Nondestructive Inspection (NDI) Committee Overview

Engineered Residual Stress Implementation (ERSI) Workshop

12 September 2019

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[1]Materials and Manufacturing Directorate, System Support Division

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- NDI Subcommittee Membership
- Summary of Current Knowledge
- Gaps
- Committee Priorities
- Progress to Date
- NDI Implementation Strategy

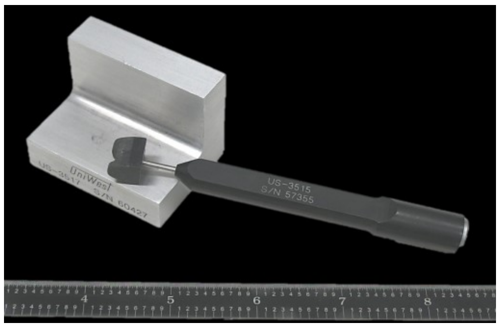
NDI Committee Members

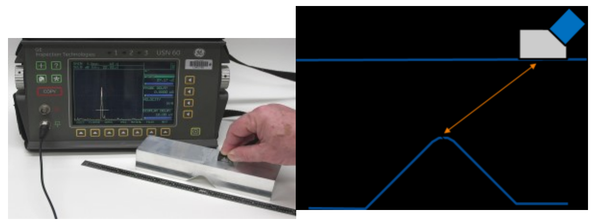
Title	First Name	Last Name	Company/Organization
Mr.	Fred	Acosta	U.S. Marine Corp (F-5 NDI Lead)
Mr.	John	Brausch	U.S. Air Force (AFRL - NDE Lead Engineer, Systems Support)
Mr.	Nicholas	Brunnell	Engineer, NDI SME AFSC/ENRB OL Robins
Mr.	Dave	Campbell	U.S. Air Force (Tinker AFB NDI Program Office Lead)
Dr.	Teodor	Dogaru	Southwest Research Institue (SwRI)
Mr.	Ward	Fong	U.S. Air Force (Hill AFB NDI Program Office Lead)
Mr.	Dave	Forsyth	Texas Research International (TRI) - Austin, Inc.
Mr.	Leo	Garza	L3 Communications (RC-135 Fleet Manager)
Mr.	Bryce	Harris	U.S. Air Force (F-16 ASIP Manager)
Dr.	Kim	Jones	U.S. Air Force (F-16 ASIP)
Mr.	Doyle	Motes	Texas Research International (TRI) - Austin, Inc.
Mr.	Tommy	Mullis	U.S. Air Force (Warner Robins AFB NDI Program Office Lead)
Mr.	Mike	Reedy	U.S. Navy (NAVAIR - Compression Systems Engineer)
Dr.	Gregory	Shoales	U.S. Air Force (Center for Aircraft Structural Life Extension (CAStLE) - Director)
Mr.	Clint	Thwing	Southwest Research Institue (SwRI)
Mr.	Jacob	Warner	U.S. Air Force (A-10 ASIP Analysis Group Lead)
Mr.	David	Wilkinson	U.S. Air Force (C-5 ASIP Manager)

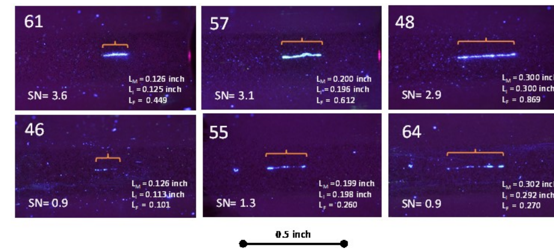
Summary of Current Knowledge

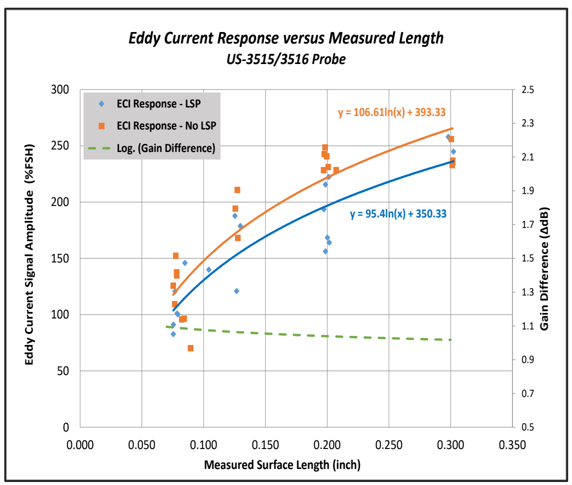
Laser Shock Peening

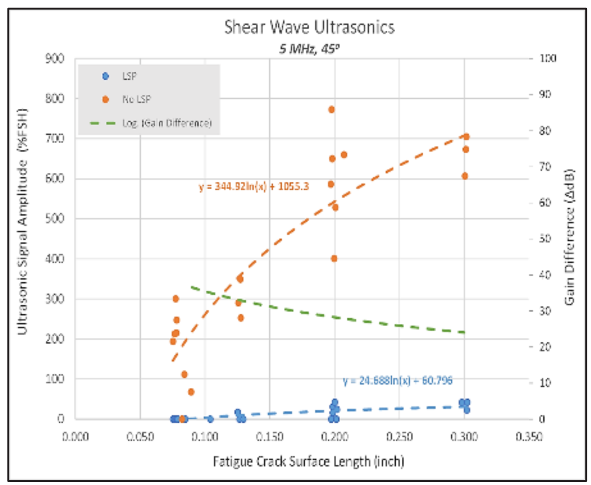
Eddy Current	Ultrasonics	Fluorescent Penetrant

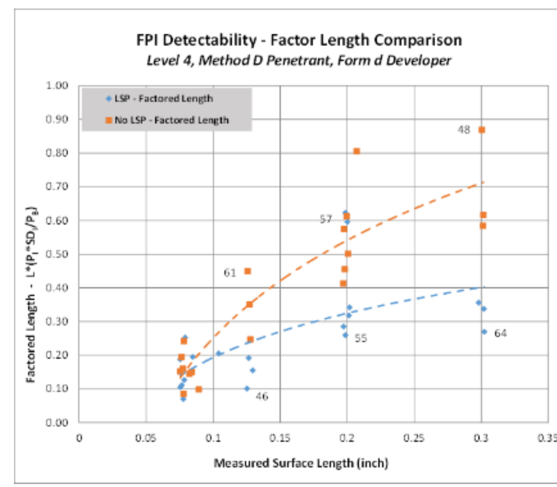












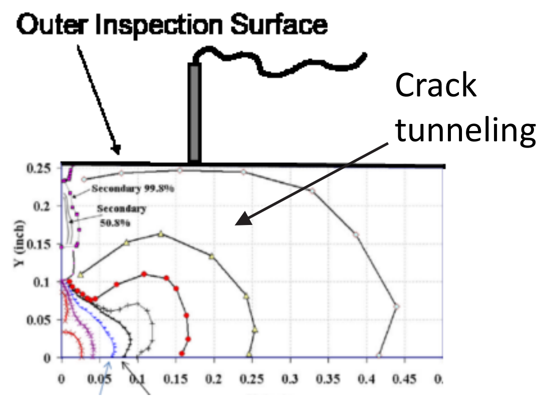
Minimal Impact	Significant Impact	Significant Impact

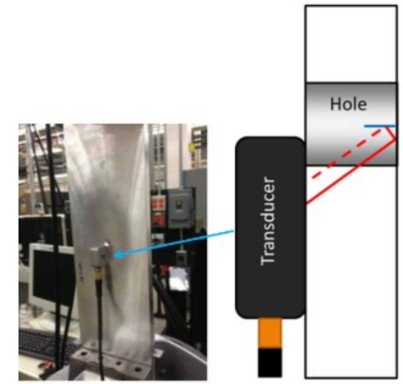
Hole Cold Working: Eddy Current, Ultrasonics

Rotary Hole Eddy Current

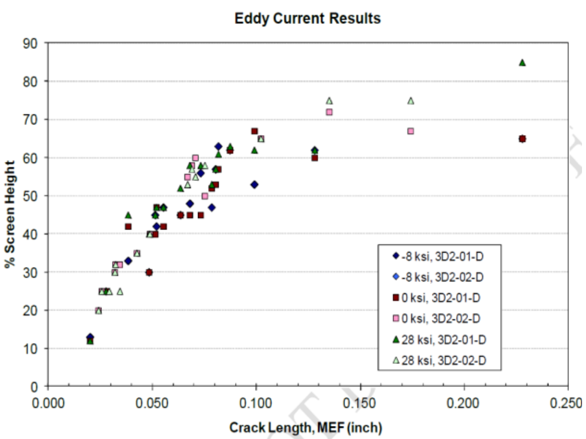
Surface Eddy Current

Ultrasonics

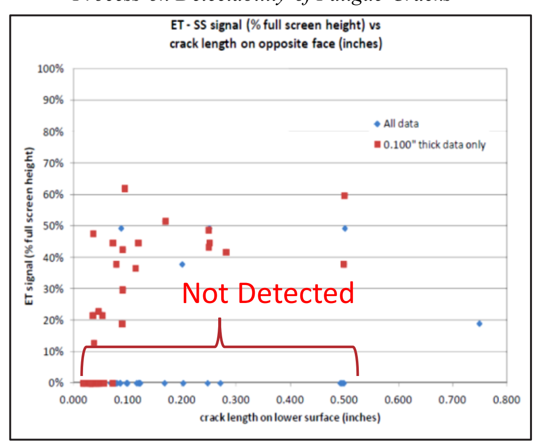




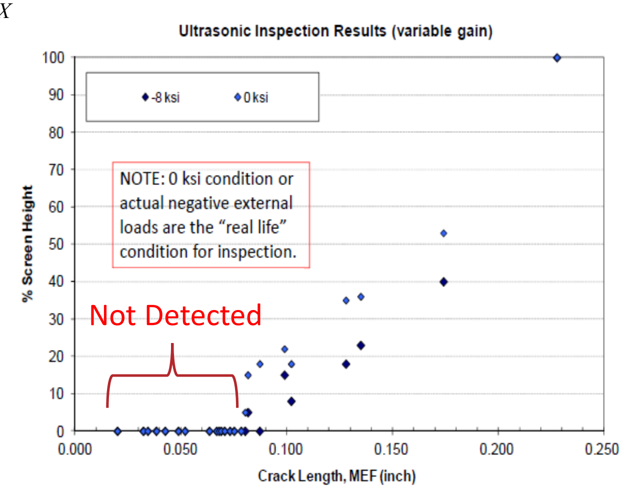
Forsythe, D., Mills, T. "Results of Study of Applied Stress and CX Process on Detectability of Fatigue Cracks"



Minimal Impact

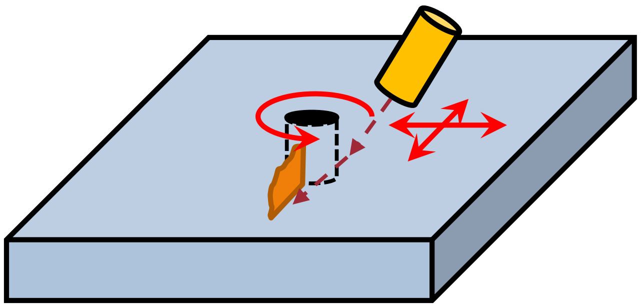


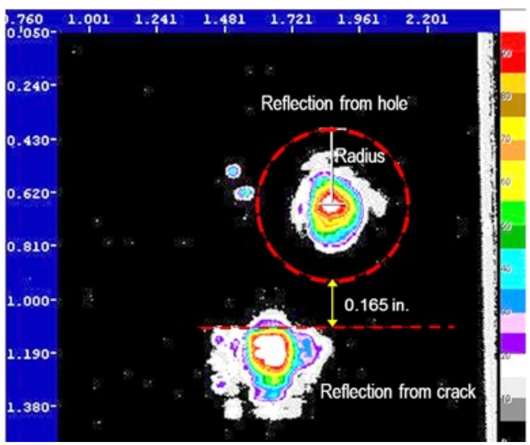
Significant Impact

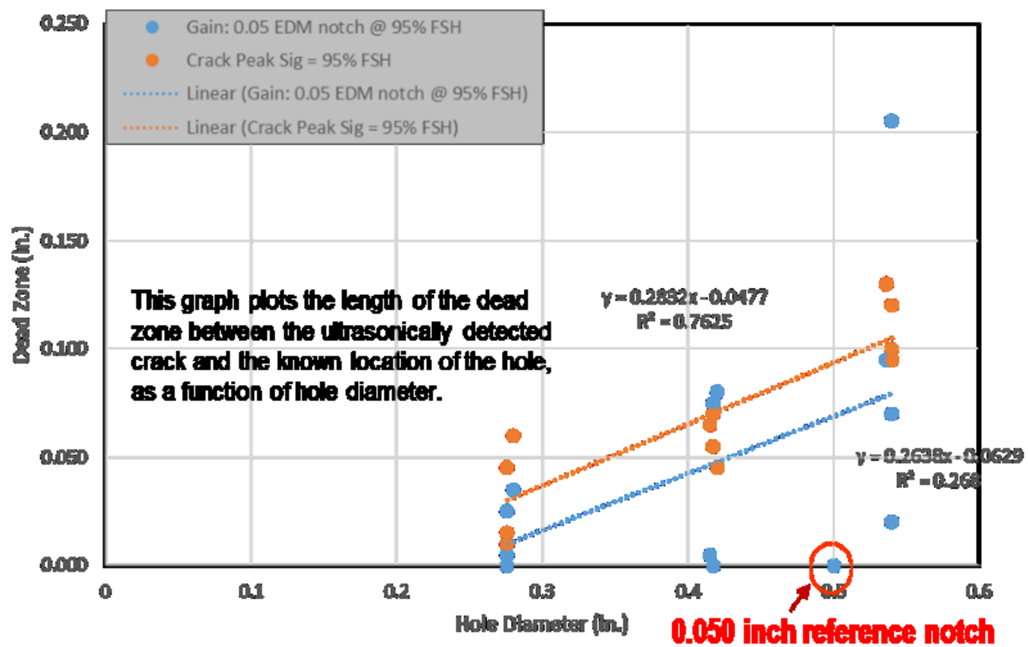


Significant Impact

Ultrasonic “Dead-Zone” in Cx Holes







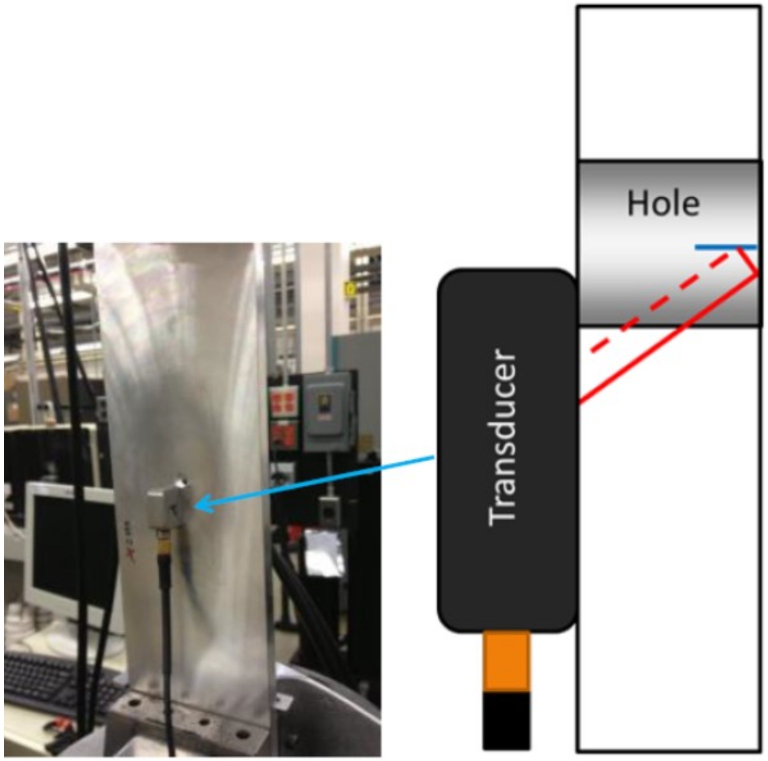
D. Stubbs, AFRL/RXSA - UDRI

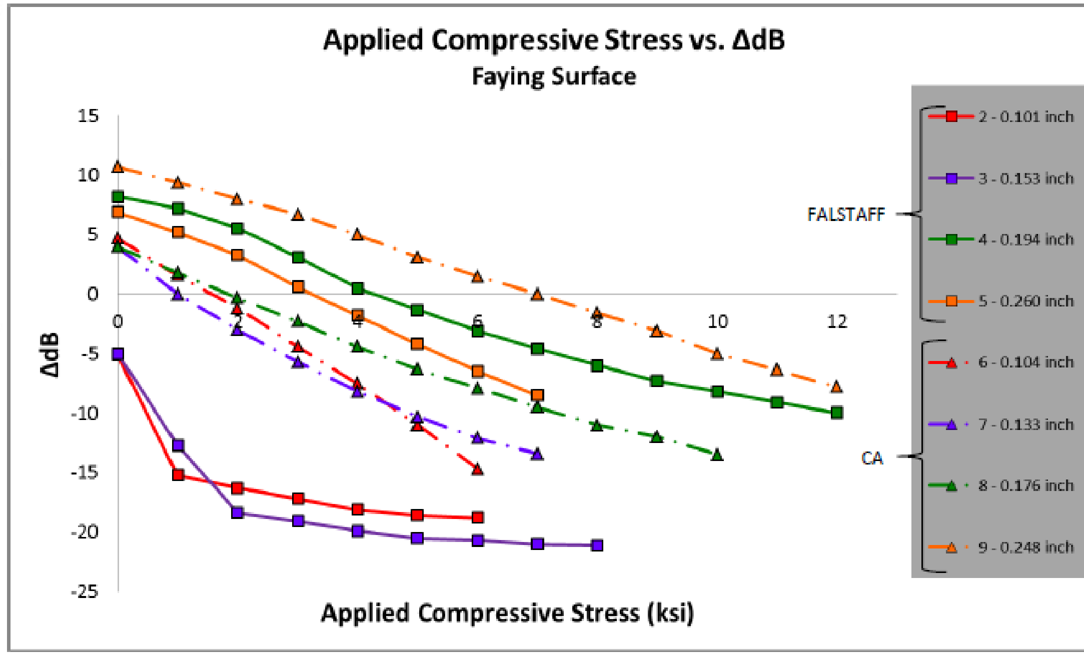
- *Dead zone proportional to hole diameter but scatter suggests other influencing factors*
- *Use upper bound of UT dead zone estimates to correct UT POD estimates for Cx holes*
- *Ultrasonic inspections must be designed to interrogate beyond the tangency of the hole*

Ultrasonic “dead zone” proportional to hole diameter.

Applied Compressive Stress: Shear-Wave Ultrasonics

Ultrasonic response from fatigue cracks under applied compressive stress.





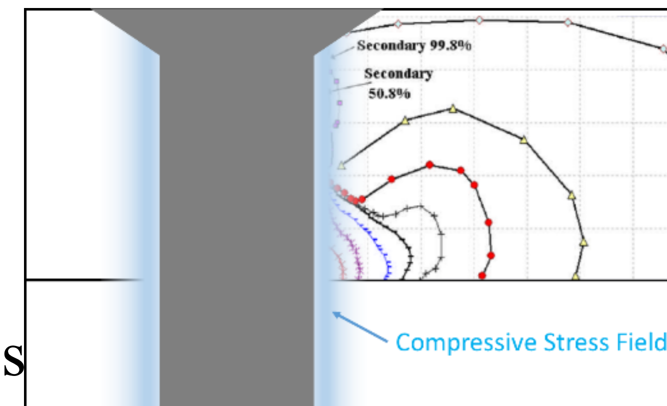
Henry, T. "Correlating Ultrasonic Responses of Fatigue Cracks Propagated Under Different Load Spectra."

Significant Impact

~6dB (50%) signal reduction per 4 ksi applied compressive stress.

Gaps

- Further Quantify Ultrasonic "Dead Zone" at Cx Holes
  - **Quantify UT "Dead Zone" for a range of Cx applied expansion ranges**
  - Investigate causes of "Dead Zone" variability
  - *Define UT POD correction factors for Cx holes*
    - ✓ ***Initial estimates documented in EN-SB-008-012***
  - *Define optimum UT system design for Cx holes*
- Fastener Installation on UT Detectability
  - Taper-Lok fasteners
  - Interference fit fasteners
- Other ERS Surface Treatments and Materials
  - Shot peening, low plasticity burnishing – on aluminum and titanium (UT and FPI focused)
  - **Laser Shock Peening (LSP) on titanium alloys**



Subcommittee Priorities

Priority I. Quantify UT dead zone in Cx holes. Correlate to hole D and T.

A. Round Robin - Map UT dead zone for Cx holes – selected specimens
- RXSA, RXCA, AFSC/ENSI Participating – In progress
- ✓ Stress profiles from Val/Ver Test Subcommittee – T. Mills

B. Impact of interference fit fasteners – repeat Round Robin

C. Evaluate Phased Array Ultrasonics
- Capture data w/ existing AFIS UT inspection system
- Build on SwRI body of knowledge

Priority II. Investigate impact of Taper-Lok fastener installation on ultrasonic fatigue crack detectability?

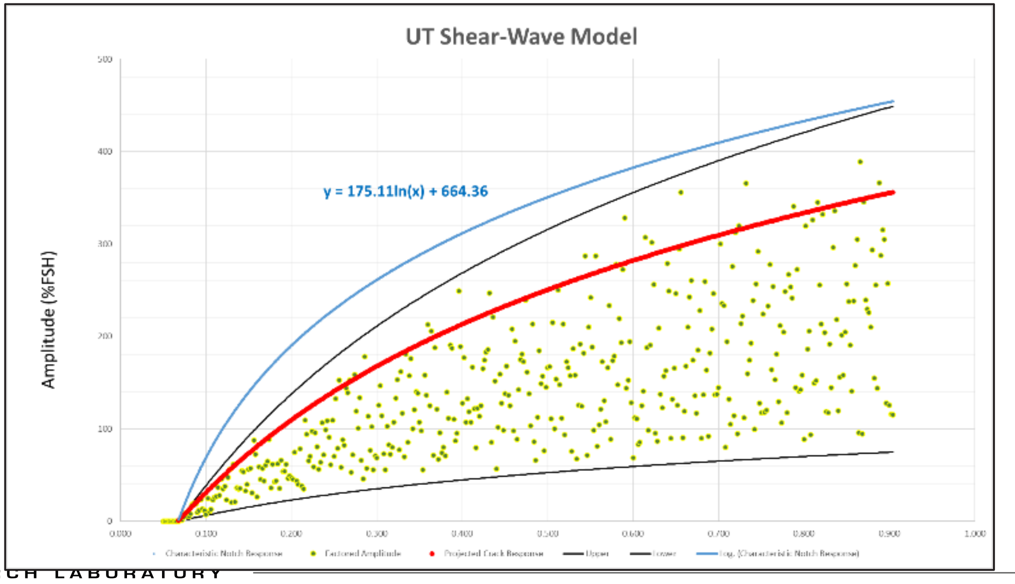
A. Model Taper-Lok stress field

B. Empirical measurements of UT response

Priority III. Characterize impact of laser-peening on titanium.
- Integrate measurements into planned a/c qual. Programs

Progress

- Published EN-SB-008-012 Rev D, April 2018
  - Impact of Cx on surface eddy current inspection
  - Impact of Cx on ultrasonic inspection of Cx fastener holes
    - Initial estimates of dead zone for POD correction
  - Guidance for FPI and UT on Laser Peened structures
- Incorporation of current knowledge into AFRL developed UT scatter model.
  - Applied compressive stress
  - Ultrasonic dead zone in Cx holes



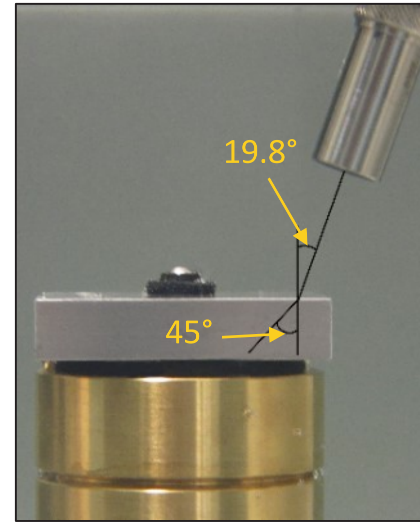
Progress: Priority I.A: Quantify UT Dead Zone

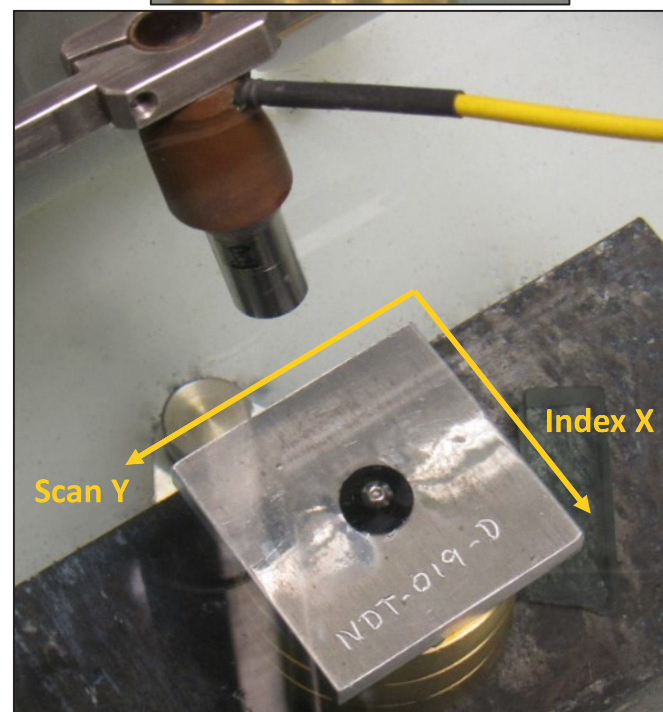
Round Robin Progress

- Test fixtures provided to AFSC/ENSI and AFRL/RXCA
- Initial setups established
- 118 Specimens, 4% cold work holes – Courtesy of Apes Engineering
  - 3 hole diameters (0.278 inch D, 0.418 inch D, 0.538 inch D)
  - 3 plate thicknesses (0.100 inch, 0.313 inch, 0.500 inch)
  - Fatigue cracks: 0.020 inch – Thru-Thickness

Testing Setup Example

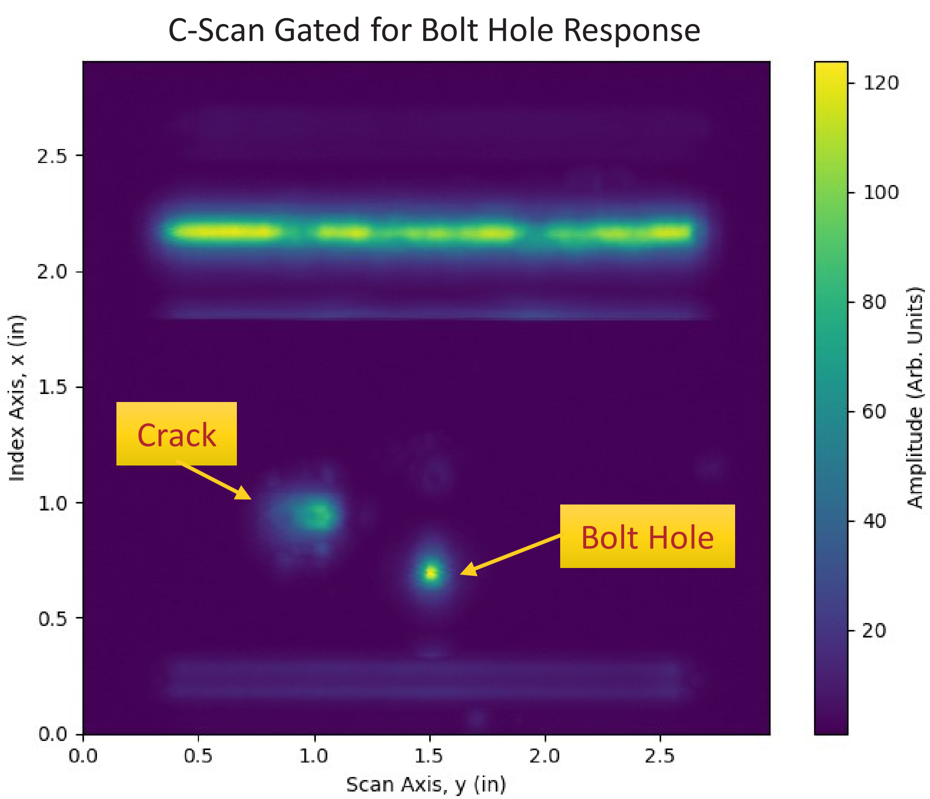
- Sample NDT-019-D (0.540 inch Dia. Hole)
- Calculated Incident Angle 19.8º
    - 45º shear angle in aluminum
- Scan Step Size: 0.006 inch
- Transducer Panametrics V327
    - 10MHz 0.375 inch Dia.
    - 3" Spherical Focal Distance
    - Approximate Mid Plane Focus

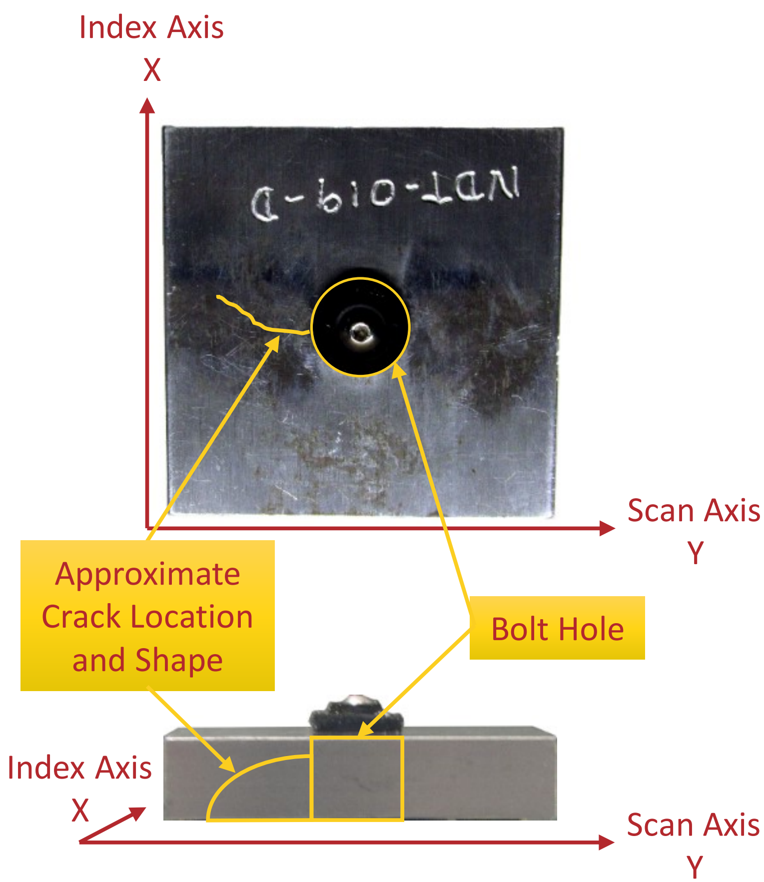




<u>Courtesy of</u>:
Mike Uchic – AFRL/RXCA
Tyler Lesthaeghe – University Dayton Research Institute
David Zainey - University Dayton Research Institute
Vicki Kramb - University Dayton Research Institute

Initial Test Results – AFRL/RXCA





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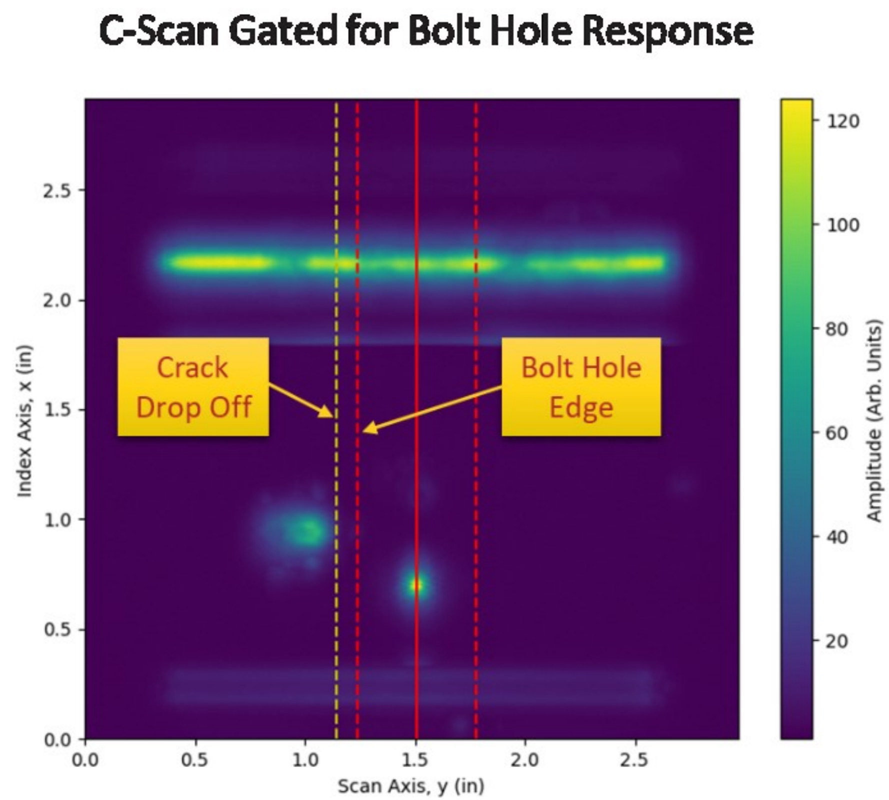
Ultrasonic Dead Zone Measurement

- Dead zone measured by locating peak amplitude response from bolt hole and using known hole diameter to determine edge location
- Edge of dead zone determined from B-Scan drop off (-6dB) from the max crack response
- Estimated dead zone: 0.0985 inch
  - Consistent with RXSA findings
- Ready to test remaining 117 coupons



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Vicki Kramb - University Dayton Research Institute

Progress: Priority I.C: Evaluate Phased Array UT

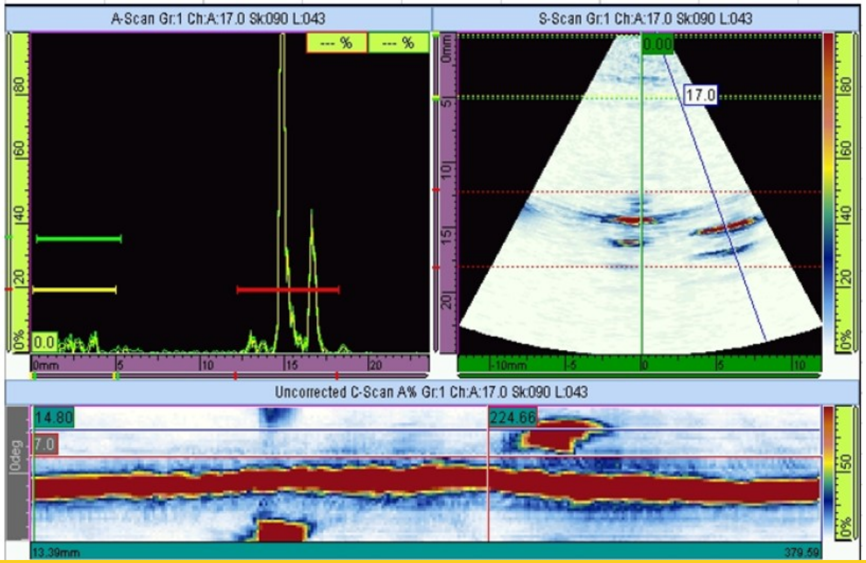
Non-Destructive Testing of cold Worked Fastener Holes

Dallen L. Andrew and Clint Thwing – SwRI and CAStLE

- Evaluation of 4% cold worked holes in lower wing skin structure and detectability of fatigue cracks via the Automated Fastener Inspection System (AFIS) and Rotoscan ultrasonic inspection systems.
  - 0.261 inch final diameter hole, 11 Coupons
  - 0.340 inch Thick 7075-T651 Plate

General Conclusions:

- Fatigue cracks >0.071 inch length detected (regardless of depth)
- Countersink cracks only detected when faying surface cracks >0.165 inch were present.



AFIS Result from 0.150 inch Faying Surface Crack

Progress: Priority III: Characterize Impact of Laser-Peening on Titanium.

- NDI characterization (FPI, ECI and UT) has been integrated into on-going Lockheed mechanical test program for laser peening of Ti-6-4
- Limited scope with limited number of subcomponents
- AFRL/RXSA is supporting these efforts
- POC: Scott Carlson, Lockheed Martin - Aerospace

NDI Implementation Strategy

- Capability impacts documented in EN-SB-008-012
- Inspection limitations could be documented in future ERSI SB
- Documentation of inspection process best practices in general procedures of T.O. 33B-1-2 where applicable

Questions?