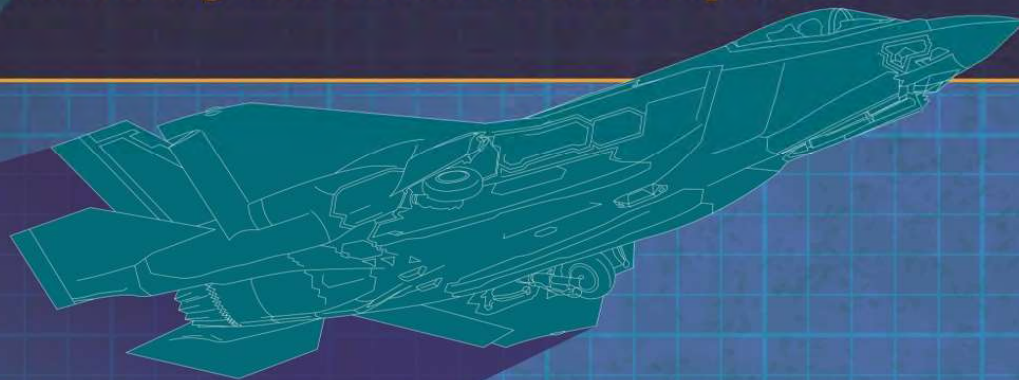


PART WORKS

Reinventing The Future Of Cold Expansion™

COLLABORATE WITH US
FOR EARLY ACCESS TO OUR
PATENT-PENDING* WORK

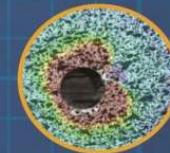


Enhanced Technology Repair for Corrosion and Fatigue Damage in Hybrid Aerostructure

AA&S 2024

Presented by Jude Restis

PARTWORKS.COM



PART WORKS

Galvanic Corrosion of Hybrid Structure

Widespread galvanic corrosion damage experienced on multiple programs with composite over aluminum in the presence of moisture



US Navy Inspector General Report
As reported in Navy Times
By Diana Stancy Correll
Oct. 5, 2021

“Between FY17 and FY20, corrosion costs accounted for \$2,086,796,553, amounting to 29.4 percent of the total maintenance cost for [F-18C-G] aircraft.”



From “In-service Corrosion Issues in Sustainment of Navy Aircraft” briefing, R. Mendoza, Aug 2012

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F-18: Canary in the Coal Mine

F-18's Awaiting Depot Induction at North Island



Typical repair:

- Ream hole to remove all corrosion
- Perform analysis
- Install oversize fastener or bushing

Navy indicated to repair a single corroded bolt hole may take several weeks and cost many thousands of dollars

Leveraging years of experience and extensive knowledge of airframe design and repair, Partworks conceived of better way to repair corroded fastener holes

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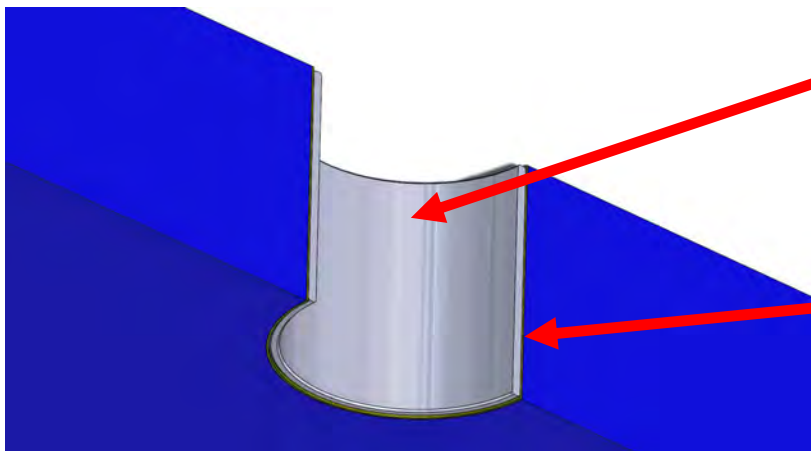
PartWorks Bushing Repair

Thin wall

- CRES Bushing barrel
- Minimizes material removal
- Maximizes e/D
- Maximizes cold expansion to the structure

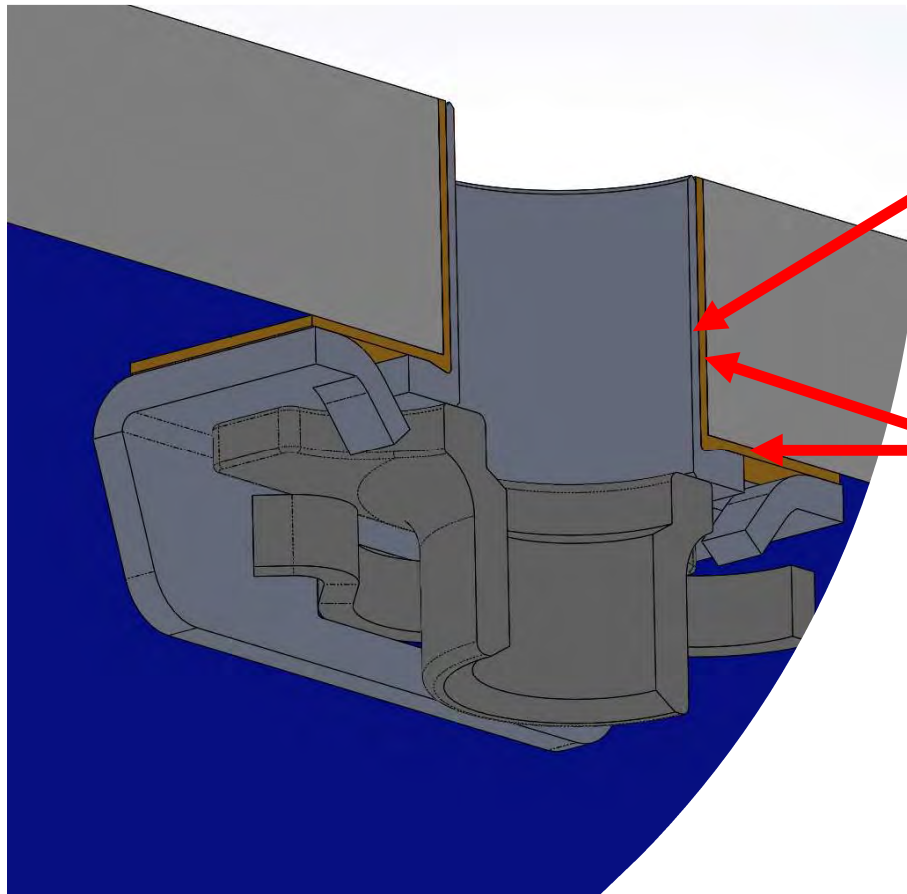
Adhesive

- Galvanic barrier
- Minimal surface preparation



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PartWorks Repair – Thin Wall Bushing or Nut Plate



Thin wall

- CRES barrel
- Minimizes material removal
- Maximizes e/D
- Maximizes cold expansion to the structure

Adhesive

- Maximizes torque-out and push out
- Galvanic barrier
- Minimal surface preparation

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Test Program

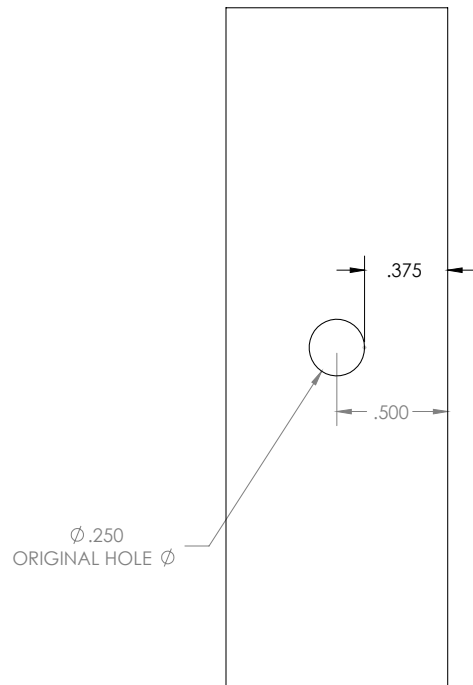
Carried out in Conjunction with:

- University of Virginia
 - Georgia Tech
-
- Quantify damage experienced in USN & USAF Fleets due to galvanic corrosion
 - Develop techniques to replicate corrosion damage on test coupons
 - Perform fatigue testing to assess debit/enhancement in fatigue life due to corrosion and Partworks repair
 - Perform computational analysis to correlate fatigue behavior and predict residual stress
 - Evaluate residual stress field using Digital Image Correlation (DIC) and correlate with X-Ray diffraction measurements and FEA
 - Develop tooling and measurement techniques to allow taking credit for repair (in-process measurements)

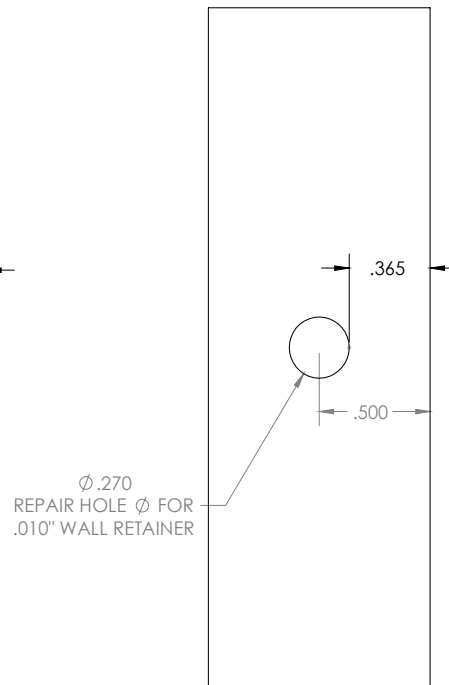
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Preserve Edge Margin

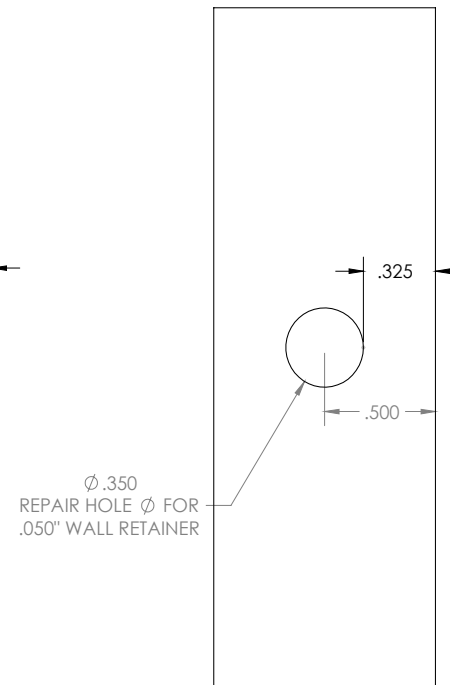
Ideal Design
 $e/D = 2.0$



PartWorks
 $e/D = 1.85$



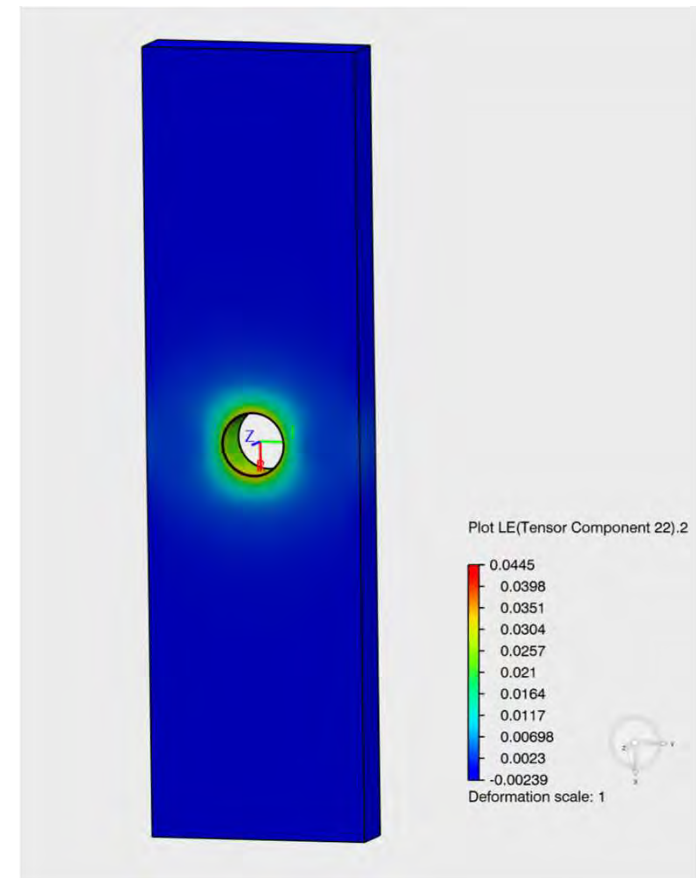
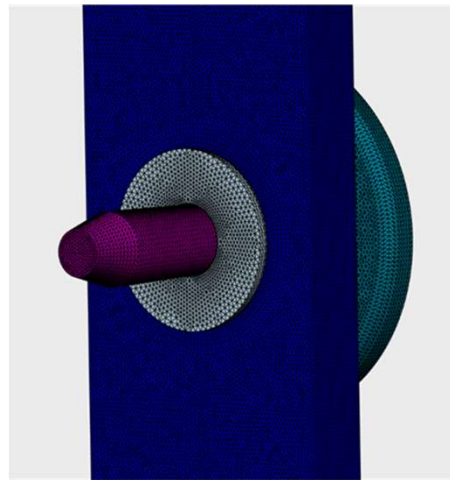
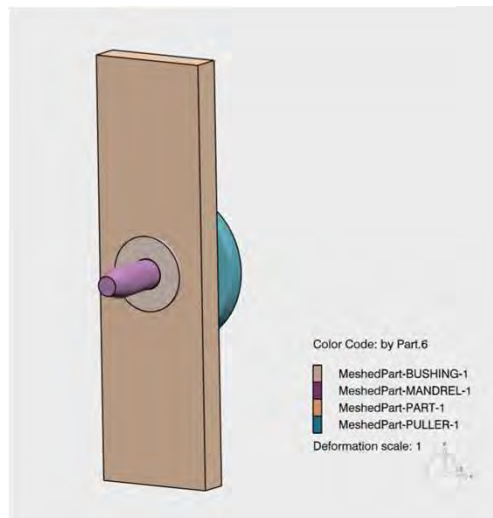
Status Quo
 $e/D = 1.43$



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FEA - Process Simulation

- 3-D Pull Through Model
- Elastic-Plastic Properties of the Material
- Contact Modeled

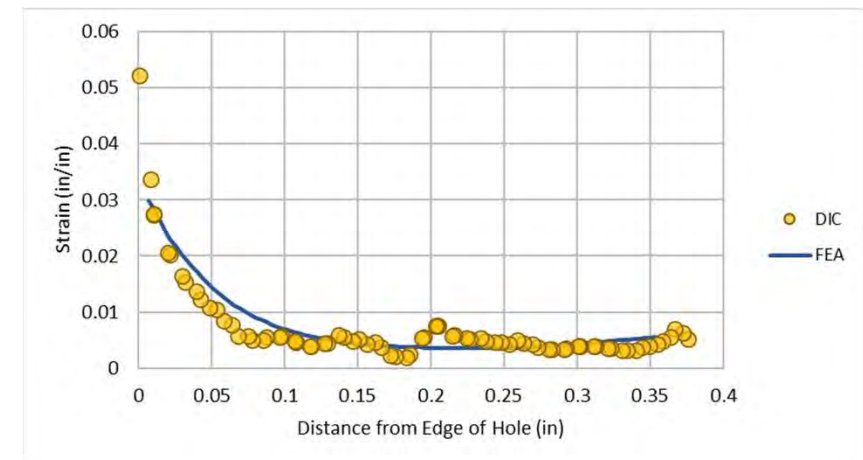
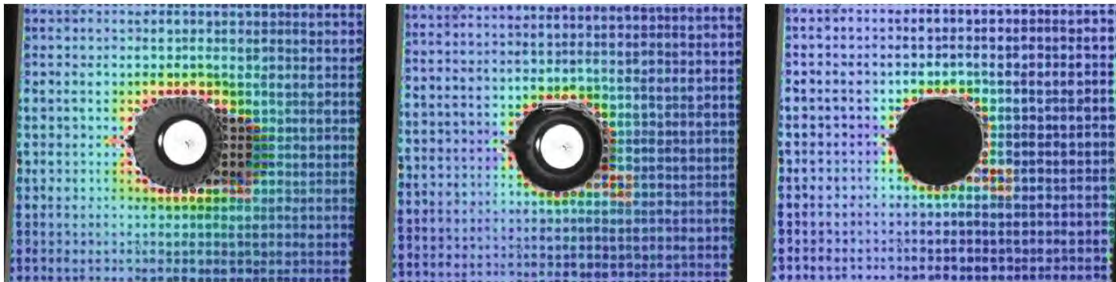


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In Situ Process Validation

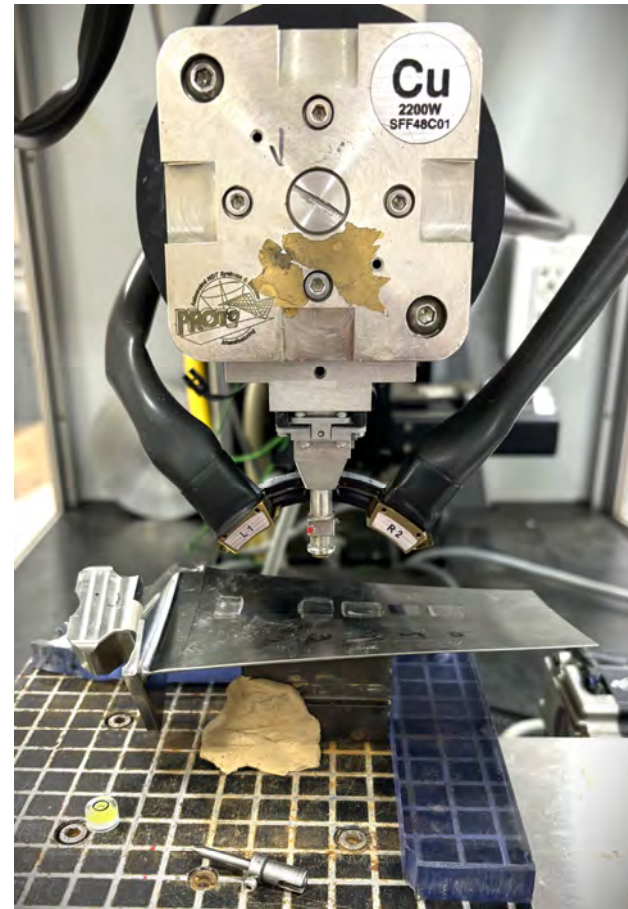
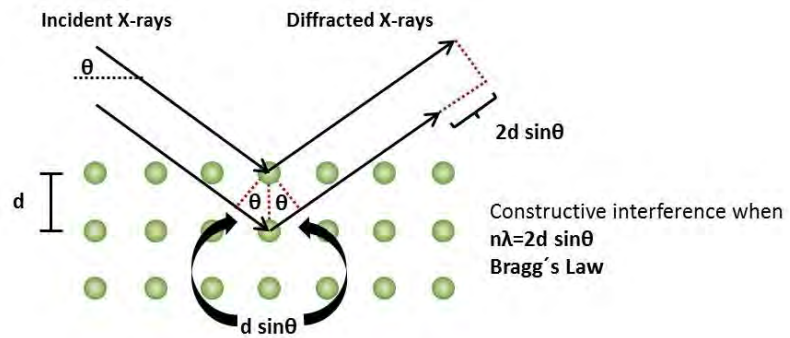
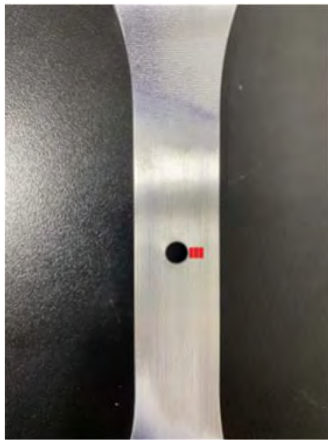
Residual Strain Visualization with DIC

- Image Capture: Before, during and after repair
 - On-tool image capture
- DIC used to correlate residual strain with FEA
- Will also be correlated to X-Ray diffraction



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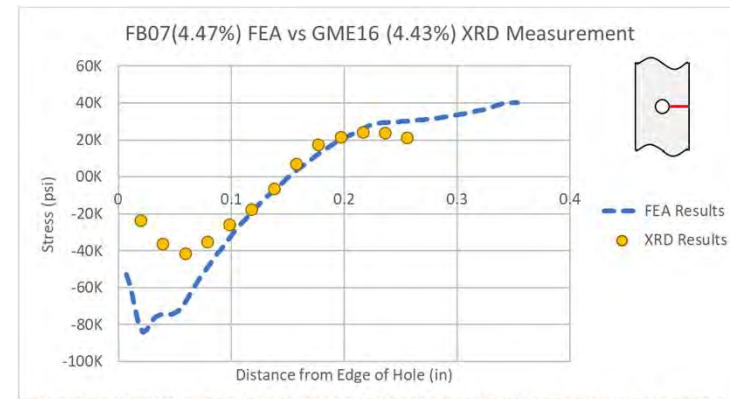
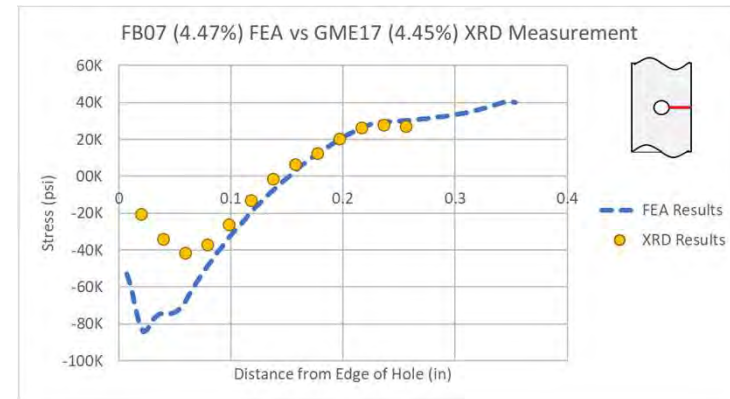
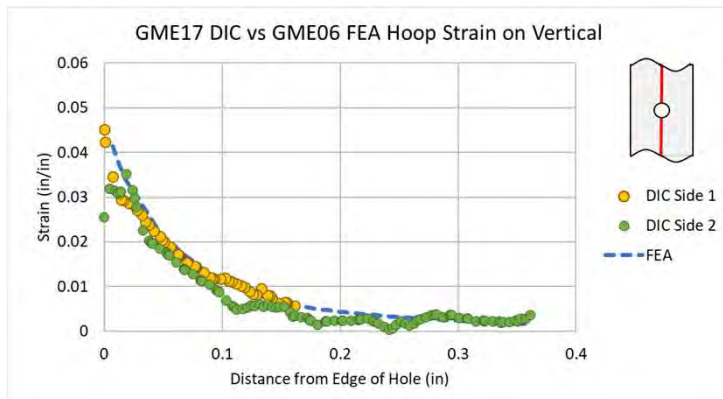
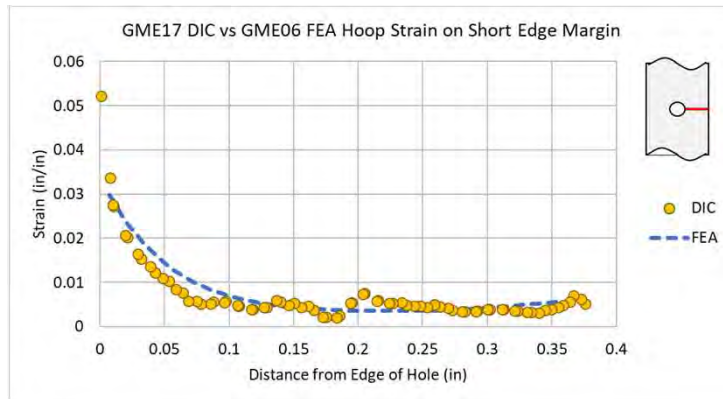
X-Ray Diffraction



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USAF Test Program

- Correlation – FEA, Digital Image and X-Ray Diffraction



Test Program

- Testing
 - Corrosion
 - Fatigue

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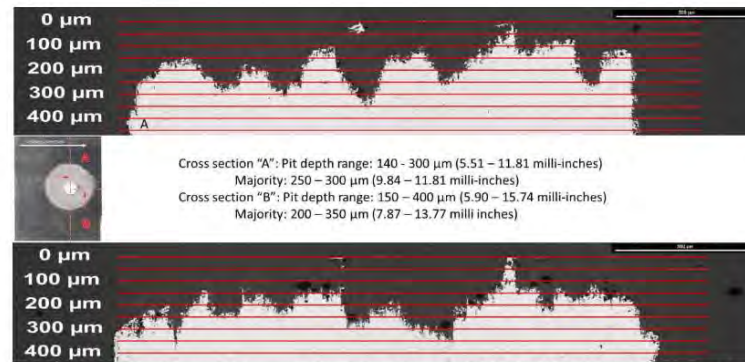
Corrosion Protocol Development



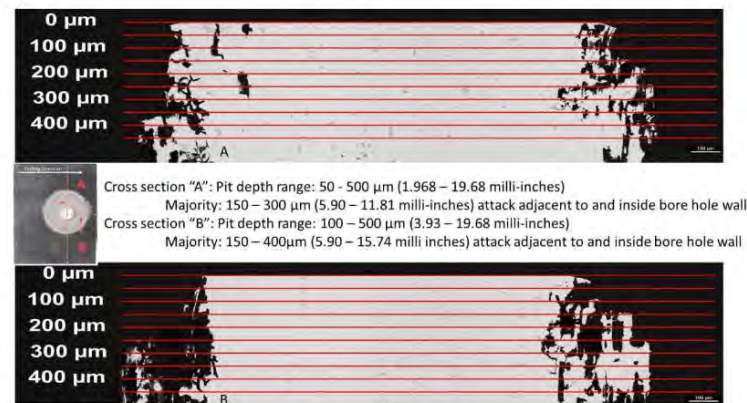
- NaCl and NaAlO₂ solution
- Dogbones masked with electroplaters tape
- 0.25 in dia. hole, 0.75 inch dia. surface exposure each side of dogbone

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Corrosion Protocol Development



0.06 thick 7050 – 120 hour corrosion protocol

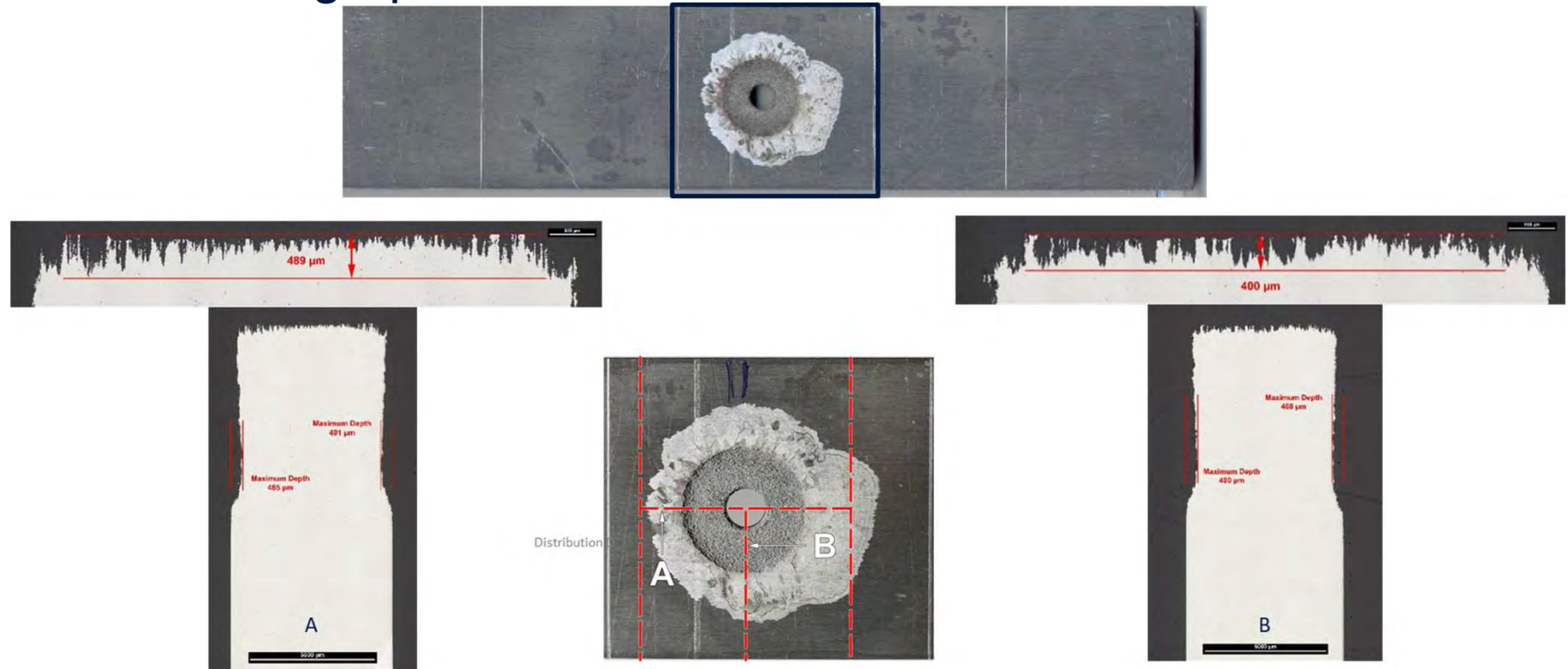


0.06 thick 2124 – 72 hour corrosion protocol

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Corrosion Protocol Development

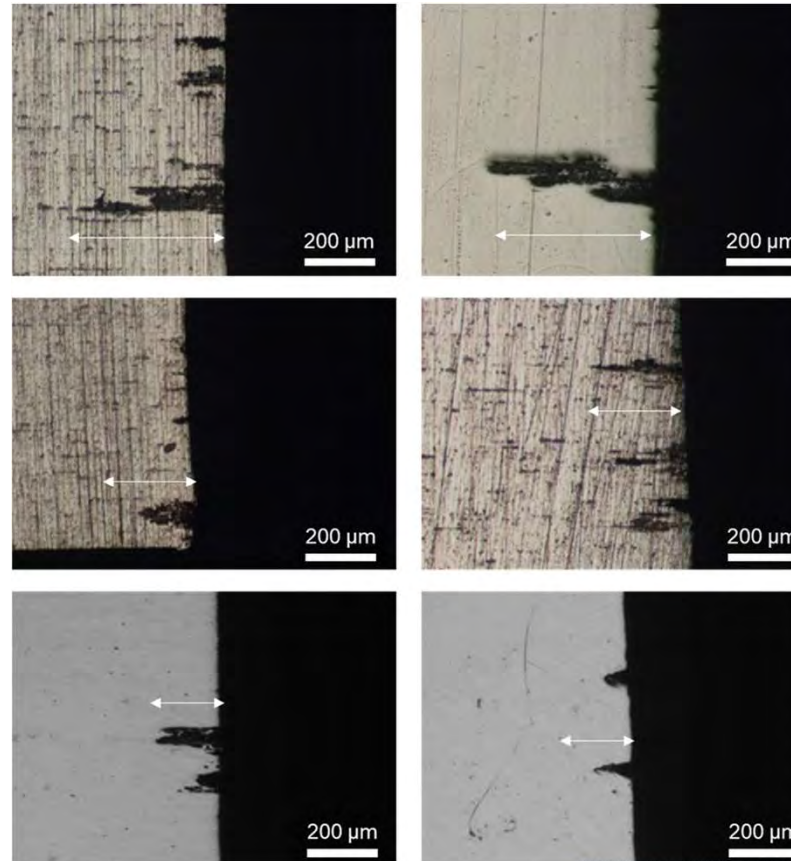
Metallographs of Plate Surface and Fastener Hole Wall



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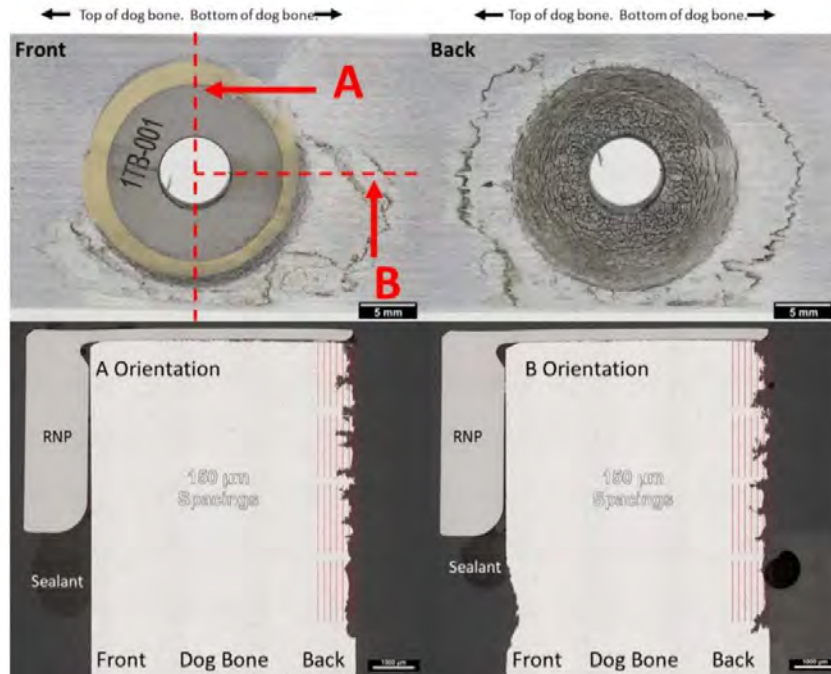
Corrosion Protocol Development

Metallographs of Plate Surface and Fastener Hole Wall



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Galvanic Barrier



7050 material – 120 hour corrosion protocol

Goal

- Contaminant tolerant
- Cold expansion compatible
- Sufficient mechanical properties
- Dielectric Insulator
- Impervious to moisture
- Permanent installation

Galvanic Barrier

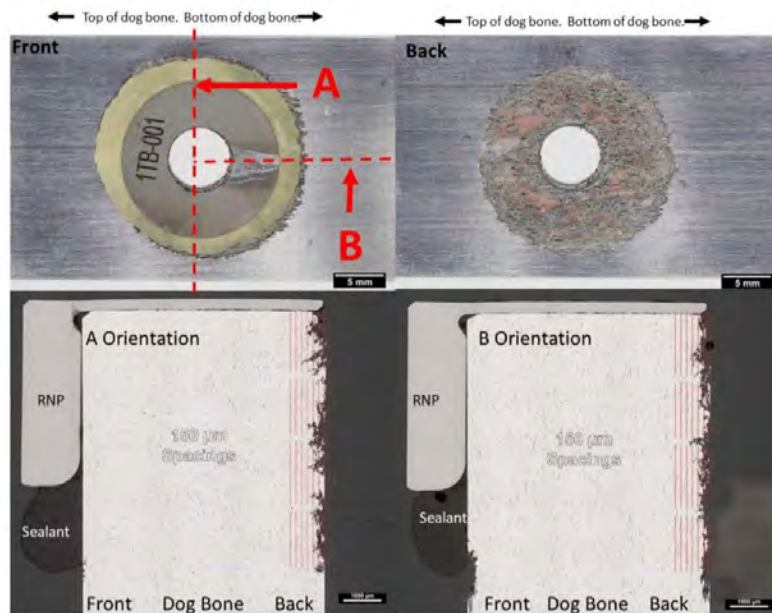


Figure 24. Dark field image of RNP-sealant/bore hole wall interface on back of dog bone. (Left) Orientation "A". (Right) Orientation "B".

2124 material – 120 hour corrosion protocol

Fatigue Test Program

Load Spectrum	Parent material
F-35	7050-T7451
F-35	2124-T8151
F-22	2124-T8151
F-22	7050-T7451

Baseline – open hole, no corrosion

Corroded - open hole

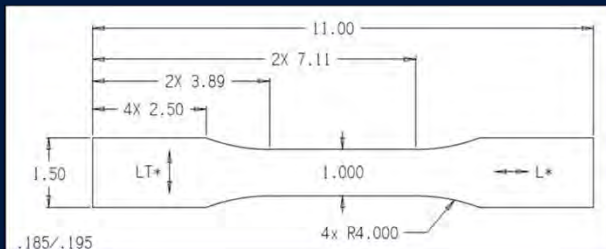
Repair - no corrosion

Corroded, reamed repaired

Corroded, reamed, repaired, corroded

Corroded, repaired (no ream)

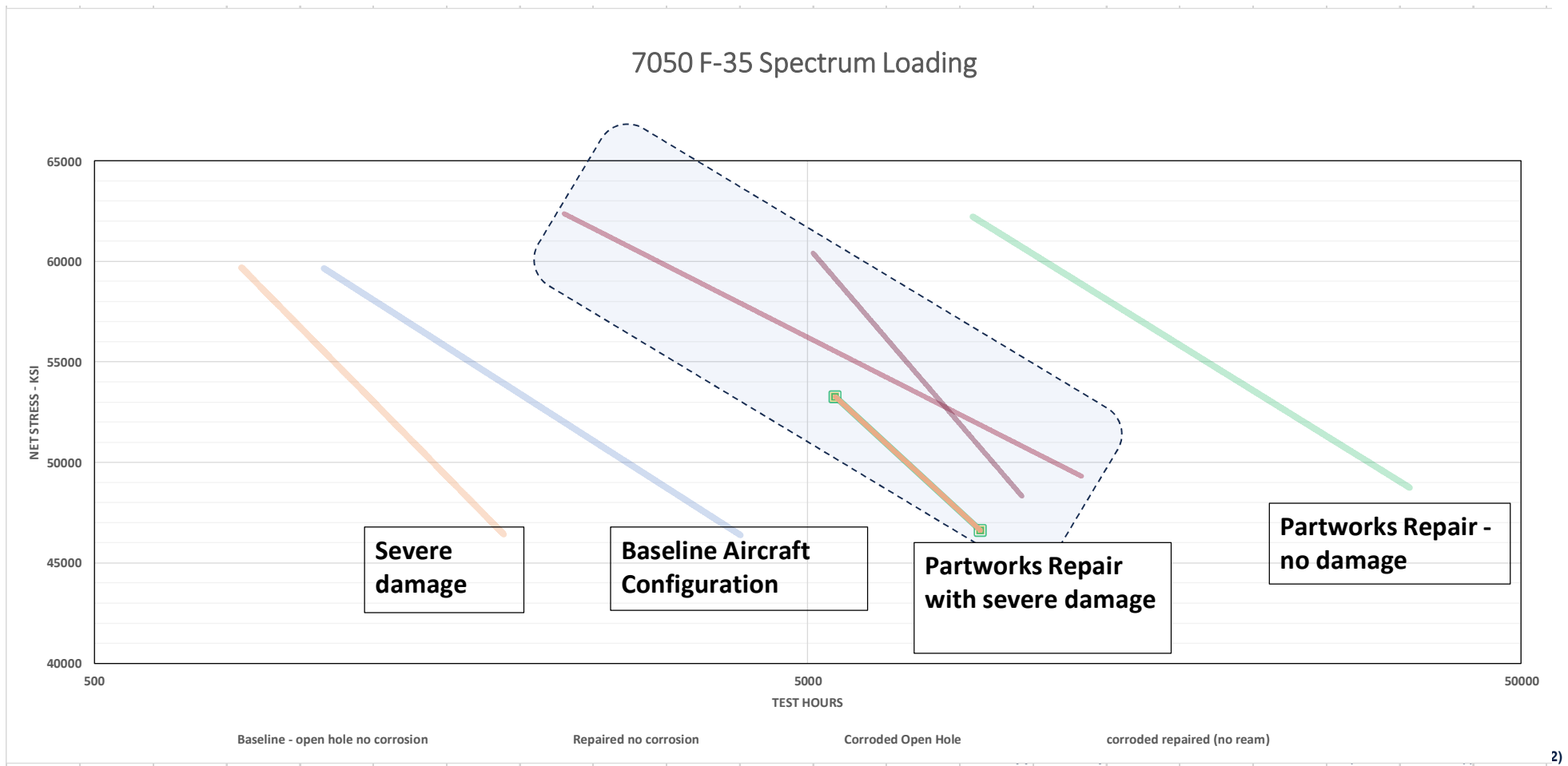
Repaired when new, cycle for 10K cycles, then corrode and cut coupon in half to look for potential corrosion between bore of hole and barrel of thin wall bushing



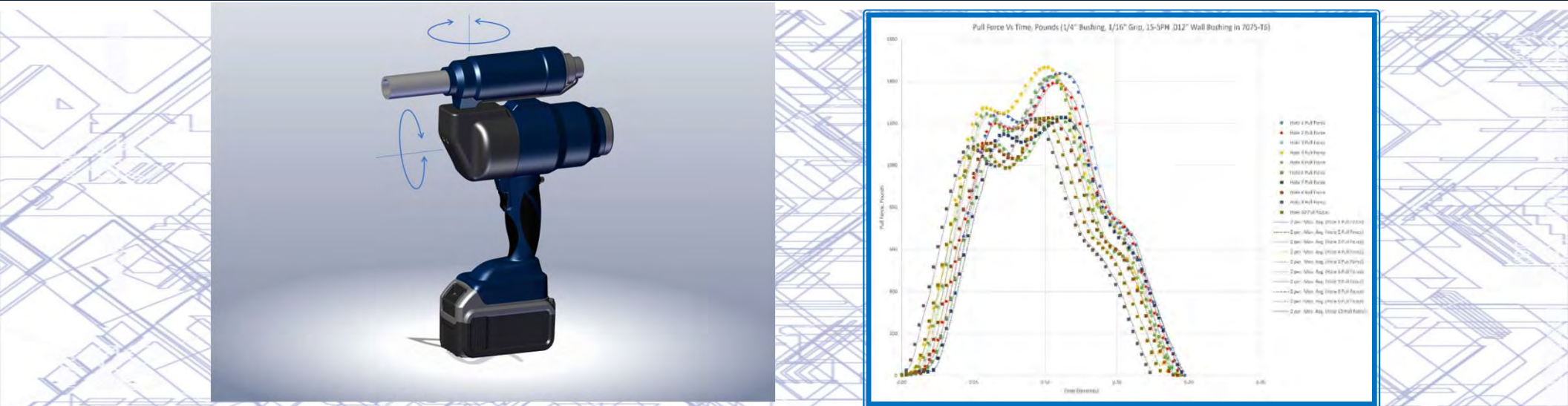
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Fatigue Testing

7050 F-35 Spectrum Loading



Process Verification - In Tool Measurement and Feedback



- Cold Expansion process parameters and pull-force documented in tool
- Pull-force data correlated to:
 - DIC
 - Test data
 - Material properties and geometries
- Good / Bad feedback provided to operator

Process Verification - In Tool Measurement and Feedback



Handheld Puller with Process Control Electronics Incorporated



Process Control Software Identifying Successful Installation



Process Control Software Identifying Unsuccessful Installation with LED and Red Graph

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Augmented Reality for Repair Tracking



- Record data real-time without operator intervention
- Validate correct hole repaired with right tooling/ fastener
- Simple set up with out complex calibration process
- Integrated scanning and mapping holes to database
- Compatible with phone/tablet/glasses/goggles
- X-ray view/Peel-away for parts where 3D model available (not required)

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What is Augmented Reality (AR)?

AR overlays digital content onto the real world in real-time, enhancing the user's perception of their environment.



Considerations for New Production



USN F-18 program spends \$690M / year on corrosion (30% of total maintenance budget)

Hybrid structure of some of the newest aircraft have similar corrosion problems

Prevent today's corrosion problems from becoming tomorrow's.

PartWorks solution incorporated in new production can mitigate corrosion in fastener holes

Thank you



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jhrestis@partworks.com

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