Inspection of Shot Peened Engine Components in Regions with Fretting Damage

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MWM sensors and MWM-Arrays covered by issued and pending patents, including, but not limited to:
5,793,206; 5,966,011; 6,144,206; 6,188,218 B1; 6,198,279 B1; 6,277,691 B2; 6,995,557 B2; 6,992,482 B2; 6,952,095 B1; 6,798,198 B2; 6,784,662 B2; 6,781,387 B2; 7,188,532 B2; 7,183,764 B2; 7,161,351 B2; 7,161,350 B2; 7,106,055 B2; 7,095,224, B2; 7,049,811 B2; 6,657,429 B1; 6,486,873 B1; 6,420,876; 6,380,747 B1; 6,377,039; 6,351,120 B1; RE39,206 E.
Outline

- Technology Overview
- Disk Slot Inspection
- Blade Dovetail Inspection
- Cracks at Edges
- Bolt Hole Inspection
- Adaptive Life Management and Risk Assessment
- Optional Baseline Subtraction
Technology Overview
Sensors, Systems, Software, and Algorithms

MWM®-Arrays and IDED®-Arrays
- Patented scanning and embeddable Eddy Current Sensor
- Patented IDED sensor and IDED-Arrays

GridStation® Systems
- Portable and Hand-Held versions

GridStation® Software using Hyperlattices™
- Performs multivariate inverse methods – i.e. fast, autonomous data analysis for decision support in NDT, CBM and SHM

Fuzzy-Hyperlattices
- Remaining Useful Life Prediction (RUL) and rapid uncertainty estimation
“Air” Calibration
Improves Robustness & Ease of Use

Air Calibration Point

Senses & Elements

Crack Response

Lift-Off

Crack (22 points)

Blue Background (~1,500 points)

Full Grid

Conductivity

Lift-Off

Patents Issued and Pending
Grid Methods
Automatically Rescales Crack Response with Lift-Off Variation

Therefore C-Scan Image **Threshold** is Independent of Lift-off
Independent Conductivity and Lift-off Imaging

- Grid Methods convert impedance into conductivity and lift-off at each point in the image
Automated Blade Dovetail Inspection
Engine Components at FRC-SE Jacksonville, FL

Patents Issued and Pending
Automated Blade Dovetail Inspection

- Inspect for cracks (goal: 0.015 in. x 0.008 in.)

MWM-Array FA57

Sensor Coverage

Scan Paths of Individual Sensing Elements

Individual Sensing Elements
Automated MWM-Array Blade Dovetail Inspection

Sensor position at edge of dovetail

Sensor position halfway down dovetail

Blade Dovetails

MWM-Array Probe

MWM-Array Sensor

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Patents Issued and Pending
Conductivity/Lift-off Measurement Grid
Blade Dovetail Inspection

Crack Signature

89-mil crack cluster with largest crack length 40 mils

Number of Points on Crack = 250

Patents Issued and Pending
Filtered MWM-Array Results

Note:
Training Set Blade “with Known Cracks”

Convex Side

Corner 2

Corner 3

42-mil Long Crack

Concave Side

Corner 1

Corner 4

75-mil Crack Cluster
(Maximum Crack Length 50 mils)

Results with Lower Threshold*

*Lower threshold designed to detect smaller cracks by increasing
sensitivity, but this may also increase false indication rate

Filtering MWM-Array Results

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Filtered MWM-Array Results

Note:
Training Set Blade Identified Prior to MWM-Array Inspection as Having “No Cracks”
Detection of Cracks at Edges with GridStation Edge Location Correction

Conductivity/Lift-Off Images (Unfiltered)
Detection of Cracks at Edges
with Edge Location Correction and Spatial filtering, using Signature Libraries

Filtered Response

Conductivity Signature

Channel 2, Lift-Off Factor = -0.69

0.30 in.

Channel 3, Lift-Off Factor = -0.96

Channel 3, Lift-Off Factor = -0.47

Patents Issued and Pending
Signature Library
Hand Held Bolt Hole Scanner

- 1st generation product
- Removable cartridges with MWM-Arrays
- One rotation
- Plunge to find position
Crack Detection / C-Scan Imaging for Bolt-holes
Without bushings

C-Scan

B-Scan

Lift-Off

Grid

Patents Issued and Pending
Rapid Risk Assessment from NDT Data

Component Adaptive Life Management (CALM) software

Cumulative probability distributions for crack size at Time $t_1$

Cumulative probability distributions for crack size at Time $t_2$

Cumulative probability distributions for cycles remaining to reach critical crack size (0.08 in.)
CALM™ Services
Component Adaptive Life Management

- POD curve generation for NDT & embedded sensors
- Risk assessment & RUL estimation
- Fleet transition support
- After market decision support
Fatigue Specimen and Scanner
for Signature Library Generation
IN718 MWM-Array Fatigue Coupon

Front side scans

0.034 in. crack cluster on front

Back Side Scans

0.113 in. crack on back

Patents Issued and Pending
Optional Difference Imaging or Baseline Subtraction
Improves Signal-to-Noise Levels to Reliably Detect Smaller Cracks

- Average of 5 repeated scans
- Difference between averaged responses for 2% crack length
- S/N > 5
- 2.8 mil growth in crack length

Channel 12

Position (inches)

Conductivity

- Crack Length
- 15 kCycles, a = 6.1 mils
- 21 kCycles, a = 8.9 mils

Titanium Alloys
A514 Grade B Steel Results

Raw data

Data with baseline subtraction

Crack on front side @43,000 cycles

Crack on back side @43,000 cycles

Patents Issued and Pending
Questions?