RAPID INSPECTION OF AEROSPACE STRUCTURES IS IT AUTONOMOUS YET?

Yoseph Bar-Cohen
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA 91109, yosi@jpl.nasa.gov

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OUTLINE

- Overview
- Major NDE needs of the aerospace/aircraft industry
- NDE scanners and technology' evolution

. Inspection crawlers

- Autonomous scanners and future crawlers

SPACECRAFT/AIRCRAFT INSPECTION
SOME MAJOR NDE NEEDS

- NDE of aging aircraft structures which does not require disassembly
- Reliable field tools for rapid NDE of large and complex-shape structures
- Ability to Perform NDE at harsh/hostile/remote conditions (extreme temperature, battle field, remote expertise, etc.)
- Access hard to reach areas, e.g., engines and fuel tanks
- NDE methods of materials properties determination
- Reliable smart NDE systems
- Real-time monitoring of structures integrity from cradle to retirement.
- NDE measurement of residual stresses
- Effective NDE for hybrid materials and detection of kissing bonds
- Industry-wide standards and accept/reject criteria for composite materials

RAPID FIELD INSPECTION OF LARGE STRUCTURES

- Wide spread use of composites is hampered by need to remove components for NDE and concern of impact damage.
- Current on-aircraft inspection is very labor intensive.
- Manual inspection involves human errors
- There is a need for a portable, user friendly inspection instruments for rapidly scanning large complex-shape structures.

NDE TOOLS FOR AIRCRAFT INSPECTION
SCANNING TECHNIQUES

Local/Manual Test

- Operator performs conventional NDE using portable instruments
- Most widely used methods are visual and tap testing

Scanners

- Remote Operation
  - Imaging/Viewing - Visual inspection using miniature CCD
  - Illumination - Thermography, shearography, D-sight
  - Beam sweeping - Laser induced UT scanning
- Surface Coupled
  - C-scanners - Manual and mechanical C-scans
  - Crawlers - miniature rovers crawling over the a/c structure

Stationary (sensors)

- Imbedded sensors - Fiber optics, dielectrics, UT, etc.
- Attached sensors - Crack fuse, resistance gauging, strain gauges, UT, ET, etc.
- Remote sensors - Eddy current, magnetic, visual, etc.
- Sensitive Coatings - Bruising paint indicators, brittle coating, etc.

ULTRASONIC SCANNERS
TECHNOLOGY TREND

- Large automated C-scan systems are widely using at lab and shop conditions.
- Various configurations of portable c-scanners are widely available:

  In the early 80's, ISIS was developed by GD under an AF contract. This transportable field C-scan was bulky and used unreliable acoustic position encoder.

  Desktop optically encoded manual bridges are the most widely used field c-scan tools

  Some portable miniature C- scanner are equipped with vacuum cups to control the adherence to a/c surfaces

ALTERNATIVE NDE SCANNERS

COUPLANT FREE TECHNIQUES

- Shearography - An emerging NDE technology, which requires deformation of the structure to cause flaw revelation.
- Thermography - Sensitive to cracks/delaminations closure.
- Reverse Geometry X-Ray - Limited in speed and size of test area. also involves personnel hazard.
- Laser Ultrasonics
  - Still in early phases of transition to practice.
  - The first system installed at McClellan AFB in March 1996.
  - Laser UT systems are very expensive.
  - Not applicable to field use yet.

MINIATURE TELE-ROBOTIC TECHNOLOGY FOR AIRCRAFT NDE REQUIREMENTS

- Provide robotic assistance in labor intensive tasks
- Augment maintenance crew activity in hard to reach areas
- Perform tasks at harsh, hostile or remote (on-site and off-site) environment
- Perform multi-tasks, e.g. paint removal and crack detection around fasteners

INSPECTION CRAWLERS

- Development in Tele-Robotics and miniature electro-mechanical systems (MEMS) introduced new mechanisms and devices that can support critical NDE scanning tasks.
- A series of crawlers were reported in recent years, including: Autocrawler, Andy, etc.
- Recently, using its Mars Exploration TeleRobotics technology, JPL developed the Multifunction Automated Crawling System (MACS)
  - MACS is a mobile platform for carrying NDE tools. It weighs about 10 lb. and have a theoretical carrying capability of up to 210-lb.
  - Using 8 large suction cups in two legs with one leg performing on-the-spot rotation functions for turning.
  - Using ultrasonic motors for low mass, low power mobility

AUTONOMOUS OPERATION

TRANSFER OF SPACE TELE-ROBOTICS TECHNOLOGY

- The distance of Mars from Earth causes a 40 minutes delay in two way communications.
  - This constraint forced JPL to develop the Mars Rover with autonomous operation capability.
  - The Rover is installed with 3D vision and collision avoidance software.
  - Task driven operation architecture controls the rover mobility
  - Tools are attached to the Rover to allow sampling/analysis of Mars soil and rocks
- NDE crawlers for a/c rapid scanning have similar needs and technology transition in underway at JPL

FUTURE INSPECTION CRAWLERS

AUTONOMOUS MINIATURE TELE-ROBOTIC INSPECTOR (AMTRI)

- Autonomy of the crawler is a key to automation of scanning the complex structure of a/c and s/c.
- A combination of visual, ET and UT payload is expected to be the AMTRI leading NDE tools
- Collision avoidance, wireless telecommunication for remote control and on-board preprocessing will enable a new era in inspection
  - Centralized remote expertise and database
  - Rapid response to inspection needs
  - Operation during a/c idle time