N92-30119

NDE RESEARCH EFFORTS AT THE FAA - CENTER FOR AVIATION SYSTEMS RELIABILITY

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SUMMARY

The Center for Aviation Systems Reliability (FAA-CASR), a part of the Institute for Physical Research and Technology at Iowa State University, began operation in the Fall of 1990 with funding from the Federal Aviation Administration. The mission of the FAA-CASR is to develop quantitative nondestructive evaluation (NDE) methods for aircraft structures and materials including prototype instrumentation, software, techniques and procedures and to develop and maintain comprehensive education and training programs in aviation specific inspection procedures and practices. To accomplish this mission, FAA-CASR brings together resources from universities, government and industry to develop a comprehensive approach to problems specific to the aviation industry. The problem areas are targeted by the FAA, aviation manufacturers, the airline industry and other members of the aviation business community. This consortium approach ensures that the focus of the efforts is on relevant problems and also facilitates effective transfer of the results to industry.

INTRODUCTION

The Center for Aviation Systems Reliability (FAA-CASR) began operation in the Fall of 1990 with funding from the Federal Aviation Administration in response to the Aviation Safety Act of 1988. FAA-CASR was established at Iowa State University because of ISU's long-standing commitment to research, development, application and education of quantitative NDE. FAA-CASR was established as a sister center to the Center for Nondestructive Evaluation which began at ISU in 1984 as one of the National Science Foundation's Industry/University Cooperative Research Centers. The mission of CNDE is to pursue research in nondestructive evaluation in problems of interest to industrial sponsors, to increase the number of students in graduate degree programs with an emphasis on NDE engineering and industrially relevant experience, and to establish a major, national focal point for NDE technology transfer to industry.

FAA-CASR utilizes research staff at ISU as well as subcontracts established with other organizations such as Northwestern University, Wayne State University, and Tuskegee University. The program involves four major projects: 1) Technology Application and Implementation, 2) Engineering Research and Development, 3) Education and Training, and 4) Economics and Management of New Technology. Project 2 utilizes the broad base of NDE knowledge and applies the appropriate technique to various areas of concern in the aviation industry such as fatigue, corrosion, adhesive bonded structures, engine inspection and cracking in airframes and propulsion systems. Project 1 applies the technology and insures its implementation through development of prototype instruments and software, standardization of procedures and techniques, as well as field experiments. In the area of technology transfer, FAA-CASR will work together with Sandia National Laboratory's Aging Aircraft Nondestructive Evaluation Center as part of the FAA research consortium. Project 3 has as its objectives to develop a comprehensive education and training program in the engineering application of nondestructive evaluation and to design a responsive program that meets the needs specific to the aviation industry through the use of classroom instruction in the theory of the technologies, hands-on laboratory practice, instructional videos and computer simulation of inspections. Project 4 links the human and economic interests into a holistic management approach to development and deployment of new inspection instruments and techniques. A brief description of selected tasks in the program are provided below.

RESEARCH EFFORTS

Probability Of Detection Models

The work underway at FAA-CASR is the first approach in which POD concepts have been integrated with actual components within a computer aided design framework to assess field inspection capabilities. The objective of this effort is to demonstrate the use of POD models as an engineering tool to aid in the quantification of the inspectability of aircraft components for eddy current, radiography and ultrasonic techniques. These efforts have their foundation in measurement models that allow the inspection parameters, measurement geometries, and component geometries to be manipulated. This provides unparalleled flexibility and cost savings over the more traditional methods used to acquire POD estimations. In addition, the human component does not enter into the calculations, insuring that decisions are based on instrumentation response allowing the independent assessment of inspector performance and training needs.

The use of POD models offers an inexpensive method to assess reliability of NDE inspection capabilities. They provide a tool for optimizing, verifying and interpreting inspection results from the design stage to in-service tests. Computational models offer a low cost tool for generating test signals for training automated inspection systems and for development of innovative approaches to training as discussed below.

Eddy Current Field Mapping Instrument

A unique new eddy current probe characterization instrument developed at Iowa State University is being evaluated for calibration and characterization of probes used in aircraft and engine inspections. The instrument uses a laser to map the electromagnetic field of the probe under consideration. This provides an objective, quantitative method for determining the quality and reliability of a probe. Much more information about the probe is obtained than would be possible with calibration on an EDM notch or with measurement of the probe's electrical characteristics. This technique will provide an effective quantitative tool to assess the reliability and sensitivity of eddy current probes used in routine airframe and engine inspections. Presently there is no universally accepted method to do this, resulting in wide variability in probe performance, consequently affecting the reliability and uniformity of eddy current inspections performed.

Corrosion Detection Techniques

Corrosion continues to be the problem of most concern to the industry. Present detection is based on visual inspection or the use of eddy current or ultrasonics to determine skin thickness. In actuality, the techniques do not detect corrosion or corrosion products but instead determine with limited accuracy the thickness of the outer skin. This does not provide necessary information on second layers. Because of the importance of this problem, FAA-CASR currently has several techniques under consideration which include x-ray backscatter techniques, x-ray energy sensitive techniques, electrochemical sensors, thermal wave techniques, ultrasonic techniques and eddy current methods.

- X-ray backscatter techniques being explored at Northwestern University offer single sided access and the use of lower energies therefore yielding a faster, less labor intensive technique.
- The use of x-ray energy sensitive techniques is being explored at Iowa State University that allows the characterization and ultimately the quantification of corrosion products which will have a different energy than the "good" material.
- Sensor development underway at Iowa State University is based on a new electrochemical NDE technique to quantitatively detect geometry and composition of corroded areas in lap joints. The technique will offer capabilities to measure metal skin thickness, depth of corroded area, and presence of solid corrosion products.
- Thermal wave imaging techniques under development at Wayne State University offer the possibility for a fast, contactless, single sided access inspection of aircraft structures. This modality is being applied to detection of disbonds, corrosion and cracks around fasteners.
- Efforts are underway at Iowa State University in use of ultrasonic techniques for detection and characterization of corrosion in adhesively bonded structures which includes lap joints, tear straps, honeycomb and composites. Initial effort will utilize squirter techniques with future work extending to contact transducers.
- An eddy current technique developed at Iowa State University for determining the depth and conductivity of layered metal structures is being adapted to determine corrosion-induced thinning of aircraft skin in lap joints. Present eddy current methods for characterizing corrosion in lap joints are only sensitive to thickness of outer layer and are based on empirical calibration of the instrument. The new method is based on swept-frequency measurements of probe impedance over a wide frequency range. This will improve quantitative determination of both skin thickness and air gap between the layers.

NDE Detection Of "Hard Alpha" In Titanium Alloys

Titanium alloys are widely used in applications that require high strength at intermediate temperatures, good creep properties and light weight. Much of the demand for these alloys in safety critical areas such as jet engine components. The criticality of these components requires that they be free of defects that could lead to failure. A concern in titanium alloys is the presence of hard alpha inclusions as discussed in FAA Titanium Rotating Components Review Team Report released in December of 1990. Hard alpha inclusions also known as high interstitial defects (HID) are regions of interstitially stabilized alpha of substantially higher hardness than the surrounding material. They are the result of very high localized oxygen or nitrogen concentrations that increase the beta transus and produce a brittle alpha region. These brittle regions then act as stress concentrators in the material and can be a source of crack initiation that eventually leads to failure. Efforts are underway at the Center for Aviation Systems Reliability and the Center for Nondestructive Evaluation both at Iowa State University to develop a comprehensive set of engineering tools for detection and classification of hard alpha defects in titanium alloys.

Design And Development Of An NDE Inspection Simulator

Existing NDE measurement models for x-ray, eddy current and ultrasonics will be coupled with computer aided design drawings of relevant aviation components in the development of an NDE inspection simulator. This will allow the user to choose a component, specify the inspection parameters and with the assistance of computer visualization techniques, enable the user to "see" the inspection results. The approach takes the measurement models discussed previously and integrates them in a user friendly computer framework. Field data and reference standards will be incorporated as a complement to the model signals enabling a comparison of model and experimental results. The flexibility of this approach allows part and flaw morphology variation in a cost and time efficient manner. The inspection simulator can be utilized as a training tool for new users and offers a flexible refresher tool for experienced users. The simulator provides a method to insure the inspectability of a component at the design stage and can also be used for optimization of inspection parameters throughout the life of the component. The simulator is being developed in phases with phase I focussing on x-ray.

The inspection simulator is just one of several innovative approaches to education and training being developed at FAA-CASR. A series of NDE videos designed to meet the specific needs of the aviation industry is under way. The cornerstone of the program will be the development of a series of instructional modules that includes both theory and practice components. The approach combines both classroom instruction and hands on practice. The first module proposed for development is a visual inspection module. Guidance in development of this effort will rely heavily on input from industry. This will insure currency and applicability to the true needs of the aviation community.

Participation by FAA-CASR in existing education programs at the University and community college levels is seen as a resource as education and training programs are developed in response to needs of the aviation industry. A one of a kind cooperative educational program is being developed within CNDE in collaboration with Northeast Iowa Community College (NICC) funded by the National Science Foundation. This program is intended to foster and enhance interactions among community colleges, universities and industry as well as to stimulate engineering student interest in NDE. The initial phases of the program include various opportunities for engineering students at ISU and students in the NDT option at NICC to participate in summer intensive NDE related work at CNDE, NICC, and industry. The final objective will be to develop an NDE minor as part of the engineering curriculum at ISU. This program will also serve as a resource for FAA-CASR and the training program that is underway within the FAA-CASR.

CONCLUSIONS

The Center for Aviation Systems Reliability (FAA-CASR) which is part of the Institute for Physical Research and Technology at Iowa State University began operation in the Fall of 1990 with funding from the Federal Aviation Administration. The mission of the FAA-CASR is to develop quantitative nondestructive evaluation (NDE) methods for aircraft structures and materials including prototype instrumentation, software, techniques and procedures and to develop and maintain comprehensive education and training programs in aviation specific inspection procedures and practices. To accomplish this mission, FAA-CASR brings together resources from universities, government and industry to develop a comprehensive approach to problems specific to the aviation industry. FAA-CASR utilizes research staff at ISU as well as subcontracts established with other organizations such as Northwestern University, Wayne State University, and Tuskegee University.

The program involves four major projects: 1) Technology Application and Implementation, 2) Engineering Research and Development, 3) Education and Training, and 4) Economics and Management of New Technology. FAA-CASR will also work with Sandia National Laboratory's Aging Aircraft Nondestructive Evaluation Center in transfer of technologies developed to industry. The problem areas are targeted by the FAA, aviation manufacturers, the airline industry and other members of the aviation business community. This consortium approach ensures that the focus of the efforts is on relevant problems and also facilitates effective transfer of the results to industry.

ACKNOWLEDGEMENT

This work was sponsored by the FAA-Center for Aviation Systems Reliability, operated by the Ames Laboratory, USDOE, for the Federal Aviation Administration Technical Center at Atlantic City, New Jersey, under Contract No. W-7405-ENG-82 with Iowa State University.