A PRACTICAL IMPLEMENTATION OF TRANSIENT EDDY CURRENTS FOR CORROSION AND CRACK DETECTION

Jesse A. Skramstad, NDT Solutions, Inc.

Robert A Smith, QinetiQ Ltd UK

Nancy Wood, Boeing Aircraft Company

The 6th Joint FAA/DoD/NASA Conference on Aging Aircraft
16 – 19 September 2002
Abstract

Future inspection techniques for aging aircraft will have to be able to acquire data over large areas of complex structure, with numerous changes of thickness, without the need for adjusting the acquisition parameters, in addition to being able to reliably detect defects of appropriate severity. Transient eddy-current technology is one of the few methods offering reliable defect detectability over a wide range of depths without the need to make adjustments at acquisition time.

While the technology exists to perform these transient eddy-current scans, further work is required to couple it to large-area scanners currently in use with the US Air Force and Civil airlines. This poster reports progress on the integration of the MAUS ® and Ultra Image IV scanners with the TRECSCAN® transient eddy-current imaging system. The first scans from a MAUS ® system using transient eddy-currents will be presented, with details of the remaining integration program, the aim of which is to link transient eddy-currents seamlessly into these scanning systems.
What is TRECSCAN®?

- TRECSCAN® is a Prototype Transient Eddy Current Inspection System
- Unique Analysis Software that Includes:
  - Edge Subtraction (Correction)
  - Lift-Off Compensation
  - Total Thickness Measurement
  - Plate Separation Effect Elimination
  - Time Domain Eddy Current
Why Is TRESCAN® Different?

- Uses a Hall sensor as a field detector instead of a coil
- Eddy current pulses are generated using a coil and the Magnetic Field is measured using a Hall sensor
- Measures and captures the complete Transient data set
What is a Hall Sensor?

In a Semi Conductive Platelet, the Hall Voltage Is Generated by the Effect of an External Magnetic Field Acting Perpendicularly to the Direction of the Current.
Hall Sensor Advantages

• Hall sensors respond to a wide frequency range allowing the capture of detailed transient data sets.

• Hall sensors provide direct measurement of the magnetic field, essential for the application of analytical theory to the transient data.

• A Hall sensor as a field detector rather than a coil, improves the spatial resolution and the detectability of deep defects.
Transient Eddy-CURRENTS:

- Digitise time-domain response to coil-current reversal
- Use Hall sensor to measure transient magnetic field directly
- Scan to measure transient as a function of position, produce images, and store full transient data set
The Transient Eddy Current Method

Coil Current $i$

$\text{input current } i(t)$

$\text{time } t$

$H_z(t)$

$\Delta H_z(\text{defect})$

$H_z(\text{air})$

$H_z(\text{specimen})$

$H_z = H_z(\text{specimen}) - H_z(\text{air})$

Ferrite core

Drive coil

Hall effect sensor

First layer

Gap

Corrosion

Second layer
Transient signals from structural changes at different depths.
Separate C-scan images can be produced from each time-slice.

TRECSCAN® stores the transient response at an exponentially distributed sequence of time points, to exploit the fact that the transient response varies much more slowly later in time. This time-slice data is saved at each probe position, permitting post-processing of the data after acquisition.
Advantages of Transient Eddy Current

- Full frequency-range is captured in a data set
- Large areas of structure with multiple variations in thickness can be scanned without the need for probe or set-up changes
- The use of a Hall sensor as a field detector improves the spatial resolution and the detectability of deep defects.
- Structure variations can be optimised during analysis
- Advanced post-processing analysis tools
Post Analysis Tools

- Lift-off compensation
- Edge subtraction (correction)
- Total thickness measurement
- Plate separation effect elimination
- Timeslice viewing
- Time domain signal processing
The Transient Eddy Current Signal Includes a Plethora of Information, Hence the Processing of the Transient Data Set is Very Important.

TRECSCAN® includes unique analytical software that untangles the different contributing responses in the transient data set as a post process analysis. This software includes:

- **Lift-off compensation** The lift-off compensation algorithm eliminates signals from variations in probe lift-off caused by variable gap in multiple-layered structures.

- **Edge subtraction** The edge subtraction algorithm helps remove signals due to edges and other systematic variations in substructures.
Lift-Off Problem DC10 Crown Splice

Layers:
1) Exterior Strap
2) Skin Panels
3) Finger Doublers
4) Longeron
5) Doublers

Probe Lift-Off from .063” Strap

Graphic Courtesy of QinetiQ Ltd.
Lift-Off Compensation
DC10 Crown Splice

Without L/O Compensation

With L/O Compensation

DC10 Specimen Courtesy Sandia National Labs, AANC
Edge Subtraction on a DC10 Crown Splice Joint

With L/O Comp

With Edge Subtraction

EDM NOTCHES
DC10 Time-Slice Examples

Time-Slices Later in Time Represent Lower Frequencies
A method for measuring the time to the peak of a balanced transient can be used to produce simple time-of-flight scans, which can be related to depth in the structure. For a given defect type the Time-To-Peak value should increase with defect depth. A calibration is required in order to calculate unknown defect depths.
Metal loss measurement in TRECSCAN® is accomplished using an analytical method that calculates percentage change in total metal thickness relative to the balance point. This method gives a percentage material loss that does not need to be calibrated, provided certain criteria are met from the assumptions of the underlying theory.
System Integration Objectives

- Integrate TRECSCAN ® into the MAUS IV ® C-scan system
- Couple TRECSCAN ® with the Ultra Image ® C-scan system
- Evaluate C-scan data collection techniques to demonstrate production environment inspection capabilities
Original TRECSCAN® System

TRECSCAN®
DLL

ANDSCAN® 2000
Software

TRECSCAN®
Interface Box

Probe: Hall Sensor
TRECSCAN®+MAUS IV®

TRECSCAN®
DLL

ANDSCAN® 2000 Software

TRECSCAN® Interface Box

MAUS IV® + Digital Position Output Card

Proof of Concept Version

Probe: Hall Sensor
TRECSCAN®/MAUS IV® INTEGRATION

TRECSCAN®
DLL

MAUS IV®
TRECSCAN® BOARD

Operator Interface Familiarity

Probe: Hall Sensor
TRECSCAN®+Ultra Image® Integration

TRECSCAN®

DLL

ANDSCAN® 2000 Software

Interface Box

Ultra Image® Scanning System

ANDSCAN ® Operator Interface

Probe: Hall Sensor
Technology Assessment

• Conduct experiments to access the range of capabilities for the TRECSCAN® transient eddy current system

• Special consideration being given to the detection and characterization of cracks and corrosion located on typical Air Force aluminum aircraft skin/structure:
  – Back side of the first layer
  – Top side of the second layer.
  – Back side of the second layer and deeper
Plans for the Future

- Focus on completing the system integration
- Conduct extensive system testing
- Demonstrate System Capabilities in Real World Trials
- Develop and Implement Aircraft/Problem Specific Inspection Procedures
Project Team Members

NDT Solutions, Inc.
The Boeing Company
QinetiQ Ltd.
SAIC Ultra Image International
Universal Technology Corporation
U. S. Air Force AFRL

With the combined corrosion detection and quantification experience of these projects partners, we are excited, and looking forward to discovering the future capabilities of TRESCAN®
References


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