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NDT Comparison of In-service Cracks, Manufactured Cracks and EDM Notches

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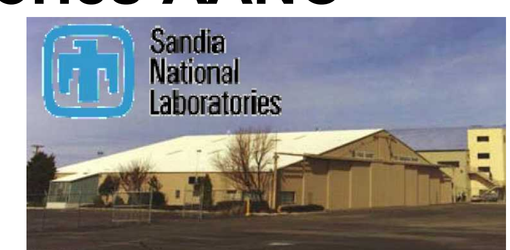


Outline

- Purpose & Background
- Aircraft Structure & Defect Descriptions
- Methodology
- Medium Frequency Eddy Current (Pencil Probe)
- Low Frequency Eddy Current (Sliding Probe)
- Rivet Check™
- Remote Field Eddy Current
- Summary, Recommendations & Future Work

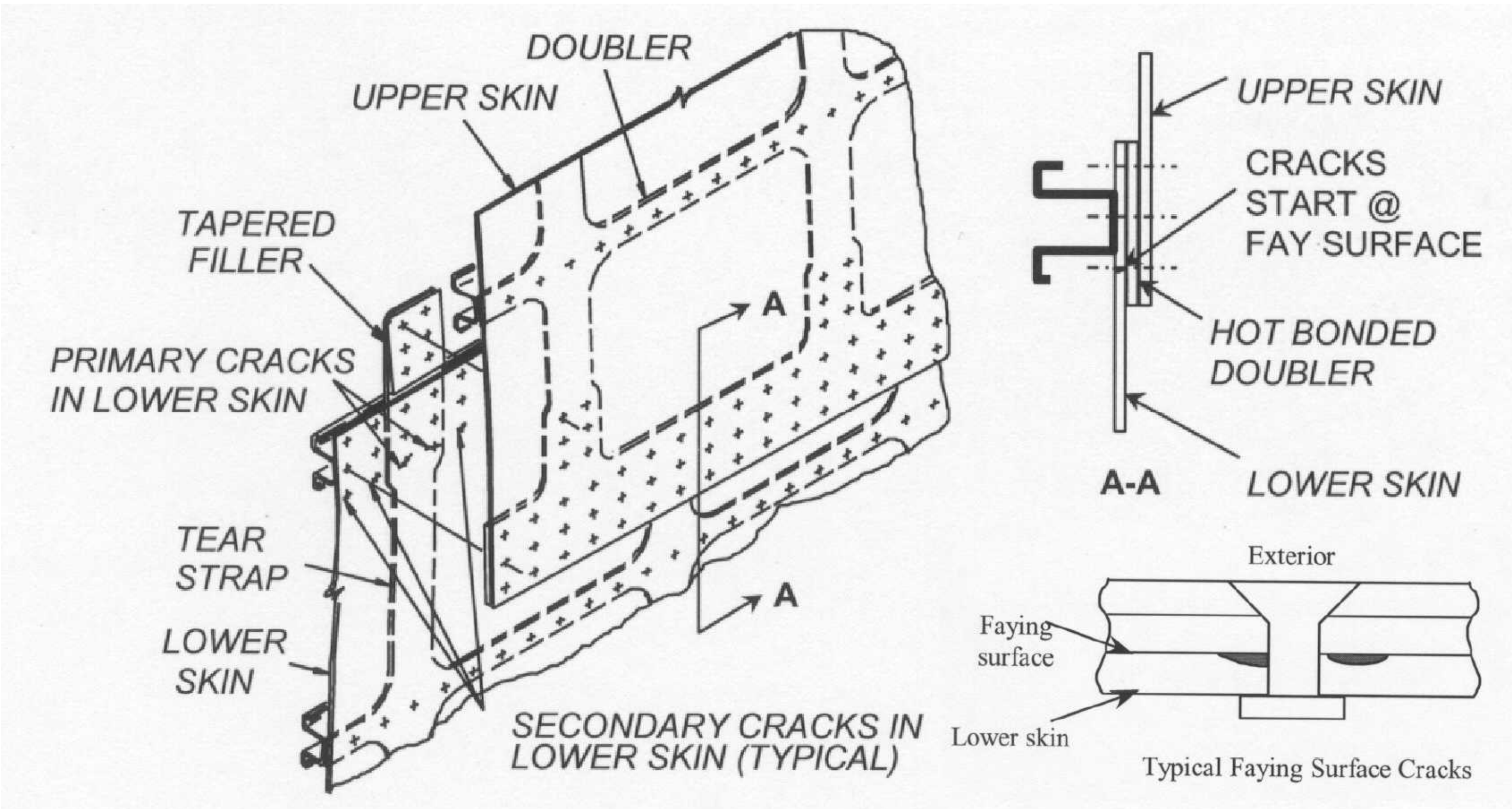
Purpose
"Not all POD Studies are Created Equal"

- Foster education & discussion within the aerospace community
  - Using EDM notches, "manufactured" cracks, and natural cracks as calibration standards and POD specimens.
- Support 1999 AAWG Recommendations
  - POD is a critical parameter required for analyses to prevent Widespread Fatigue Damage (WFD)
  - EDM Notch vs Crack study was started, not finished – Finish it!
- Use data generated by B727 Teardown, and previous POD studies
  - compare signal responses of conventional and emerging NDI technologies for common WFD susceptible aircraft structures.
- Support MAPOD efforts
  - Create database of deviations of responses of natural cracks from expectations for ideal cracks
  - Develop initial rough order of magnitude "knockdown" factors to support the Model Assisted POD working group efforts in developing POD transfer function models.

Background

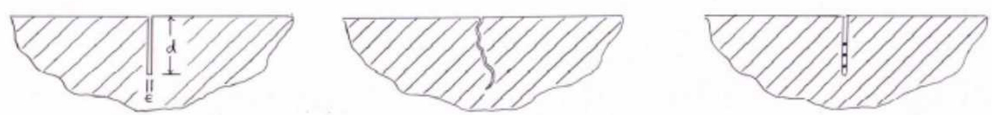
- The B727 Teardown Program
  - Assessed capabilities of existing and emerging NDT methods to detect multiple site damage (MSD)
  - Characterized fuselage lap joint cracks (MSD) of a retired Delta 727-200 aircraft at Design Service Goal
- AAWG Delta Panel POD Program
  - Assessed capabilities of conventional NDT as applied by airline/MRO inspection personnel to detect MSD/WFD
  - Utilized specimens harvested, characterized and reassembled from B727 lap joint repairs
- AANC Inner Layer Crack POD Program
  - Assessed reliability of conventional and emerging NDT to detect simulated WFD in typical B737 lap joints
  - Used ideal manufactured cracks in simulated lap joint

Aircraft Structure
Typical Lap Joint



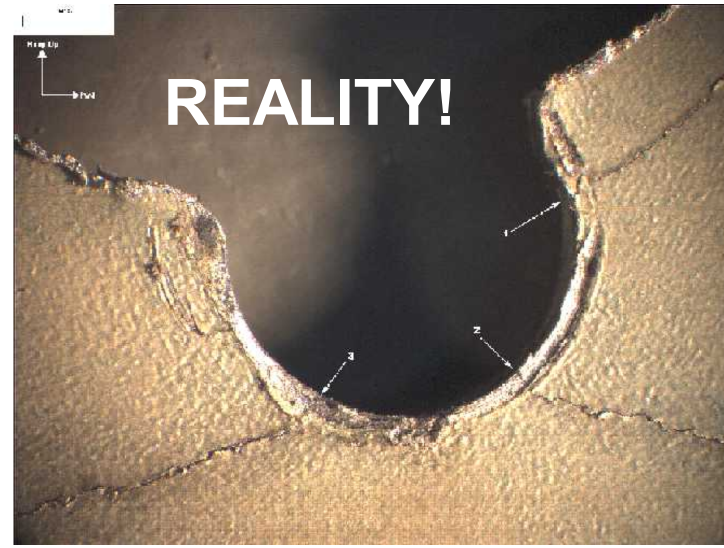
Crack Differences Can Affect Signals

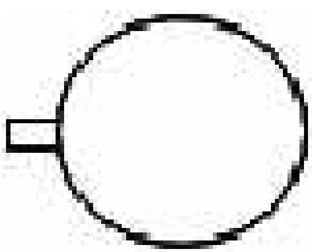
Ideal Mathematical Crack | Morphology Effects | Electrical/Mechanical Contact Effects



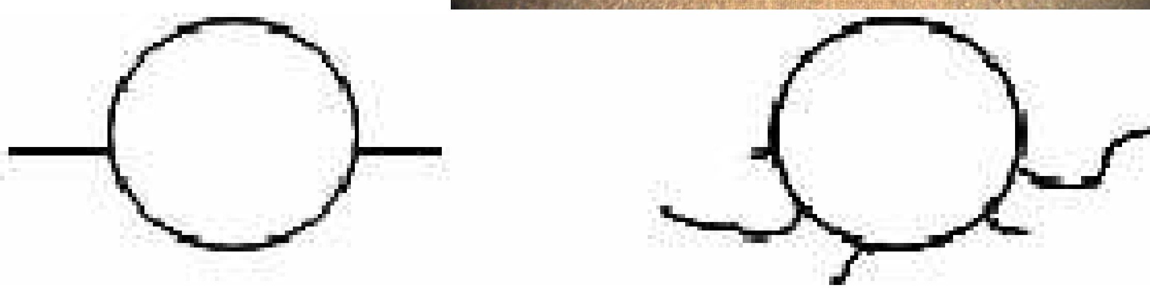
Material Mechanisms
- Growth along grain boundaries
- Non-uniform residual stresses

- Oxides and other debris
- Contacting asperities
- Sheared faces





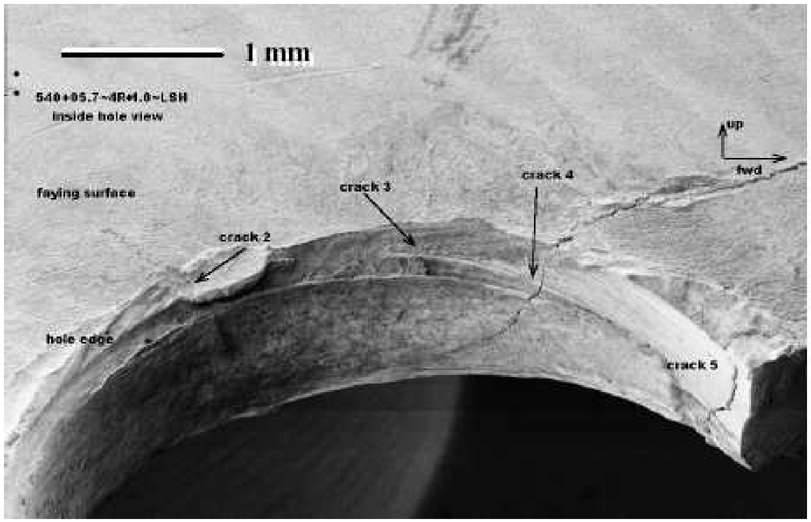
EDM Notch



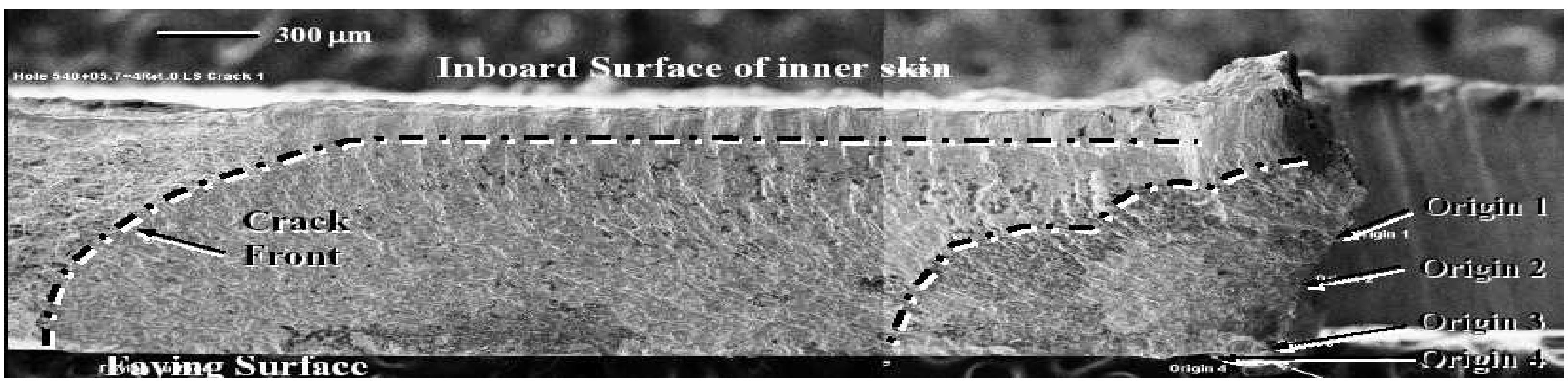
Manufactured Cracks

Natural Cracks

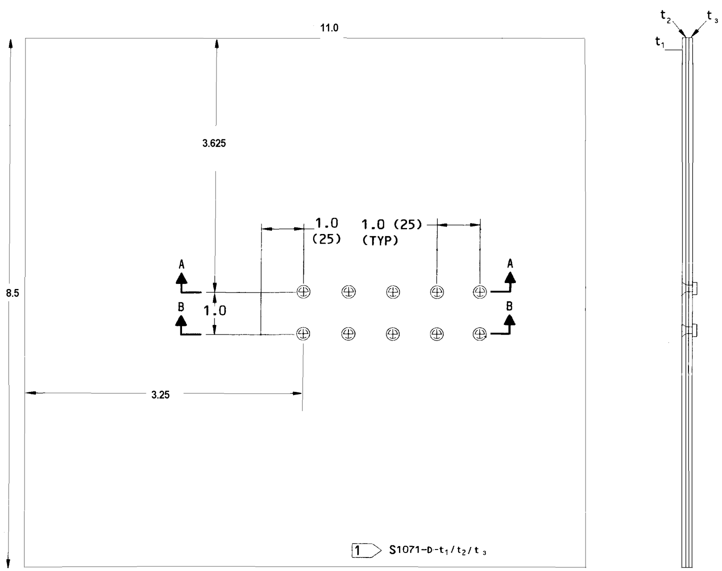
Issues that Affect Crack Signals

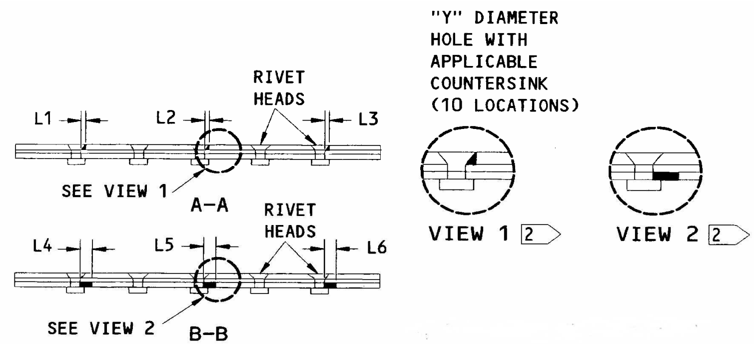


- Multiple cracks forming a starburst
- Multiple crack origins: rivet hole and faying surface
- Crack tunneling under clad layer – negates visual inspection
- Orientation effects – affects all NDT
- Consistency of sealant between layers – negates UT
- Faying surface origin – negates BHEC



EDM Notch Reference Standard





2 EDM NOTCH LENGTHS (SEE VIEW 1 AND 2 ABOVE):

L1 0.030 INCH (0.76)
L2 0.040 INCH (1.00)
L3 0.050 INCH (1.27)
L4 0.050 INCH (1.27)
L5 0.100 INCH (2.54)
L6 0.150 INCH (3.81)

Crack Specimens

MANUFACTURED ASSEMBLED

AANC 2nd Layer

NATURAL REASSEMBLED

Delta 2nd Layer

NATURAL AIRCRAFT

Retired B727

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Delta TechOps Aviation Excellence Worldwide

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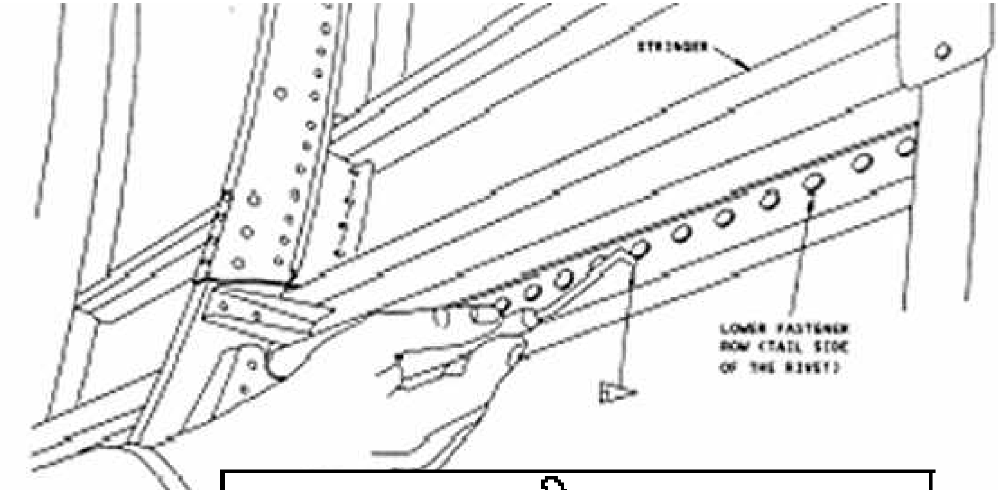
Methodology

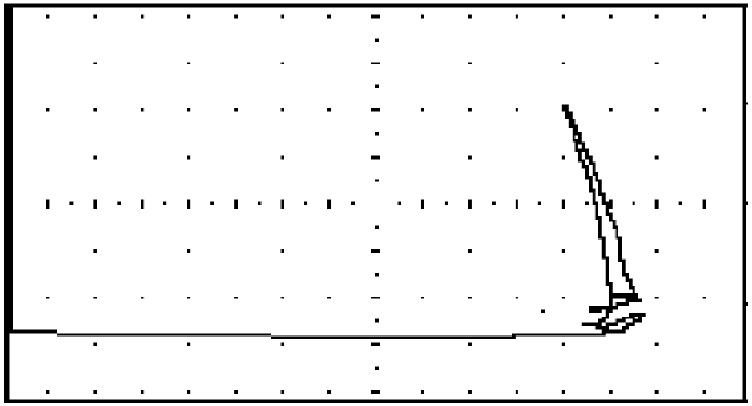
- **NDT Eddy Current Methods**
  - **Internal Medium Frequency**
  - **External Low Frequency**
  - **External Rivet Check™**
  - **External Remote Field**

- **Specimen Variations**
  - Natural, In-service: B727 Teardown, FAA Contract DTFA03-02-C-00044
    - 0.040/0.020/0.040" stack-up; characterized by teardown inspection
  - Natural, Reassembled: Internal specimens at Delta used for AAWG project
    - 0.071/0.040" stack-up; In-service lower skin, new top-skin and fasteners
  - Manufactured: Specimens at AANC (Sandia) used during FAA projects
    - 0.040/0.040/0.040" stack-up; Starter notches, fatigued in tension-tension, notched removed
  - EDM notches: various calibration standards
    - NDT 3019 – 0.040/0.040" stack with 0.050, 0.100, and 0.150" bottom of top layer angled EDM notches used for MFEC
    - NDT 2018B - 0.080/0.040" stack-up with 0.050, 0.100, and 0.150" 2nd layer EDM notches used for LFEC
    - NDT S1071 – 0.040/0.020/0.040 stack with 0.050, 0.100, and 0.150" 3nd layer EDM notches used for Rivet Check™ and Remote Field

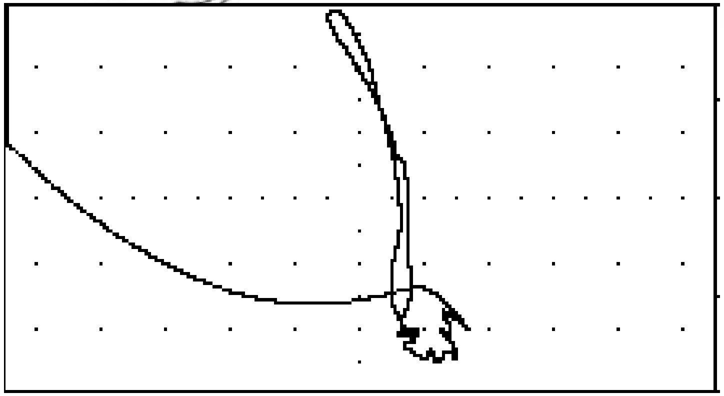
Medium Frequency Eddy Current Pencil Probe

- Internal MFEC (Spot Probe)
  - B727 NDTM, Part 6, 53-30-27, Figure 17





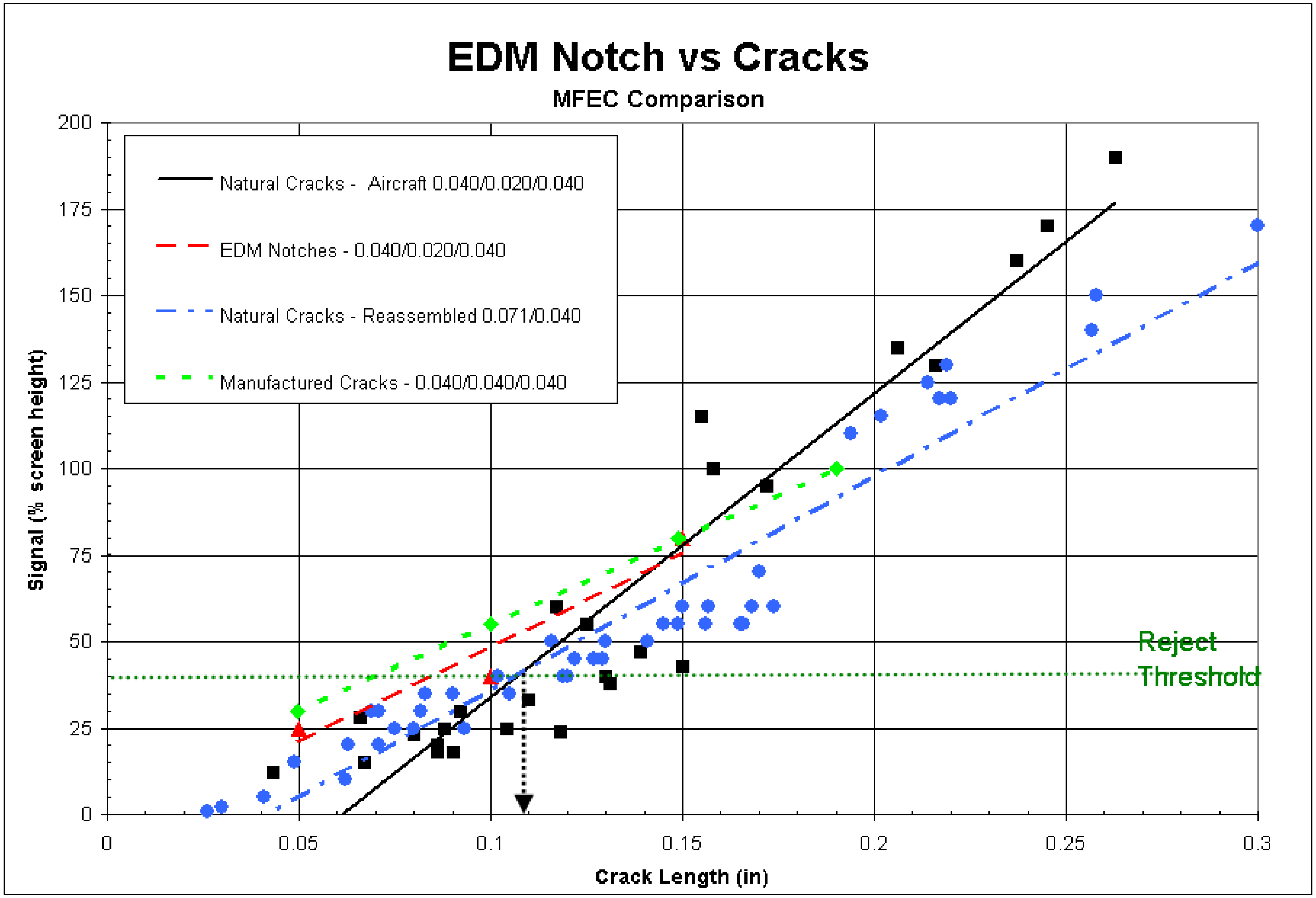
MFEC signal from 0.150" angled EDM notch



MFEC signal from 0.156" real crack

Medium Frequency Eddy Current

Signal from 0.1" EDM Notch = Signal from 0.110" Natural Aircraft Crack



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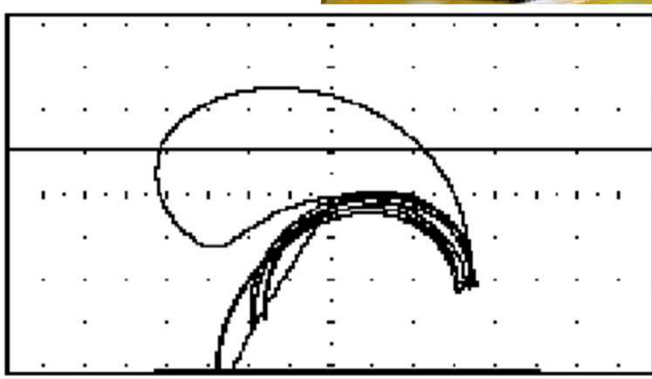
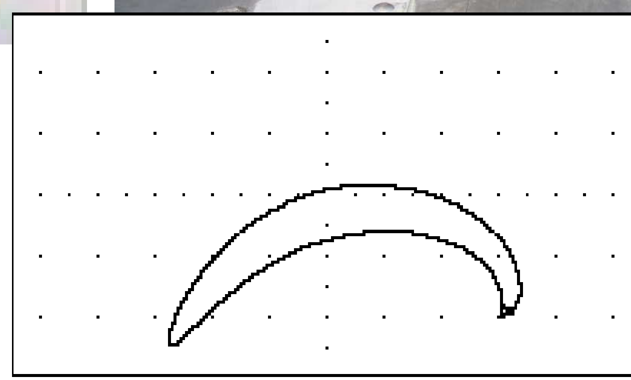
Low Frequency Eddy Current Sliding Probe

- External LFEC Sliding Probe
- B727 NDTM, Part 6, 53-30-27, Figure 13
- Crack Orientation Sensitive



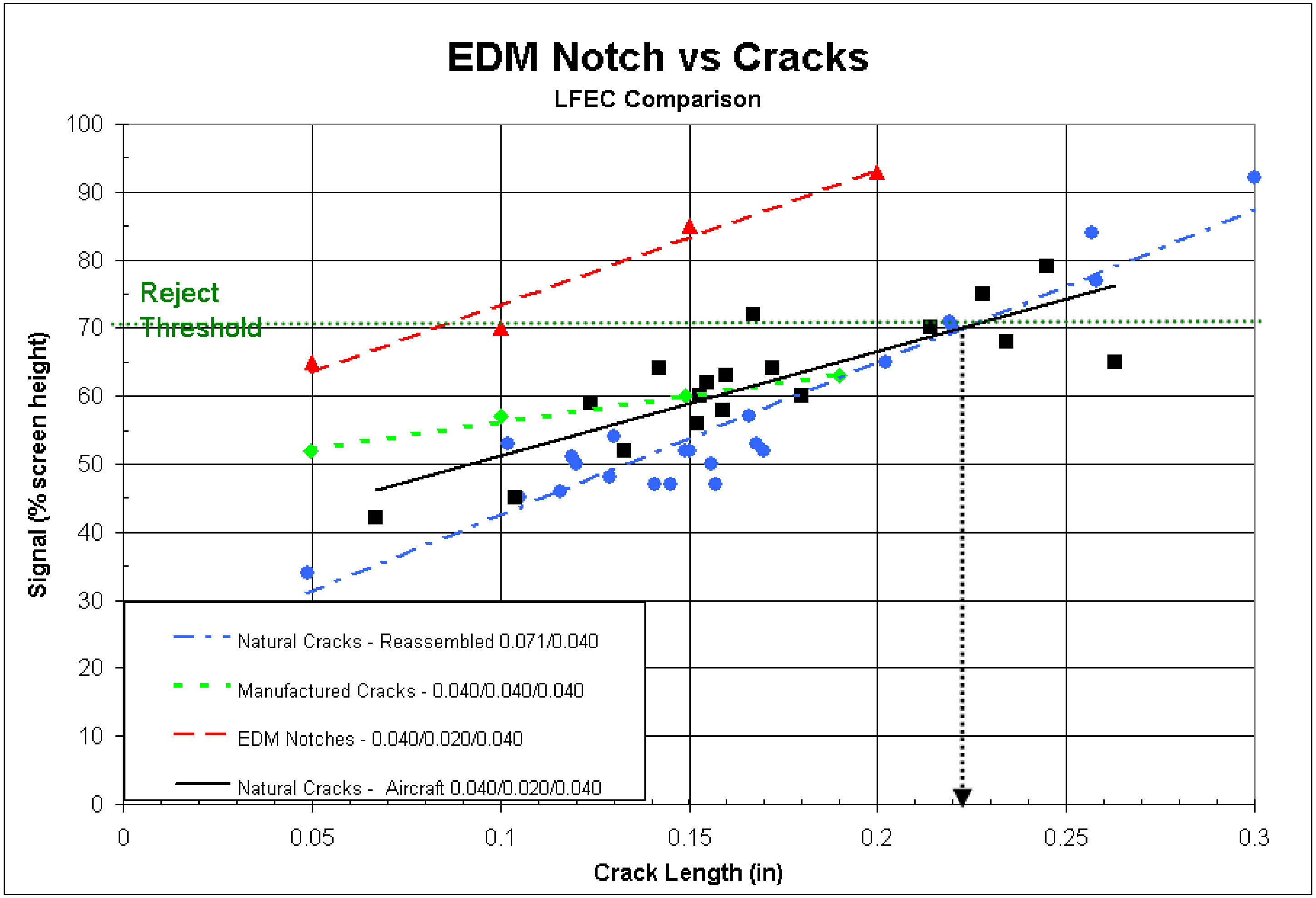
LFEC sliding probe signal from 0.200" EDM calibration notch



LFEC sliding probe signal from 0.258" real crack

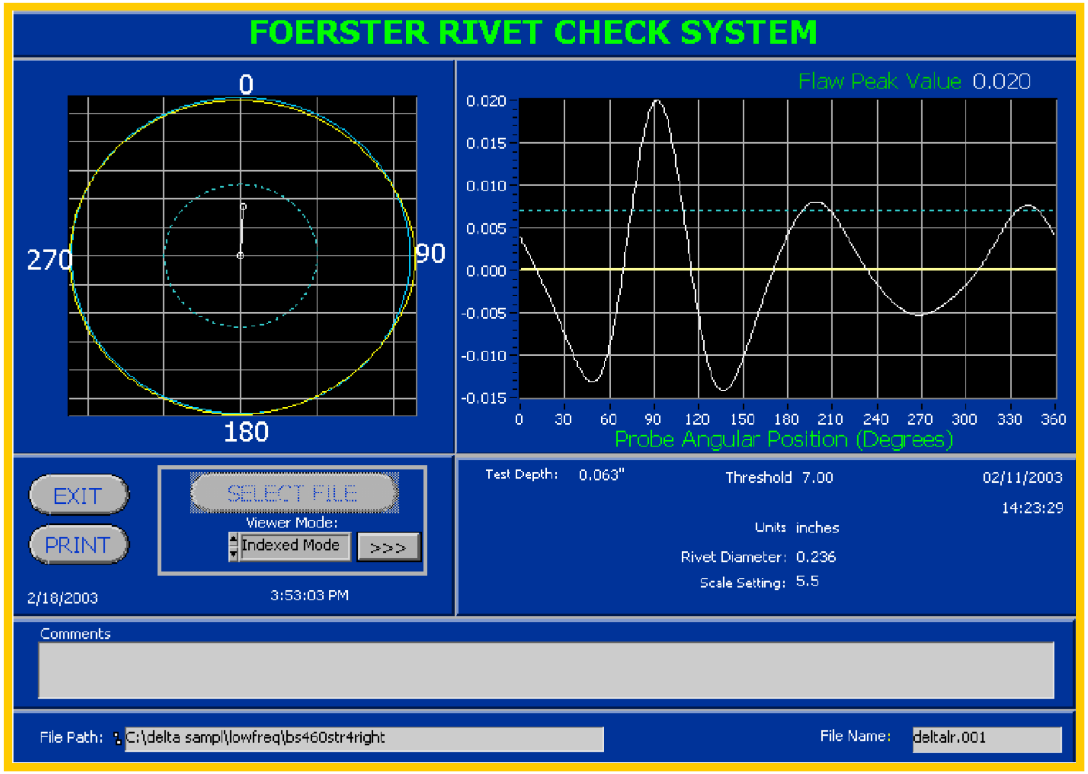
Low Frequency Eddy Current

Signal from 0.1” EDM Notch = Signal from 0.225” Natural Aircraft Crack



Rivet Check™
Low Frequency Rotating Eddy Current

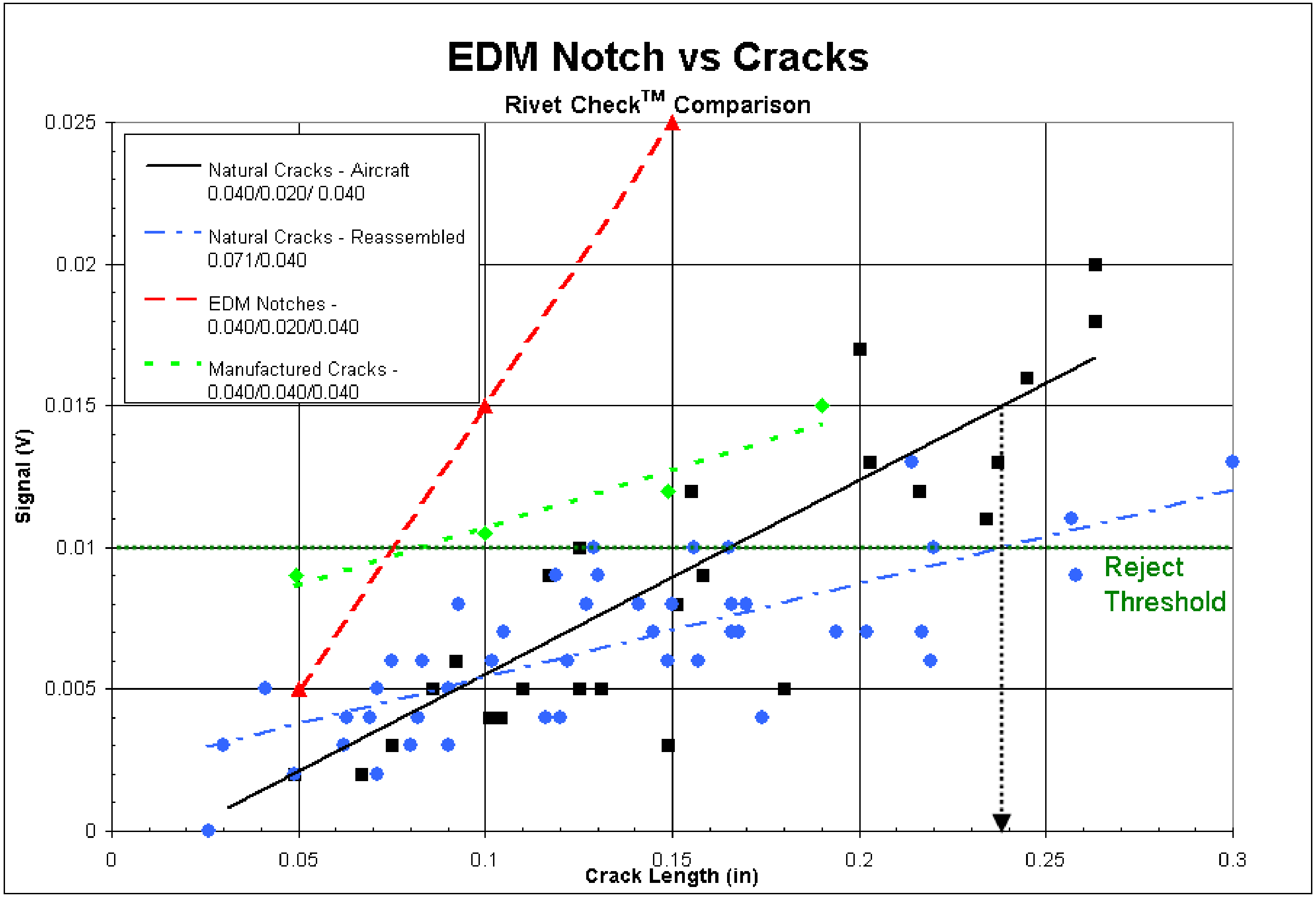
- Low Frequency Self-nulling rotating probe
- Uses Rivet Edge
- B727 NDTM, Part 6, 51-00-00, Figure 25



Rivet Check™ signal from 0.100" EDM calibration notch

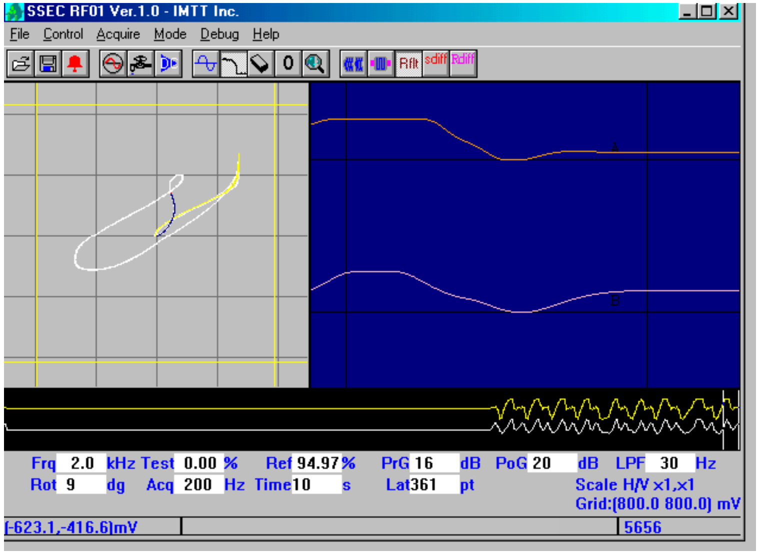
Rivet Check™

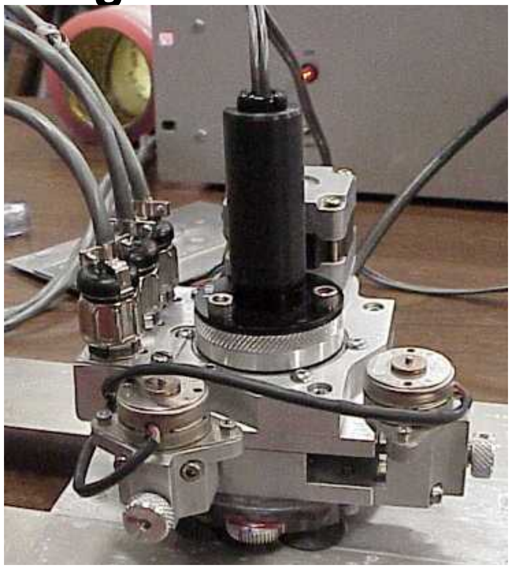
Signal from 0.1” EDM Notch = Signal from 0.240” Natural Aircraft Crack

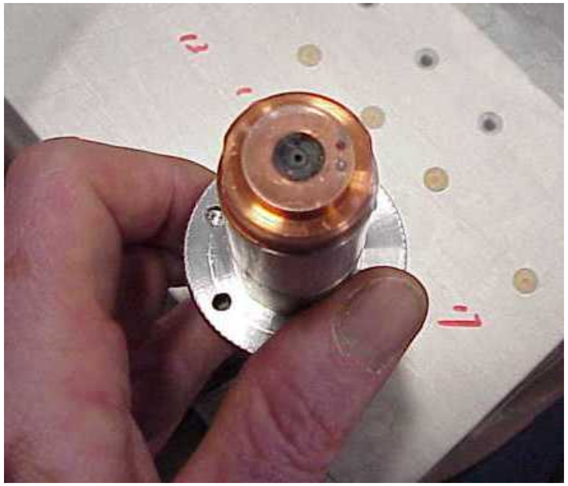


Remote Field Eddy Current
Automated Centering Rotating Eddy Current

- **IMTT**
- **Super Sensitive Eddy Current (SSEC)**
- **Recent Improvements to auto-centering and signal processing algorithms**



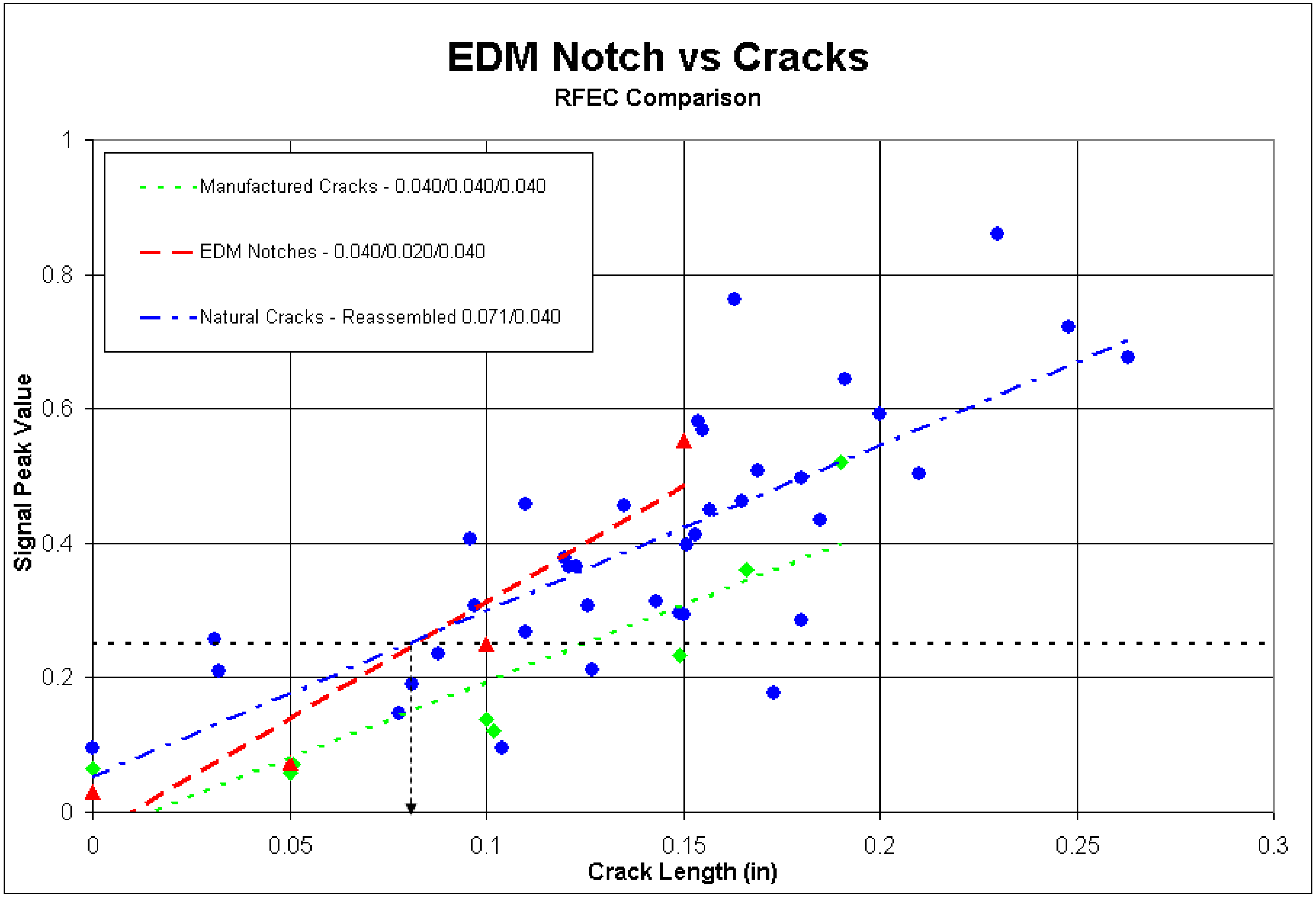




POD Data from inspection of aircraft natural cracks expected in Fall 2006

Remote Field Eddy Current

Signal from 0.1” EDM Notch = Signal from 0.080” Natural Reassembled Crack



Summary

- Much variation observed in the average signal response peaks between EDM notches, manufactured cracks and natural cracks.
- High scatter of signal response for natural cracks likely due to large variability in crack growth morphology
- Low scatter of signal response for EDM notches and manufactured cracks likely due to highly controlled and consistent defect fabrication methods.
- “Knockdown” factors presented for MFEC & LFEC

Recommendations

- EDM notches can provide a reasonable simulation of natural defects in certain situations.
- Efforts to model signal responses for MAPOD activities must address the stochastic nature of natural crack growth and it's effect on signal response.
- MAPOD efforts must resolve the effects of MSD on signal response.

Future Work

- Design experiments to identify critical factors influencing signal responses, and quantify those effects
- Similar quantitative studies based on other widely used inspection methods, such as ultrasonic techniques
- Attempt to refine conversion factors for conventional NDI methods in commonly used aircraft inspection procedures