic composite medium, which consists of a homogeneous matrix containing a statistically homogeneous random field of nanofibers with prescribed random orientation. Estimation of effective elastic moduli of nanocomposites was performed by the effective field method (MEF, see for references and details Buryachenko, Applied Mechanics Reviews, 2001, v.54, 1-47) developed in the framework of quasi crystalline approximation when the spatial correlations of inclusion location take particular ellipsoidal forms. These “correlation holes” including the representative fibers are prohibited for the location of centers of surrounding fibers (since they cannot overlap) and compatible with mutual orientations of fibers. The independent justified selection of shapes of inclusions and correlation holes provide the formulae of effective moduli which are completely explicit and easy to use. Moreover, the nanofibers are cylinders with the smooth ends rather than the prolate spheroids. Therefore, the modeling of the nanofiber shape by the shape of a prolate spheroid is only approximation accepted by the authors with the aim to use the analytical Eshelby solution. In the current work, a single cylindrical fiber with the smooth ends embedded in a large matrix sample is analyzed by the finite element analysis (FEA) for six different unit external loading that allows a strain polarization tensor averaged over the volume of the fiber. In particular, the fiber axial ratio, and the ratio of the Young modulus of the fiber to that of the matrix was considered in the analysis of elastic load transfer inside the cylindrical fiber embedded in the matrix subjected to the axial loading. The axial stress distribution along the fiber axis estimated by the FEA was found to be greatest at the center, decreased steadily over most of the fiber length and fell rapidly to zero near the fiber end. However, the main advantage of the proposed approach is that it eliminates some of the drawbacks of the Mori-Tanaka method (MTM), which can generate tensors of effective moduli which fails to satisfy a necessary symmetry requirement. Three random orientations of fibers were considered: aligned fibers parallel to one axis (1-D uniform random orientation), uniform plane random orientation of fiber parallel to one plane (2-D uniform random orientation), and 3-D uniform random orientation. In the case of 3-D uniform random orientation of nanofibers, the effective Young modulus is close to experimental data. The same approach was used for the estimation of effective coefficient of thermal expansion (CTE). As expected, the estimations by both MTM and by MEF coincide for both 1-D and 3-D uniform random orientation for both the anisotropic and isotropic spheroidal fibers (and differ for the cylindrical fibers). However, for 2-D uniform random orientation, the estimations carried by the MTM and MEF qualitatively differ from one another; in doing so the effective stiffness matrix estimated by the MTM is not symmetric. Replacement of spheroidal fibers on cylindrical ones leads to lowering of predicted effective Young’s modulus on 13.7 % and 9.5 % at the using of the MEF and MTM, respectively. The simplified model takes the average fiber length instead of the full length distribution. The proposed model demonstrates that length distribution of fibers leads to the softening of composites if the average fiber length is fixed. The parametric numerical analyses revealed the most sensitive parameters influencing the effective properties which are defined by the axial elastic moduli of nanofibers rather than their transversal moduli as well as by the justified choice of correlation holes, concentration and prescribed random orientation of nanofibers. †Corresponding author ‡Presenting author

PROBABILISTIC FAILURES AND FLUTTER IN PANELS UNDER AERODYNAMIC NOISE LIMITED BY VISCOELASTIC FUNCTIONALLY GRADED DESIGNER MATERIALS

Prof Harry H. Hilton†‡ and Mr Daniel H. Lee

University of Illinois at Urbana-Champaign; Urbana, IL

Past studies [1–3] have shown that distinct regions of relaxation moduli curves contribute most significantly to the development of lower stresses and higher dissipation energy rates, and thus constitute the primary influence regarding optimum viscoelastic material selection. This pattern continues to manifest itself in preliminary results for viscoelastic plates under aerodynamic noise (pres-sure fluctuations) and thermal loads. Designer materials are tailored to utilize inherent viscoelastic material damping properties to minimize panel displacements, stresses and sound transmission. Increases in temperatures accelerate dissipation rates, but also induce thermal stresses, degrade failure stresses and may lead earlier to panel flutter. Consequently, conditions that improve deformations and noise abatement, may adversely affect failures and shorten life expectancies. Because of the high levels of complexity, analytical solutions are not realizable and inverse solution protocols are employed. Thus, designer materials are analytically constructed from prescribed relaxation modulus functions and then verified and evaluated by computer-generated simulations to perform specific tasks, such as for instance maximum energy dissipation, small deformations, low failure probability, long survival times, delayed panel flutter, etc., in response to aerodynamic noise and thermal loads. Previously developed deterministic and stochastic combined load invariant failure criteria [4] are used to determine the onset of delamination in viscoelastic plates. Creep buckling and panel flutter are considered as additional non-material failure conditions. Probabilities of delamination onset are established for various loads and environmental conditions, and as functions of structural survival times. [1] Hilton, Harry H. and Sung Yi (1992) "Analytical formulation of optimum material properties for viscoelastic damping," Journal of Smart Materials and Structures 1:113–122. [2] Beldica, Cristina E. and Harry H. Hilton (1999) "Analytical simulations of optimum anisotropic linear viscoelastic damping properties," Journal of Reinforced Plastics and Composites18:1658–1676. [3] Hilton, Harry H. (2003) "Optimum viscoelastic designer materials for minimizing failure probabilities during composite cure," Journal of Thermal Stresses 26:547–557. [4] Hilton, Harry H. and Ariaratnam, S. T. (1994) "Invariant anisotropic large de-formation deterministic and stochastic combined load failure criteria," International Journal of Solids and Structures 31:3285–3293. †Corresponding author ‡Presenting author

<u>Session V: Manufacturing</u> **Room E163B**

Chair: Dr. Ruth Sikorsky

A NEW ROLLING MILL DEFLECTION MODEL USING TIMOSHENKO BEAM FINITE ELEMENTS WITH MULTIPLE COUPLED ELASTIC FOUNDATIONS

Mr Arif S Malik†‡ and Dr Ramana V Grandhi

Dept. of Mechanical & Materials Engineering, Wright State University; Dayton, Ohio

This research extends the technology for the high-quality rolling of metal strip on various types of mills for the purpose of improving flatness of the rolled strip. A new semi-analytical modeling technique that couples Finite Element Analysis with classical solid-mechanics has been developed to model the deflection of the rolls and strip while under load. Using 3-dimensional Timoshenko beam elements with multiple coupled Winkler elastic foundations, a concise linear model of the rolling

mill deflection is obtained. The Winkler foundation moduli, required due to contact-surface interaction, are established using the elastic half-space solutions of Hertz and Boussinesq. The proposed technique to solve the roll-stack deflection problem offers several important advantages over traditional methods. In particular, it includes continuity of elastic foundations, non-iterative solution when using constant foundation moduli, and determination of mill dynamic characteristics through solution of the eigenvalue problem together with global stiffness and mass matrices. Application of the proposed method to the most complex of rolling mill configurations is demonstrated with examples involving the 20-roll Sendzimir mill. It is further shown that the proposed method is applicable to any type of structure involving adjacent beams coupled elastically along their axes. †Corresponding author ‡Presenting author

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THE APPLICATION OF UBET IN BULK DEFORMATION PROCESSES

Dr Vipul Ranatunga†‡

Miami University; Middletown, OH

The main objective of this discussion is to highlight the application of Upper Bound Elemental Technique (UBET) on modeling forming processes including profile ring rolling, closed-die forging, and perform design for forging/rolling, and highlight future research expectations on numerical modeling. Significant advances in the design tools for material processing have been made in the last few decades. The advent of low-cost, high-performance computing equipment, reliable numerical algorithms, and accurate modeling of manufacturing processes have enabled a general acceptance of powerful computational tools such as the finite-element method by industrial analysts. However, the use of these analysis methods has not completely solved most of the challenges in bulk deformation processes such as simulation of multi-pass profile ring rolling, and design of preform shapes for forging and profile ring-rolling. The basic research reported in this presentation highlight the application of UBET as an alternative tool for modeling bulk-deformation processes. Both forward and backward simulations with UBET are explained as alternative tools for load estimation, prediction of intermediate geometries and profile/die fill, etc. Results obtained through simulations have been compared with finite element results as well as actual ring-rolling experiments. Additionally, future research expectations involving local industry and university are discussed during the presentation. Keywords: forging, profile ring rolling, upper bound method, perform design. †Corresponding author ‡Presenting author

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THE UNIVERSITY OF DAYTON INDUSTRIAL ASSESSMENT CENTER PROGRAM

Mr Carl W Eger, III‡ and Dr John K Kissock†

University of Dayton Industrial Assessment Center; Dayton, Ohio

The University of Dayton Industrial Assessment Center is one of twenty-six university-hosted Industrial Assessment centers in the United States. Each center is funded by the United States Department of Energy Industrial Technologies Program to perform 25 energy assessments per year for “mid-sized” industries, at no cost to the industrial client. Energy, waste, and productivity cost saving measures are recommended to increase economic competitiveness. The University of Dayton Industrial Assessment Center has completed over 730 assessments since 1979. The Industrial Assessment Center program allows undergraduate and graduate students to apply engineering skills in real industrial situations. This presentation will provide an overview of the University of Dayton Industrial Assessment Center program and discuss the methodologies used to identify savings opportunities. These methods include utility analysis, lean energy analysis, and application of the “Inside-Out” approach. Savings opportunities for lighting, process heating, compressed air, pumping, heating/ventilation/air conditioning, process cooling, and motor drive systems will be discussed. †Corresponding author ‡Presenting author

HYBRID SHAPE SENSITIVITY ANALYSIS OF METAL FORMING PROCESSES

Ms Jalaja Repalle†‡ and Dr Ramana V Grandhi
Wright State University; Dayton, OH

Metal Forming processes produce many industrial and military components, such as gear blanks, cylinders, aircraft structural parts, etc., as well as many consumer goods. The fundamental requirements of the process are to form the desired products precisely and ensure that no defect should be present in the formed part. In metal forming, the final precision, the material flow pattern, tool wear, stress distributions, and loads significantly depend on the dies' shapes. The development of analytical shape sensitivity analysis techniques allow the metal forming community to design effective and economical die shapes. Hence, this research focuses on developing a hybrid shape sensitivity analysis which utilizes continuum deformation process mechanics and commercially available finite element analysis packages. The explicit sensitivity formulation is derived by defining an adjoint finite element analysis and identity integral from nonlinear constitutive laws of the deformation process. The approach significantly reduces the computational cost by avoiding the calculations on whole domain. Additionally, it opens a new era in shape sensitivity analysis by combining continuum plasticity mechanics and commercial software analysis packages without intervening in the finite element matrices. Also, sensitivity analysis reduces the computational cost of design optimization and assists in industry trade-off designs. The detailed design sensitivity analysis for the steady-state extrusion process is presented and the extension to nonlinear forging process is proposed. †Corresponding author ‡Presenting author

PIECES & PARTS: A SIMULATION INVESTIGATION OF MANUFACTURING COSTS

Mr John M Byrnes
Air Force Research Laboratory; WPAFB, OH

The problem is to develop aircraft system cost models for use in the Air Force Research Laboratory and possible for the broader AF community. In this first phase, the investigation will seek a broad cause & effect understanding of the primary drivers of acquisition costs. The initial task, highlighted in this presentation, shall concentrate on the simulation of the manufacturing process. A System Dynamics (SD) methodology will provide the quantitative means to develop and experiment with potential primary manufacturing cost drivers. This simulation method and software shall be explained and several commercial off the shelf (COTS) SD models shall be demonstrated. These will be: a manufacturing main chain, a work flow process, a shipping process and a product production process. The presentation will end with a call for ideas on potential upgrades or improvements to effect cost reductions in the manufacturing portion of the acquisition process.

THE EFFECTS OF LASER POWER DISTRIBUTION AND MELT POOL BEHAVIOR ON MICROSTRUCTURE IN LASER- DEPOSITED MATERIALS

Mr Srikanth Bontha†‡ and Dr Nathan W Klingbeil
Wright State University; Dayton, Ohio

Analytical and numerical modeling approaches are used to investigate the effects of laser power distribution and melt pool behavior on microstructure in laser-deposited materials. The analytical approach is based on the superposition of the well-known Rosenthal solution for a moving point heat source traversing an infinite substrate. Plots are developed based on the superposed Rosenthal solution for various laser power distributions that relate solidification cooling rate and thermal gradient to laser deposition process variables for both small-scale (low power) and large-scale (higher power) processes. These results are then plotted on solidification maps to predict grain morphology in Ti-6Al-4V. The effect of melt pool behavior (steady-state vs. transient vs. stationary) on solidification cooling rates and thermal gradients and thereby on the resulting microstructure is

investigated using thermal FEA. Results suggest that solidification microstructure may be sensitive to both the exact distribution of laser power and the behavior of the melt pool. †Corresponding author ‡Presenting author

Session VI: Turbomachinery — Room E157

Chair: Dr. Dave Car

EFFECT OF SUPER-COOLED WATER DROPLET CHARACTERISTICS ON FAN ROTOR-ICE ACCRETION

Mr Kaushik Das†‡, Mr Debashis Basu, and Prof Awatef Hamed

University of Cincinnati; Cincinnati, OH

A numerical study is conducted to develop and investigate a methodology for numerical simulations of super-cooled three-dimensional (3-D) water droplet trajectories through aeroengine rotating machinery that includes the effect of energy exchange between the droplets and flow. Both the flow and droplets' governing equations are formulated and solved in the rotating blade frame of reference. An Eulerian-Lagrangian approach is used for the continuous and discrete phases with a one-way interaction model to simulate the aerodynamic effects on the three-dimensional droplet trajectories. The temperature of supercooled droplets is calculated from the energy exchange equation based on convection heat transfer physics. The methodology is applied to the flow field and droplet trajectories in NASA rotor R-67. The computed 3-D turbomachinery flow field is presented for three different levels of grid refinement and compared with existing experimental data. Both the medium and fine grids showed nearly identical predictions that were in agreement with the experimental data. The relative Mach number contours show complex 3-D shock structure in the fan rotor. Computed results are presented for the droplet trajectories in the rotor reference frame. Results are also presented for the computed water collection efficiency and impingement temperature distribution over the fan blade surface for different droplet sizes and initial temperatures. The results indicate that droplet size has a significant effect on both droplet trajectory and temperature as droplets travel through the rotor flowfield. In general, the blade surface collection efficiency is higher for larger droplets and the impingement temperature is higher for smaller droplets. The energy exchange does not alter the droplet trajectories or blade surface collection efficiency but strongly affects the impingement temperature and hence the type of ice formed on the blade. †Corresponding author ‡Presenting author

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VERIFICATION OF A FLUID STRUCTURE INTERACTION MODEL FOR THE PREDICTION OF THE FORCED RESPONSE OF A STATOR VANE DUE TO GUST LOADING

Mr Jason E. Perry‡

University of Kentucky; Lexington, KY

Dr Vincent R. Capece† and Dr John R. Baker

University of Kentucky; Paducah, KY

The forced response of a compressor flat plate stator vane subjected to the gust loading of a rotor blade wake near the 2nd mode of vibration has been predicted using a hybrid model. The predictions from this model are correlated with experimental data acquired from a flat plate stator vane mounted in the University of Kentucky Low Speed Research Compressor (LSRC). The pressure loading has been computed using a potential flow solver for 2-D compressible flow in a cascade which can

compute the flow around a harmonically oscillating airfoil with any chordwise bending mode shape. A 3-D finite element model of the stator vane has been built, and the natural frequencies and mode shapes of the vane have been predicted using a modal analysis. The 2nd mode shape has then been used by the flow solver to compute the self-induced portion of the pressure loading at each location along the span of the vane. The forced response of the vane at resonance due to the summation of the gust portion and the self induced portion of the pressure loading has been predicted using a harmonic excitation analysis. The response amplitude has been seen to be in good agreement with experimental results coming from an accelerometer mounted on a stator vane in the LSRC operating at an engine speed to excite the vane near mode 2. †Corresponding author ‡Presenting author

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MODELING OF SURFACE ROUGHNESS ON ROTATING TURBOMACHINERY FAN COMPONENT

Prof Awatef Hamed, Mr Rudranil Manna†‡
University of Cincinnati, Cincinnati, OH

Solid particles ingested are one of the major reasons of surface degradation of Turbomachinery Fan blades. Solid particles may be ingested during sand storms or from volcanic ash clouds. Even particles of one to thirty microns have been reported to cause significant damage to the blade surface. Erosion damage in fan is manifested in pitting of leading edges and blade chord reduction. These elevated levels of surface roughness alter both the aerodynamic and thermal performance of the Turbomachinery system including earlier boundary layer transition, increase in frictional losses and enhancement in heat transfer. Numerical models have been developed for simulating the associated loss in aerodynamic performance. In the present study particle trajectory, particle bounce and surface degradation through elevated level of surface roughness are modeled in the NASA Rotor-67 Fan blades. Smaller particles tend to follow the flow field whereas larger particles are dominated by inertia. Moreover there is a significant different in particle trajectories as one moves from hub to tip direction. The particles near the hub impacts the pressure surface near the leading edge whereas particle near the tip impacts the pressure surface towards the trailing edge. Particle surface interaction for trajectory computation is based on experimentally based bounce models. Based on computational impact statistics Surface Roughness is simulated. Simulated results show that there is a significant variation in the spatial distribution of Surface Roughness. †Corresponding author ‡Presenting author

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A COMPARISON OF TURBULENCE/TRANSITION MODELS FOR SOLUTIONS OF A TURBOMACHINE CASCADE SOLUTIONS OF A TURBOMACHINE CASCADE SOLUTIONS OF A TURBOMACHINE CASCADE

Dr Darryl M Whitlow‡ and Prof Vincent R Capece†
University of Kentucky; Paducah, Kentucky

A compressible, three-dimensional, viscous unsteady turbomachinery computational flow solver is used to compute steady flow solutions of the NASA transonic flutter cascade. The governing equations are the Reynolds-averaged Navier-Stokes equations coupled with a turbulence model. In addition, the turbulence model used is supplemented with a transition model. Results achieved with the Spalart-Allmaras turbulence model are compared to those of the k-e model. The transition model is the Solomon-Walker-Goestelow model. The results are correlated with measurements at large mean incidence where the flow separated in the leading edge region and also for a low mean incidence angle. The airfoil section is representative of current low aspect ratio fan blade tip sections. Steady airfoil surface pressure measurements are compared with the numerical simulations for a test section Mach number of 0.5 and a Reynolds number of 0.9 Million. †Corresponding author ‡Presenting author

A COMPARISON OF REDUCED ORDER MODELING TECHNIQUES FOR MISTUNED ROTORS

2d Lt Clinton L Laing†‡ and Mr Jeffrey M Brown
Air Force; Wright Patterson Air Force Base, Ohio

Probabilistic Mistuning Analysis requires a large population of mistuned modal solutions. Reduced Order Models (ROM) provide a more efficient method of generating this population. The purpose of this project is to compare ROM techniques to determine which of the existing methods is more suited to analyzing the blade mistuning phenomenon in turbine rotors. The current progress of the project is at setup completion for the Component Mode Synthesis (CMS) model of an academic bladed rotor finite element model. The next phase will be a comparison between the CMS and the Subset of Nominal Modes (SNM) method. †Corresponding author ‡Presenting author

Session VII: Heat Transfer & Thermal Management — Room E156A

Chair: Dr. Rengasamy Ponnappan

ENHANCING THERMOELECTRIC ENERGY RECOVERY VIA MODULATIONS OF SOURCE TEMPERATURE FOR CYCLICAL HEAT LOADINGS

Mrs Robin G McCarty†‡ and Dr Kevin P Hallinan
University of Dayton; Dayton, OH
Dr Brian Sanders
AFRL; Dayton, OH
Dr Thada Somphone
Tuskegee University; Tuskegee, AL

Very recent thermoelectric (TE) device materials improvements have pushed this technology to the cusp of usefulness in converting waste heat to electricity in a variety of applications – from automotive to aerospace. For applications where the heat loading is cyclical or non-constant, the effect of active control to maintain the source temperature at or near the peak allowable temperature while maximizing the temperature difference across a TE temporally on the power output to power input ratio is investigated. Power ratios for constant heat loading applications that are not at near peak allowable temperatures are also investigated. The modulation of the source temperature would be achieved through the use of a 'thermal switch' or 'active thermal potentiometer' between the heat source and the thermoelectric device. Two methods are used to model the thermoelectric energy recovery system. First, an RC equivalent model is used to define the controlling factors for the TE efficiency on a first order basis. Second, a numerical model is created to investigate the system in more detail. Both models demonstrate that maximizing the energy of the source by maximizing its temperature during off-peak heat loadings is capable of improving the time-averaged power output to power input ratio of a thermoelectric device. For some conditions, improved time averaged power ratios of more than 4 times are realized. Criteria defining the operation space where power ratio improvements are realized are also developed. †Corresponding author ‡Presenting author

ELECTROCHROMICS FOR THERMAL CONTROL OF SPACECRAFT

Kelli M. Ashbrook†‡
Wright-Patterson AFB; AFRL/PRPS; Dayton, OH

It is important to maintain spacecraft within certain temperature limits to ensure that all components remain operational at harsh space temperatures. Thermal control can be accomplished with active or passive coatings. One active method involves the developing technology called electrochromics,

very similar to photochromics. Photochromic technology is used in sunglasses to change lens' transmissive properties when exposed to sunlight. Similarly, electrochromic technology is used to change reflective properties of a system of electrochromic coatings by the application of electric potential. Electrochromic coatings are thin, lightweight, and flexible, making them more practical than current heavier devices such as louvers. Active coatings such as electrochromics have the ability to vary emissivity, a ratio of how well a body can radiate energy as compared with a blackbody, whereas passive coatings do not. In a calorimetric experiment established in AFRL, emissivity is measured to characterize both active and passive thermal control devices for their ability to improve thermal control. This setup, designed to simulate space conditions, is comprised of a vacuum chamber and a liquid nitrogen blackbody shroud. The test sample, insulated by a heat shield, radiates IR energy to the blackbody. By applying an energy balance to the sample, emissivity is determined from the heater power as a function of sample temperature. The test was calibrated with standard samples and shown to be accurate. The measured emissivities fall within error limits determined in an error analysis. Results of electrochromic sample testing are expected to validate spectrometric measurements and qualify electrochromics for thermal control. †Corresponding author ‡Presenting author

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COMPUTATIONAL MODEL TRACKING PRIMARY ELECTRONS, SECONDARY ELECTRONS AND IONS IN THE DISCHARGE CHAMBER OF AN ION ENGINE

Mr Sudhakar Mahalingam‡ and Dr James A Menart†
WSU; Dayton, OH

Computational modeling of the plasma located in the discharge chamber of an ion engine is an important activity so that the development and design of the next generation of ion engines may be enhanced. In this work a computational tool called XOOPIC is used to model the primary electrons, secondary electrons, and ions inside the discharge chamber. The details of this computational tool and preliminary results from XOOPIC are presented. The results presented include particle number density distributions for the primary electrons, the secondary electrons, and the ions. In addition the total number of a particular particle in the discharge chamber as a function of time, electric potential maps and magnetic field maps are presented. Modeling ions and secondary electrons, as well as the primary electrons, will greatly increase our ability to predict different characteristics of the plasma discharge used in an ion engine. †Corresponding author ‡Presenting author

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EFFECT OF MULTIPLE PHASE CHANGE MATERIALS (PCMS) SLAB CONFIGURATIONS ON THERMAL ENERGY STORAGE

Dr Khalid Lafdi†‡
AFRL/MLBC, WPAFB; Dayton, OH

The present work involves the use of a two dimensional control volume based numerical method to conduct a study of a combined convection-diffusion phase change heat transfer process in varied configurations of composite PCM slabs. Simulations were carried out to investigate the impact of using different configurations of multiple PCM slabs arrangements with different melting temperatures, thermo-physical properties and varied sets of boundary conditions on the total energy stored as compared to using a single PCM slab. The degree of enhancement of the energy storage has been shown in terms of the total-energy stored rate. The numerical results from the parametric study indicated that the total energy charged rate can be significantly enhanced by using the composite PCMs as compared to the single PCM. This enhancement in the energy storage can be of great importance to improve the thermal performance of latent thermal storage systems.
†Corresponding author ‡Presenting author

TOPOLOGY OPTIMIZATION OF A CURVED THERMAL PROTECTION SYSTEM

Mr Muthumanikandan Prithivirajan†‡ and Dr Ramana Grandhi
Wright State University; Dayton, OH
Mr Mark Haney
Dayton, OH

Topology optimization of curved panels using Evolutionary Structural Optimization (ESO) method is performed by the removal of inefficient elements from the design domain, such that the structure evolves towards the optimum. The purpose of Thermal Protection System (TPS) is to protect the spacecraft from the extreme environmental conditions during its re-entry into atmosphere. TPS undergoes harsh aero-thermal loads making its design critical, which is based on the principle that the energy transmitted by the hot boundary-layer flow must be absorbed or rejected by the TPS. The high aerodynamic heating on the curved panel causes it to exhibit large deformation, thereby making it necessary to perform non-linear finite element analysis during the topology design. The ESO algorithm developed by Kim et al, is extended to improve the dynamic characteristics of the TPS design for the case of large deformations. The conventional ESO method is used to reduce the thermal stresses during the evolution, thereby improving the static characteristics. The contribution of each finite element towards dynamic and static characteristics of the structure is derived from their control parameters. The algorithm is implemented in a commercial FE software capable of handling large deformations. †Corresponding author ‡Presenting author

<u>Session VIII: Sensors & Instrumentation</u> Room E156B

Chair: Dr. James Gord

DEVELOPING OPTICAL DIAGNOSTIC SENSORS FOR MONITORING PULSED LASER DEPOSITION OF LONG LENGTHS OF YBA2CU3O7-X WIRES

Mr Carl J. Druffner†‡, Dr Glen P. Perram, and Maj Patrick D. Kee
Air Force Institute of Technology; WPAFB, Ohio
Dr Rand R. Biggers
Air Force Research Laboratory; WPAFB, Ohio

The high temperature superconducting properties of YBa2Cu3O7-x make possible new novel power generation and directed energy applications. One of the manufacturing keys to incorporating high temperature superconducting YBa2Cu3O7-x wires into these applications is the ability to manufacture continuous long lengths of wires with uniform superconducting properties over the entire piece. A real-time monitoring system must be developed to ensure wire integrity and production reproducibility. Pulse Laser Deposition is one of several potential commercial processes for producing viable YBCO superconducting wires and films. Optical sensing of the plume emissions during pulsed laser ablation of YBa2Cu3O7-x has the potential to yield real time information on the growth and quality of the films during deposition. Several sensors, including an intensified gated CCD camera, are currently being used to determine the key optical identifiers and information present in the emissive portion of the plume. Plume emissions have been examined at all positions along the target to substrate path and at different times after plume initiation for a range of deposition conditions and equipment setups. Plume imagery has been obtained utilizing band pass filters to restrict the data collection to specific component emission wavelengths of the plume (including Ba, Cu, Y, O, and YO). Many equipment and experimental factors (such as laser

wavelength, fluence, spot size, repetition rate, oxygen pressure, etc.) affect the YBCO deposition. Changes in these manufacturing factors can be detected by monitoring the spectral content and dynamics of the plume flight. A fast gated CCD camera was used to obtain the full chamber time of flight (TOF) measurements. The TOF data will be presented along with a discussion of the forward peaked nature of the plume relative to material quality. The CCD camera has allowed the plume dynamics to be studied with high spatial (200µm) and temporal resolution (10ns). Plume images have also been analyzed to characterize the time-of-flight speed distributions and to investigate how TOF data is evaluated. Usage of the full chamber imaging techniques incorporated in this study can enhance the portability, transfer, and application of controlled growth sensing for PLD systems. †Corresponding author ‡Presenting author

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PRESSURE AND TEMPERATURE SENSITIVE PAINT – A REVIEW AND STATE OF THE ART

Mr Mark W McQuilling†‡ and Dr Mitch Wolff
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Dr. James W. Crafton
Innovative Scientific Solutions, Inc; Dayton, OH

Pressure and Temperature Sensitive Paint (PSP/TSP) offers accurate pressure and temperature measurement with increased spatial resolution when compared to conventional taps, transducers, and thermocouples. Its non-intrusive property allows direct measurement of surface pressure and temperature without disturbing the flow field under investigation. PSP and TSP systems have gained wide acceptance and use since their inception in the 1950's, and this presentation seeks to shed some light on the fundamentals of the science as well as recent developments and the current state of the art. Recent examples of use from industry and academia found in the open literature will demonstrate capabilities as well as some limitations of the technique. The integration of PSP systems with existing diagnostic techniques will also be covered. †Corresponding author ‡Presenting author

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ANALYZING AREA OF INTEREST COVERAGE FROM MULTI-SENSOR UAV SWARMS

Capt Patrick Baldwin
USSTRATCOM; Omaha, NE
Dr Michael L Talbert†‡
Air Force Research Laboratory; WPAFB, OH

This article discusses foundations for modeling the quantification of the quantity and quality of information obtainable from data collected via sensor coverage data for a swarm of Unmanned Aerial Vehicles bearing data-collecting sensors. We use the term "information expectation" to capture the measure of corroboration or time-space coverage that may support any reported data item. Areas of interest (AOI)s, over which sensed data are requested and collected are analyzed from the standpoint of a time-space active network of observers, to determine the quantity, and by extention, quality of coverage afforded by a swarm of multiple sensor-laden UAVs. This work investigates the coverage of areas of interest as determined by the number of visits the swarm gives to sectors of an area of information collection interest, over designated times. By comparing the coverage of several different swarm configurations, we gain an understanding of how varying swarm sizes and configurations affect coverage. Coverage is an indirect measure by which we estimate information expectation. †Corresponding author ‡Presenting author

DEVELOPMENT OF AN A.C. PLASMA ANEMOMETER FOR AEROSPACE APPLICATIONS

Dr Sivaram P Gogineni†‡
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Dr Eric Matlis and Prof Thomas Corke
University of Notre Dame; Notre Dame, IN

A working prototype of a miniature 2 MHz a.c. driven, weakly-ionized plasma anemometer for measurements at hypersonic Mach numbers has been developed. This device uses a plasma discharge between two encapsulated electrodes as the primary sensing element. The discharge is driven by a low power (less than 5 Watt) a.c. source at voltages on the order of 350 Vrms at atmospheric pressure with electrode gaps of 0.0762 mm (0.003 in.). The discharge has demonstrated sensitivity to mean and dynamic mass-flux variations at Mach numbers up to 5.0 and at frequencies of 200 kHz. In principle, a frequency response in excess of 1 MHz is possible. The advantages of the plasma anemometer are that it requires no frequency compensation up to its a.c. carrier frequency, has an amplitude-modulated output that has excellent common-mode rejection with a signal-to-noise ratio that is much better than a hot-wire, is robust with no sensor element to break, can have a small spatial volume, and is insensitive to temperature variations making calibration easier than thermal-based sensors. This sensor has applications for measurements in gasturbine machinery, shock tubes, shock-boundary layer experiments, high-enthalpy hypersonic-fows, and in plasma tunnels.
†Corresponding author ‡Presenting author

PICOSECOND COHERENT ANTI-STOKES RAMAN SCATTERING THERMOMETRY IN FUEL-RICH HYDROCARBON-AIR DIFFUSION FLAMES

Dr James R Gord†‡ and Ms Amy C Lynch
Air Force Research Laboratory, Propulsion Directorate; Wright-Patterson AFB, OH
Dr Sukesh Roy and Dr Terrence R Meyer
Innovative Scientific Solutions, Inc.; Dayton, OH

We report the first experimental demonstration of broadband coherent anti-Stokes Raman scattering (CARS) spectroscopy using picosecond lasers. There are three promising advantages of picosecond CARS spectroscopy: (1) it improves accuracy by reducing or eliminating the nonresonant contribution to the CARS signal when the probe beam is delayed with respect to the pump beam, (2) it minimizes the effect of collisions on the CARS signal, thereby reducing modeling uncertainty and increasing signal-to-noise ratio, and (3) it improves sensitivity and may enable the detection of minor species because of the reduction or elimination of interference from the nonresonant background. These advantages have the potential to significantly enhance the performance of CARS thermometry in high-pressure or fuel-rich, liquid-fueled combustors of practical interest by overcoming the known limitations of nanosecond-based systems. †Corresponding author ‡Presenting author

TUNABLE DIODE-LASER ABSORPTION SPECTROSCOPY FOR HIGH-SPEED COMBUSTION MONITORING

Mr Joseph D Miller‡, Dr Terrence R Meyer†, and Dr Sukesh Roy
Innovative Scientific Solutions, Inc.; Dayton, OH
Dr James R Gord
Air Force Research Laboratory, Propulsion Directorate; Wright-Patterson AFB, OH
Mr Thomas N Anderson and Prof Robert P Lucht
School of Mechanical Engineering, Purdue University; West Lafayette, IN

Tracking global combustion instabilities and ignition/blowout phenomena in practical combustors can require sensors with detection frequencies well over 2000 Hz. In the current work, compact, high-speed-tunable, diode-laser-based laser sources are developed for ultraviolet (UV) and mid-infrared (MIR) absorption spectroscopy of combustion species at rates up to 20 kHz. Demonstration measurements are performed in a C2H4-air diffusion flame stabilized over a¬ Hencken burner as well as in the flame-zone and exhaust of a liquid-fueled model gas-turbine combustor. Good agreement with theoretical predictions and calibration measurements indicate that these lasers sources will enable studies of highly unsteady phenomena in combustors of practical interest.

†Corresponding author ‡Presenting author

<u>Session IX: Fluid Dynamics II</u> Room E156C

Chair: Dr. Datta Gaitonde

USING TRAILING EDGE DEFLECTION TO MINIMIZE INDUCED DRAG: A VERIFICATION STUDY

Mr Ernest D Thompson†‡
AFRL PRTT/VAAC / University of Dayton; Dayton, OH
Mr Scott C Monsch
University of Clemson / AFRL VASD; Clemson, SC

Initial steps were taken towards the long-term goal of implementing multiple trailing edge flaps through zero-mass flow boundary condition to control the spanwise lift distribution over a finite wing for minimizing induced drag. The first part of this project compared Computational Fluid Dynamic results of an untwisted, finite rectangular wing using no flap deflections against theoretical baseline for verification of the methodology. Dividing the wing into twenty spanwise sections and using a surface integral of pressure at each section provided a method from which to extract a spanwise lift distribution from the solution. A comparison of the numerical and theoretical lift distributions, under flow conditions representing subsonic and transonic flows at small angle of attack, showed good agreement with an average error of 2.4% over the wingspan. Implementation of a wake integral method via a Trefftz Plane analysis provided an approximation of the induced drag. Since wake mixing and numerical dissipation occur, a correction factor capturing the entropy change downstream should account for the discrepancy that shows up in the drag prediction. The implementation of a zero-mass flow boundary condition was utilized to directly inject momentum into the flowfield via trailing edge control surfaces will mimic geometric deflections of trailing edge flaps. The next phase of this project will further explore this functional relation and calibrate the settings by duplicating an elliptic distribution. The end goal will be to close the control loop and incorporate all aspects of this analysis into a single package to couple with the optimization process.

†Corresponding author ‡Presenting author

ADVANCES IN DENSE-SPRAY IMAGING USING ULTRAFAST LASERS

Dr Terrence R Meyer†‡
Innovative Scientific Solutions, Inc.; Dayton, OH
Dr James R Gord and Mr Barry V Kiel
Air Force Research Laboratory, Propulsion Directorate; Wright-Patterson AFB, OH
Dr Megan Paciaroni, Mr David Sedarsky, Prof Mark A Linne
Combustion Physics Department, Lund University; Lund, Sweden

A significant limitation to the current understanding of fuel-spray behavior is the inability to image the dense, near-field region with conventional optical techniques. In the current work, new developments in ultrafast ballistic imaging for dense-spray diagnostics are discussed, along with an application to the near field of a liquid jet in gaseous crossflow. Demonstration images illustrate the ability of the measurement system to capture liquid core break-up, liquid column stripping, ligamentation, and droplet-size distributions for various gaseous in-flow conditions. In addition, the potential use of ultrafast ballistic imaging for measurements of liquid-surface velocity or acceleration in the near field of dense sprays is presented. †Corresponding author ‡Presenting author

APPLICATION OF PLASMA DISCHARGE ARRAYS TO HIGH-SPEED FLOW CONTROL

Roger L Kimmel†‡ and James R Hayes
Air Force Research Laboratory; WPAFB, OH
Prof James A Menart and Prof Joseph S Shang
Department of Mechanical and Materials Engineering; Wright State University, OH

Surface DC plasma discharges were created in the boundary layer of a plate in a Mach 5 flow. The electrodes consisted of three circular cathodes and three pin anodes arranged to create transverse discharges. The cathodes were arranged linearly along the centerline of the plate, with the anodes displaced laterally. The cathodes and anodes were each held at common voltages. The discharge was run in two configurations, one with a single cathode-anode pair lit, and one in which all three cathode-anode pairs were lit. The discharge from these electrode configurations and its effect on the flow were strikingly different from the streamwise discharge created by linear electrodes. Flow modification from the circular electrode discharges was confined primarily to the boundary layer. The circular electrode discharges act similarly to crossflow jets or bumps, creating a weak wave structure with a pronounced vortex in the boundary layer downstream of the cathode. In contrast to the linear electrode discharges, surface static pressures and the inviscid flow above the boundary layer were largely unaffected by the circular electrode discharge. Substantial boundary layer distortion from the circular electrodes occurred at powers as low as 15 Watts. The circular cathode arrays have potential applications as high-bandwidth vortex generators. †Corresponding author ‡Presenting author

NUMERICAL INVESTIGATIONS OF TRANSONIC CAVITY FLOW CONTROL USING STEADY AND PULSED FLUIDIC INJECTION

Mr Debashis Basu†‡, Mr Kaushik Das, and Prof Awatef Hamed
University of Cincinnati; Cincinnati, OH

A numerical study is conducted to investigate steady and pulsed fluidic actuation in transonic flow over an open cavity. Numerical results are obtained for the unsteady three-dimensional flow with three different steady mass injection rates and one pulsed injection upstream of the cavity. The simulations are carried out using the full 3-D Navier Stokes equations with the two-equation k-ε based Detached Eddy Simulation (DES) model to calculate the flow and acoustic fields. A number of cavity flow simulations with actuation have reported the effect of either steady or unsteady

injection in the tone attenuation process, but did not compare both of them on the same geometrical configuration and operating condition. The comparative effect of high frequency unsteadiness as opposed to the mean mass flow rate in the noise suppression mechanism is not completely explored. In the present work, numerical simulations are carried out to gain an understanding of the control mechanism of transonic cavity flows for steady blowing and high frequency mass actuation. The cavity geometry has a L/D (length-to-depth) ratio of 5.0 and a W/D (width-to-depth) ratio of 0.5. The 3-D simulations are carried out using 3rd order Roe scheme and implicit Beam-Warming time integration with sub-iterations. The computational grid consists of 2.88´106 points at a Reynolds number of 0.60×106/ft and free stream Mach number of 1.19. Active flow control was simulated by specifying constant mass flux rates through the injection region for steady blowing; and specifying a velocity profile exiting through the injection region for pulsed injection. Turbulence has been simulated using k-e two-equation based Detached Eddy Simulation (DES) model. The DES method has been demonstrated to provide the required dynamic range resolution with computational resources comparable to URANS. The computational results at different mass injection ratios for the steady blowing and unsteady actuation are compared with experimental data and LES simulations. Computational results are presented for unsteady pressure fluctuations, vorticity contours and kinetic energy profiles at different injection ratios. The sound pressure level (SPL) and the kinetic energy spectra highlight the effectiveness of actuation in tone attenuation at peak frequencies. The predictions from the steady blowing indicate a 7–8 dB reduction in SPL at the peak frequency using an injection mass ratio of 0.6, 0.9 and 1.2. Unsteady blowing results in a higher reduction. The computed turbulent kinetic energy spectra revealed an overall reduction in amplitude. The TKE profiles indicate that the energy level decreases downstream of injection. The vorticity contours indicate that injection is responsible for the reduction of fine scales inside the cavity and lifting of the shear layer. †Corresponding author ‡Presenting author

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HIGH SPEED WIND TUNNEL TESTING RELATING TO AFT RELEASE OF A STORE

Maj Tim Jung‡ and Dr Mark F Reeder†
AFIT; WPAFB, OH

Store release is a very complicated problem with a number of important design considerations. Among the potentially important aspects of the problem to consider are high acoustic levels in the weapons bay, which could lead to damage in the weapons electronics and the unsteady forces and moments acting on the store, which could hamper clean release. A study is underway at the Air Force Institute of Technology which is focused on issues related to aft release of stores at high speeds. The investigation includes flow visualizations using a high-speed schlieren photography system operated at a frame rate up to 94,500 frames per second in a Mach 2.9 free stream. Additionally, fast response pressure transducers have bee applied to the surface of a variety of models. The effect of the proximity of the secondary object (store) to the primary object (carrier) will be discussed. †Corresponding author ‡Presenting author

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SIMULATION WITH METAMODELING TO OPTIMIZE CESSNA A-37 WEAPON LOADING

Capt Stephen Leggiero‡†, Dr. Robert A. Canfield, Dr. Sharif H. Melouk
AFIT; WPAFB, OH
Dr. Ramana V. Grandhi
Wright State University; Dayton, OH

Aircraft usage profiles (weapons loads and flight profiles) determine aircraft service life (how many cycles the wings can be loaded until failure). Countries can save maintenance and recapitalization resources by maximizing the service life of the aircraft currently in their inventory. While flight

profiles and the amount of weapons carried cannot be modified without negatively affecting the mission, the location of the weapons loaded on the wing can be prioritized to maximize aircraft service life. Each weapon pylon location has maximum load ratings, but this report will provide the methodology and guidelines to prioritize which weapon pylons should be loaded first to minimize the stress on the aircraft and maximize the aircraft service life. This report models (via Finite Element Analysis), metamodels (via regression), and analyzes (via sensitivity analysis) the subsonic Cessna A-37 Dragonfly wing structure to optimize weapon loading. The research emphasis is on: the simulation methodology, orthogonal experimental design, fractional factorial design, metamodeling, and sensitivity analysis to solve this complex aircraft issue. †Corresponding author ‡Presenting author

Session X: Materials Processing — Room E163A

Chair: Mr. Gerald Govin

SEVERE PLASTIC DEFORMATION OF AA6061

Mr Balakrishna Cherukuri‡ and Dr Raghavan Srinivasan†
Wright State University; Dayton, OH

Ultra-fine grain (UFG) structures in metals offer the possibility of increased strength at lower temperatures, by the Hall-Petch effect, while making the material more formable at elevated temperatures. Severe plastic deformation (SPD) to large strains is a route for producing ultra-fine grain structures. Several processing techniques like, equal-channel angular pressing (ECAP), high-pressure torsion (HPT) and multi-axial compressions/forging (MAC/F) were developed in the past decade to obtain severe plastic deformation in bulk materials. Methods like Accumulative Roll Bonding (ARB) were developed to obtain UFG structures in sheet materials. AA6061, a commercially available aluminum alloy was SPD processed by different techniques. Forging and heat treatment studies were carried out on the SPD processed material. The results show marked difference between the starting material and the severely deformed UFG material. The results of this investigation will be presented in the light of enhanced properties and processing cost savings for industrial application of SPD material. †Corresponding author ‡Presenting author

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ALLOY DEVELOPMENT AND FRICTION STIR WELDING

Dr Carter Hamilton†‡
Miami University; Oxford, Ohio
Dr Iulian Gheorghe
Universal Alloy Corporation; Canton, Georgia

Due to the high cost of new airframe programs and the price of the aircraft themselves, the United States military is compelled to maintain a fleet of "aging" aircraft and extend their service lives until replacement programs can be enacted. In many instances, the service lives of the airframes are extended well beyond their intended design life. The Service Life Extension Program (SLEP), sponsored by the Naval Air Systems in Patuxent River, MD, focused on the P-3 Orion and represents an excellent example of aging aircraft initiatives. Initially developed in the early 1950's with an intended service life of 30 years, the P-3 still flies today – twenty years beyond its design life with a new retirement date set at 2015. Research on these alloys focused on material characterization, including mechanical properties, fatigue and fracture characteristics, corrosion behavior and heat treatment/temper optimization for the different chemistries. In addition, the program studied the joining characteristics of these alloys through Friction Stir Welding (FSW), a

novel, solid-phase welding technology that is replacing conventional welding methods in the industry. Service life extension and alloy development for aging aircraft will be primary driving forces in the aerospace industry of the 21st century. †Corresponding author ‡Presenting author

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ROLLING OF AS-CAST BORON MODIFIED TI-6AL-4V

Mr Mats D Bennett‡ and Dr Raghavan Srinivasan†
Wright State University; Dayton, OH

Additions of small amounts of boron to form titanium mono-boride (TiB) has been shown to reduce the as-cast grain m, which is the same size as thatμsize in several titanium alloys to about 200 obtained after extensive thermomechanical processing of conventional VAR titanium alloy ingots. This leads to the possibility that as-cast boron containing alloys can be directly used for secondary deformation processing operations, thereby eliminating or substantially reducing the ingot breakdown stage in titanium alloy processing. Consequently, there would be a decrease in the cost and lead time for obtaining titanium alloys. This paper will present the results of a study on the rolling of as-cast Ti-6Al-4V, the workhorse alloy for the aerospace industry. Results will include a comparison between conventional Ti-6Al-4V and boron modified Ti-6Al-4V with 0.1Wt% B in terms of the rolling loads, macro- and microstructure of the alloys. †Corresponding author ‡Presenting author

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PLASTIC DISSIPATION ENERGY FROM CYCLIC LOADING OF BIMATERIAL INTERFACE CRACKS

Mr Jeremy S Daily‡
Universal Technologies Corporation; Beavercreek, OH
Prof Nathan W Klingbeil†
Wright State University; Dayton, OH

Bimaterial interface occur in systems including soldering, layered manufacture, welding, and any process that deposits a material onto a substrate. Often it is more energetically favorable for a crack to grow along the interface than to propagate into either of the base materials. As such, a recently introduced theory relates the fatigue crack growth rate to the energy dissipated in the reverse plastic zone during cyclic loading. The purpose of the current research is to describe the plastic dissipation energy of a general layered material with cracking along the interface. To this end, mismatches in both elastic and plastic properties must be considered to completely describe the problem. This means the elastic modulus, plastic constraint, hardening modulus and yield strength mismatch must all be considered. Results are obtained using 2-D elastic-plastic plane strain finite element analysis of a perfectly sharp crack along a bimaterial interface. Bimaterial cracks have an ambiguous definition of the mode mix. Therefore, a proposition for defining the mode based on the minimum plastic dissipation energy is presented along with some results for the cyclic plastic dissipation energy for bimaterial interfaces. Results show that the plastic dissipation energy has a large dependence on the mode mix ratio followed by the dependence on the elastic mismatch. †Corresponding author ‡Presenting author

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THREE-DIMENSIONAL MODELING OF MELTPOOL GEOMETRY AND SOLIDIFICATION MICROSTRUCTURE IN LASER DEPOSITED TI-6AL-4V

Ms Deepika R Gaddam‡ and Dr Nathan W Klingbeil†
WSU; Dayton, OH

Laser deposition of titanium alloys and other metallic materials is under consideration for aerospace applications, and offers significant advantages in efficiency and flexibility compared to conventional manufacturing methods. However, the success of this promising technology will ultimately depend on the ability to predict and control the microstructure and resulting mechanical properties of the

deposit. In previous studies, the evolution of microstructure in laser deposition of Ti-6Al-4V has been simulated using a combination of thermal FEM modeling and 3-D cellular automaton solidification modeling. For a given set of process variables (laser power and velocity), thermal history output from a ProCast model was used as input for subsequent CAFE3D cellular automaton modeling of grain nucleation and growth. This previous work has been limited to a rectangular shaped model of the melt pool, with boundary conditions which simulate 1-D heat transfer. However, the actual melt pool has a curvilinear shape, and the actual heat transfer is 3-D. The current work extends the modeling procedures developed for the rectangular shaped melt pool to develop a more realistic melt pool model. The data required for the melt pool dimensions and boundary conditions are taken from the 3-D Rosenthal solution for a moving point heat source, which results in a curvilinear melt pool with an axisymmetric thermal history. The resulting melt pool models are used to investigate the effects of changes in laser deposition process variables (laser power and velocity) and process size-scale on solidification microstructure (grain size and morphology) in laser-deposited Ti-6Al-4V. †Corresponding author ‡Presenting author

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NAVY AIRCRAFT ARRESTMENT SHANK: A MATERIAL SELECTION AND COST BENEFIT CASE STUDY

Mrs Sarah JH Kuhlman†‡
University of Dayton Research Institute; Dayton, OH

The Arrestment Shank is currently fabricated from AF1410 steel. The integrity of the arrestment shank is critical to the well being of the aircraft and pilot. However, maintenance costs and readiness constraints are making it desirable to extend the interval between depot inspections for this component. Given the service loads and operating environment, this presentation examines the material selection options for the arrestment shank in terms of strength, fracture toughness, corrosion resistance, weight, and cost. The high strength steels AF1410, 300M, and Aermet100 will be examined in detail. Novel materials will be considered more generally. †Corresponding author ‡Presenting author

Session XI: <u>Human Factors</u> Room E163B

Chair: Dr. John Blanton

THE CHARACTERIZATION OF SPINAL COMPRESSION IN VARIOUS-SIZED HUMAN AND MANIKIN SUBJECTS DURING +GZ IMPACT

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ABSTRACT Background: During +Gz impacts such as those encountered during ejection, the human torso and spine compress or slump due to the inertial forces acting on the body. Spinal compression can be characterized by a second-order differential equation involving coefficients such as damping ratio, natural frequency and spring constant. Objective: To characterize spinal compression resulting from +Gz impacts and determine how well test manikins replicate responses of similar size humans. Methods: Various-sized humans were tested with identical conditions on a vertical drop tower. Seat and chest accelerations were used to calculate the damping ratio, natural frequency and spring constant of each subject. Data analysis was performed examining individuals' sitting height, torso mass, and gender type to determine what correlations exist. Results: Results show spinal compression had no correlation sitting height, torso mass, gender, damping ratio, undamped natural frequency or spring constant. Utilizing the Weibull Cumulative Distribution the

range of chest displacement were -2.5” to -1.1” and -3.6” to -2.4” for the Vertical Impact Protection Seat and ACES II Seat respectively. The Large JPATS, Large ADAM and LOIS manikin were found to align closely with human spinal compression. †Corresponding author ‡Presenting author

QUANTITATIVE METHOD FOR DETERMINING CUSHION COMFORT

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Ejection seat cushions in current U.S. Air Force aircraft are not optimized for comfort during extended missions. Physiological problems such as buttock, leg and back pain, numbness and tingling, and overall fatigue have been documented in past laboratory and operational use. Designing a single cushion to address the physiological problems of the entire aircrew population is a significant challenge. Cushion material selection, cockpit space restrictions, and limited ability to reposition contribute to discomfort during extended missions. Ejection seat dimensions and contours are fixed, causing accommodation problems. Oftentimes the cushion itself is the only item that can be replaced to improve comfort. A study was performed to investigate objective test methods for determining cushion comfort. Twenty-two human volunteer subjects were tested on operational and prototype cushions, including one dynamic cushion. Tests were conducted over eight-hour durations, during which subjective survey data and cognitive performance data were gathered. As comparative objective data, seated pressures and contact areas, muscular fatigue levels, and lower extremity oxygen saturation were recorded. Peak seated pressures ranged from 1.22 – 3.22 psi. Oxygen saturation in the lower extremities decreased over the eight hours. Cognitive performance increased over time regardless of cushion with the exception of the dynamic cushion, which induced a decrease in performance for females. Muscular fatigue increased throughout the eight hours regardless of cushion, with the exception of the dynamic cushion which promoted muscular recovery. Subjective comfort levels declined over the eight hours. Subjective measurements correlated with objective parameters for the static cushions. Trade-offs in performance and fatigue mitigation were apparent in the dynamic cushion which also highlighted differences between genders. These results will be used to develop cushion design guidelines, both to prevent deep vein thrombosis and to promote comfort for long duration use. †Corresponding author ‡Presenting author

IMPROVED HEALTH MONITORING USING RANDOMDEC SIGNATURES

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Vibration based structural health monitoring has become an active research field over the past decades. Structures degrade during their service life. Degradation is usually comprised of cracking, delamination, or fastener loosening. Detection of damage is commonly based on modal features such resonant frequencies, damping ratios, and mode shapes. Random decrement technique allows to obtain vibration signatures that are related to correlation functions. Being sensitive to changes in the dynamic properties of the system, the signatures were used in the past for detecting the damage. However, little research has been done on using the signatures to resolve the spatial location of the damage. In this work, we attempt to derive the features from the signatures that will allow not only to detect, but also to locate the damage. †Corresponding author ‡Presenting author

HUMAN FACTORS RESEARCH IN MULTISENSORY INTEGRATION FOR THE COCKPIT

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Spatial Disorientation (SD) in the cockpit has been blamed on many pilot deaths and loss of aircraft. The USAF still regards SD and loss of situational awareness (SA) as major contributing factors in operational Class-A aircraft mishaps. Air Force Safety Agency data show 71 Class A ($1M in aircraft loss and/or pilot fatality) SD mishaps from 1991-2004. These resulted in 62 fatalities and an aircraft cost of $2.0B. These losses account for 21% of the USAF's Class A mishaps during those 14 years. Even non-mishap SD events negatively impact aircrew performance and reduce mission effectiveness. The Human Effectiveness Directorate has been conducting multisensory cueing research to increase the pilot's information baud rate during flight. Tactile and auditory cues have been developed to provide additional aircraft attitude information for the pilot. Specialized off-boresight flight symbology has been developed to provide the pilot with aircraft attitude information on a helmet-mounted display as they look off boresight during flight. This presentation will summarize the development of multisensory cues and basic research results with this technology.
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INTEGRATING THE EFFECTS OF ACCELERATION ON HUMAN COGNITION AND PERFORMANCE INTO FLIGHT SIMULATIONS

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Introduction: The stress of acceleration-induced hypoxia can have a significant impact on a fighter pilot's cognitive ability to perform critical flight tasks. This report provides an overview of a research program (5 of 12 studies complete) that is working toward assessing cognitive performance decrements during high Gz maneuvers to produce more realistic flight simulations. A model of each cognitive ability will be integrated with models of 11 other mission critical cognitive ability models to describe overall cognitive performance decrements. This becomes useful in ground-based flight training and planning air combat missions or sorties. Methods: Each completed study utilized between eight and ten subjects to perform a one of twelve cognitive tasks during a 3, 5, 7 Gz 15-sec plateau, and a 7 Gz SACM (simulated air combat maneuver) on each of 3 test days. Data collection was performed on the Dynamic Environment Simulator (DES) centrifuge at Wright-Patterson AFB OH. Time, Gz, trial completion time, and task performance metrics were recorded for each of the profiles. A separate model of the changes in the task performance was then constructed for each task using Microsoft Visual C++ 6.0. Results/Conclusions: Three of the five completed studies demonstrated significant decreases in cognitive performance at 5 and 7 G. Primarily, considerable decrements were apparent for the pursuit tracking, perception of object relative motion, and motion inference abilities. Each model of cognitive performance will be integrated into the larger overall cognitive performance model; however they must still be validated. †Corresponding author ‡Presenting author

USE OF THE DYNAMIC ENVIRONMENT SIMULATOR FOR HUMAN FACTORS RESEARCH

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The Dynamic Environment Simulator (DES) centrifuge is man-rated and located in the Air Force Research Laboratory. The DES has been used for research since 1969 and it is one of three human centrifuges in the USAF. The DES is unique in that it is gimbaled and has the capability of exposing subjects/pilots to multi-axes of sustained acceleration. The DES has a 10-ft diameter cab/gondola with a facsimile ejection seat and cockpit mockup. The visual simulation is projected onto a 6-ft diameter hemispherical screen. The DES can be integrated with other simulators and is part of a Distributed Mission Simulation system. The device has been used over the years for sustained acceleration performance and protection research and has more recently been used for spatial disorientation research. The human factors research projects on the DES will be summarized and the capability of the device for dynamic flight simulation research will be highlighted. †Corresponding author ‡Presenting author