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Lower Layer Crack Detection in Thick Complex Aircraft Structures Using Flat Geometry Remote Field Eddy Current Technique

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Outline

- Background on CF
- Limitation of Current Technologies
- Understanding Remote Field Eddy Current as Applied to Flat Geometries (FG_RFEC)
- Description of Test Pieces (3 CF Inspection Problems)
- Results of FG_RFEC applied to the 3 Inspection Problems
- Further Work

Background

- The Canadian Forces (CF) is currently flying many aging fleets:
  - CC130 (over 40 years old)
  - CP140 (P3) (over 25 years old)
  - CF118 (F18) (over 25 years old)
  - CH124 Sea King (over 40 years old)
  - CC114 Buffalo (over 50 years old)

Background

- Recent aging aircraft issues have required detailed inspections of thick complex structure
  - SB82-790 for the CC130 CW
  - Risk Analysis of Lower Wing Splices of the CP140 (P3) as determined from the Service Life Assessment Program (SLAP)
  - Risk Analysis of the F18 front spar as determined from IFFOS

Limitations of Current Technologies

- UT
  - Many of the CF multi-layer structures (i.e. CP140 and CC130 wing planks) are not bonded between faying surfaces required for the transmission of sound
- ET
  - Traditional applications of eddy current affected by thick structure, ferrous fasteners, and complex geometry (first and second layer edges)
- RT
  - Insufficient sensitivity to sought defect size and orientation

Understanding RFEC

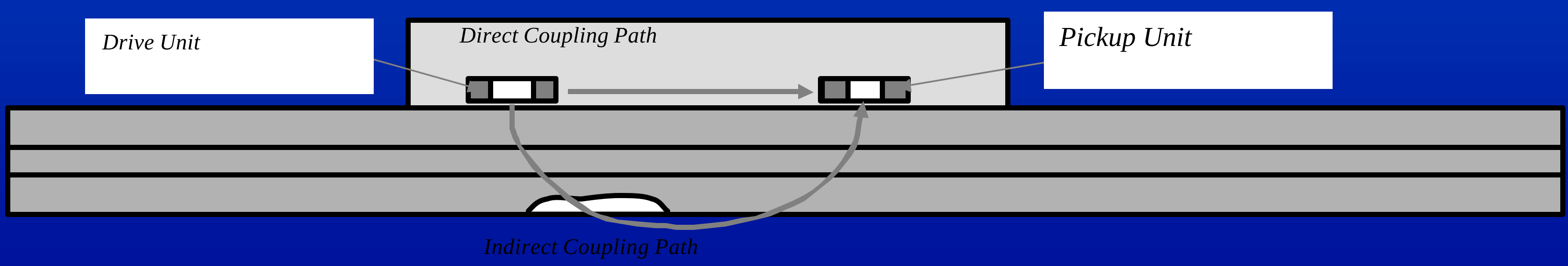
- Remote field eddy currents are generated by the same electromagnetic phenomena as traditional eddy currents
- First application in 1951 and widely used since for NDT of metallic pipes and tubing
- Requires a driver pick-up or reflection-differential coil configuration (Rx coil must be isolated from Tx coil)
- In tube/pipe inspections the pick-up coil signal is a function of:
  - Wall condition
  - Thickness
  - Permeability and
  - Conductivity

Understanding RFEC

- The pick-up coil phase angle has an approximate linear relationship with the wall thickness when placed 2-3 diameters away from the excitation coil
- For tubes the RFEC technique is characterized by its equal sensitivity to both ID and OD defects, insensitive to probe wobble/lift-off and <u>not as limited by penetration depth</u>
- This same phenomenon can be applied to flat geometries
- In the 1990s Mr. Sun applied RFEC to flat geometries

Applying RFEC to Flat Geometries

- As noted previously, the EM energy flow passes through the plate wall twice.
- In the tube case the induced eddy currents inside the wall restricts the flux pattern from expanding axially resulting in the rapid attenuation of the direct coupling field
- If the direct coupling field can be restricted in flat geometries, then the sensing coil will only detect the EM energy that follows the indirect path

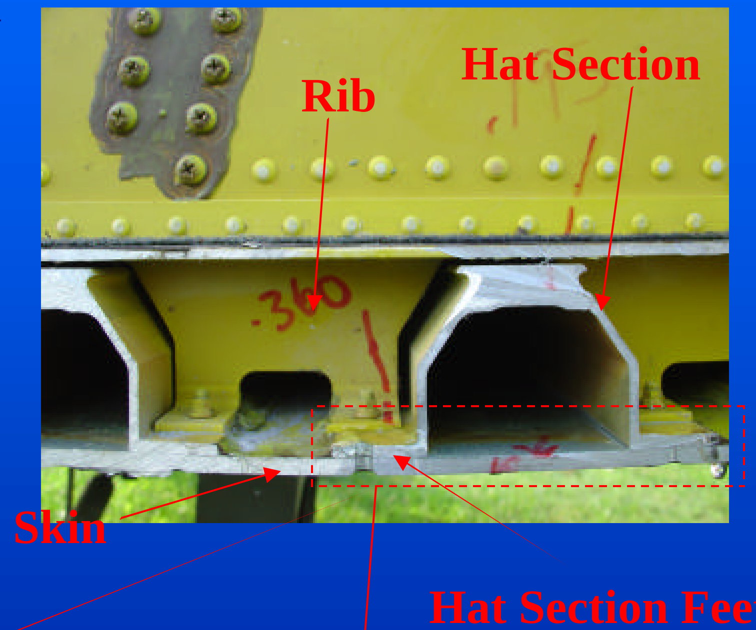


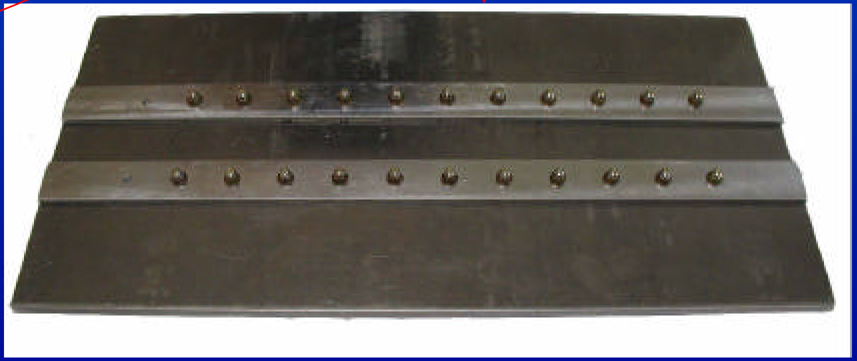
Applying RFEC to Flat Geometries

- At this point the entire signal received by the pickup unit has passed through the wall twice and carries the whole information about the wall condition
- The signal can be extremely weak, but is clean and without noise coming from the driving unit
- IMTT has developed a Super Sensitive Eddy Current (SSEC) System to exploit the RFEC characteristics in Flat Geometries using shielded probes.
- This technology has has initial success in addressing key inspection problems of aging aircraft in the Canadian Forces

Problem #1 – CC130

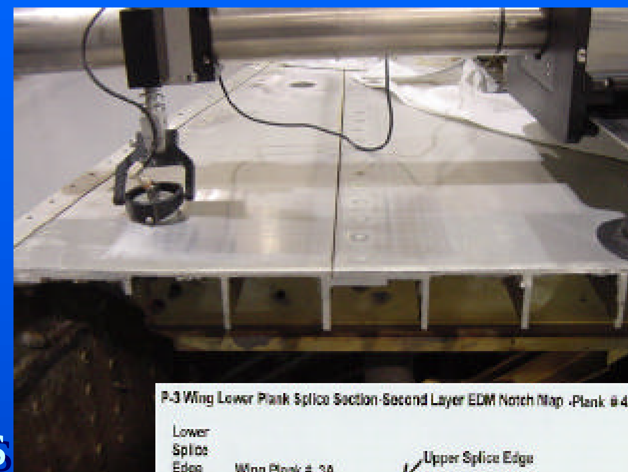
- Each lower surface of the CC130 CW box is comprised of 3 skin panels ranging in thickness from 0.150" to 0.175" fastened to hat sections of approximate thickness 0.140"
- Test Piece represents the skin and stringer (skin Al 7075-T7351 0.250" thick, stringer feet same material 0.140" thick with ferrous fasteners)

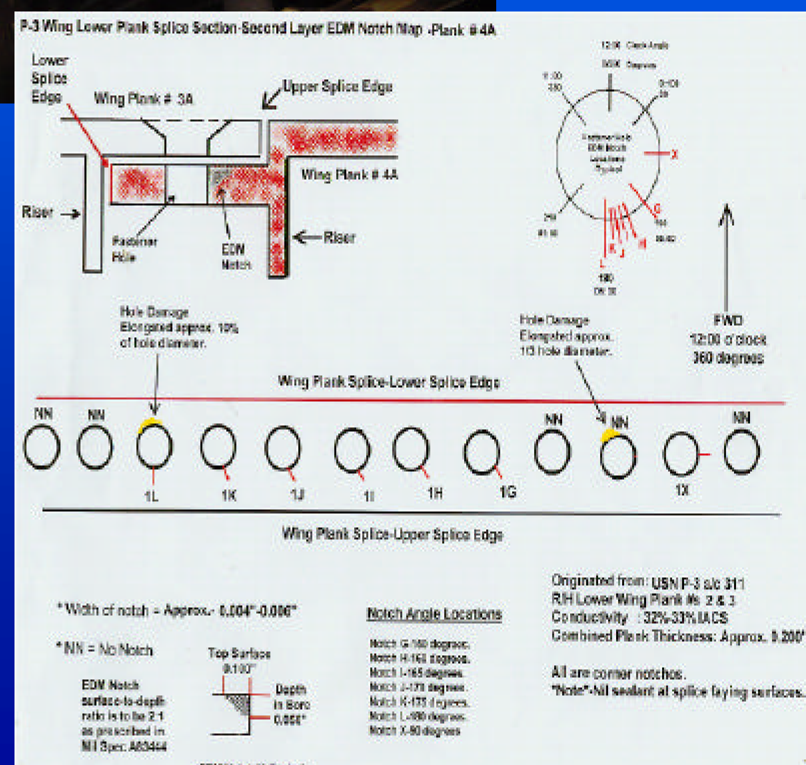


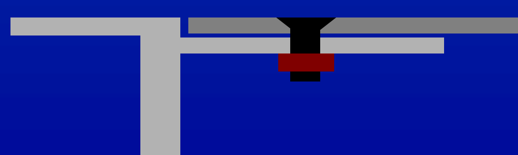


Problem #2 – CP140 (P3)

- The lower wing skins of the CP140 involve extruded planks with risers (vice stringers) and typically a single row of ferrous fasteners
- Skin thickness typically vary from 0.080” – 0.320”
- Test piece represents wing splice with first layer thickness of X and second layer thickness of Y

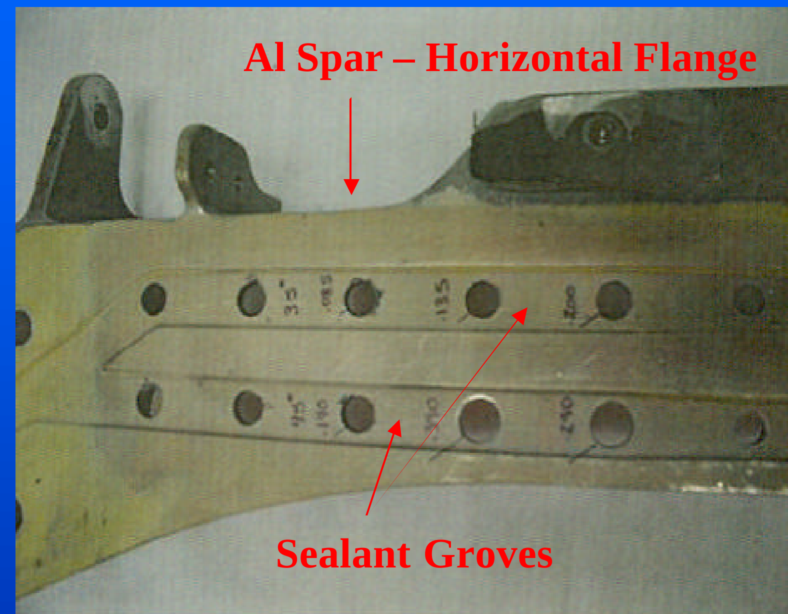






Problem #3 – F18

- The front spar of the F18 is a thick Al structure and is attached to the thick composite (graphite) skin with ferrous fasteners
- The test piece involves horizontal flange of the spar 0.140” thick and the a composite skin of 0.750” thick



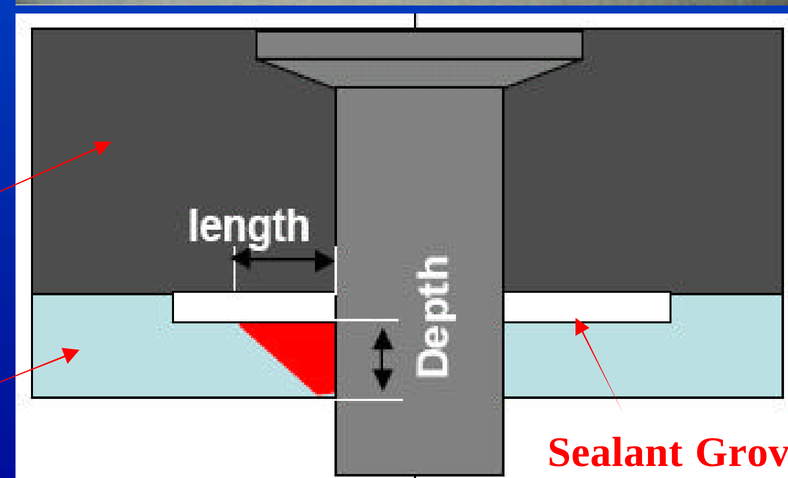
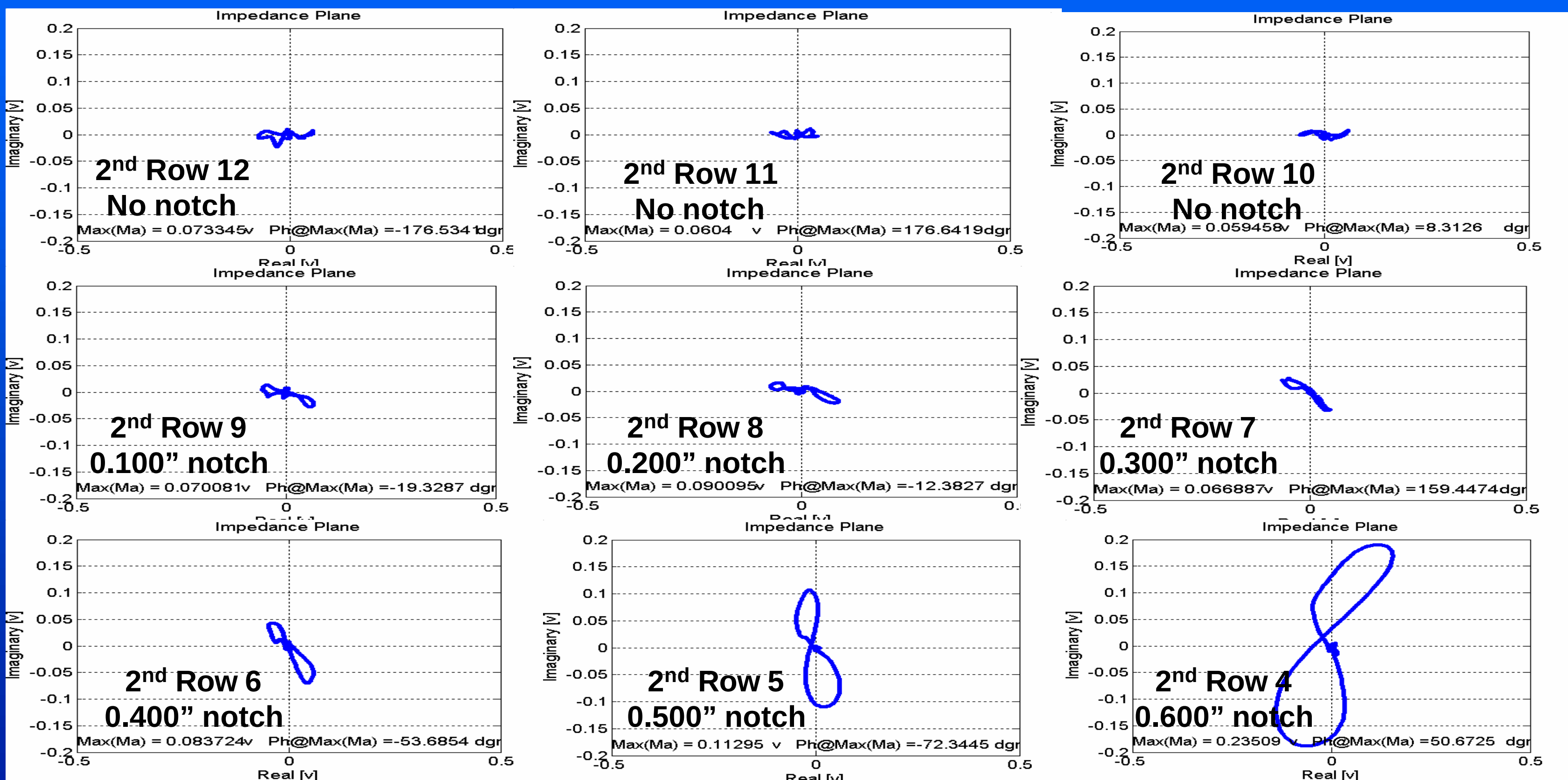
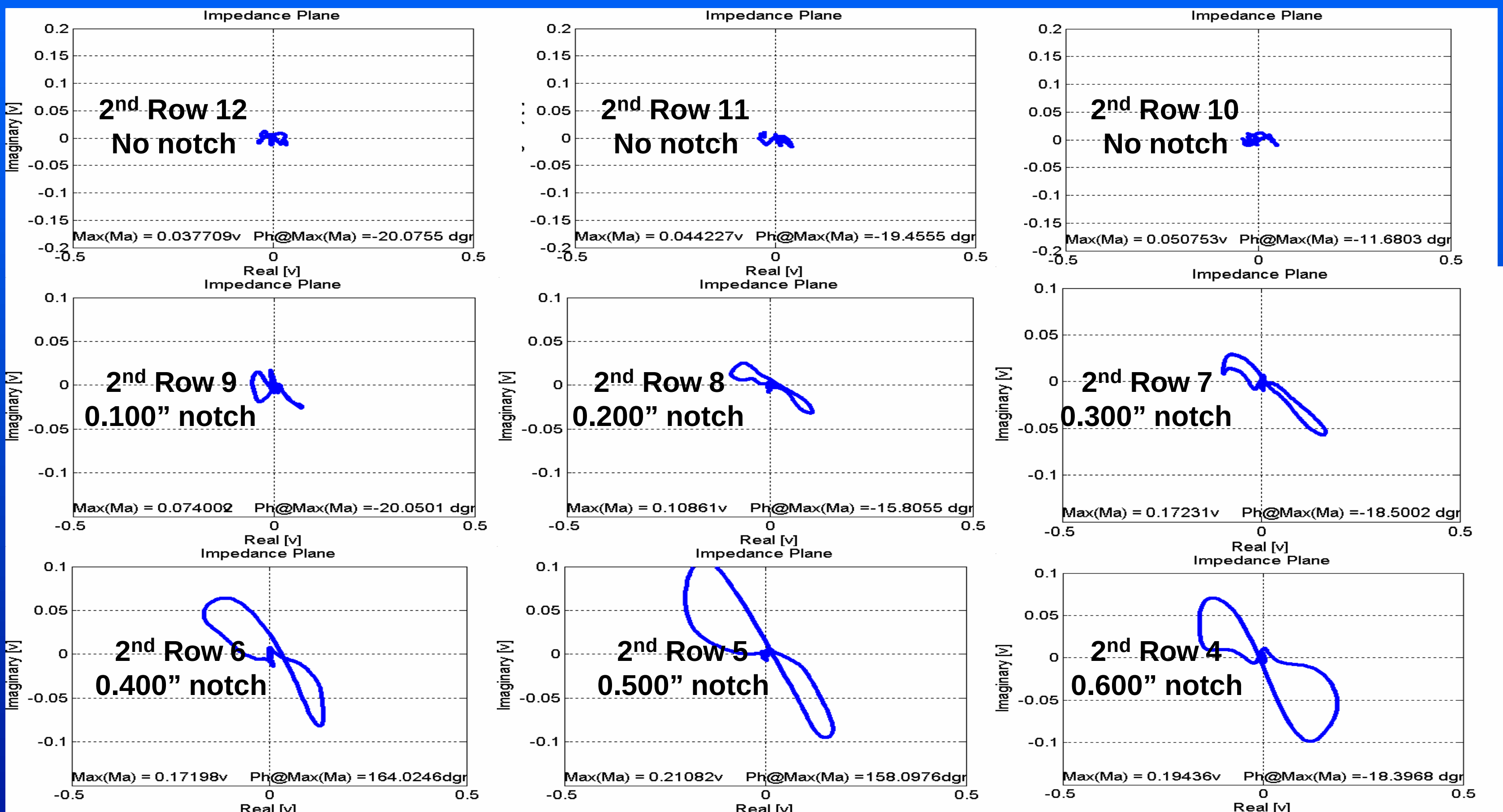


Illustration of Impedance Planes for 1st Layer Defects In the CC130 Test Piece (Faying Surface 3:1 Triangle Notches)



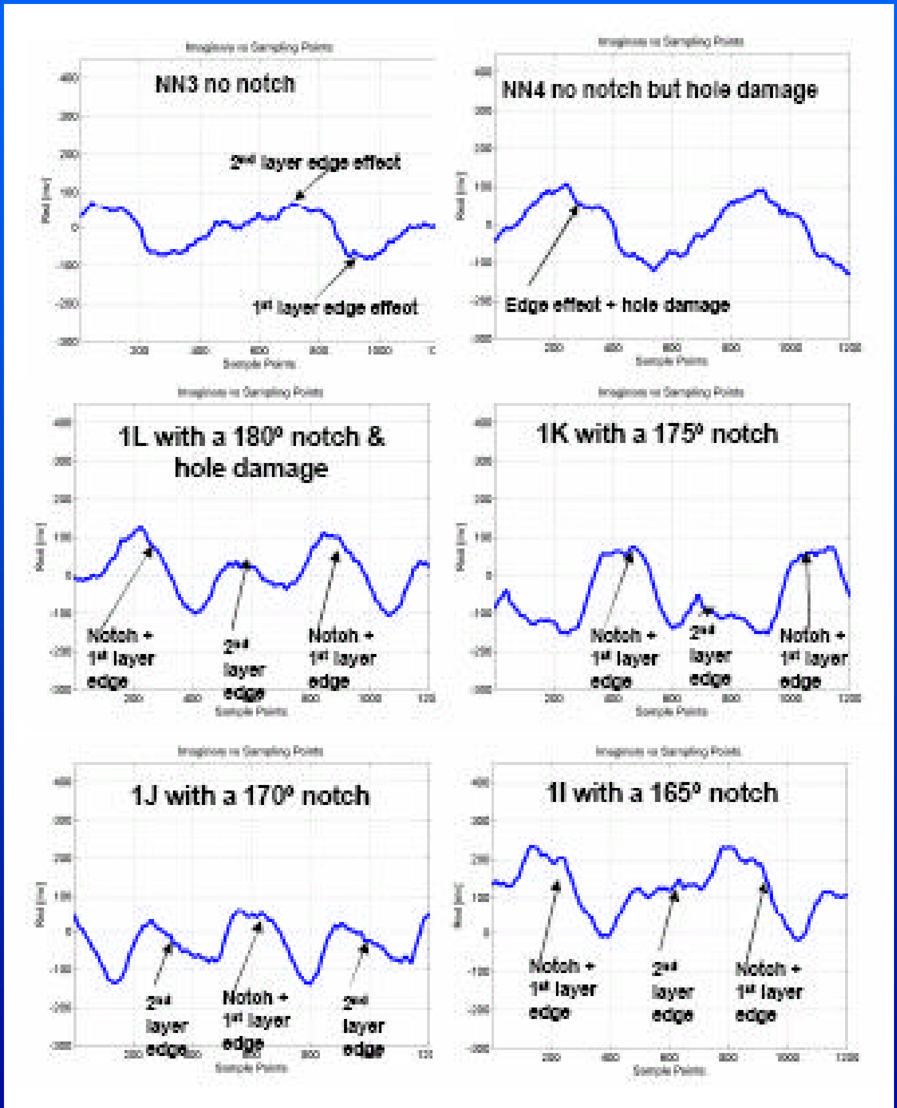
Note the immediate rotation of phase with the first EDM notch (0.100"), and the increasing phase rotation and amplitude with increasing notch size

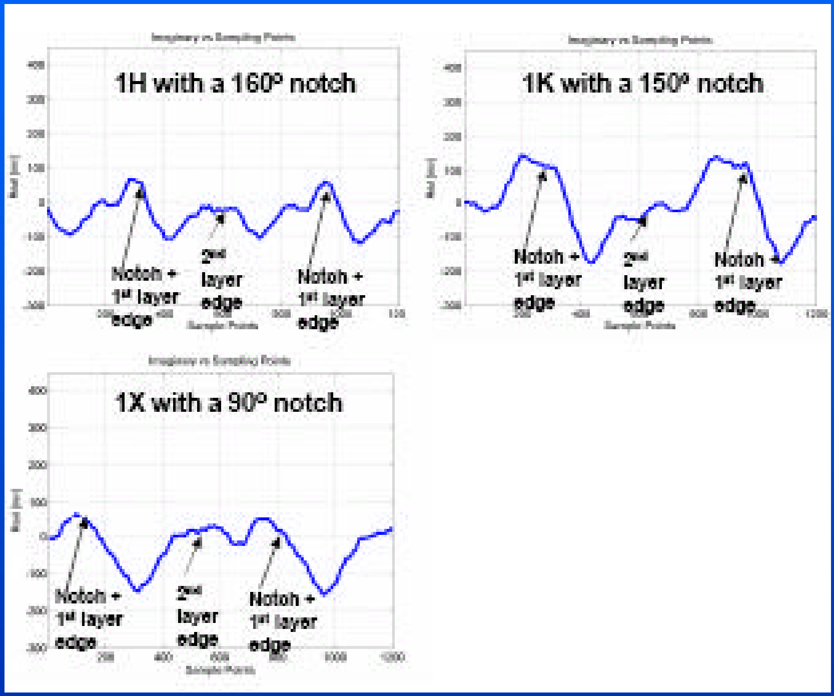
Illustration of Impedance Planes for 2st Layer Defects In the CC130 Test Piece (Through Notches)



Again note the rotation of phase and increase in amplitude with increasing EDM size

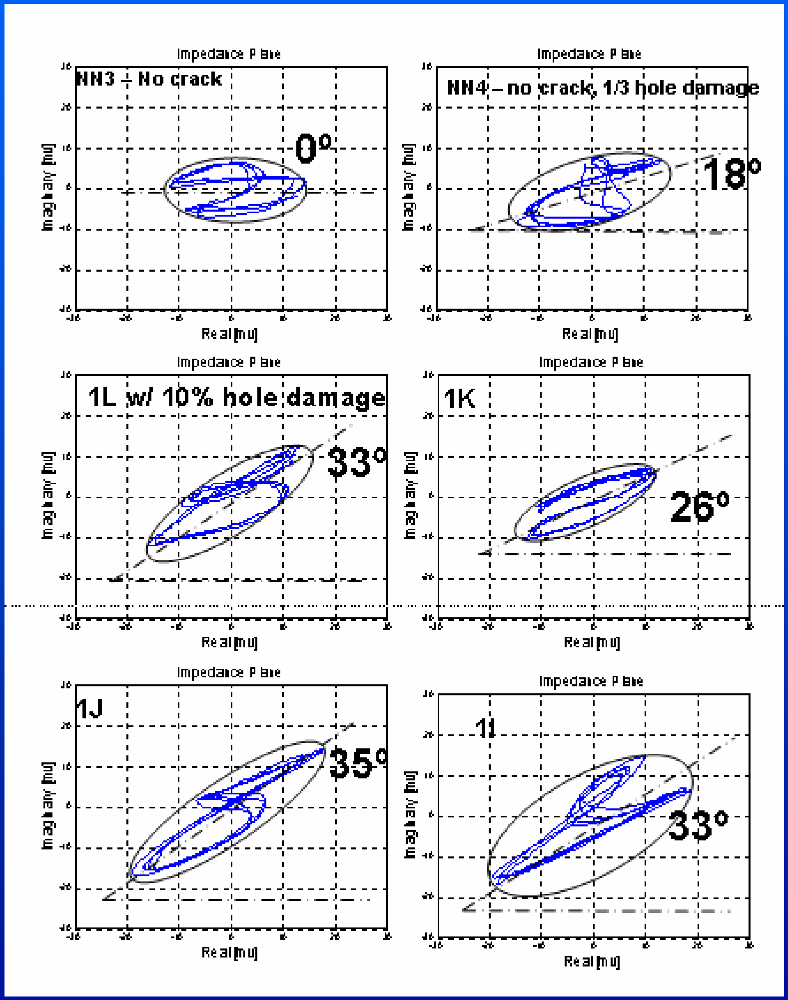
Imaginary Component of Impedance Planes for 2nd Layer Defects in the P3 Test Piece (Corner Notches)

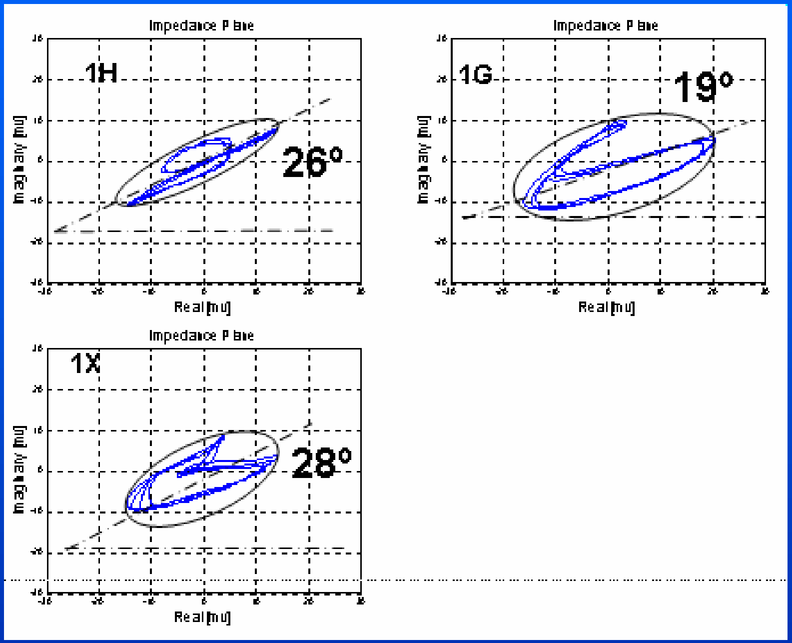




All the EDM notches are the same size. Variances in signals occur to the notch proximity to the 1st and 2nd layer edges. Note the increase in amplitude and increase in slope for the notched. (Driving frequency=1.6kHz)

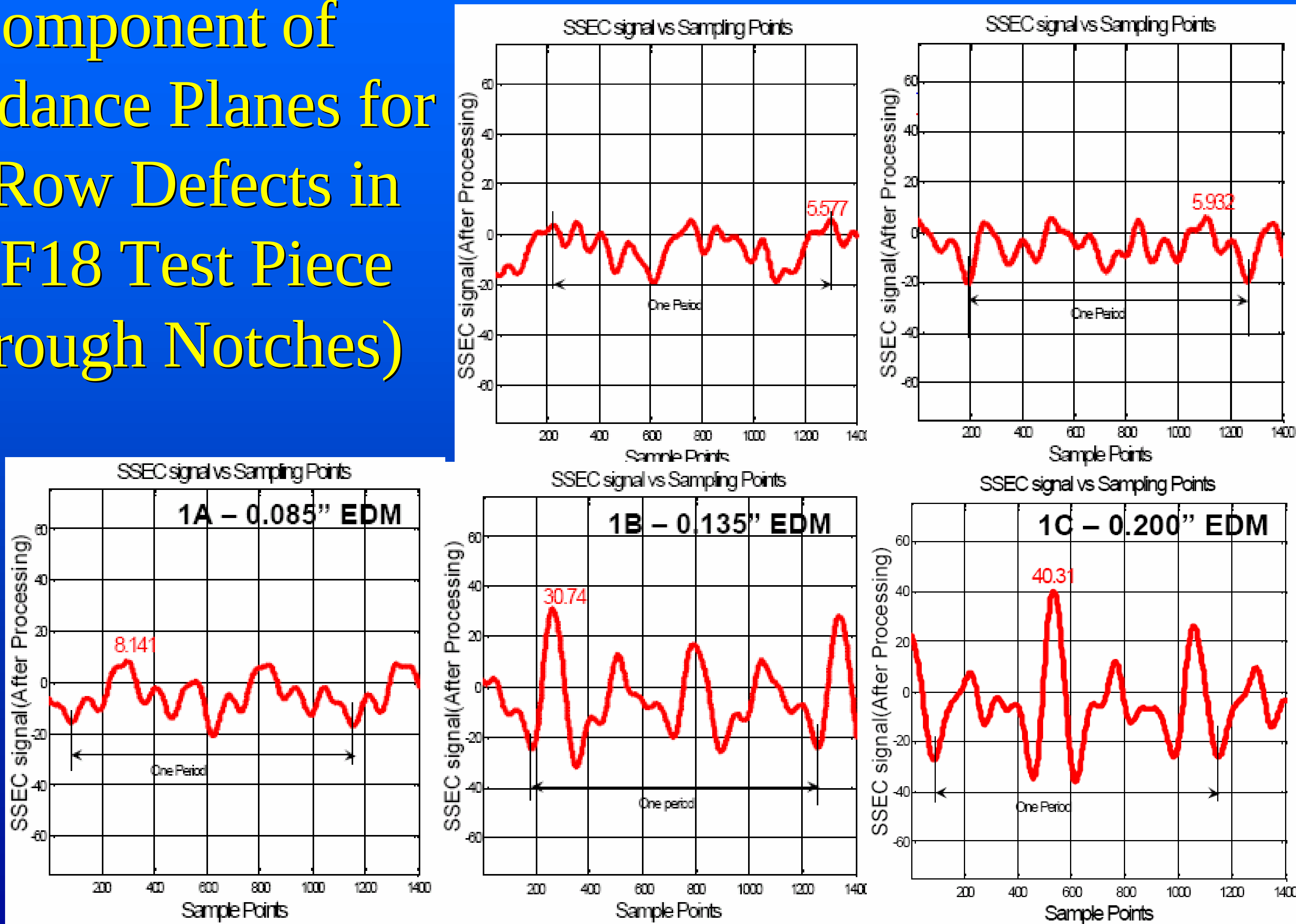
Imaginary Component of Impedance Planes for 2nd Layer Defects in the P3 Test Piece (Corner Notches)



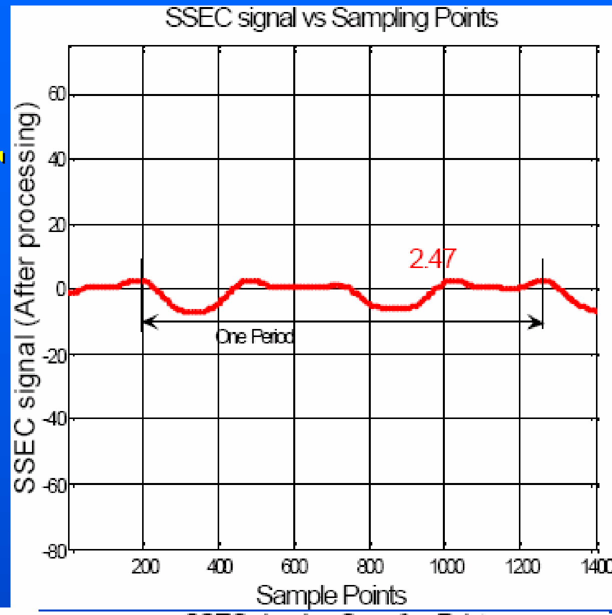


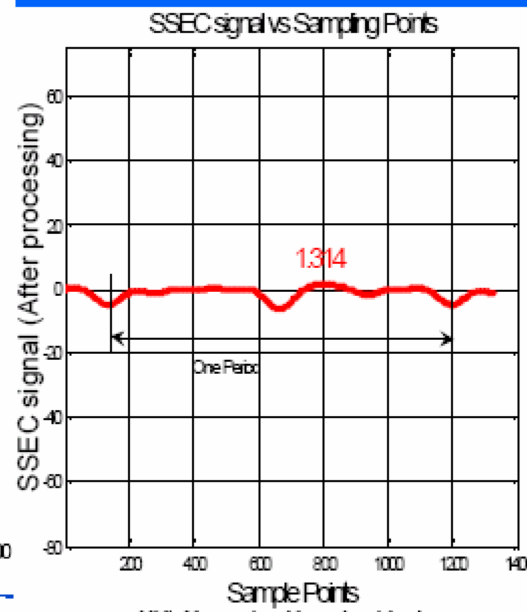
All the EDM notches are the same size. Variances in signals occur to the notch proximity to the 1st and 2nd layer edges. Note the increase in phase angle in impedance plane for the notched. (Driving frequency=0.8kHz)

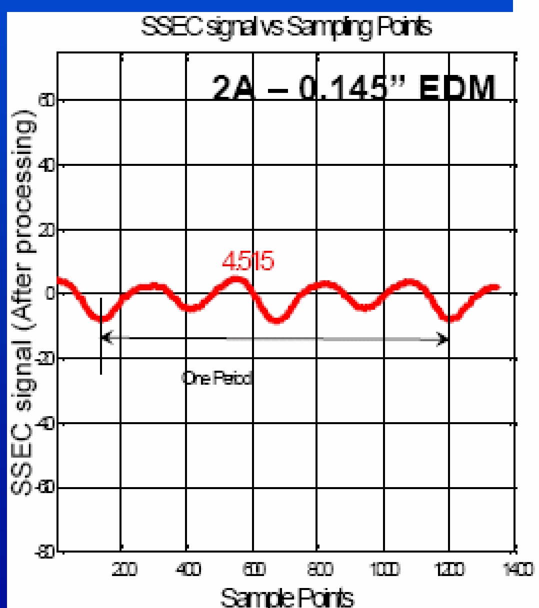
Imaginary Component of Impedance Planes for 1st Row Defects in the F18 Test Piece (Through Notches)

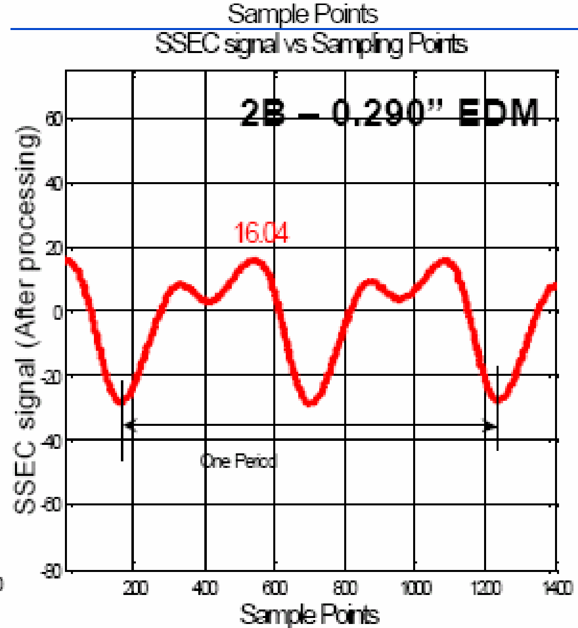


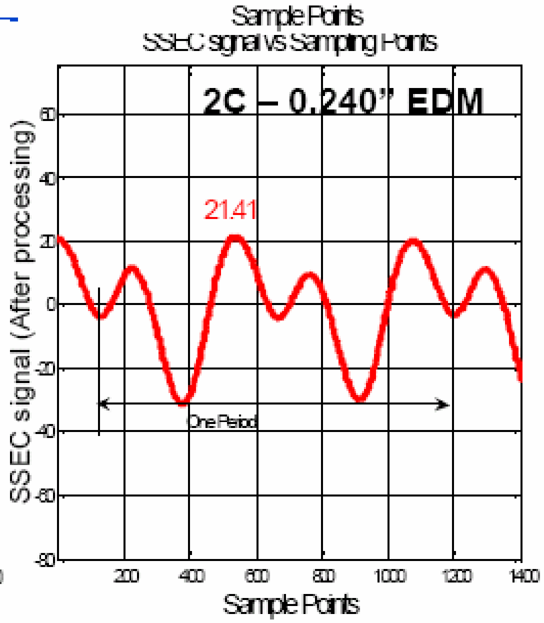
Imaginary Component of Impedance Planes for 2nd Row Defects in the F18 Test Piece (Through Notches)











Summary of F18 Test Piece Results

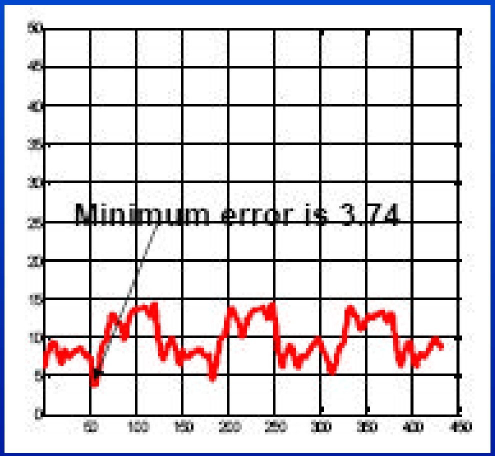
- EDM notches as small as 0.135" were detected " in 0.134' aluminum through 0.750" of composite material with an S/N > 3.
- Test results were influenced by nearby fasteners and the sealant groves (edge effects) in the second layer
  - Can be overcome by probe offset or probe enhancements

Comparison:
Before & After Post-Processing

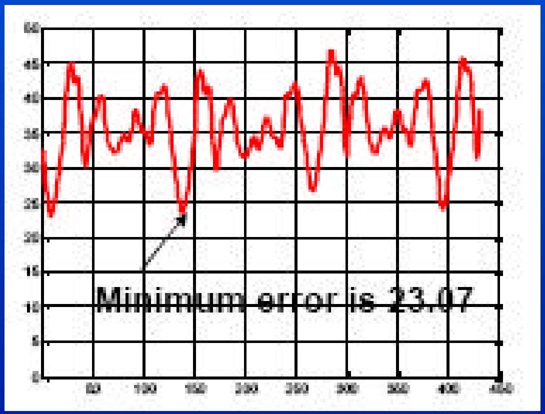
Fastener No.	Notch Signal		S/N	
	Before Processing	After Processing	Before Processing	After Processing
1NN1	61.2	5.58		
1NN2	62.9	5.93		
1A (35 ° , 0.085" long)	75.7	8.14	1.20	1.37
1B (35 ° , 0.135" long)	110.8	30.74	1.76	5.18
1C (35 ° , 0.200"long)	131.2	40.31	2.09	6.80
2NN1	29.9	2.47		
2NN2	22.4	1.31		
2A (45 ° , 0.145" long)	30.3	4.52	1.01	1.83
2B (45 ° , 0.290" long)	132.9	16.04	4.44	6.49
2C (45 ° , 0.240" long)	132.7	21.41	4.44	8.67

Recent Trials on the F18 Test Piece

- Application of reference subtraction variation
  - Use wavelet method to do the fit every 10 points
  - For every fitting calculate RMS error
  - Plot RMS error



Fastener with no defect: low RMS error



Fastener with 0.120” x 0.200” EDM Notch: large RMS error

Further Work

- For the P3 test pieces
  - Repeat inspection on test pieces with simulated differential reflection
  - Vary the digital filter parameters
  - Apply methodology to real P3 structure with real defects
- For the CC130 test pieces
  - Apply methodology to test pieces with 1st and 2nd layer defects in chordwise direction
  - Apply methodology test pieces with raised head fasteners
  - Apply methodology to Lockheed SB92-790 inspections
- For F18
  - Trail inspections on F18 wings

Further Work

- Investigate possibility of combining FG_RFEC technology with C-Scan capabilities
- Real time post data analysis

Conclusion

- The FG_RFEC technology has been successfully applied to test pieces representative of thick complex aircraft structures
- Further work is ongoing
  - New test pieces
  - On wing trials
- Thank you to Mr Yushi Sun of Innovative Materials Testing Technologies (IMTT) for his assistance to the Canadian Forces ASIP program