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AGING AIRCRAFT NDI DEVELOPMENT AND DEMONSTRATION CENTER (AANC) - AN OVERVIEW*

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SUMMARY

A major center with emphasis on validation of nondestructive inspection techniques for aging aircraft, the Aging Aircraft NDI Development and Demonstration Center (AANC), has been funded by the FAA at Sandia National Laboratories. The Center has been assigned specific tasks in developing techniques for the nondestructive inspection of static engine parts, assessing inspection reliability (POD experiments), developing test beds for nondestructive inspection validation, maintaining a FAA library of characterized aircraft structural test specimens, and leasing a hangar to house a high flight cycle transport aircraft for use as a full scale test bed.

INTRODUCTION

The three principal government sponsored locations where research on application of nondestructive inspection (NDI) to aging aircraft is occurring are at the National Aeronautics and Space Administration (NASA), Langley, VA, the Center for Aviation Systems Reliability (CASR) at Iowa State University, and at the Aging Aircraft NDI Development and Demonstration Center (AANC) at Sandia National Laboratories (SNL), Albuquerque, NM. The last two centers are under the sponsorship of the Federal Aviation Administration (FAA). The AANC was established August 6, 1991. Initial funding for this Center was $3.4M with its projected scope a minimum of $15M over 5 years. Sandia is the prime contractor and has established contractual relations with Science Applications International Corporation (SAIC) and New Mexico State University (NMSU) who are partnering in this Center. Initially, SAIC is involved with the NDI of static engine parts as well as probability of detection (POD) studies, and NMSU is involved with coherent optic inspection techniques. Both of these activities are discussed later.

The fact that these centers have been established is, at least in part, at the request of FAR 121 operators, repair modification centers, transport and general aviation manufacturers (foreign and domestic), and other government agencies such as NASA and NTSB.

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Recommendations (ref. 1) from the 1988 International Conference on Aging Airplanes included: "the FAA should sponsor research and development for improvement of NDI technology." Additional specifics associated with this recommendation were: "the FAA would acquire a test bed and using that vehicle would evaluate existing and new NDI methods with full participation of the operators and manufacturers." This conference, which was held shortly after the Aloha accident, was not the first time that a recommendation had been made that additional NDI resources be applied to aircraft inspection. After a crash of a cargo flight enroute to Lusaka, Zambia, on May 14, 1977, Flight International (ref. 2) quoted: "Big advances have been made in non-destructive testing (NDT) techniques. High frequency and low frequency eddy current probes, x-rays, ultrasonics, acoustics, dye-penetrants, and so on are a long way from the white coated inspector with his torch and magnifying glass. He is still the most valuable detective, but he needs help as structures get more complicated. He has nothing to cover the whole aeroplane, including its innermost recesses, for incipient cracks." The cause of the crash in Zambia was determined (ref. 3) to be due to the fact that the aircraft's right hand stabilizer rear top chord spar had failed prior to flight due to fatigue.

It is the intent of the AANC to address many of the NDI related issues of the preceding paragraph. Mindful of the recommendations contained in reference 1, full participation of the manufacturers and operators is both welcome and encouraged. This paper will clearly define the goals and current technical activities of the AANC.

GOALS OF THE CENTER

It is first appropriate to discuss the resources that SNL brings to the AANC which hopefully will in time benefit the manufacturers and operators. Sandia is an engineering laboratory. Its prime mission is to design, develop, and test nuclear weapon systems. These systems are placed into production in adherence to a strict time schedule. Subsequent quality in the weapon stockpile is monitored over the life of the weapon program (which is comparable to the lifetime of an aircraft). Three thousand engineers and scientists have advanced degrees in such requisite disciplines for aircraft inspection as NDI, reliability and statistics, human factors, structural and fracture mechanics, corrosion, robotics, and image processing. More important, SNL is a national laboratory, and therefore, has the potential to serve as a neutral party between the regulators, manufacturers, and operators. The principal goal of the AANC is to satisfy its customer, the FAA, while gaining acceptance from the manufacturers and operators as a contributor to their respective industries. These contributions must recognize both the need for reliability in their application to aircraft inspection and the competitive nature of these industries (i.e. they must be cost effective!).

Specifically, SNL's agreement with the FAA calls for three phases associated with its program. Phase 1 (complete in six months) includes initiating tasks defined by the FAA, recommending pilot NDI projects to the FAA, and providing test bed definition. The tasks defined by the FAA include both developing and implementing methodologies for POD studies for select inspection techniques for transport and commuter aircraft. Also included in the FAA defined tasks is the establishment of a basis for the evaluation of static engine parts. It is interesting to note that these tasks, along with the definition of test beds for NDI technique validation, all resulted from recommendations from the 1988 International Conference on Aging Aircraft. It is envisioned that pilot projects proposed by the AANC will be submitted to a manufacturer/operator screening committee before submittal to the FAA for approval. Phase 2 (complete in 18 months) involves the initiation of technology transfer to the operators based on results from phase 1, as well as continuation of phase 1 projects including test bed implementation. Phase 3 (complete in 5 years) involves continuing technology transfer, pilot automation inspection projects, and implementation of multiple inspection modalities to increase flaw POD.

An FAA library of characterized test specimen, now at the John Volpe Transportation Systems Center, will be housed at the AANC and used for NDI technique validation. The number of test specimen will be increased as required to fulfill industry requirements. Test specimen will be made available to industry on a limited basis to be determined by the AANC or at the request of the FAA. These specimen, as well as the test beds, will be housed in a hangar to be leased as soon as possible at the Albuquerque International Airport.

CURRENT CENTER ACTIVITIES

The AANC is functionally organized with staff in place in the structural, inspection reliability, and NDI (radiography, coherent optics, ultrasonics, visual, thermography,...) areas. Sandia consultants in fracture mechanics, corrosion, and robotics have been identified. A Navy lieutenant has been assigned to the program for a three-year period to help identify and transfer cost effective technology from the DoD to the AANC. Contracts are in place with both SAIC and NMSU for their support. Another contract is currently being negotiated with the City of Albuquerque for a hangar. That hangar contains approximately 17,000 square feet of floor space and 10,000 additional square feet of office/storage space. It is located next to a large aircraft maintenance facility.

The hangar is envisioned as a location to validate various NDI techniques for their applicability to the FAA's aging aircraft initiative. The hangar will house various test beds, the test specimen library, and hopefully a high flight cycle aircraft of the McDonnell Douglas DC9 or Boeing 737 size category. Aircraft useage requirements are currently being defined. The test specimen library has been requested from the John Volpe Transportation Systems Center and should soon be shipped to SNL.

Initial focus of the AANC has been on configuring itself to be a long term resource for the FAA. While the average AANC member has over 20 years experience, each is acutely aware of the need to familiarize himself with the FAA regulatory system, airframe structures, and inspection facilities. Outside consultants have been hired to provide training in damage tolerance analysis and corrosion in aerospace structures. The FAA has been consulted through its Technical Center, National Resource Specialists, Principal Maintenance Inspectors (PMIs), and local Flight Standards District Offices (FSDOs). AANC members have visited both Boeing and McDonnell Douglas as well as McClellan AFB. Several trips have been made to Mesa Airlines where members were extended the courtesy of spending one day observing tear downs of Pratt and Whitney PT6 engines and one entire night observing structural inspections in their maintenance hangar. U S Air has been briefed on AANC activities and has invited Center members to participate in D checks of their aircraft. AANC members spent one day with flashlights and a FAA corrosion expert inspecting a 1963 vintage Boeing 707 at the USAF Phillips Laboratory to gain needed experience. Numerous manufacturers of NDI inspection equipment have contacted the AANC. All of these contacts are welcome and it is recognized that more are required.

A significant amount of commercial NDI hardware is available in industry which is not being implemented in maintenance programs by the operators. This is due both to lack of proven effectiveness of this hardware through an extensive evaluation program and to lack of approval by the FAA for inclusion in operator maintenance programs. One objective of the AANC is to provide hardware evaluation to complement that of the manufacturers and operators. Where evaluation results are encouraging, and additional improvement is required, technology transfer and limited funding to equipment manufacturers can be provided. The objective is not to "reinvent the wheel" but to take advantage of existing technology. Some examples which illustrate potential technology which could be considered include:

Advanced Shearography - A laser based optical technique for full field video imaging of subsurface flaws identified through changes in strain (Laser Technology, Inc.).

Autoscan Flaw Detection - An ultrasonic scanner using shear waves and operating in the pulse-echo mode for fatigue cracks of rivets (Systems Research Laboratories, Inc.).

Diffracto-Sight or D-Sight - An optical technique used for visualizing surface distortions created by a change in surface topography greater than 10 micrometers (Diffracto Ltd.).

Fiber Optic Strain Sensors (FIBERTRONIC System) - A fiber optic strain sensor which uses optical time domain reflectometry to identify structural deflections and locations due to cracks and delaminations (G2 Systems Corporation).

Flight Loads Recorder - A microprocessor based recording system capable of recording flight structural parameters (ESPRIT Technology, Inc.).

Magneto-Optic/Eddy Current Imager (MOI) - An eddy current inducing and magneto-optic sensing element for detecting cracks and corrosion through real-time imaging (PRI Instrumentation).

Mobile Automated Ultrasonics Scanner (MAUS) - An ultrasonic and eddy current scanner providing a fast pseudocolor image of the scanned surface (McDonnell Douglas).

In addition to these technologies, one can readily conceptualize other productive areas for contributions. Inspectors flashlights could be improved to enhance visual inspections. Eddy current probes could include hybridized electronics and transmit their signals via a two-way rf data link to a personal computer for analysis and storage. This probe design would enhance human factors by eliminating bulky impedance scopes and/or meters, enhance data analysis, and be cost effective to implement. Additional examples exist.

An initial project assigned to the AANC involves an investigation of the POD associated with various inspection techniques. POD curves are an integral part of damage tolerance analysis in that they are necessary for deriving rational inspection intervals. The valid estimation of the POD requires that the data be taken under the conditions (including people, facilities, equipment, and procedures) in which aircraft are actually inspected. For eddy current lap splice inspections, the POD is currently estimated using 14 year old data taken across Air Force facilities or from laboratory experiments.

The AANC has initiated a program to design an experiment that is capable of providing the required data for estimating POD curves applicable to eddy current inspection of lap splices. The primary concern of the program is to identify and address "human factors" issues. Human factors have to be considered not only as part of the target study (i.e. their influence on the inspection results), but also in assessing to what degree the experimental conditions can be taken as an adequate model of the inspection process. From this initial POD study, it is hoped to expand to other inspection techniques (e.g. visual). This work is intended to support both transport and commuter type aircraft.

Another task assigned to the AANC by the FAA involves the NDI of static engine parts. This FAA assigned task, mentioned earlier, was derived from inputs at the first International Conference on Aging Airplanes. This conference stated the need for the development of enhanced inspection needs for static engine parts (cases and static structure).

An actuarial analysis of the JT8D engine was undertaken by SAIC to identify static engine components which caused engine shutdowns and unscheduled engine removals using FAA Service Difficulty Reports and Air Carrier Aircraft Utilization and Propulsion Reliability Reports. The JT8D component failure pattern over a two-year period identified three components for which enhanced NDI procedures may be beneficial. One of the failures was cracking in the weld of the fuel drain bosses of the outer combustor case. The other two failures were cracking in the #6 oil bearing tube and in the 13th stage bleed air duct. An enhanced NDI ultrasonic scanning technique was developed for detecting the cracks in the weld of the fuel drain boss.

As an extension of this work, SNL contracted SAIC to perform three tasks. Task one directs SAIC to develop NDI procedures for detecting cracks in the #6 oil bearing tube and the 13th stage bleed air duct of the JT8D engine. Task two instructs SAIC to investigate whether cracking of the weld of the fuel drain bosses of the outer combustor case of the JT9D and CF6 engines is a problem. If a problem also exists in the latter two engines, SAIC will develop an ultrasonic scanner to inspect these welds. A field demonstration with the engine on wing is planned for the ultrasonic scanning technique. The third task is to carry out the actuarial analysis retroactively for a 36 month period for the JT9D, CF6, and PT6 engines to identify any static engine components for which advanced NDI procedures may be beneficial. The work is to be completed in one year.

CONCLUSION

Work assigned to the AANC by the FAA in NDI reliability (POD studies), inspection of static engine parts, and test bed development is in process. The test specimen library has been requested from the FAA for shipment to the AANC. A hangar to house the AANC is in the process of being leased. Coordination with airframe and engine manufacturers, airline operators, NDI equipment manufacturers, and the DoD is occurring. Technical suggestions for and interactions with this Center by manufacturers and operators is welcome and solicited.

REFERENCES

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3. Boeing 707 321C G-BEBP Report on the accident near Lusaka International Airport, Zambia, on 14 May 1977; Department of Trade; ACCIDENTS INVESTIGATION BRANCH; Aircraft Accident report, pp. 30-32, September, 1978.