I< APIi) 1 NSPECTION OF AEROSPACE STRUCTURES - IS IT AUTONOMOUS YET?

Yoseph Bar-Cohen, Paul Backes and Benjamin Joffe
JPL, California institute of 'Technology, 4800 oak Grove Dr. (1 25-224)
Pasadena, CA 91109, yosi@jpl.nasa.gov

INTRODUCTION

The trend to increase the usage of aging aircraft added a great degree of urgency to the ongoing need for low-cost, rapid, simple-to-op erate, reliable and efficient NDE methods for detection and characterization of flaws in aircraft structures. The 1988 failure of the Boeing aircraft operated by Aloha Airlines heightened the level of attention to the issue of aging commercial aircraft from manufacturers, users and the Federal Aviation Administration (FAA). In many cases, the problem of inspection is complex due to the limitation of current technology and the need to disassemble aircraft structures and testing them in lab conditions. Labor intensive inspection in field conditions demands great attention to details by inspection personnel and is subject to human errors and limited in reliability. This interpretation depends critically on the inspectors' experience, competence, attentiveness and meticulous dedication. For instance, rivet crack inspection with eddy current detectors is known to be a mundane and painstaking task, which can lead to a significant decrease in the inspector attention during a long inspection session . On the other hand, disassembly of structures is costly and not practical in many cases. This inspection limitat ions are hampering the growth of use of composite structures for aircraft construct ions. To overcome these limitations, reliable field inspection tools are being developed for rapid NDE of large and complex-shape structures, that can operate at harsh, hostile and remote conditions (extreme temperature, battle field, remote expertise, etc.) with minimum human interference .

In recent years, to address the need for rapid inspection in field conditions, numerous portable scanners were developed using various NDE methods, including ultrasonics, shearography, and thermography. This paper is written with an emphasis on ultrasonic NDE seamers, their evolut ion and the expected direction of growth.

RAPID INSPECTION SCANNERS

Ultrasonics has been one of the leading NDE methods fir more than four decades. The development of seamers made its biggest impact on the level of use of this method since it allowed to obtain a detailed map of the inspected structure with an outline of the flaw size and location. Further, the process of recording the data became consistent and simplified the standardization of the inspection technique. For a long time, this automated capability was available in lab conditions and the inspection in tile field could be perform only manually. With the evolution of personal computers and microelectronics, tools became available that allow the development of portable ultrasonics C-scanners [1]. Initially, such seamers were limited to a simple bridge and a mobile set of boxes that were carried to the field to allow scanning, data acquisition and recording of the results. Methods were developed for position encoding, including acoustics (ISIS used this concept and was developed by General Dynamics under a contract from the Air Force), optical scales, and various other encoding techniques. The use of acoustics was determined as an unreliable form of position encoding so the technology evolved in the direction of optical encoders in a rotary form to allow producing a compact system. To inspection of surfaces vertically or test under the surface of aircraft wings, strapping techniques were developed as well as vacuum cups were added to the bridge (e.g., QMI's portable scanner) to secure the attachment. Since the aircraft has a complex geometry, the use of flat portable bridges was encountered with scanning and accuracy difficulties. The PANDA Scanner (made by Tektrend) addressed this issue by developing a flexible arm that holds the probe and by attaching it to the surface of the aircraft it allows following its contour.

The various portable c-scan bridges made an enabling automated technology for inspection in field condition and significantly improved the reliability of ultrasonic NDE. Unfortunately, the fact that the bridge itself is stationary limits the size of the inspected area to the bridge scanning range. once a scan is completed the operator needs to move the bridge to another location to cover the desired new inspection area,

MULTIFUNCTION AUTOMATED CRAWLING SYSTEM (MACS)

Automated devices which can attach to and maneuver on an aircraft skin to perform inspection can greatly benefit aircraft inspection. Increasingly crawling devices are being reported in an attempt to address the limitation of stationary portable c-scan bridges. The use of suction cups has become a leading form of controlled adherence to aircraft Surfaces and several successful devices were reported in the last several years. The Automated Non Destructive Inspector and the Autocrawler are some of the more known mobile portable scanners. In recognition of the need to have a small, more maneuverable crawler, JPL recently developed for the inspection of aircraft external surfaces a small, highly maneuverable crawler with a payload to weight ratio of about 1 (J: 1. This Multifunction Automated Crawling System (MACS) was designed to perform robotic tasks [patent pending]. MACS employs ultrasonic, motors for mobility and suction cups for surface adherence. MACS has two legs for linear motion and a rotation element for turning, enabling any simultaneous combination of motion from linear to rotation about a central axis. In Figure 1, MACS is shown crawling vertically on the surface of an Air Force C-5 aircraft.

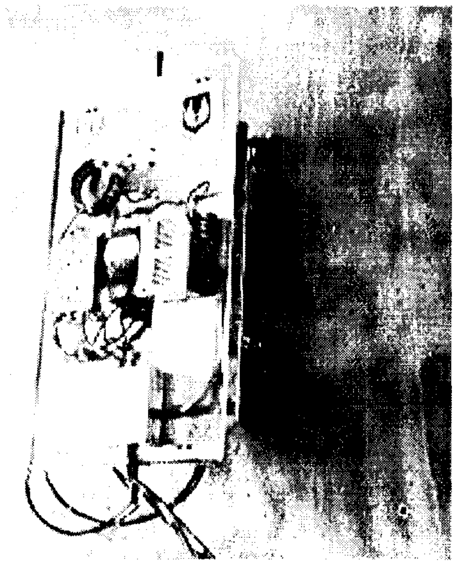

Figure 1: MACS crawling on the C-5 aircraft [patent pending].

Applications of the MACS crawler include inspection of repairs, composite materials, and structures of aging aircraft, detection of cracks, corrosion, impact damage, unbends, delaminations, fire damage, porosity and other flaws, paint thickness measurement, perform specific tasks such as identification of dents, and individual fasteners, etc. The development of the MACS crawler is benefiting from leveraging of ongoing NASA miniature planetary rover, telerobotics and NDE technology.

AUTONOMOUS CRAWLER - THE FUTURE OF PORTABLE RAPID SCANNERS

Autonomy of NDE crawlers is a key technology for automation of scanning complex aerospace structures. An autonomous crawler can be remotely monitored by centrally located experts that are equipped with know-bow, database and accept/reject criteria. Such a capability will allow rapid response to inspection needs, particularly in cases of a crisis where a flaw is discovered and there is a need to examine a full flight of the particular aircraft model all over the world. Also, an autonomous crawler can be operated during aircraft idle time allowing to reduce the need to ground aircraft for inspection, A combination of visual, ET and UT payload are expected to be the leading NDE tools that will serve as payload of an autonomous crawler.

The technology that enables such capabilities are being developed at such organizations as JPL to enable such capabilities. Miniature robotics technologies with on-board intelligence are needed for rovers to collect samples from Mars. Since communication lag between Earth and Mars is about 40 minutes, the need for autonomous operation on Mars has become a critical technology. MACS, currently, uses an umbilical cord for power, communication/control and to provide air pressure to control the vacuum caps position and form vacuum. Future efforts will involve increased autonomous operation of MACS. A potential future technology is development of a miniature on-hoard vacuum pumps to enable operation without an umbilical cord.

ACKNOWLEDGEMENT

The development of MACS was done under a Jet Propulsion laboratory, California Institute of Technology, contract with the Air Force Material Command, Kelly Air Force Base.

REFERENCES

1. Backes and Y. Bar-Cohen, "Miniaturization Technologies for Aircraft Inspection," JPL Report D-13876, (July 1996).
2. Y. Bar-Cohen, B. Joffe and P. Backes "Multifunction Automated Crawling System (MACS)", Disclosure of New Technology, Item No. 9460, Docket 19847, November 29, 1995. (Patent Pending, CIT **2432,** Submitted on August 1, 1996).