Airport & Aircraft Safety R&D Notes

FAA Airport & Aircraft Safety R&D Division April-June 2003

Ground Tests of Aircraft Flight Deck Smoke Penetration Resistance

Testing has been completed to support an Aviation Rulemaking Advisory Committee harmonization working group using the Fire Safety Branch's Boeing 747SP and 727 aircraft. The group was tasked with developing draft regulations and advisory material to implement an International Civil Aviation Organization (ICAO) agreement to include security considerations into the type certification of new aircraft. Results were recently documented in the technical note titled "Ground Tests of Aircraft Flight Deck Smoke Penetration Resistance," DOT/FAA/AR-TN03/36, April 2003.

One of the requirements of the ICAO agreement was to include specific design features to prevent smoke and gases from entering the flight deck following the activation of an explosive or incendiary device anywhere in the aircraft except the flight deck itself. The threat from this scenario would be the smoke and gases from the ensuing fire. Ground tests were conducted in both aircraft to either measure or demonstrate the positive pressure differential between the flight deck and surrounding areas needed to prevent smoke penetration into the flight deck. Bleed air from the aircraft's auxiliary power unit was used to run the air-conditioner packs, and every possible combination of each aircraft's ventilation system settings was tested. The needed pressure differential was not directly measurable using a differential pressure gauge with a resolution of 0.005 inch of water (0.00018 psi) at any ventilation system configuration in either aircraft.

To test the positive and negative pressure differential, a thin sheet of plastic was placed over the flight deck door opening. Enough plastic was used so that the plastic sheet would deflect either forward or aft based on the airflow direction. When airflow into the flight deck of the B-727 was maximized and the cabin airflow was minimized, the plastic sheet clearly deflected into the cabin area, indicating a positive flight deck pressure differential.

A theatrical smoke generator was used to determine if this positive flight deck pressure differential was sufficient to

Inside This Issue

prevent smoke penetration. The smoke generator was placed in the cabin of the B-727 with the output nozzle pointing at the closed flight deck door, approximately 8 feet away. The generator was turned on at its maximum output, completely filling the forward cabin section of the B-727 with smoke. No smoke penetrated into the flight deck for this ventilation condition. These tests were repeated at every other ventilation system setting that did not cause the plastic sheet to deflect into the cabin area, and smoke penetrated into the flight deck in every case. Similar tests were conducted in the B-747 aircraft. None of the ventilation settings caused a deflection of the plastic sheet into the cabin area in this aircraft, and smoke penetrated into the flight deck in every test regardless of the ventilation system settings.

The technique of using a plastic sheet to demonstrate a positive pressure differential and theatrical smoke generators to demonstrate the effectiveness of that pressure differential will be described in a new Advisory Circular as an acceptable method of demonstrating compliance with the new regulations. The availability of functional test aircraft greatly enhances the Fire Safety Branch's ability to provide timely and realistic test results for FAA regulatory support.

The photograph above shows the plastic sheet installed over the flight deck door opening of a B-727.

The photograph above shows the differential pressure gauge used to measure the pressure differential between the flight deck and the surrounding area.

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Gust Specialists Seminar

The FAA William J. Hughes Technical Center hosted a Gust Specialists Seminar on May 21-22, 2003, to review and document the Statistical Discrete Gust (SDG) Method. This method has been under consideration as an alternative procedure of estimating severe gust and turbulence loads. A draft of the SDG technical report, prepared under contract to the FAA, was the focus of the review.

To survive extreme cases of encounters with atmospheric turbulence, aircraft designs have to have sufficient structural strength. Mathematical models of turbulence are used to assist in the design process.

The Power-Spectral-Density (PSD) model of continuous turbulence, Federal Aviation Regulations (FAR) 25.341(b), is based on the concept that, at least in patches of limited extent, random turbulence can be represented by a spectrum of harmonic gust waves across the frequency range, with the instantaneous gust velocity having a Gaussian distribution about the mean. The PSD has limitations as a means of representing the most intense and highly localized wind fluctuations, which are most relevant for structural design and tend to be more severe than implied by a Gaussian velocity distribution.

The tuned Isolated Discrete Gust (IDG) Model, FAR 25.341(a), addresses the problem of correctly representing extremely large localized gusts. However, the IDG's use of just a single-shape gust profile severely limits its ability to relate the gust loads on aircraft with widely differing dynamic response characteristics, which can tune to gust patterns of different shapes.

The SDG method provides a specification that accounts for both the non-Gaussian statistical structure of the more intense turbulence fluctuations and the dynamic response of a flexible aircraft. SDG can be interpreted as a generalization of the existing tuned IDG model, which takes account of tuning to gust patterns of different shapes. SDG can also be expressed in a statistical format that parallels the PSD method, thus making it applicable to both the Mission Analysis and Design Envelope forms. While the PSD method neglects the influence of phase correlations in the calculation of critical loads, the SDG representation takes account of the effects of the phase correlations in measured severe turbulence. This results in the associated statistics being highly non-Gaussian. This is achieved by modeling the localized discrete fluctuations explicitly in terms of ramp-shaped gust components and expressing the statistical description of severe/extreme turbulence in the form of probability distributions of patterns, comprising both single- and multiple-ramp components. The scaling law relating gust amplitude to gust gradient distance and the probabilities attached to localized patterns in the form of sequences of ramp gusts containing different numbers of components are based on the analysis of measured data. These include both turbulence measurements recorded by specially instrumented research aircraft and records obtained from severe gust encounters during routine operational flying by civil airlines.

From 1986-2001, an international team of specialists, convened by the FAA, met periodically to re-evaluate the gust criteria for future generations of commercial transport aircraft. The goals of this international ad hoc committee were to

reduce the number of design criteria to be met, and to recommend a design method with the ability to handle advanced technologies such as airplanes with active controls and gust load alleviation systems.

The SDG has been identified as the only existing method that can handle both discrete gust events and relatively continuous turbulence and, moreover, can be used to evaluate highly nonlinear systems. The SDG, however, has not been recommended by the Gust Specialists Committee for consideration as a revised airworthiness requirement, at least in part, because of its perceived computational complexity.

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Metallic Materials Properties Development and Standardization Update

The 3rd Metallic Materials Properties Development and Standardization (MMPDS) Coordination Meeting was held April 14-17, 2003, in Las Vegas, NV. The meeting was well attended with over 50 participants and was held in concert with the first release of the MMPDS-01 Handbook, the replacement document for MIL-HDBK-5. The Handbook is recognized internationally as a reliable source of aircraft materials data for aerospace materials selection and analysis. Consistent and reliable methods are used to collect, analyze, and present statistically based material and fastener allowable properties. The Handbook is the only publicly available source in the U.S. for material allowables that the FAA generally accepts for complying with the FAR for material strength properties and design values for aircraft certification and continued airworthiness. Moreover, it is the only publicly available source worldwide for fastener joint allowables that comply with the FARs.

This year marks the first publication of the MMPDS Handbook and the final publication of MIL-HDBK-5. For this year only, MMPDS-01 and MIL-HDBK-5 will be technically equivalent. In the spring of 2004, when the 1st Change Notice of MMPDS-01 is published, MIL-HDBK-5 will be designated noncurrent, and the MMPDS will become the only government-recognized source in the U.S. of published design allowable properties for metallic commercial and military aircraft structures and mechanically fastened joints. This maintains the 65-year legacy of MIL-HDBK-5, and its predecessor ANC-5.

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International Committee on Aeronautical Fatigue

During the week of May 5, 2003, Dr. Cathy Bigelow (AAR-400) and Dr. John Bakuckas (AAR-450) attended the 28th Conference and 22nd Symposium of the International Committee on Aeronautical Fatigue (ICAF) in Lucerne, Switzerland. ICAF was established in 1951 in response to fatigue problems in aircraft structures. The primary objectives of ICAF are to stimulate contacts between people actively engaged in aircraft fatigue problems and to exchange information, experience, opinions, and ideas concerning aircraft fatigue. ICAF biennial meetings are comprised of a 2-day conference followed by a 3-day symposium.

The conference and symposium were well attended with over 200 participants from academic institutions, research establishments, regulatory authorities, and aircraft manufacturers worldwide.

At the 2-day conference, the national delegates from the 12-member countries presented reviews of their country's research activities in aeronautical fatigue over the past 2 years. Of particular interest was the presentation of the USA national delegate, James Rudd from the Air Force Research Lab, Wright-Patterson Air Force Base. Of the ten research topics presented, representing the major research accomplishments within the USA, four were aging aircraft activities led by the FAA William J. Hughes Technical Center: (1) widespread fatigue damage, (2) development of fracture mechanics parameters, (3) the Metallic Materials Properties Development Standardization effort, and (4) aircraft loads monitoring.

The 3-day symposium opened with the 19th Plantema Memorial Lecture (named after the founder of ICAF) by Boud Vogelesang on the history and development of fiber-metal laminates. The symposium consisted of 33 presentations in the areas of loads development, fatigue damage assessments, full-scale testing, fatigue behavior of aircraft structures, fatigue modeling, fatigue and corrosion, and repairs. In addition, two sessions were dedicated to 31 poster presentations.

At the symposium, Bakuckas presented a paper titled "Characterization of Fatigue Behavior of Fuselage Structure." The presentation described the testing and analysis done using the Full-Scale Aircraft Structural Test Evaluation and Research facility to study the initiation and development of multiple-site damage (MSD), effects of MSD on the residual strength behavior, and methods to reduce fatigue-related problems using polyisocyanurate foam. Results showed that the majority of fatigue life was spent in initiating and forming cracks from the inner-faying surface at rivet holes in the outermost fastener row in the lap joints and progressed through the thickness. Once first linkup occurred, crack growth was very rapid. Although small multiple cracks did not have an effect on the global strain response, it significantly reduced the fatigue life and residual strength. Polyisocyanurate foam was effective in reducing out-of-plane crack bulging and cracking.

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FAA Cosponsors Camp at Tuskegee

When the Negro Airmen International, Inc. kicked off its Summer Flight Academy this year, over Memorial Day weekend, 384 participants celebrated the centennial of flight, and 123 participated in the FAA's Aviation Career Education (ACE) Camp. Thanks to last minute negotiations, the flight academy, cosponsored by the FAA's Air Transportation Centers of Excellence (COE), has chosen to adopt and adapt the FAA's ACE Camp as a model. Chris Seher, Director of the Airport and Aircraft Safety R&D Division, provided additional funding for this spectacular COE outreach effort.

The FAA Central Region's Aviation Education (AVED) Program Manager, Stephanie Webb, assisted the COE Program Office, the Airport and Aircraft Safety R&D Division, and the COE for Airworthiness Assurance team members in coordinating

the camp at Tuskegee University, AL. The FAA cosponsorship of the ACE camp re-energized the COE's relationship with the university. While this is the COE's fifth cosponsored summer aviation outreach effort scheduled for this summer, it is the first in an anticipated multiyear COE agreement with Tuskegee.

The photograph above shows three boys constructing an aircraft wing section at the ACE camp.

The FAA's COE and AVED programs have been working together since early fall 2002 on an agreement to jointly sponsor new ACE camp initiatives through the COE university network across the country. The national COE and AVED offices have set a goal to initiate one new COE and ACE camp in each FAA region within the next year.

Seher acknowledged the unique role the Tuskegee Airmen played in influencing social change in the armed forces and throughout America. "As we celebrate 100 years of powered flight and the 60th anniversary of the Tuskegee Airmen's first deployment, it's encouraging to see diverse partners working together to inspire the next generation of explorers, inventors, and innovators to pursue exciting careers in math, science, and engineering," Seher said.

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Airport Concrete Pavement Technology Program Enters Third Year With Expanded Research Activities

The Airport Concrete Pavement Technology Program (ACPTP) got its start in the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century, known as AIR-21. AIR-21, passed in 2000, authorized the FAA to make grants to nonprofit research foundations to improve concrete airport pavement design, construction, and rehabilitation. As a result, the Airport Technology R&D Branch (AAR-410) and the Innovative Pavement Research Foundation (IPRF) joined forces in a cooperative agreement to establish the ACPTP. Since the cooperative agreement was initiated in 2001, three research projects have been completed, and a fourth is in its final phases. Projects are intended to have a direct benefit to airport construction practices. For example, one of the first projects completed was the publication of the report titled "Best Practices for Airport Portland Cement Concrete Pavement Construction (Rigid Airport Pavement)," (available at http://www.iprf.org/products/main.html) that distills the experiences of airport contractors. Another project demonstrated the use of maturity meters at airports to nondestructively evaluate the strength of placed concrete in real time. In 2003, the ACPTP will enter its third year and will significantly expand into a new area of research—alkali silica reactivity (ASR) mitigation. In fiscal year (FY) 2003, the ACPTP has a budget of $3 million and can allocate up to $1 million to ASR research projects.

ASR refers to a potentially destructive chemical reaction that takes place in the presence of water between alkaline cement and the silica compounds present in concrete aggregates. ASR has long been recognized as a problem in highway and bridge construction, but its impact on airports has not been looked at systematically until recently. If unchecked, ASR can cause cracking, heaving, joint distress, and premature failure. Traditionally, the engineering approach to ASR has been to use known nonreactive aggregates. However, as the supply of such aggregates depletes, more attention has been given to using chemical additives, such as lithium salts, to prevent or mitigate ASR.

ASR research projects will look at prevention, identification, and mitigation. The projects proposed for FY 2003 include an accelerated laboratory study to determine whether pavement deicing fluids commonly used at airports increase a pavement's susceptibility to ASR and experimentally deploying various ASR mitigation technologies at airports that have been identified by the FAA as experiencing ASR distress. The latter project will be a cooperative effort between the FAA, IPRF, airport owners, and manufacturers of ASR treatments.

The photograph above shows a joint misalignment typical of ASR in a concrete airport pavement. Planned research under an FAA-IPRF cooperative agreement will address ASR, a common distress caused in concrete airfields, and other airport pavement issues.

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Wide-Body Overrun at JFK

An MD-11 cargo plane (inbound from Brussels) overshot the end of runway 4R at John F. Kennedy International Airport (JFK) on May 30, 2003. The crew of three escaped injury, and the plane was undamaged. The nose gear traveled approximately 115 feet into a bed of cellular cement known as the engineered material arresting system (EMAS). (See photograph on the right.) This bed of soft material is specifically designed to safely stop planes that overshoot runways. As the airplane's wheels crushed the soft cellular cement material, the kinetic energy of the plane was transferred to the bed, and the plane came to a safe stop. Four years ago, a Saab 340 with 30 people onboard stopped 240 feet into the runway 4R EMAS. The National Transportation Safety Board (NTSB) reported that the Saab would have plunged into Thurston Basin without the arrestor bed.

The FAA, the Port Authority of NY and NJ, and Engineered Systems Company jointly developed, tested, and deployed this system through a series of technology transfer partnerships over the last 10 years. Currently, there are eight arrestor beds in place across the United States.

Jim White, AAR-411, is the project lead for EMAS. He is also the FAA project lead for runway surface research, including issues related to slipperiness and traction. He was asked by the NTSB to investigate factors related to the MD-11 overrun at JFK with their Airports Group.

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FAA-AANC Notes

Commuter Nondestructive Inspection (NDI) Program—AANC personnel conducted Supplemental Inspection Document procedures on the Cessna 402A aircraft as part of the Evaluation of Airworthiness for Aging Small Aircraft program funded by the FAA with Wichita State University. The primary areas of focus are the horizontal stabilizer front spar and the main wing spar for corrosion and cracking. The inspection techniques used were the eddy-current ring probe, the eddy-current reflection spot and surface probe, the eddy-current sliding probe, the Magneto-Optic Imager, the Ultra Image Scanning System, and the Mobile Automated Scanner (MAUS). On the left wing, the only findings were four cracks in the top layer of material (skin) at the spar; no corrosion was found. The inspections completed on the horizontal stabilizer identified no cracks; however, several small areas of possible corrosion were detected that will have to be investigated further during teardown.

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Space Shuttle Accident Investigation Team—The AANC was asked to attend a NASA Technical Interchange Meeting (TIM) regarding NDI techniques to inspect the reinforced carbon-carbon (RCC) heat shields on the Space Shuttle Orbiter. The RCC components are part of the leading edge structural subsystem. The inspections will assess the deterioration in the laminate caused by stresses and breaks in the silicon carbide coatings. At the meeting on May 8-9, 2003, AANC proposed pitch-catch ultrasonics, mechanical impedance analysis, resonance (all deployed on a MAUS scanner system), thermography, shearography, and radiography. All of these are based on the AANC's direct experience with these methods for solid laminate composite structures. After the TIM, AANC was asked formally by NASA to participate in the inspection development activity.

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NDI Capabilities Characterization—This project surveys candidate NDI technologies and assesses their performance. As part of this ongoing project, the AANC has worked with several NDI developers to identify appropriate inspection applications and to perform initial evaluations. The current task areas are (1) identification of widespread fatigue damage (WFD) prior to crack initiation and (2) detection of small, WFD cracks (< 0.100 inch) around fasteners in the second and third layers of lap splice joints. For the first task, a set of specimens with known levels of fatigue damage are being inspected with photon-induced positron annihilation technology and ultrasonic

tomographic instruments. For the second task, AANC is evaluating several technologies developed to detect small cracks around fasteners. NASA-developed self-nulling rotating eddy current, remote field eddy current, and meandering winding magnetometer eddy-current technologies are being evaluated for reliability of small crack detection. AANC is using specimens that will provide a full quantitative probability of detection curve rather than a more general capability assessment. While this project is a long-term effort that looks at technologies during all stages of development, the immediate results from the assessment of mature technologies are being fed into an ongoing study for second-layer crack detection for WFD.

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Reports Corner

- The Response of Aircraft Oxygen Generators Exposed to Elevated Temperatures, DOT/FAA/AR-TN03/35, April 2003.
- Minimum Performance Standard for Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems, DOT/FAA/AR-TN03/6, April 2003.
- Ground Tests of Aircraft Flight Deck Smoke Penetration Resistance, DOT/FAA/AR-TN03/36, April 2003.
- Characterization of In-Plane Shear-Loaded Adhesive Lap Joints: Experiments and Analysis, DOT/FAA/AR-03/21, May 2003.
- Assessment of Effects of Mixed-Phase Icing Conditions on Thermal Ice Protection System, DOT/FAA/AR-03/48, May 2003.
- Test and Evaluation of the Effectiveness of a Small Airport Firefighting System (SAFS) in Extinguishing Two- and Three-Dimensional Hydrocarbon Fuel Fires, DOT/FAA/AR-03/45, May 2003.
- On-Wing Testing of Large Turbofan Engines, DOT/FAA/AR-03/32, May 2003.
- Damage Tolerance and Durability of Selectively Stitched, Stiffened Panels, DOT/FAA/AR-03/46, June 2003.
- Statistical Loads Data for Bombardier CRJ100 Aircraft in Commercial Operations, DOT/FAA/AR-03/44, June 2003.

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

Upcoming Events

- Aging Transport Systems Rulemaking Advisory Committee, FAA Headquarters Washington, DC, Bessie Coleman Conference Room, July 9-10, 2003, http://www.mitrecaasd.org/atsrac/schedule.html.

- Review of Progress in QNDE Conference, KI Convention Center, Green Bay, WI, July 27-August 1, 2003, http://www.cnde.iastate.edu/qnde/qnde.html.

- 7th Joint DoD/FAA/NASA Aging Aircraft Conference, Hyatt Regency, New Orleans, LA, September 8-11, 2003, http://www.agingaircraft.utcdayton.com/index.html.

- 3rd Annual Joint Centers of Excellence Meeting, Hilton Daytona Beach Oceanfront Resort, 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, Renaissance Hotel, Baltimore, MD, August 19-21, 2003, http://aar400.tc.faa.gov/aar424/Workshop2003/.

- 46th Annual NDT Forum, Delta Centre-Ville Hotel, Montreal, Quebec, Canada, September 22-25, 2003, http://www.airlines.org/public/events/display2.asp?nid=6859.

- 52nd IWCS/Focus Symposium, Philadelphia Marriott, Philadelphia, PA, November 17-20, 2003, http://www.iwcs.org/.

- 2003 USAF Aircraft Structural Integrity Program, The Westin Savannah Harbor Resort, Savannah, GA, December 2-4, 2003, http://www.asipcon.com.

Airport and Aircraft Safety R&D Notes
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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.