Airport & Aircraft Safety R&D Notes

FAA Airport & Aircraft Safety R&D Division | January-March 2003

Fuel Tank Inerting

In recent months, significant progress has been made in developing a practical and cost-effective onboard inerting system to prevent fuel tank explosions. An inerting system reduces the concentration of oxygen in a flammable fuel mixture to a level that will not support combustion. Briefly, engine bleed air is passed through an air separation membrane, a device that separates air into two streams— nitrogen-enriched air (NEA) and oxygen-enriched air (OEA). The system developed by the FAA inerts the fuel tank with the NEA generated by the air separation membrane and discharges the OEA overboard.

Building on previous research on ground-based inerting, an onboard system was designed and installed in the B747SP test aircraft. The FAA was challenged by industry to develop a practical and reliable system that could be installed on commercial airliners within the next several years. Previous onboard designs, developed and used by the military, were relatively heavy and experienced poor dispatch reliability, something that could not be tolerated by the airlines. Ground-based inerting was an improvement, but required an airport infrastructure to supply nitrogen at each gate and a dedicated technician to transfer the nitrogen into the fuel tank, all at great expense. A simple concept was designed by Ivor Thomas, the FAA's National Research Specialist for Fuel System Design. Fire Safety Branch personnel, under the direction of Dick Hill, built a system from Thomas' design and installed it in the B747SP. Much of the work was done by Mike Burns and Rob Morrison. The design incorporated a clever and relatively simple dual-flow design for generating NEA in flight. By using high-purity and low-flow NEA during ascent and cruise and lower-purity and high-flow NEA

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during descent, analytical modeling showed that most aircraft and flight regimes would render the fuel tank inert upon landing. Moreover, earlier experiments showed that the fuel tank would continue to remain inert while the aircraft was on the ground, negating the need for labor-intensive and costly ground operations. The industry was impressed by the simplicity of the design and the positive modeling results.

On December 12, 2002, a major press conference was held for the national news (includes newspapers, magazines) and TV media at the FAA William J. Hughes Technical Center to highlight the recent significant progress in fuel tank inerting. Nick Sabatini, AVR-1, and John Hickey, AIR-1, presented the full scope of the FAA's program to protect fuel tanks, which was followed by a number of demonstrations. After viewing the inerting system, which was installed in the cheek area of the B747SP, the media witnessed its operation from the instrumentation room onboard the aircraft. The newspaper articles and TV coverage were generally positive, and the FAA Administrator Marion Blakey characterized the inerting system as a major breakthrough.

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Portable Industrial Process Monitor for Vacuum Arc Remelting

Vacuum arc remelting (VAR) is a process widely used throughout the specialty metals industry to produce finished cast ingots of superalloys and aerospace titanium alloys. In this process, the electrode tip is carefully heated in a controlled manner in vacuum, using a direct current electrical arc. The result is uniform electrode melting into a water-cooled copper mold. Successful VAR processing produces high-quality ingots that are free of oxide and nitride inclusions, as well as any of the several types of defects associated with uncontrolled solidification during casting. Because virtually all material used for forged rotating parts in gas turbine engines goes through a final VAR processing step, it is especially important that this process be carefully monitored to ensure production of defect-free material of uniform high quality.

The VAR Process Monitor is a process evaluation tool designed to aid in ensuring successful VAR processing. The monitor was developed jointly by the FAA, Sandia National Laboratories, and the Specialty Metals Process Consortium. It is compact, portable, and incorporates the latest advancements in process characterization, modeling, and data filtering. The heart of the system is a multistate process observer developed as a result of more than 10 years of process research. Monitoring a VAR furnace with this system gives the remelting engineer real-time estimates of important process parameters impacting the successful production of defect-free castings, including some parameters that cannot be directly measured and are, therefore, unavailable by

any other means. The monitor employs an intelligent measurements filter that can be used to eliminate questionable data points and flag the user when subtle process upsets occur. (See the photograph on page 1 for a view of the main output screen.) All monitor outputs are easily saved to data files that can be imported into common spreadsheet and plotting software. When used on a day-to-day basis, this technology can detect small changes in process conditions that normally go undetected and can, over time, degrade the quality of critical aerospace materials.

Joseph Wilson, AAR-460, (609) 485-5579

AAR-490's Rutgers University Project

For the past 9 years, Rutgers University has been funded through AAR-490, the Risk Analysis Branch, (formerly AAR-424) to develop analytical methods and prototype tools for aviation safety risk analysis. This work has led to the development of the following research products:

- The Intelligent Safety Performance, Evaluation, and Control (InSPEC) System
- Performance Measure (PM) Reduction Tool
- ClusterGroup Decision Support System
- Aviation System Risk Model (ASRM)

InSPEC, a software prototype, is an intelligent decision support system for aviation safety analysis. It is comprised of modules containing neural network and statistical models for Service Difficulty Report forecasting; expert systems for inspection diagnostics; univariate and multivariate data analysis techniques for control charting; and an Intelligent Referencing System for hypertext links to inspection regulations, handbooks, etc.; risk analysis models for event rate forecasting; component reliability prediction; and accident causation assessment. Some of InSPEC's capabilities will be considered in future enhancements of the FAA Safety Performance Analysis System (SPAS).

The PM Reduction Tool is a software prototype that applies an analytical methodology to evaluate the relative marginal information content gained from the addition of safety performance measures. The tool may assist in prioritizing new PMs and provide a systematic method for approaching the possible reduction in the number of PMs. This prototype has been forwarded to the SPAS analytical teams for their use.

The ClusterGroup Decision Support System is a software prototype that uses cluster analysis techniques to facilitate the prioritization of the importance of aviation safety risk factors by groups of experts. The underlying methodology eliminates the necessity of performing numerous pairwise comparisons and initial results with both synthetic and real-world data sets are promising. Preliminary results show up to an 80% reduction in the number of computations, yet results compare favorably with more traditional methods such as the Analytic Hierarchy Process.

The ASRM is a software prototype that uses the flexible, probabilistic approach of Bayesian Belief Networks and influence diagrams to model the complex interactions of aviation system risk factors. The ASRM

is currently being enhanced and further developed by the NASA Aviation Safety Program Office to evaluate the projected impact on system risk reduction of multiple new technology insertions and interventions into the National Airspace System.

During the research period, the principal investigator, Professor James Luxhøj, and his team published 9 journal articles, 20 conference proceedings, and 3 electronic publications. Twelve undergraduate students, eight masters students, and six Ph.D. students participated in the research.

Roseanne Weiss, AAR-490, (609) 485-4370

New Pulsed Eddy-Current Technique

Inspection technology provides many safety benefits for the aviation industry. For today's aging fleet, the detection of cracks and corrosion remains a high priority. A variety of methods are used for defect detection. The particular method chosen depends on the component geometry, material, expected defect location, defect type, size, and inspection cost. Eddy-current inspection (ECI) is a primary method used to detect cracks and corrosion in aluminum structures. This method is sensitive to small defects, detecting surface cracks that are typically 0.1″ and smaller. The inspection is used on a routine basis and has proven quite cost-effective. However, as the fleet ages and as designs become more complex, detection in multiple layers and at greater depths becomes more important. Detection and quantification of corrosion has also risen in priority for the commercial and military sectors.

Funded as part of the FAA's Airworthiness Assurance Center of Excellence, the Center Aviation Systems Reliability (CASR) at Iowa State University has developed a new improved crack and corrosion detection technique, which addresses limitations of the conventional eddy-current method. The technique is called Pulsed Eddy Current (PEC). In contrast to the conventional ECI method, PEC induces a range of frequencies in a single measurement. This has the advantage of inspecting multiple depths in a single pass, which is a more cost-effective and thorough approach. The PEC system uses a Hall sensor to measure the eddy-current signals rather than the induction coil used in the conventional ECI method. The sensitivity of an induction coil drops off with decreasing frequency. With the Hall sensors, the sensitivity does not drop, even with frequencies below 100 kHz. This is extremely useful when looking for deep penetration where information is contained in the very lowest frequencies.

A Hall device-based PEC inspection instrument is expected to offer a number of advantages over conventional ECI systems in the aerospace industry: deeper penetration through the use of solid-state magnetic field sensing devices, the capability to distinguish between flaws in different layers and to compensate for liftoff, and readily adapted to work with array sensors.

The CASR staff has worked with several industry partners in developing the technology and testing of specific applications. The pulsed eddy current was recently demonstrated at the Air Transport Association Nondestructive Testing Forum, held in Houston, TX, October 1-3, 2002.

Cu Nguyen, AAR-480, (609) 485-6649

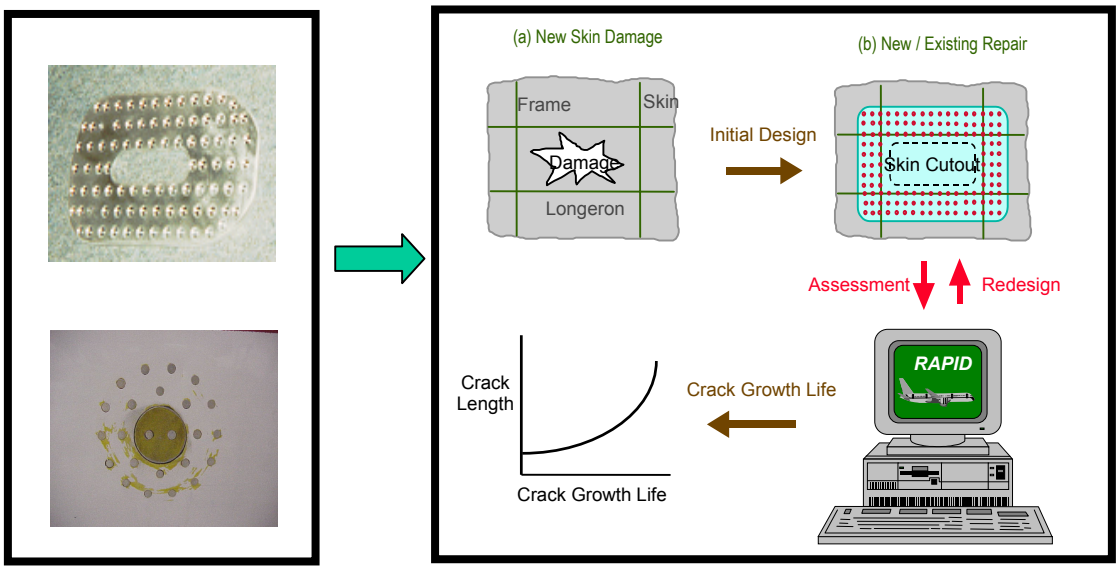
Damage Tolerance-Based Skin Repair Software RAPIDC

The effect of structural repairs on aircraft structural integrity is a critical issue that needs to be addressed for continuing airworthiness and operational safety. The Aging Airplane Safety Interim Final Rule was published on December 6, 2002. This rule requires the use of damage tolerance-based inspection programs on airplanes with multiple engines and ten or more passengers used in scheduled operations (operations within the state of Alaska are exempt). There is a need for a damage tolerance-based analysis tool to assist the FAA Aircraft Certification Office engineers and the FAA's Designated Engineering Representatives in complying with the safety rule.

In the past few years, the FAA has funded the research and development of Repair Assessment Procedure and Integrated Designs for Commuters (RAPIDC) analysis software for the anticipated need. RAPIDC is an automated static strength and damage tolerance analysis tool for skin repairs and antenna installations.

RAPIDC, Version 2.0, was released January 31, 2003, through the Internet at the following website http://aar400.tc.faa.gov/Programs/AgingAircraft/Commuter/RAPID. It is a PC Windows-based software with user-friendly, point-and-click graphical user interface features. It has an advisory system to provide repair guidelines as needed. An extensive material and fracture parameter database is included in the program for easy data access.

The latest version includes a built-in finite element method (FEM) module, an automatic FEM mesh generator, a load spectrum generator, and static and damage tolerance analysis modules for fuselage skin repairs and antenna installations. A detailed repair assessment report is automatically generated and documents all the design parameters and configurations, analysis methodologies, and results from damage tolerance analysis.



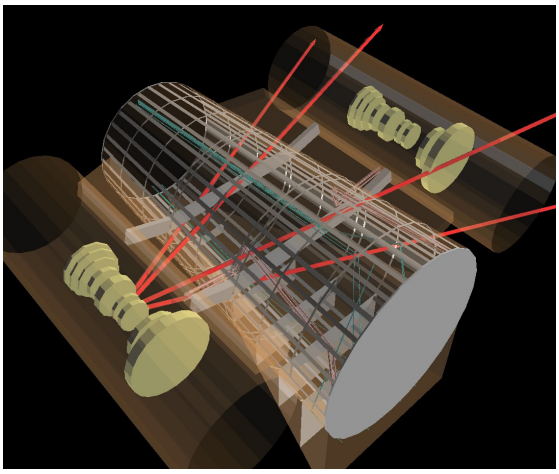
Michael Shiao, AAR-450, (609) 485-6638

Uncontained Engine Debris Damage Assessment Training

On February 25-27, 2003, the Aircraft Catastrophic Failure Prevention Program held a training workshop for the Aviation Rulemaking Advisory Committee (ARAC), Power-Plant Installation Harmonization Working Group. Embraer hosted the training session at their Ft. Lauderdale, Florida, facilities. Representatives from Boeing, Airbus, Pratt & Whitney, Bombardier, Cessna, Lockheed Martin, the FAA, and the U.S. Air Force participated in the training.

The user's manual, briefing materials, and generic examples were provided to lead the attendees through the uncontained engine debris damage assessment model in a very detailed lesson. Modeling tools were used to model and analyze a simplified airplane, which gave all participants experience using the debugging routines and the many analysis features. At the next ARAC meeting, participants will report back on their experience and requirements for using the tool as an acceptable means of performing the multiple-fragment threat analysis that will be required under 14 CFR Part 25.903(d) and AC 20-128B.

The tool uses a Monte Carlo analysis to analyze the hazard to the airplane in accordance with the rotor burst guidance. The figure at the right shows the generic business jet model used in the program in AC 20-128B. This twin aft engine design covers the burst zone in the rear of the aircraft. The rays spreading out from left to right are shot lines of fragments from the engine failure point.



To complete the aircraft analysis, each engine rotor must be analyzed. The hazard for each rotor is calculated, and the probability for the aircraft is summed up in accordance with AC 20-128B. It is clear from the feedback received from the training class that the program is a valuable tool. The tool is also of interest to the Amendment 25-87 ARAC group. This group deals with fuselage decompression and is interested in calculating the hole size from uncontained failures. The Uncontained Engine Debris Damage Assessment Model could be expanded to provide this output.

William Emmerling, AAR-460, (609) 485-4009

FAA COE Student Named 2002 DOT Student of the Year

Wichita State University (WSU) aerospace engineering graduate student, Ms. Lamia Salah was named the 2002 Department of Transportation (DOT) Center of Excellence (COE) Student of the Year. Ms. Salah was selected from amongst more than 50 universities and colleges from the four FAA COEs. Ms. Salah is attending WSU, a member of the FAA Airworthiness Assurance Center of Excellence (AACE). At WSU, she is currently working on a master's degree in aerospace engineering in the field of structures and solid mechanics. She was nominated for the prestigious award based on her FAA project work experience.

As an undergraduate, Ms. Salah worked on the FAA-sponsored project titled "Determination of Temperature/Moisture Sensitive Composite Properties." Ms. Salah received her bachelor's degree in aerospace engineering at WSU in August 2000, graduating magna cum laude. She is a member of the Sigma Gamma Tau, Tau Beta Pi, Golden Key, and Phi Kappa Phi National Honor Societies.

Lamia Salah, Wichita State University, with her winning poster.

For her master's thesis, Ms. Salah is currently working on the FAA-sponsored project titled "Bonded Repair of Aircraft Composite Structures." The Boeing Company, several airlines, (United, Delta, Lufthansa, and USAirways) and the FAA Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) in Albuquerque, NM, are participating in this project. In November 2002, Ms. Salah won an award in the student poster competition for this project at the FAA Centers of Excellence 2nd Joint Annual Meeting held in Wichita, Kansas.

As the 2002 DOT COE Student of the Year, Ms. Salah was honored as 1 of 33 students selected throughout the country by the DOT on January 13, 2003, in Washington, DC, at the 12th Annual University Transportation Centers Outstanding Student of the Year Awards.

The DOT honors the most outstanding students for their past achievements as well as their promise for future contributions to the transportation field. DOT Students of the Year are selected based on their accomplishments in such areas as technical merit and research, academic performance, professionalism, and leadership. Our congratulations go to Lamia Salah, her advisor, Dr. John Tomblin, WSU, and AACE.

Pat Watts, AAR-400, (609) 485-5043

New Center of Excellence

The FAA intends to establish a new Center of Excellence (COE) for Aircraft Noise Mitigation at a qualified university or college. The FAA COE program will hold an information meeting on May 6, 2003, in Arlington, VA. The purpose of this meeting will be to explain the FAA research needs, procedures, and criteria for the selection of the FAA Aviation Research Center of Excellence for Aircraft Noise Mitigation. According to Dr. Patricia Watts, the FAA COE Program Director, the preliminary scope of the Center will be to research socioeconomic effects of noise and noise mitigation, noise abatement flight procedures and supporting technologies, compatible land use management, and airport operational controls. It is expected that the future scope of activities may be expanded to other aviation environmental efforts such as aviation gaseous emissions and particulate matter.

Dr. Watts noted that a draft solicitation will be provided to attendees, and their suggestions and comments will be addressed at this meeting. Those wishing to attend this meeting are requested to register by 4 p.m. on April 28, 2003. To register or to obtain more information about the meeting, contact Patricia Watts at the FAA COE Program Office via email at patricia.watts@faa.gov or Jim Lignugaris at jim.lignugaris@faa.gov. Registration may also be done by facsimile at (609) 485-9430. For additional information about the FAA COE Program, visit http://www.coe.faa.gov.

Jim Lignugaris, AAR-400, (609) 485-4431

FAA-AANC Notes

Structural Repair of Aging Aircraft Program for Mobile Automated Scanner (MAUS) V Development and Validation—The AANC at Sandia National Laboratories, Boeing, and the University of Dayton completed a Structural Repair of Aging Aircraft program aimed at reducing costs associated with depot maintenance processes using advanced nondestructive inspection techniques. The tasks were focused on applications prioritized by the B-52, KC-135, and E-3 programs at the Oklahoma City Air Logistics Center. The versatility of the MAUS system was improved to better address wing inspections for corrosion and crack detection and to apply MAUS bond testing capabilities for evaluation of bonded repairs. Automated, rotational scanning around rivet heads was added to the MAUS platform to locate cracks under rivet heads. The approach taken for the enhanced large area scanning system was to integrate the advantages of the rotational scanning approach with the large area scanning capability, demonstrated with the MAUS IV system. The performance of the MAUS rotating probe, ultrasonic shear wave inspection system was quantified along with ultrasonic techniques tailored for detecting intergranular corrosion and damage in thick composite doublers.

Dennis Roach, AANC, (505) 844-6078

AANC Support for USDA Forest Service Firefighting Fleet—The USDA Forest Service, Fire and Aviation Management, requested assistance from the AANC to address airworthiness issues for the large air tanker fleet operated by private contractors

for the Forest Service. During the 2002 fire season, two aircraft were lost in firefighting operations because of in-flight structural failures. The FAA has issued Airworthiness Directives (AD) for the Lockheed C-130A and P-2V aircraft used in firefighting operations. These ADs call for immediate and continuing inspections of wings to detect cracking and the development of a Damage Tolerance Assessment for the C-130A. The AANC has previously assisted the FAA Aircraft Certification Office on inspection requirements and alternate means of compliance for the C-130A AD. The AANC will focus its experience in airworthiness issues and advanced, state-of-the-art maintenance and inspection techniques on USDA Forest Service large air tanker contract aircraft (the P2V, P-3, DC-4, DC-6, and DC-7). The results will allow the Forest Service to better understand the structural condition of their fleet of aircraft to more efficiently manage these aircraft for required maintenance and inspection.

Dick Perry, AANC, (505) 844-6078

Reports Corner

- DOT/FAA/AR-02/129, Side Load Factor Statistics From Commercial Aircraft Ground Operations, January 2003.

- DOT/FAA/AR-02/117, Crack Growth-Based Predictive Methodologies for the Maintenance of Structural Integrity of Repaired and Nonrepaired Aging Engine Stationary Components, January 2003.

- DOT/FAA/AR-02/130, Analytical Modeling of ASTM Lap Shear Adhesive Specimens, February 2003.

- DOT/FAA/AR-02/122, Practices and Perspectives in Outsourcing Aircraft Maintenance, March 2003.

- DOT/FAA/AR-02/128, Paint and Bead Durability Study, March 2003.

- DOT/FAA/AR-TN03/22, Development of Methods for Determining Airport Pavement Marking Effectiveness, March 2003.
- DOT/FAA/AR-02/121, Guidelines for Analysis, Testing, and Nondestructive Inspection of Impact-Damaged Composite Sandwich Structures, March 2003.

- DOT/FAA/AR-02/110, Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer, March 2003.

- DOT/FAA/AR-02/109, Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Unidirectional Prepregs, March 2003.

To obtain copies of these reports, visit http://actlibrary.tc.faa.gov and click on the Search the Library's Catalog button.

Personnel Notes

Joseph Wolff has retired after over 40 years in government service with the federal government and the Federal Aviation Administration. Joe was a part of the field-testing team that tested runway friction, using the K.J. Law friction tester and the Saab Friction Tester. He was also involved in the building and fabrication of the test equipment used to collect data at the Denver International Airport to measure pavement performance.

Sonceré Whitecloud-Woodford, AOS-540, is currently serving a 6-month detail supporting the Risk Analysis Branch, AAR-490. During the course of this detail assignment, Ms. Whitecloud-Woodford will manage the Title 14 Code of Federal Regulations Part 137 Modeling task and assist the AAR-490 core team representative on the Systems Approach to Safety Oversight Integrated Product Team.

Gerald Walter has retired after working for the government for over 41 years. His most recent assignment was as the technical specialist responsible for fuel testing in the Propulsion and Fuels Systems Branch, AAR-460. He provided superb leadership in the design and building of the fuels laboratory, and through his efforts, the FAA has a first-rate fuel testing program that is responsive to our sponsors' needs and is being done in close coordination with industry.

Upcoming Events

- 7th Joint DoD/FAA/NASA Aging Aircraft Conference, Hyatt Regency—New Orleans, LA, Sept. 8-11, 2003, http://www.agingairccraft.utcdayton.com/index.html
- 3rd Annual Joint Centers of Excellence Meeting, Daytona Beach, FL, November 5-7, 2003, http://www.erau.edu/research/FAA_COE_Meeting/index.html
- 5th Workshop on Risk Analysis and Safety Performance Measurements in Aviation, Baltimore-DC area, August 2003.
- Semiannual Center of Excellence for General Aviation Research meeting, University of Alaska, Anchorage, Alaska, June 11-12, 2003, http://www.cgar.org

Announcing: The Airport and Aircraft Safety R&D Division FY02 Technical Highlights are now available on the web at http://aar400.tc.faa.gov/HighlightsFY02.pdf

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Editor
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Airport and Aircraft Safety R&D Notes is published quarterly. If you have any questions about this issue or have ideas for future issues, please contact the editor, Jason McGlynn via email at jason.mcglynn@faa.gov.