2011 Defense Working Group
December 7, 2011
Williamsburg, VA

Inspection of Shot Peened Engine Components in Regions with Fretting Damage

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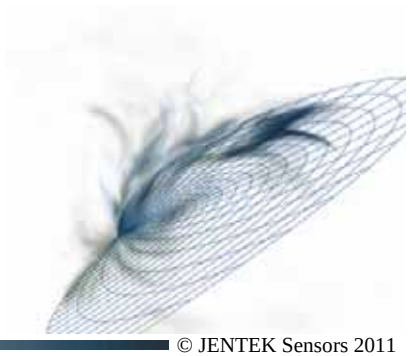
7 December 2011

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; 6,727,691 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; 6,486,673 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

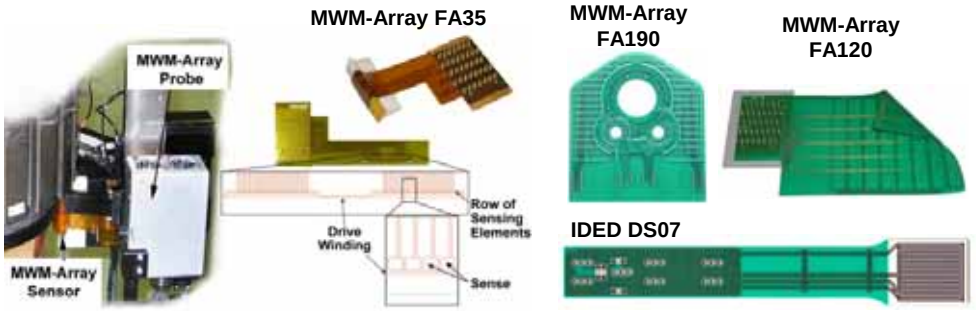


Technology Overview

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

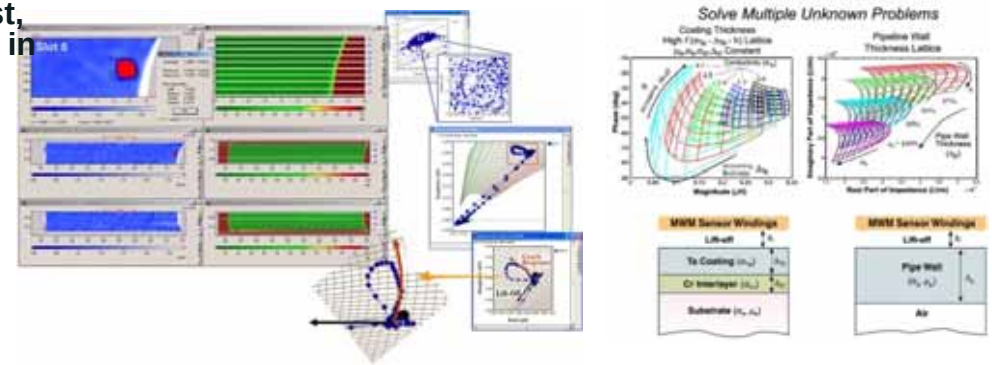
- Portable and Hand-Held versions

GridStation® Software using Hyperlattices™

- Performs multivariate inverse methods – i.e. fast, autonomous data analysis for decision support in NDT, CBM and SHM

Fuzzy-Hyperlattices

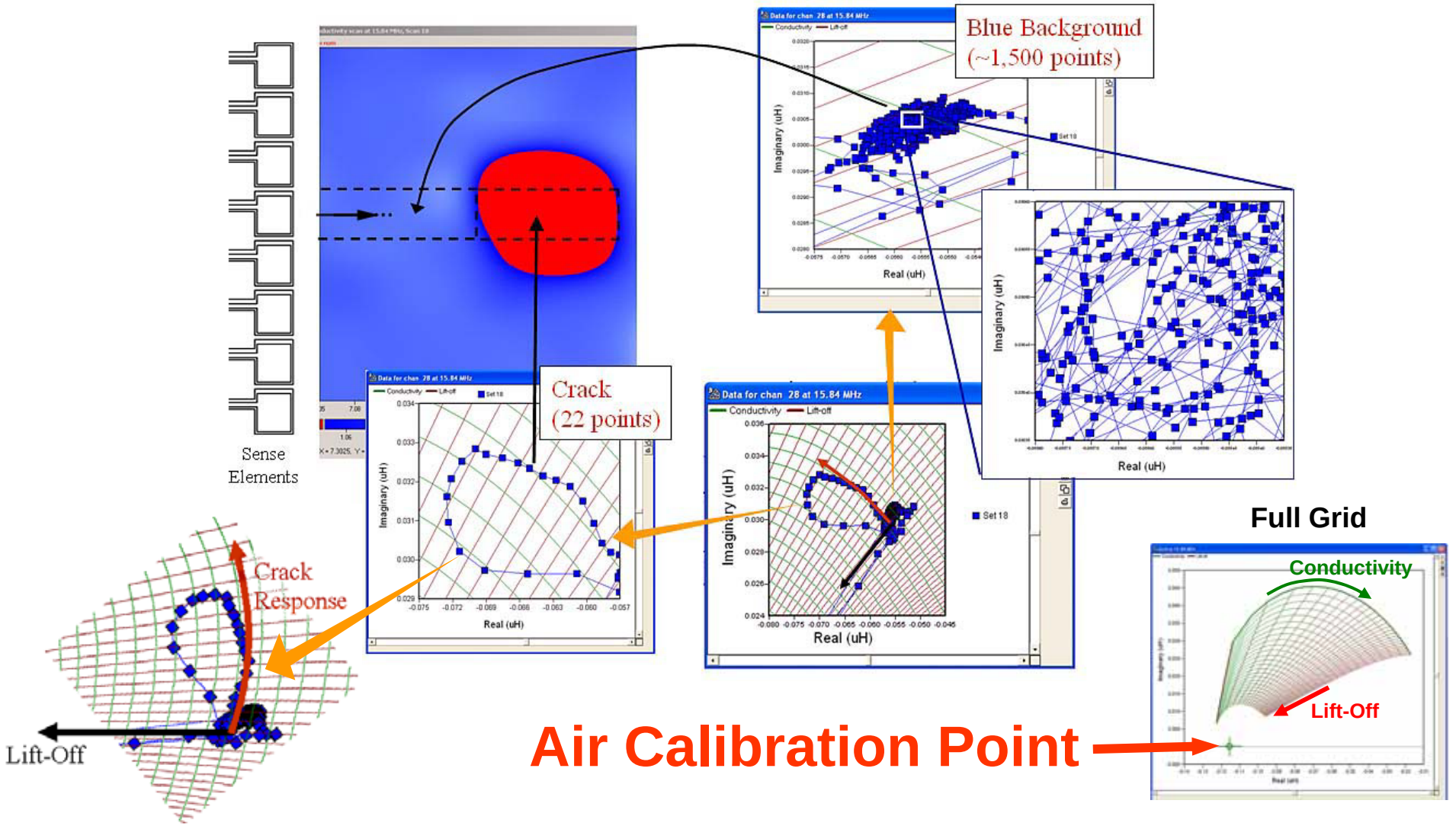
- Remaining Useful Life Prediction (RUL) and rapid uncertainty estimation



Patents Issued and Pending

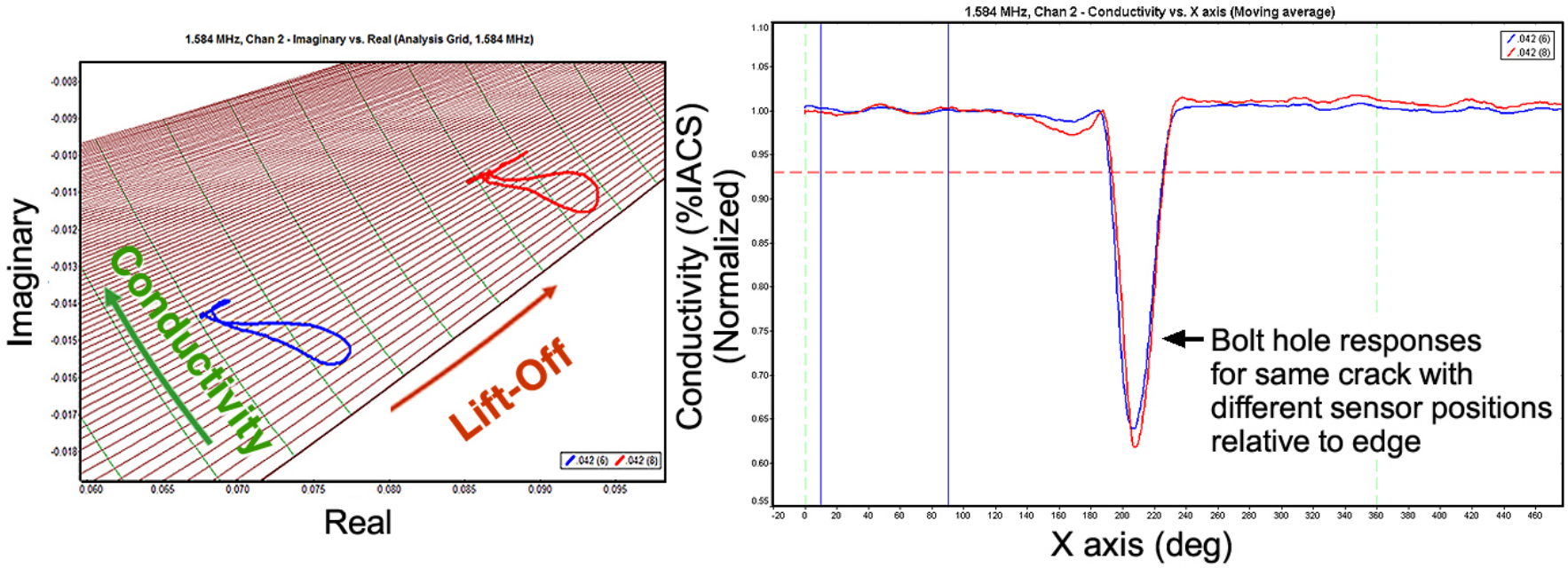
“Air” Calibration

Improves Robustness & Ease of Use



Grid Methods

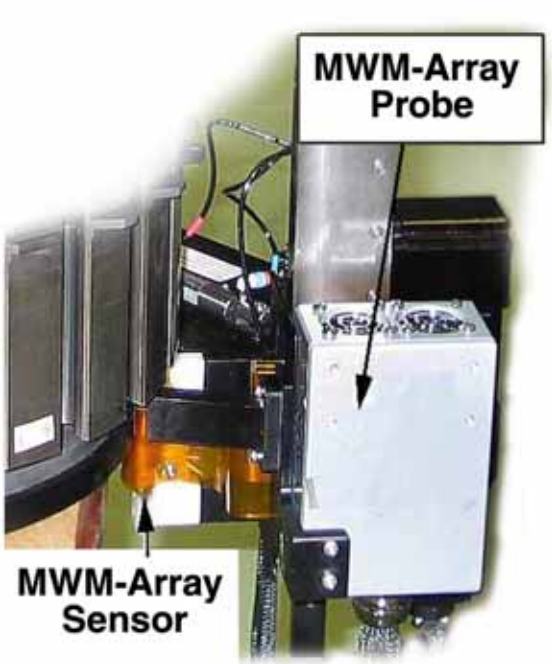
Automatically Rescales Crack Response with Lift-Off Variation



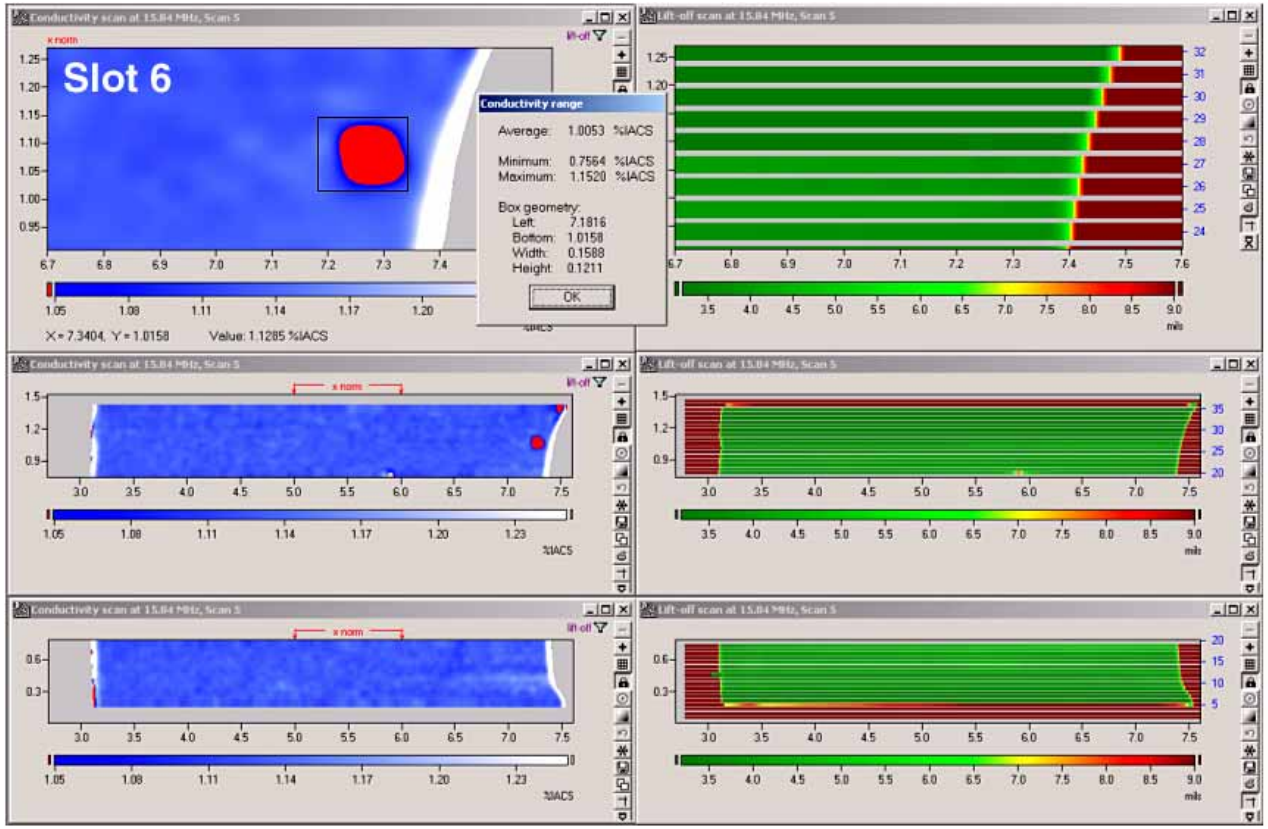
Therefore C-Scan Image Threshold is Independent of Lift-off

Independent Conductivity and Lift-off Imaging

- Grid Methods convert impedance into conductivity and lift-off at each point in the image

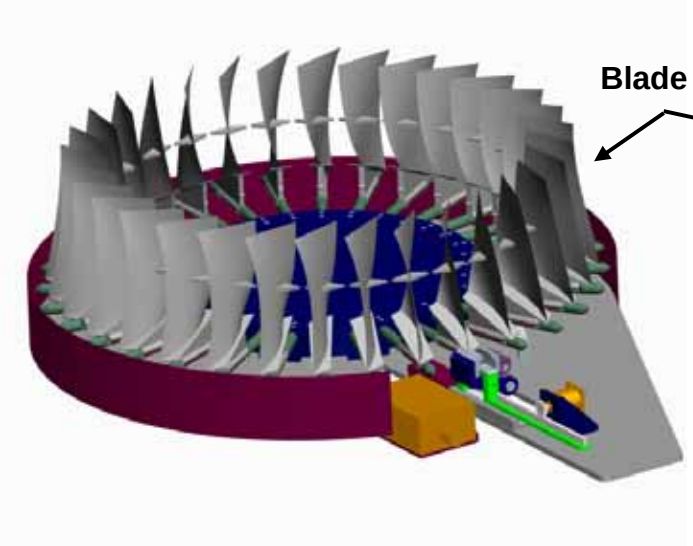


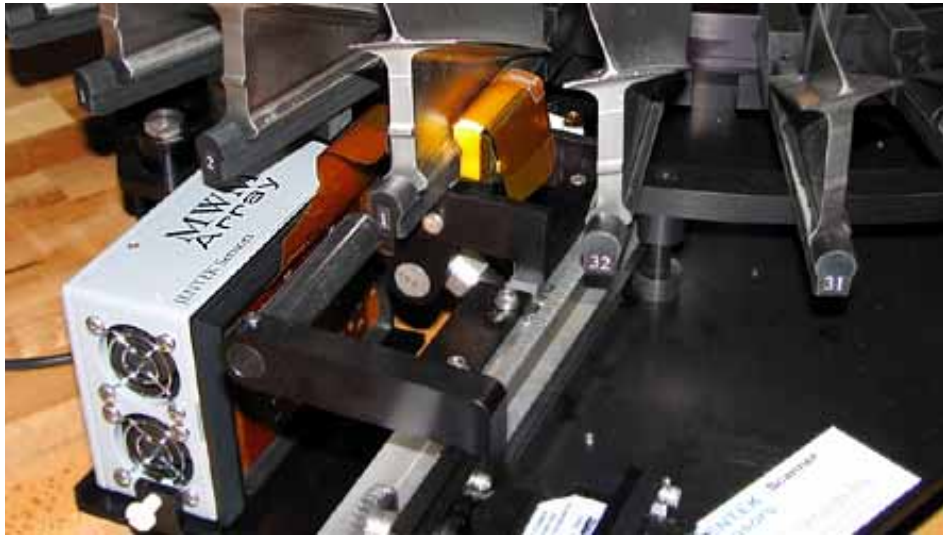
Conductivity **Lift-Off**



Automated Blade Dovetail Inspection

Engine Components at FRC-SE Jacksonville, FL



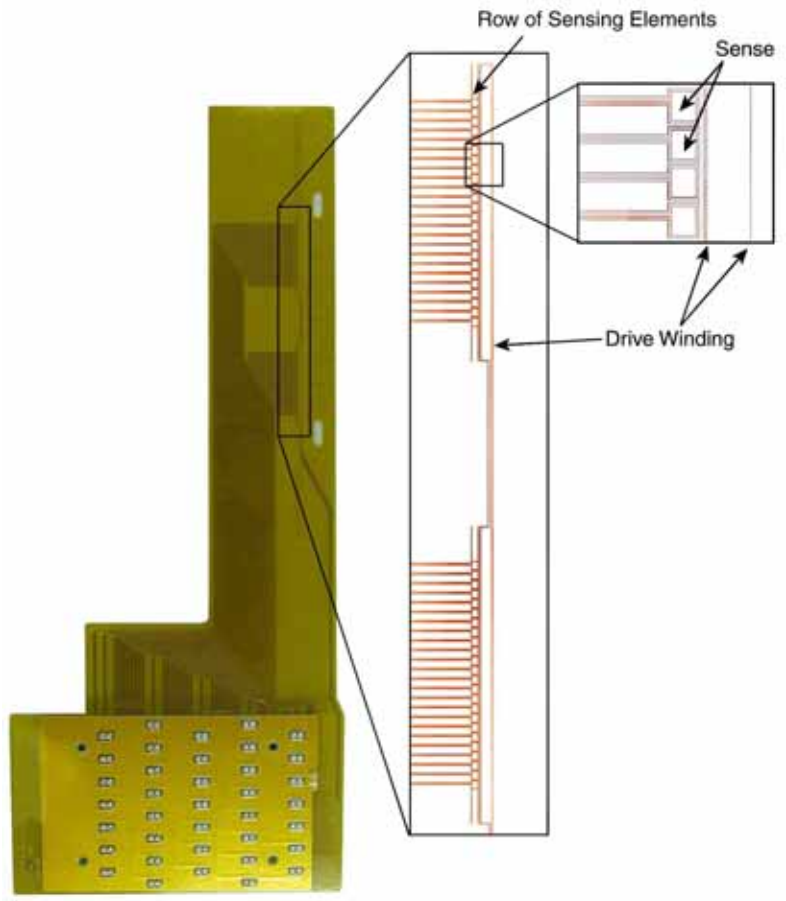


Patents Issued and Pending

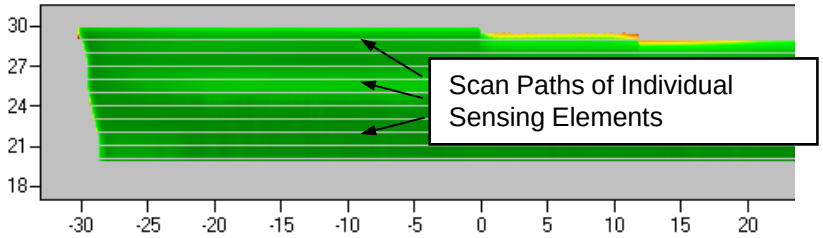
Automated Blade Dovetail Inspection

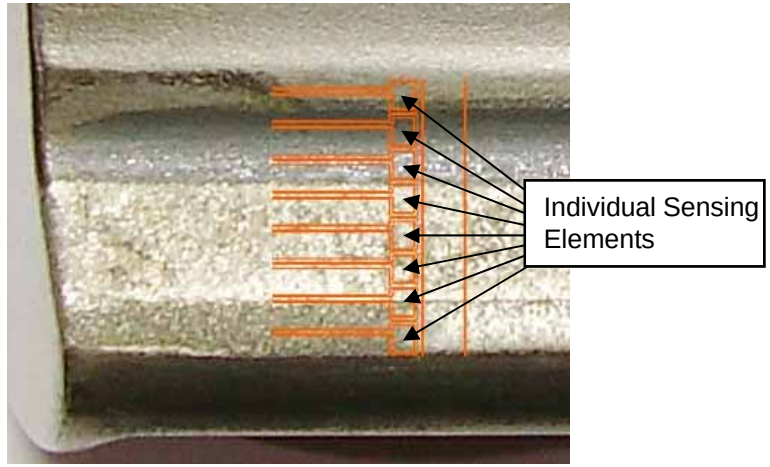
- **Inspect for cracks (goal: 0.015 in. x 0.008 in.)**

MWM-Array FA57



Sensor Coverage

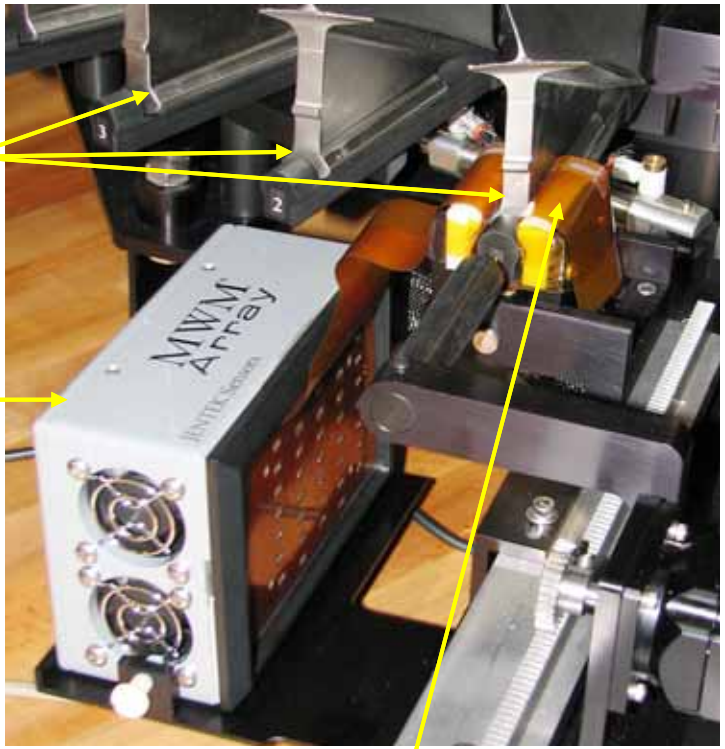




Automated MWM-Array Blade Dovetail Inspection

Blade Dovetails

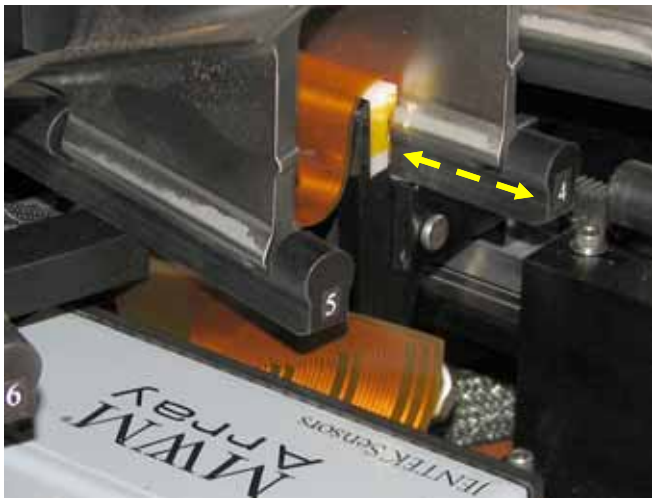
MWM-Array Probe



MWM-Array Sensor

Sensor position at edge of dovetail

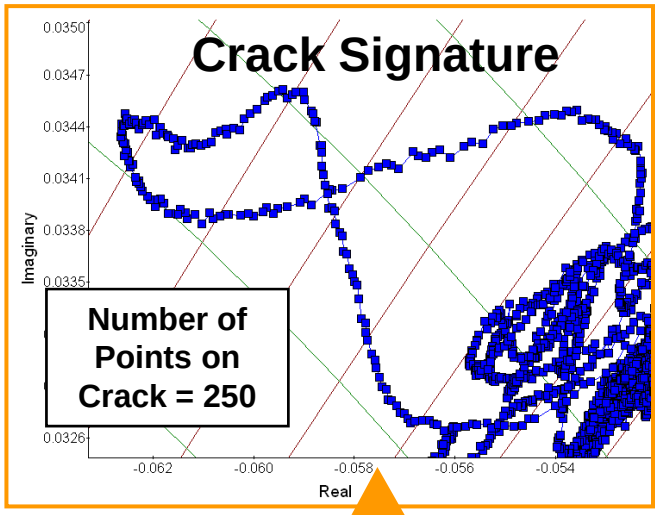
Sensor position halfway down dovetail



Patents Issued and Pending

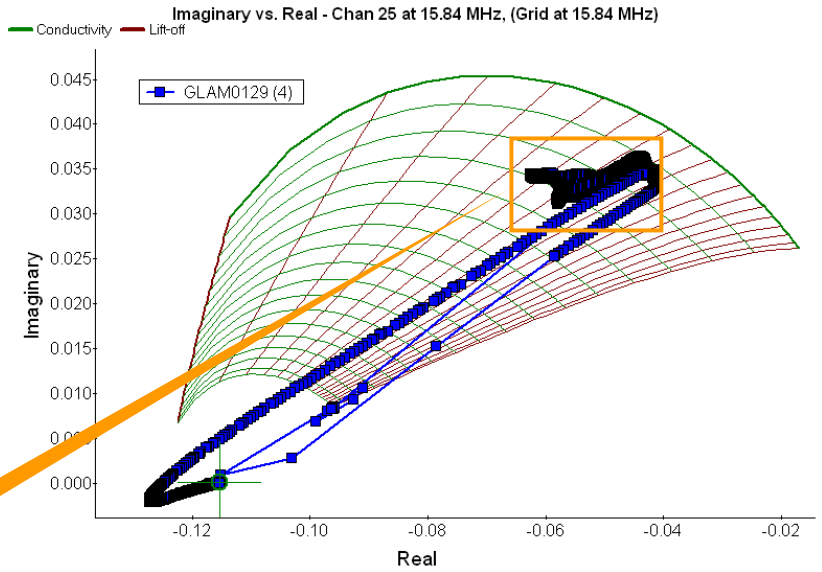
Conductivity/Lift-off Measurement Grid

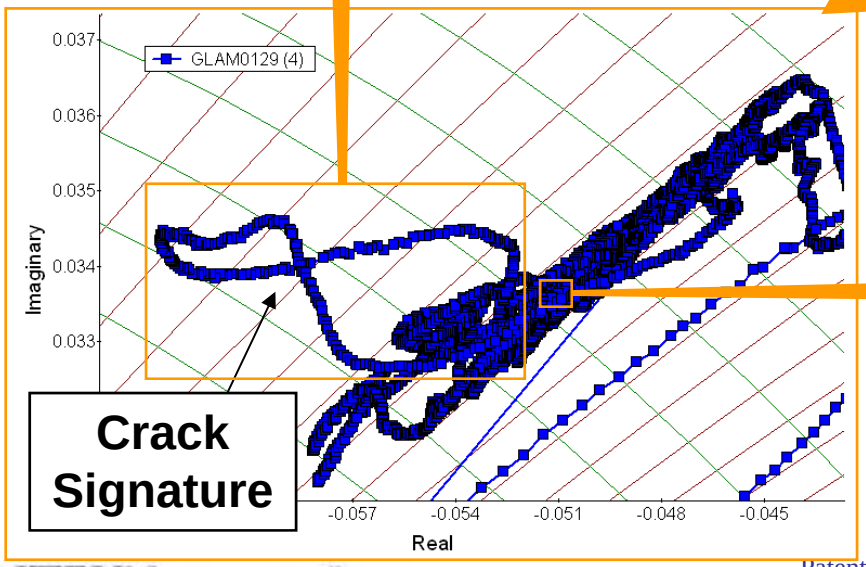
Blade Dovetail Inspection



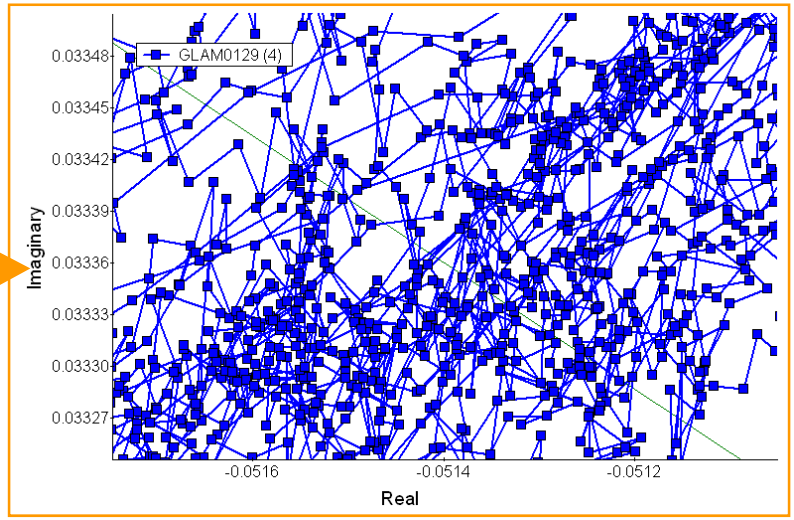
89-mil crack cluster with largest crack length 40 mils

Number of Points on Crack = 250





Crack Signature



Patents Issued and Pending

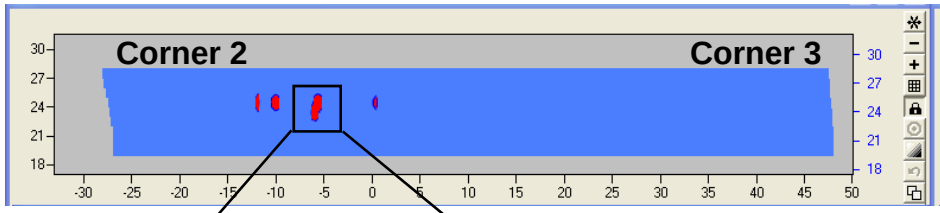
Filtered MWM-Array Results

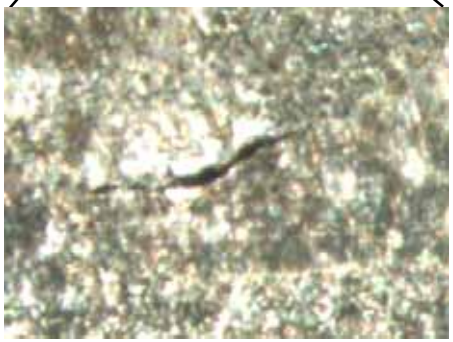
Note:

Training Set Blade “with Known Cracks”

Results with Lower Threshold*

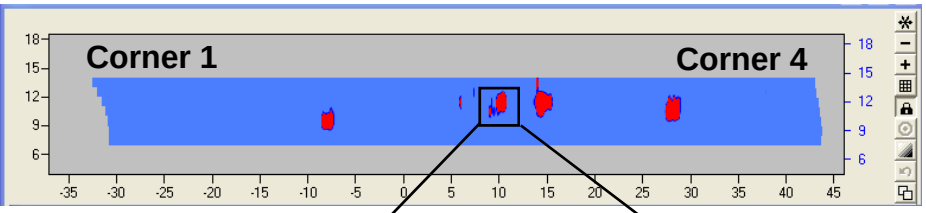
Convex Side

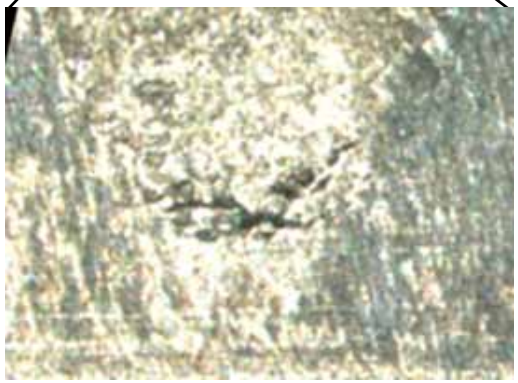




42-mil Long Crack

Concave Side





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

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

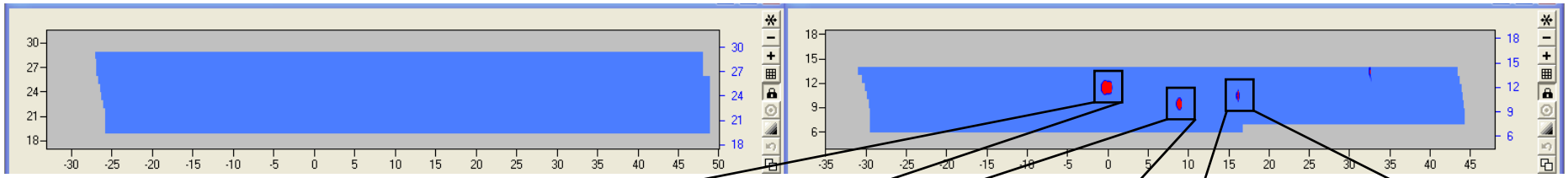
Filtered MWM-Array Results

Note:

Training Set Blade Identified Prior to MWM-Array Inspection as Having “No Cracks”

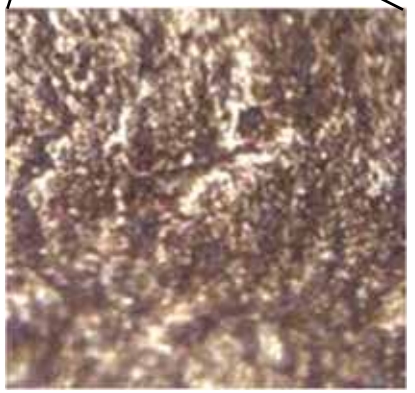
Convex Side

Concave Side



20-mil Crack

15-mil Crack

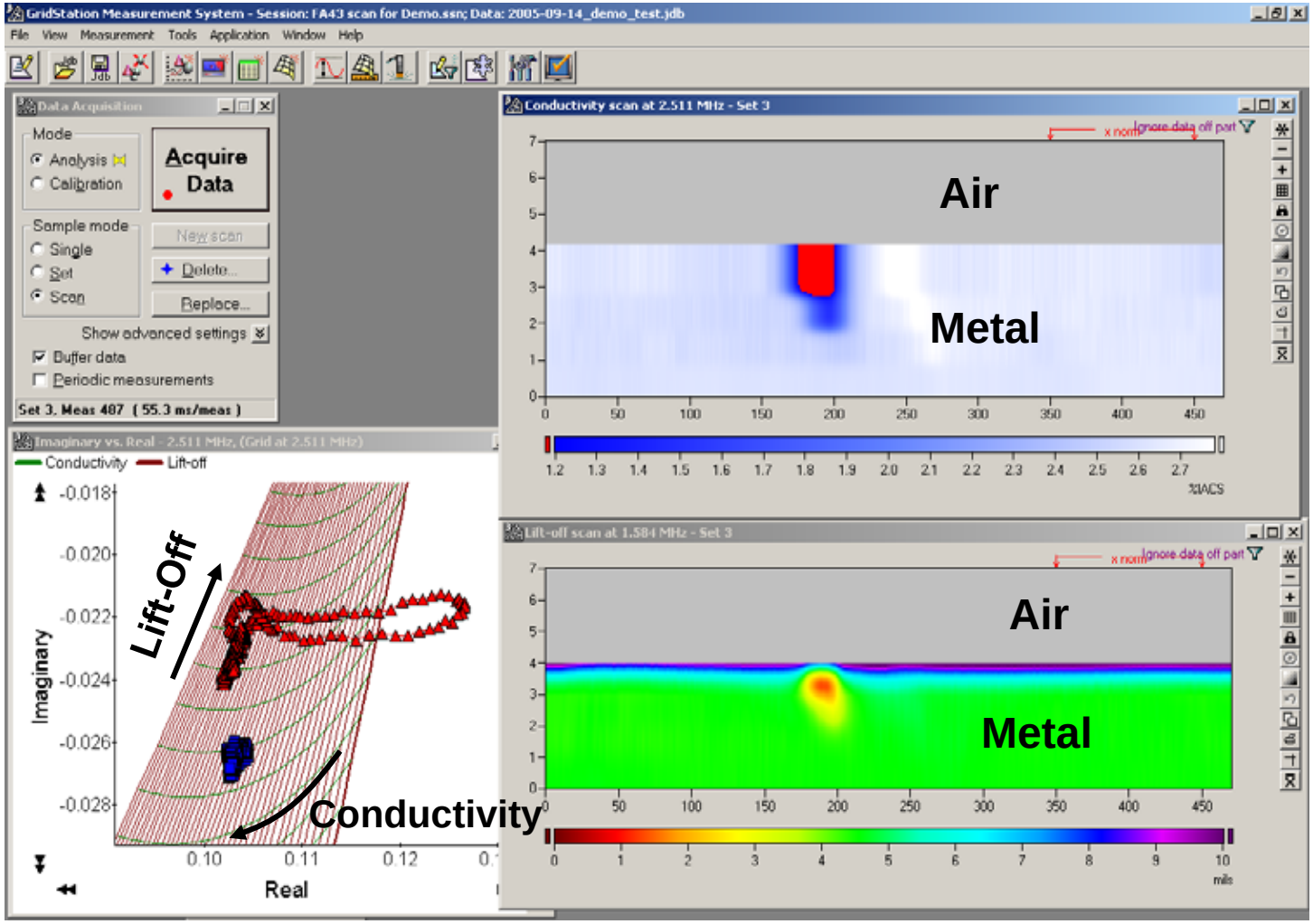


15-mil Crack

Detection of Cracks at Edges

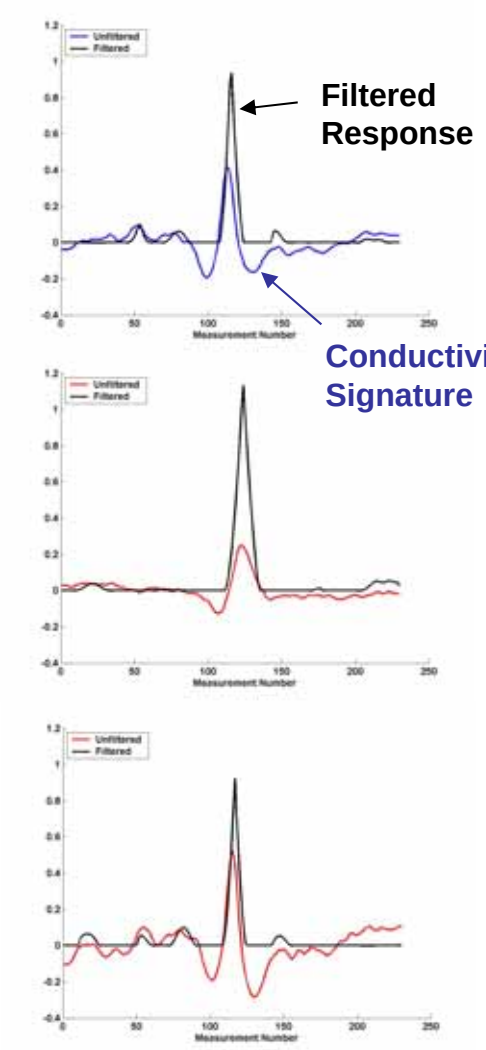
with GridStation Edge Location Correction

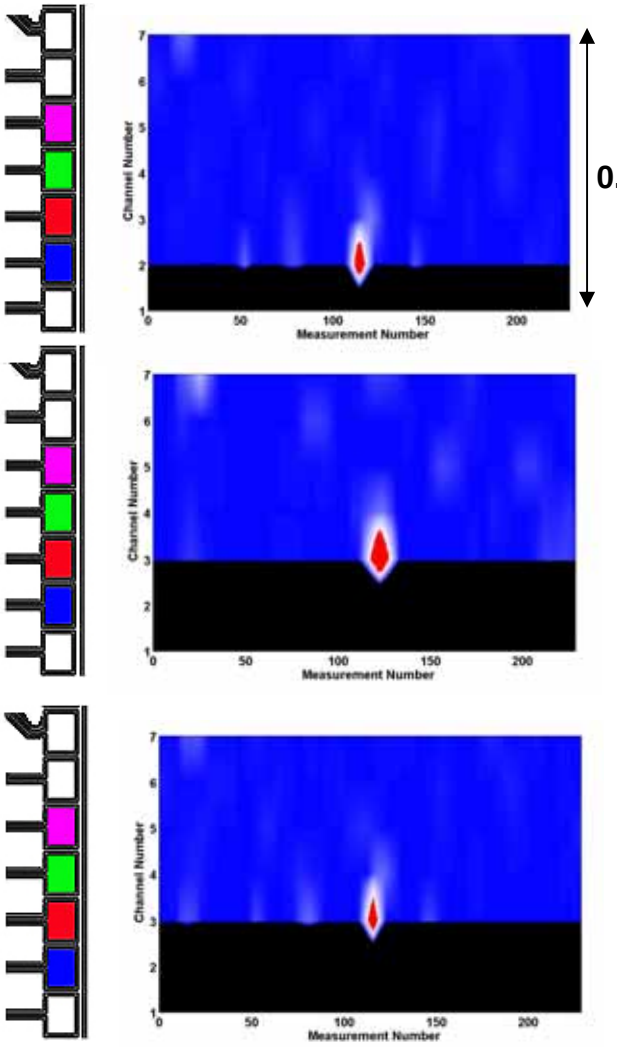
Conductivity/Lift-Off Images (Unfiltered)



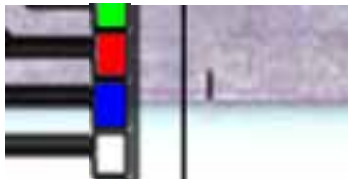
Detection of Cracks at Edges

with Edge Location Correction and Spatial filtering, using Signature Libraries





Channel 2, Lift-Off Factor = -0.69

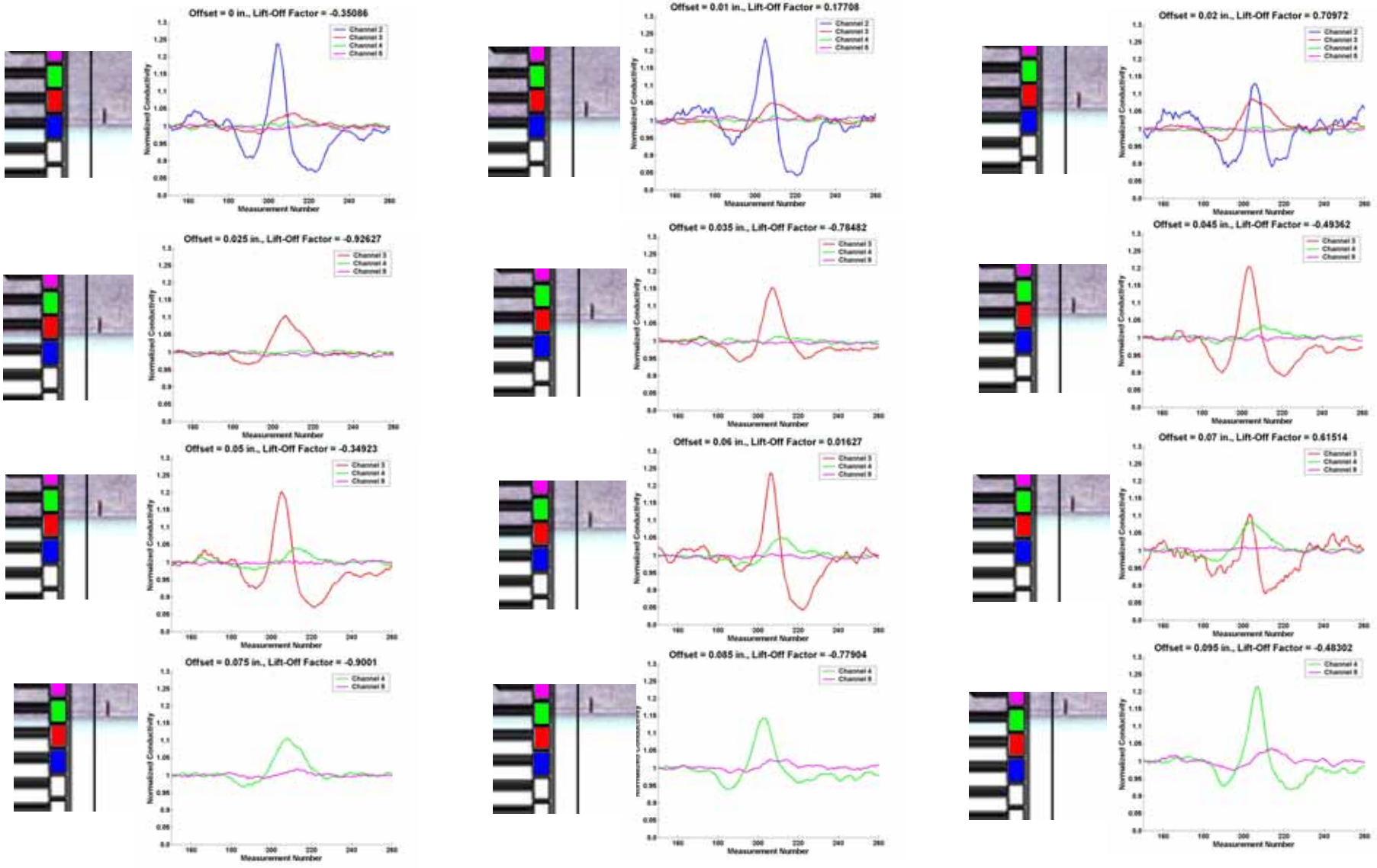


Channel 3, Lift-Off Factor = -0.96

Channel 3, Lift-Off Factor = -0.47

Patents Issued and Pending

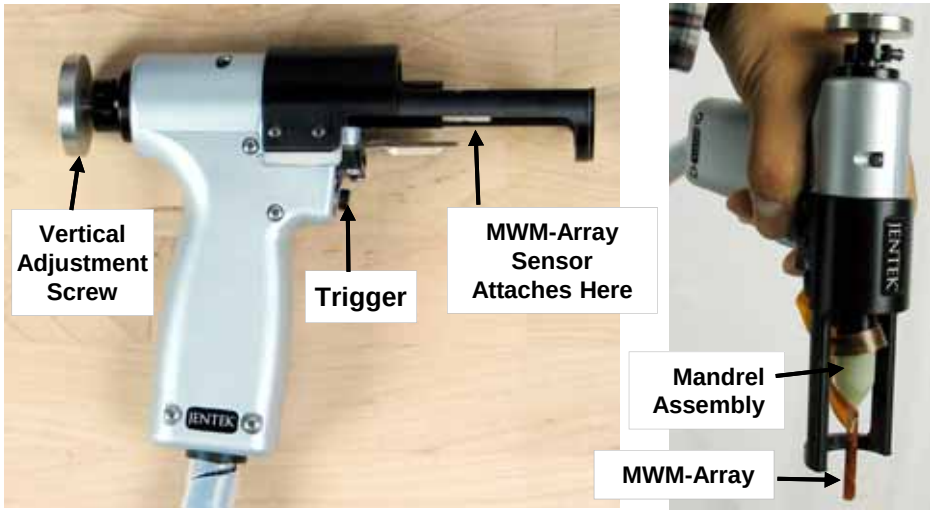
Signature Library



Patents Issued and Pending

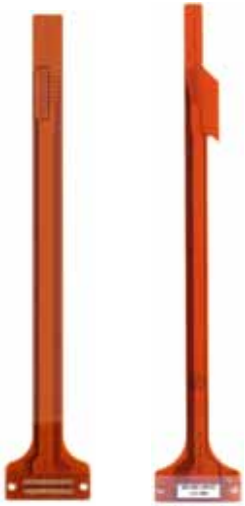
Hand Held Bolt Hole Scanner

- 1st generation product
- Removable cartridges with MWM-Arrays
- One rotation
- Plunge to find position



Mandrel Assembly with interchangeable MWM-Arrays

FA166 FA182



Patents Issued and Pending

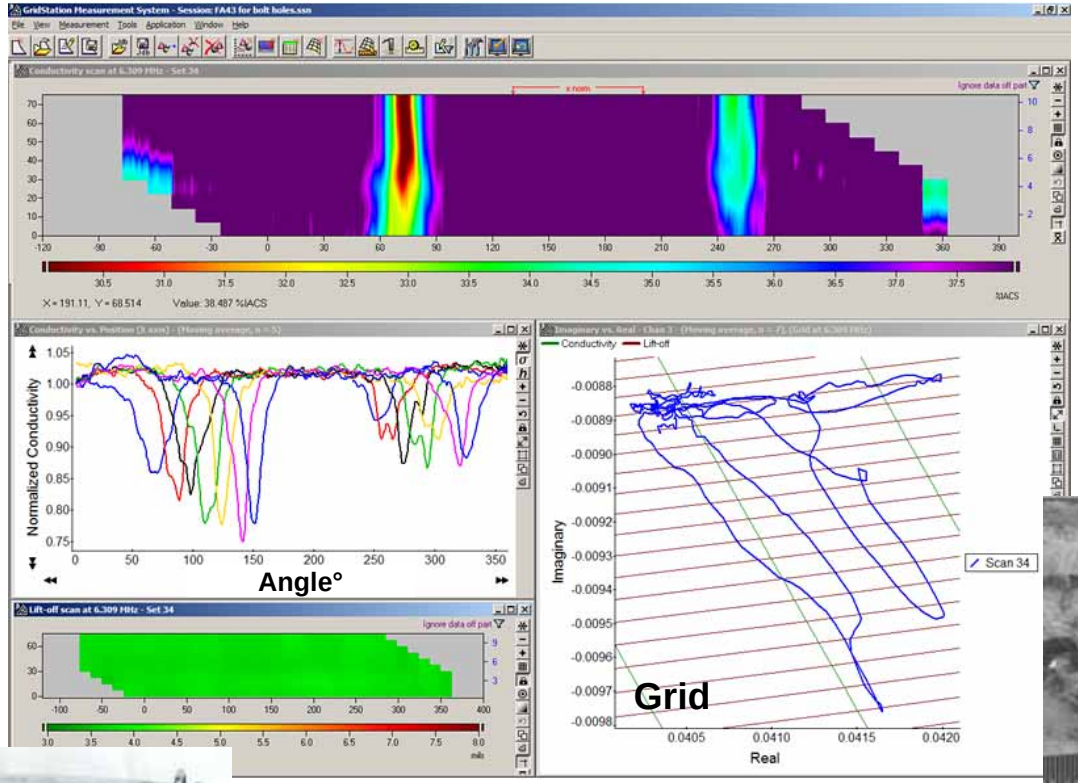
Crack Detection / C-Scan Imaging for Bolt-holes

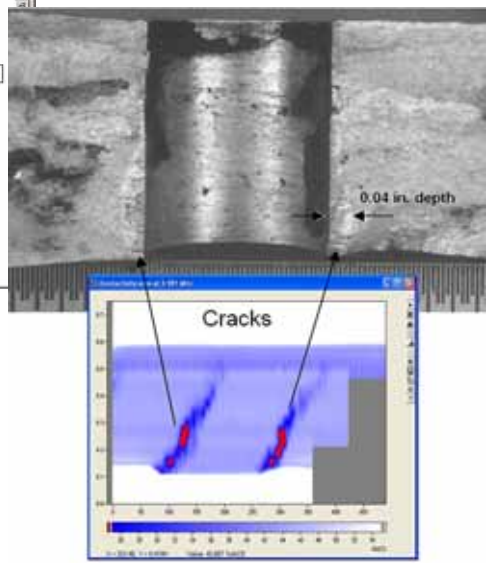
Without bushings

C-Scan

B-Scan

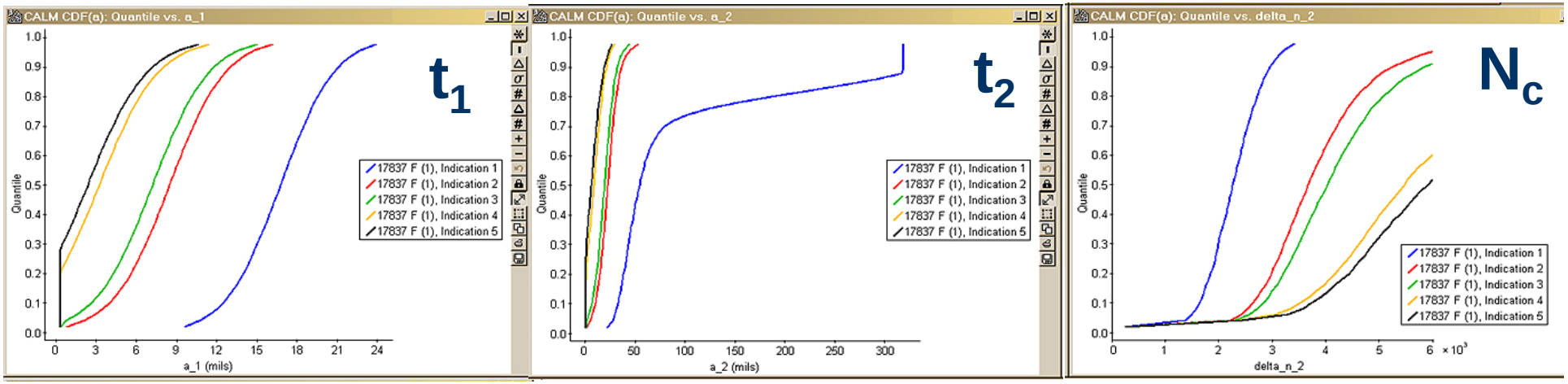
Lift-Off





Rapid Risk Assessment from NDT Data

Component Adaptive Life Management (CALM) software



Cumulative probability distributions for crack size at Time t_1

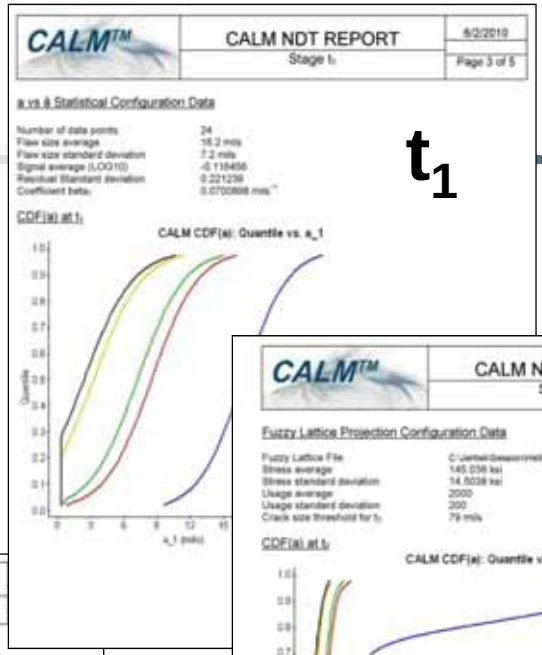
Cumulative probability distributions for crack size at Time t_2

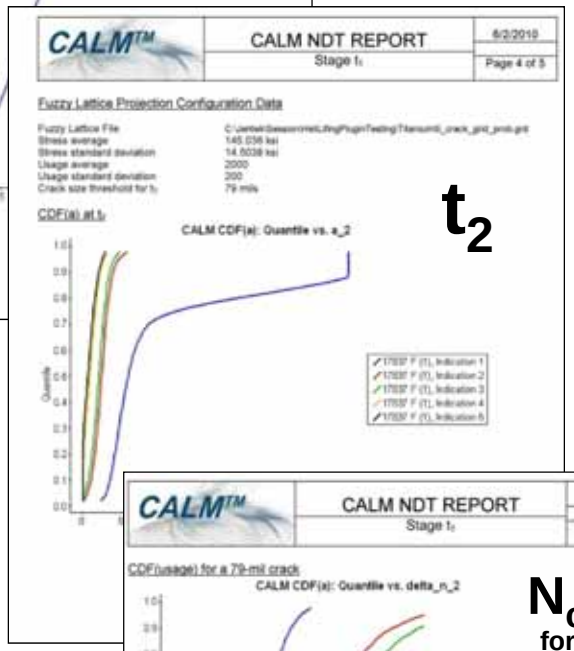
Cumulative probability distributions for cycles remaining to reach critical crack size (0.08 in.)

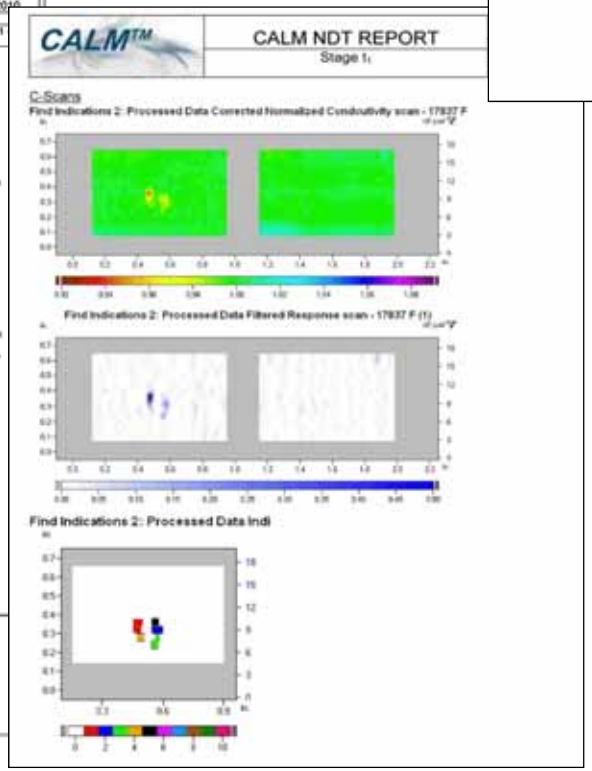
CALM™ Services

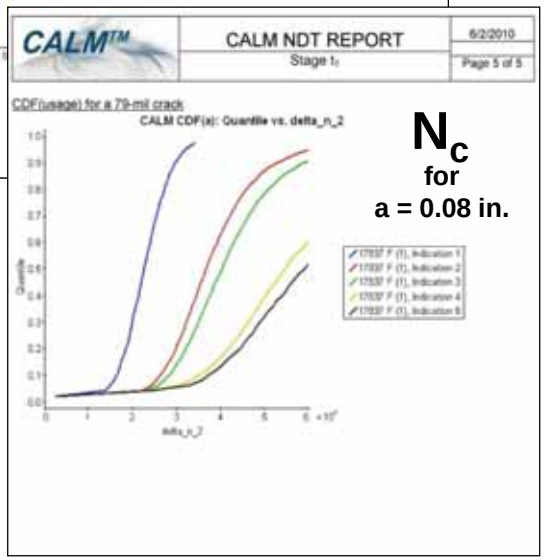
Component Adaptive Life Management

- POD curve generation for NDT & embedded sensors
- Risk assessment & RUL estimation
- Fleet transition support
- After market decision support



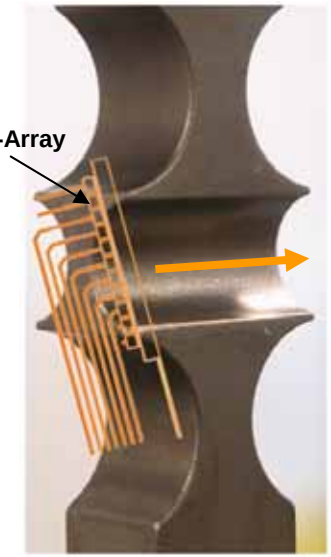




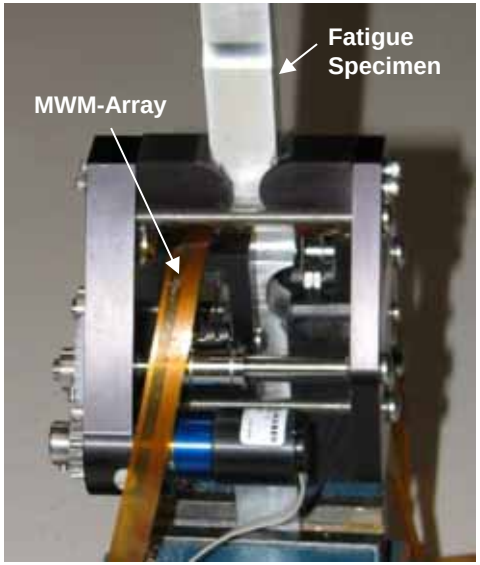


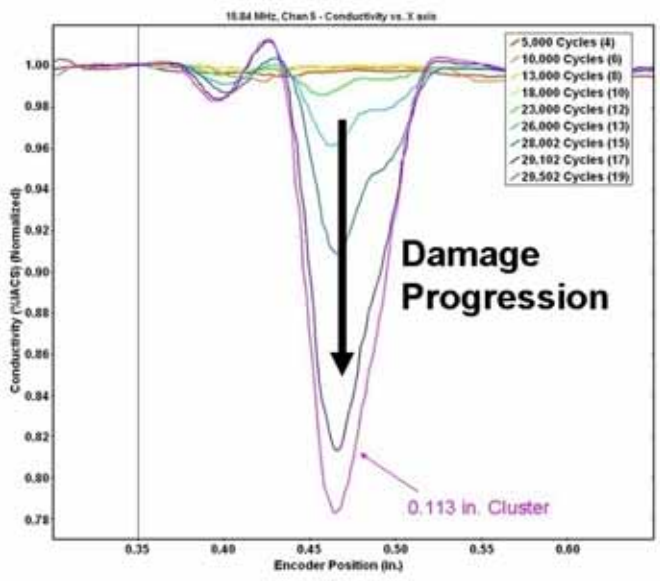
Patents Issued and Pending

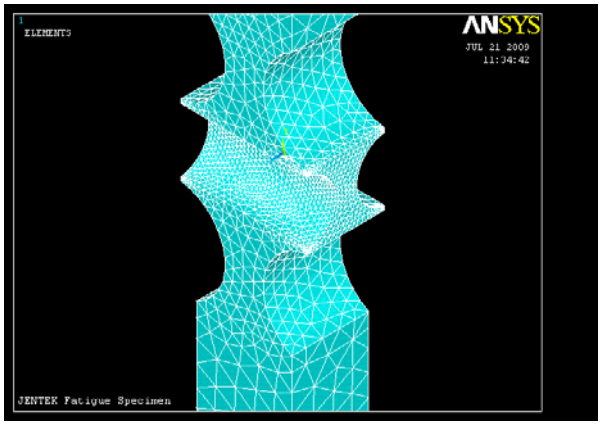
Fatigue Specimen and Scanner
for Signature Library Generation

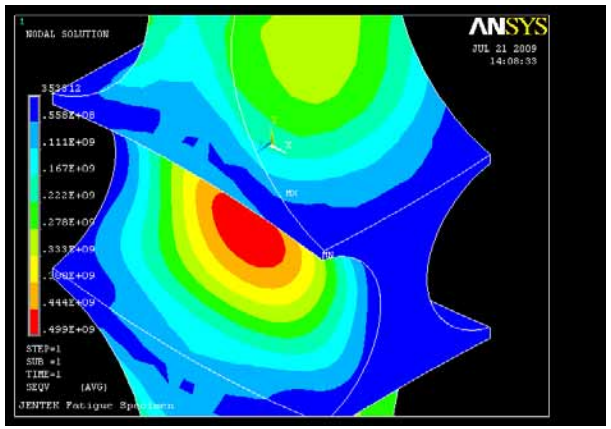


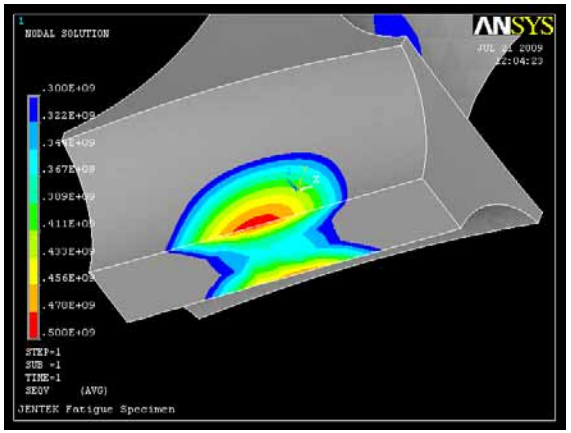
Scan Direction





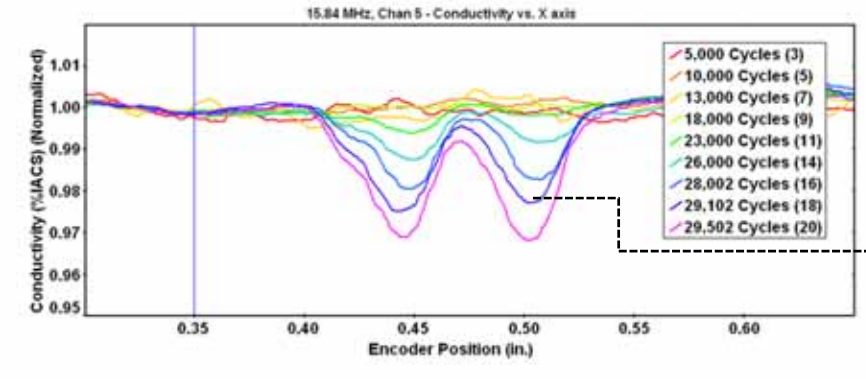




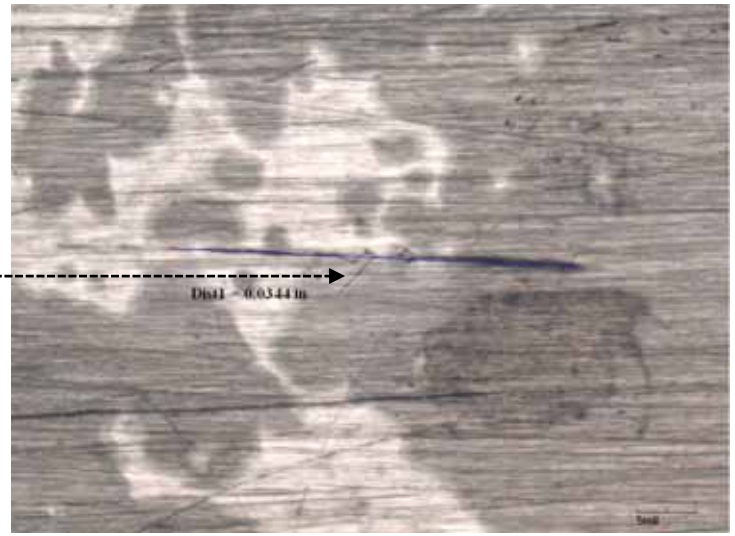


IN718 MWM-Array Fatigue Coupon

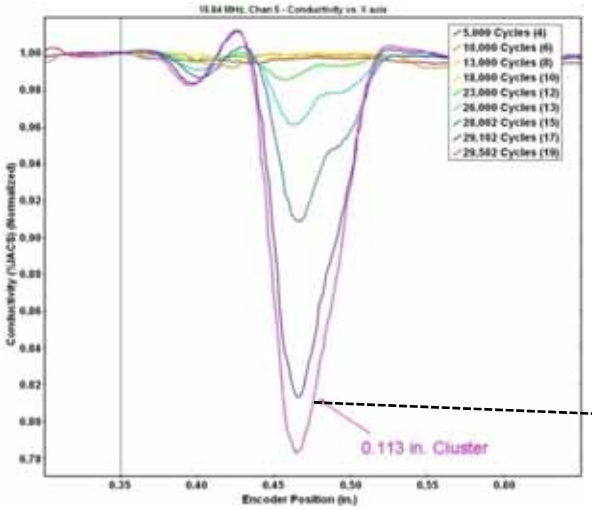
Front side scans



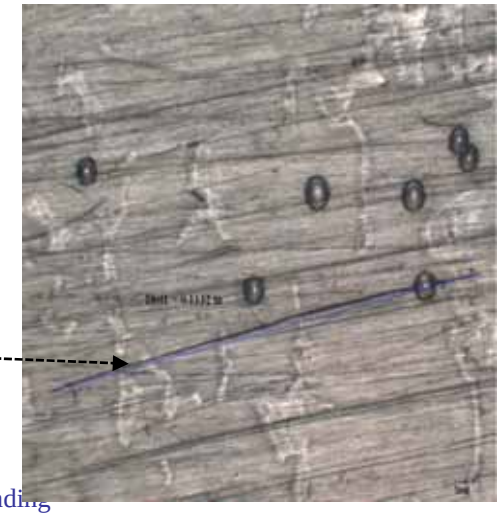
0.034 in. crack cluster on front



Back Side Scans

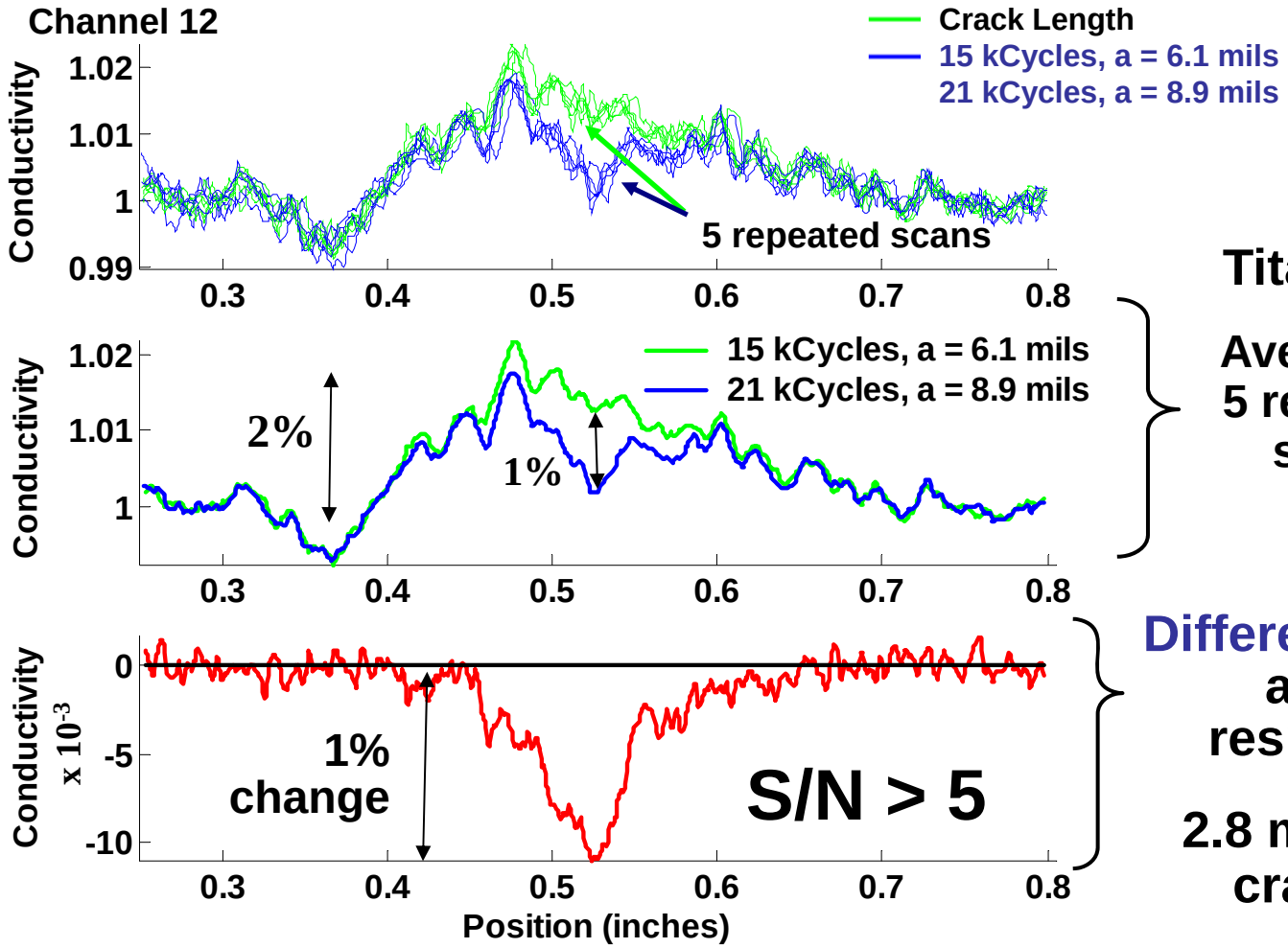


0.113 in. crack on back



Optional Difference Imaging or Baseline Subtraction

Improves Signal-to-Noise Levels to Reliably Detect Smaller Cracks



Titanium Alloys

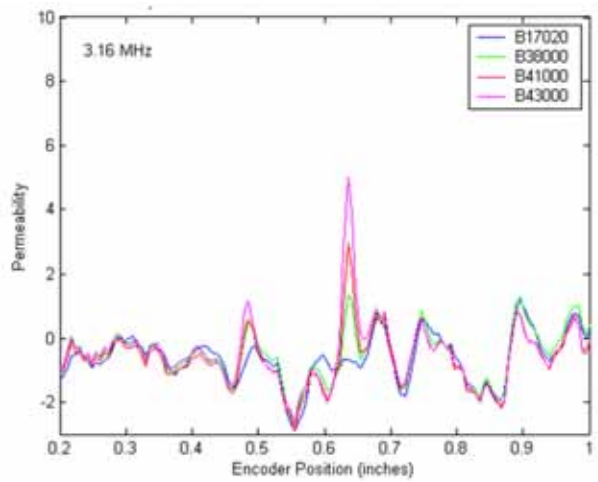
Average of 5 repeated scans

Difference between averaged responses for

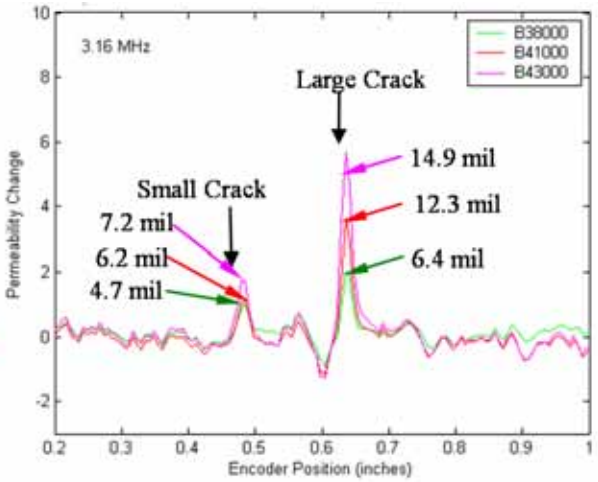
2.8 mil growth in crack length

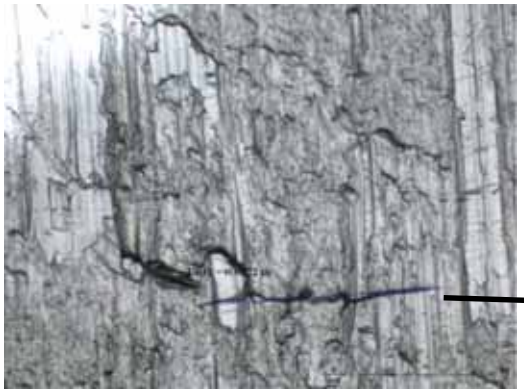
A514 Grade B Steel Results

Raw data

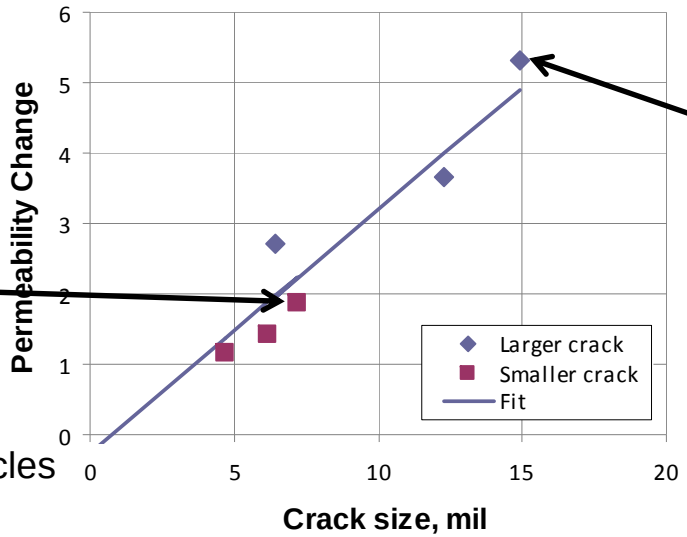


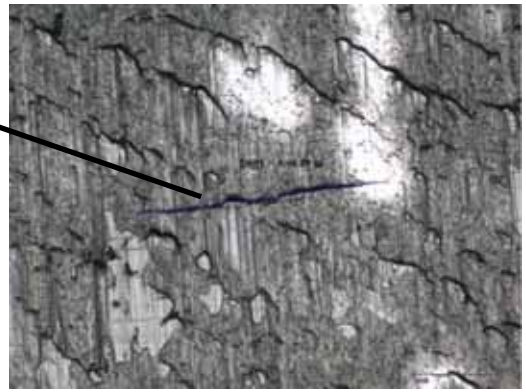
Data with baseline subtraction





Crack on front side @43,000 cycles





Crack on back side@43,000 cycles

Patents Issued and Pending

Questions?