Characterization of MSD in Emerging Metallic Structures Technology for Fuselage Lap Joints

Presented to: International Committee on Aeronautical Fatigue and Structural Integrity

By: Kevin Stonaker

Date: June 29, 2023

Agenda

- Program Overview
- Test Setup
- Results
- Summary

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- Ron Weddle
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- Dave Stanley
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- Danielle Stephens
- Burak Kumas
- Walt Sippel
- Patrick Safarian
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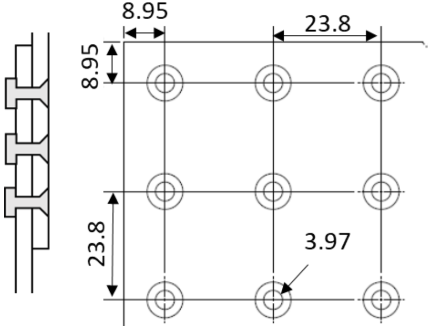
Program Overview

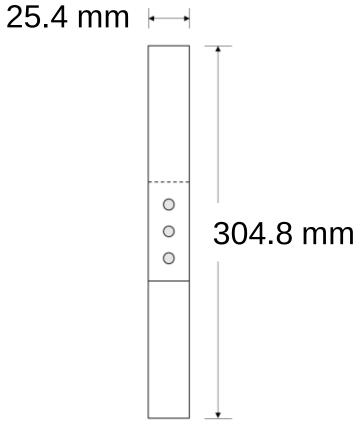
Dimensions in mm



OBJECTIVE: For a generic lap joint configuration, compare Multi-Site Damage (MSD) initiation and growth characteristics in baseline 2524-T3 alloy and advanced 2060-T8 Al-Li alloy

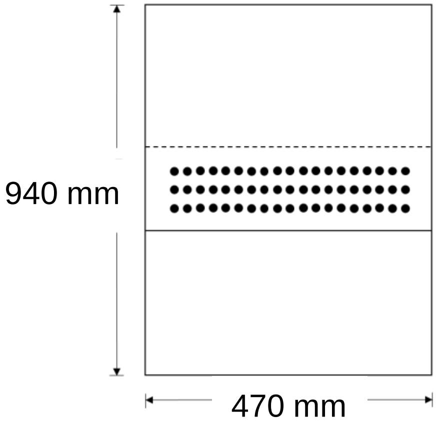
Single Rivet Column

(Tests by FAA and Embraer)



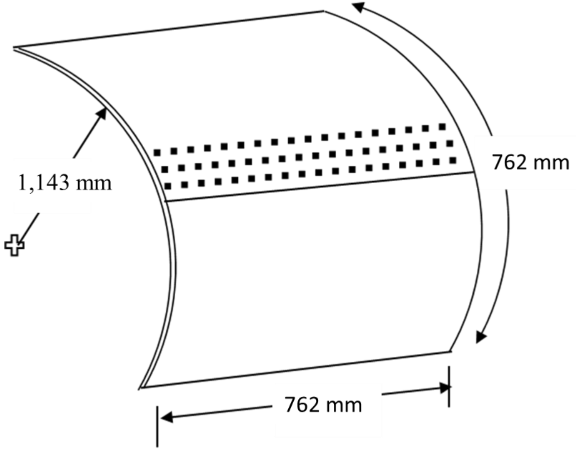
Wide Flat Panels

(Tested by FAA)



Curved Sub-scale Panels

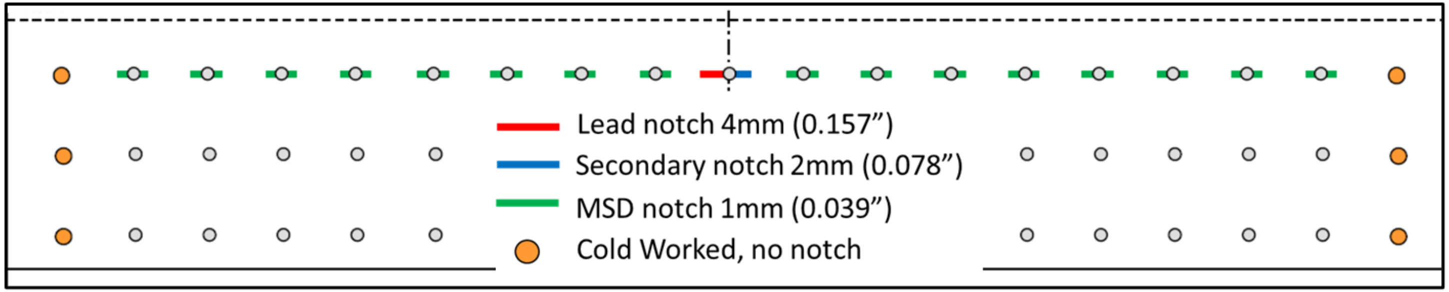
(Tested by Embraer)



MSD Growth Evaluation

OBJECTIVE: MSD growth from a common initial EDM notch configuration for wide flat and curved sub-scale panels. Comparison of coupon size and secondary bending effects.

Test Conditions: 87.5 MPa farfield stress
R=0.1

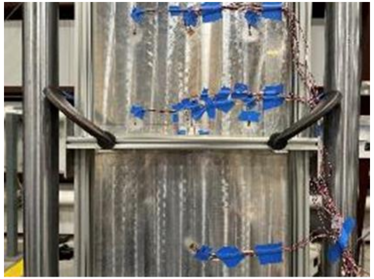


Sheet Material	Rivet Type	Quantity		
		Wide Flat Panels		Curved Sub-scaled Panel
		Unconstrained	Constrained	
2524-T3 (growth from MSD scenario)	MS14218AD5	2	2	3

Test Setups

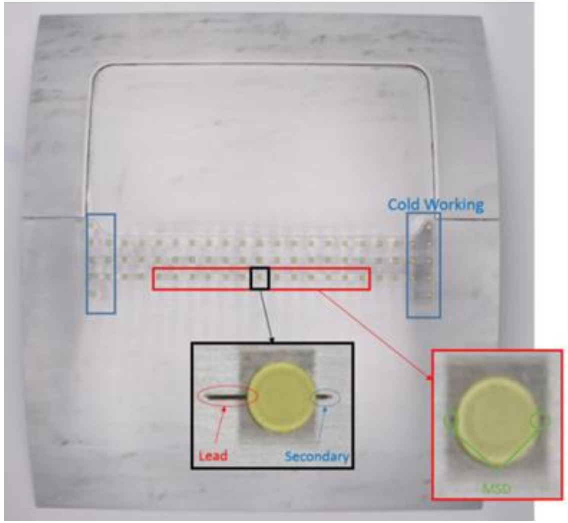
Wide Flat Panels

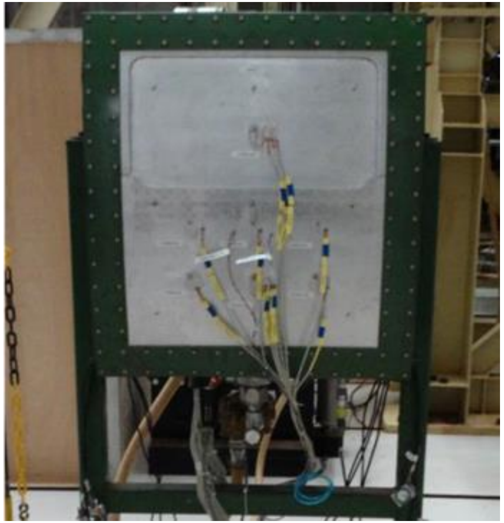
(Tested by FAA)



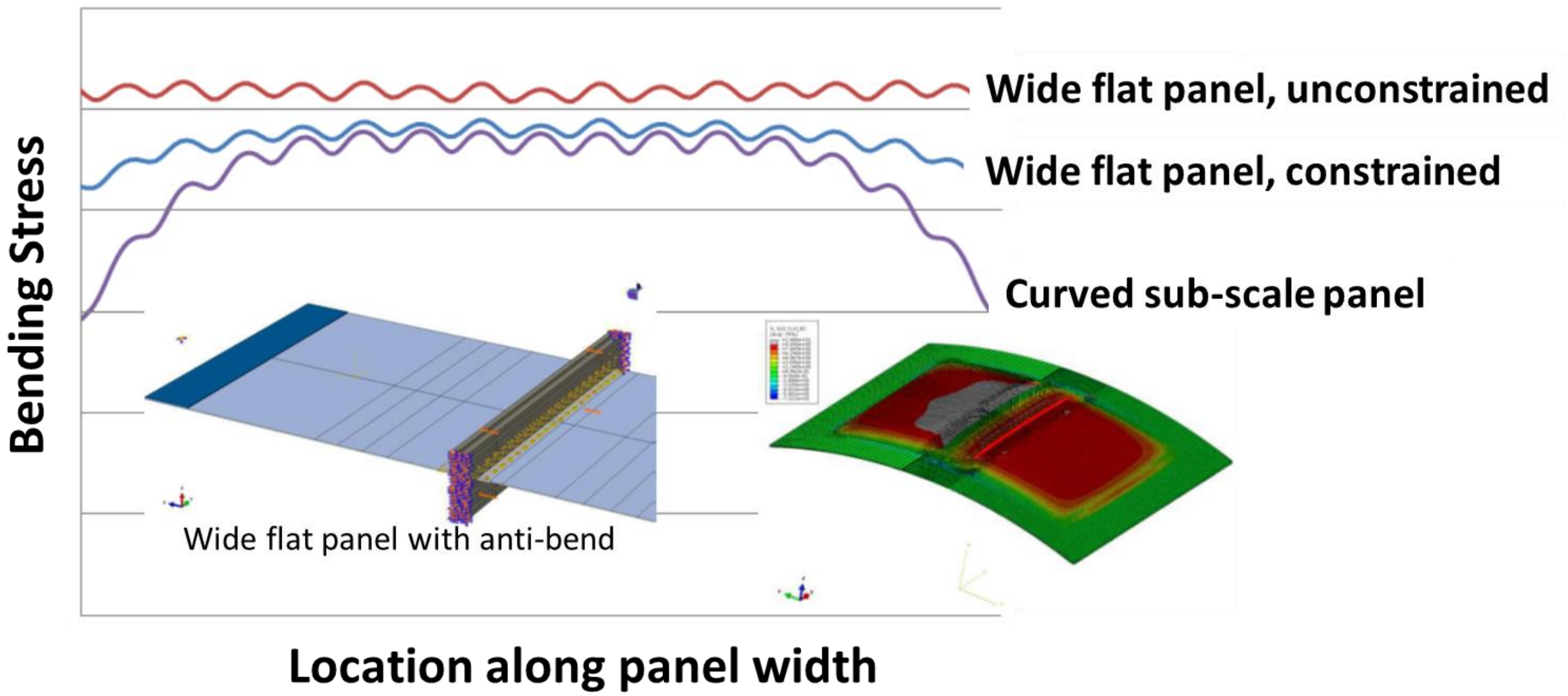
Curved Sub-scale Panels

(Tested by Embraer)

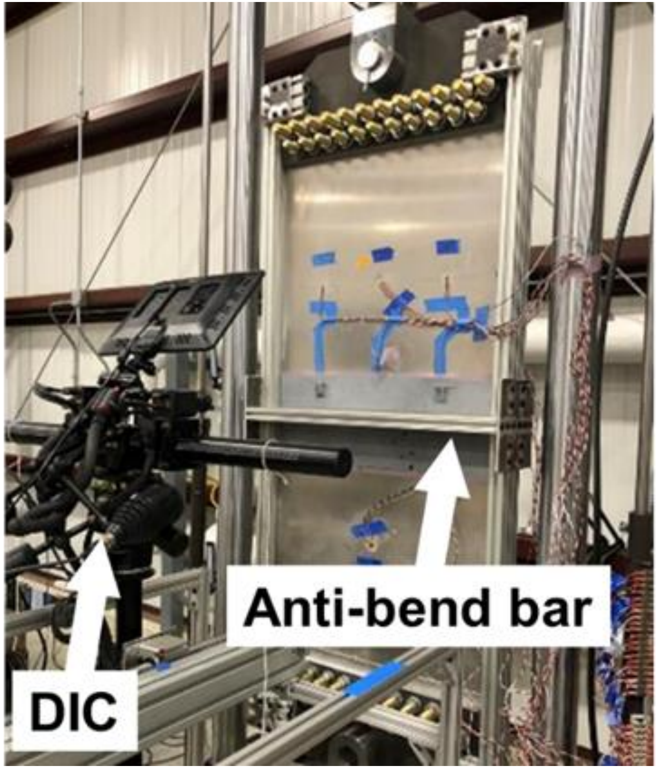


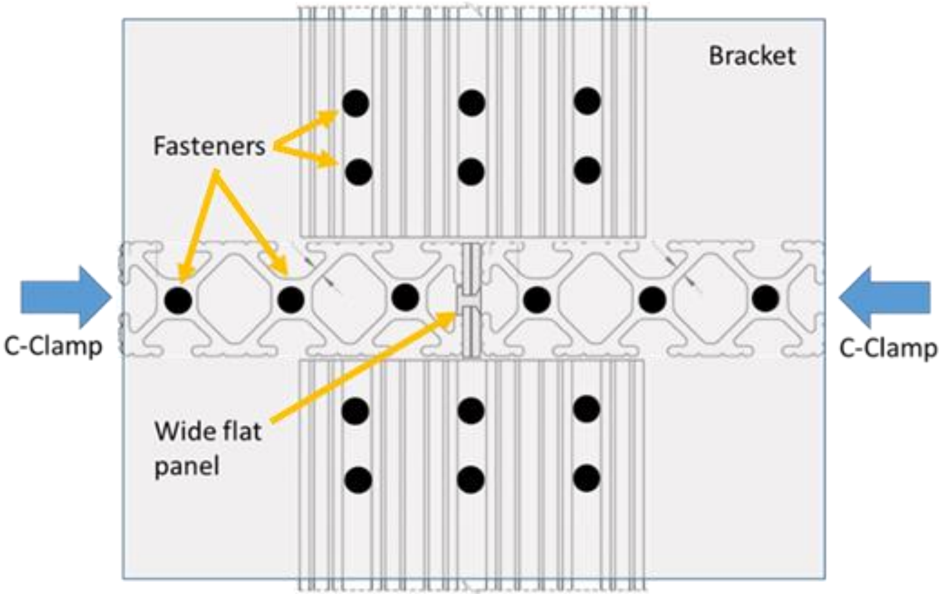


Pre-test Analysis



Flat Panel Anti-bend Device

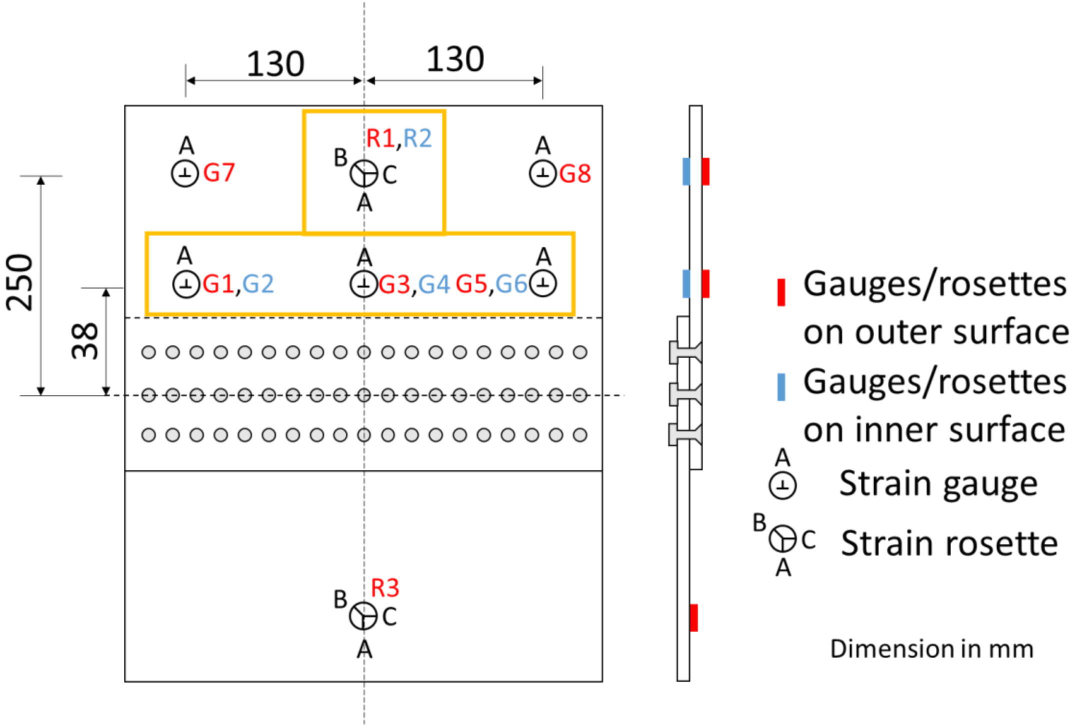




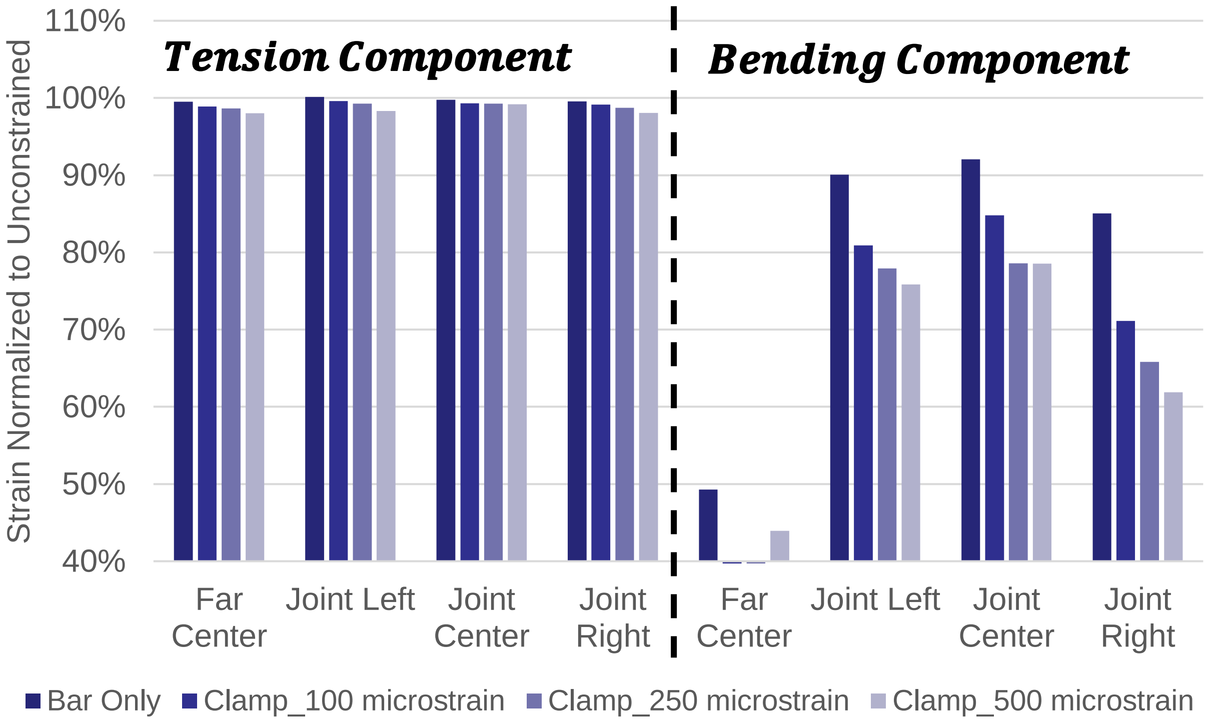
Instrumentation and Inspections

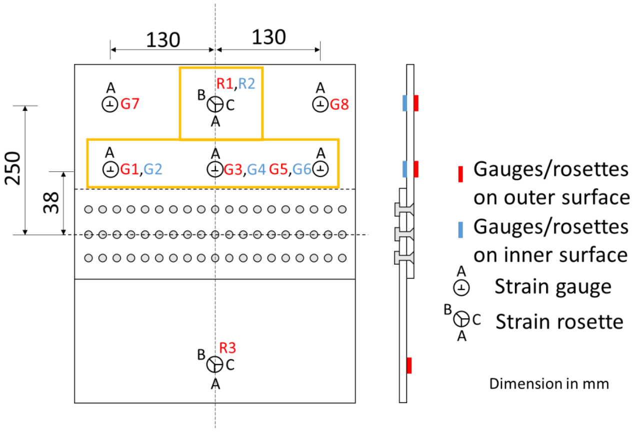
Inspections performed at regular intervals throughout the test, including:

- Strain surveys
- Visual inspections
- Eddy current inspections
- Digital image correlation
- Marker band sequences coordinated with inspection pauses



Flat Panel Constraint

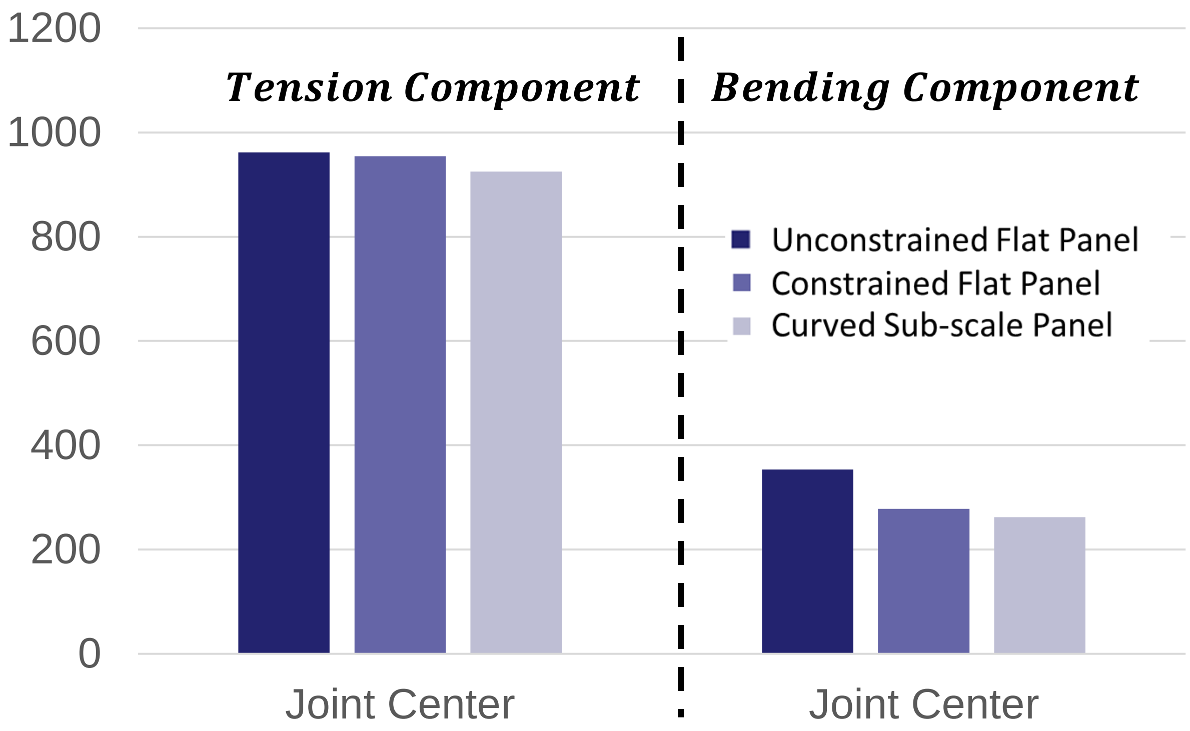


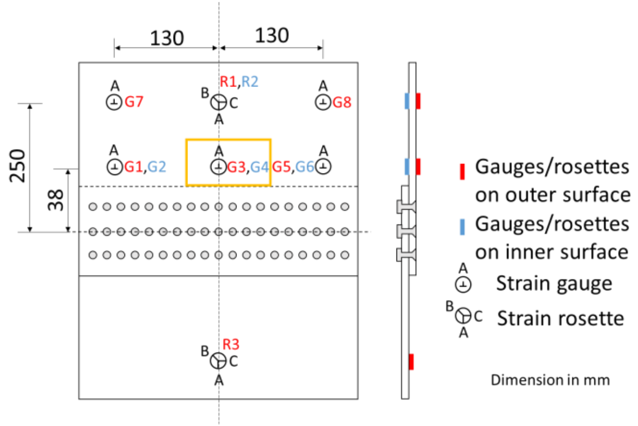


$$Tension = \frac{1}{2}|\varepsilon_1 + \varepsilon_2|$$

$$Bending = \frac{1}{2}|\varepsilon_1 - \varepsilon_2|$$

Flat Panel Constraint

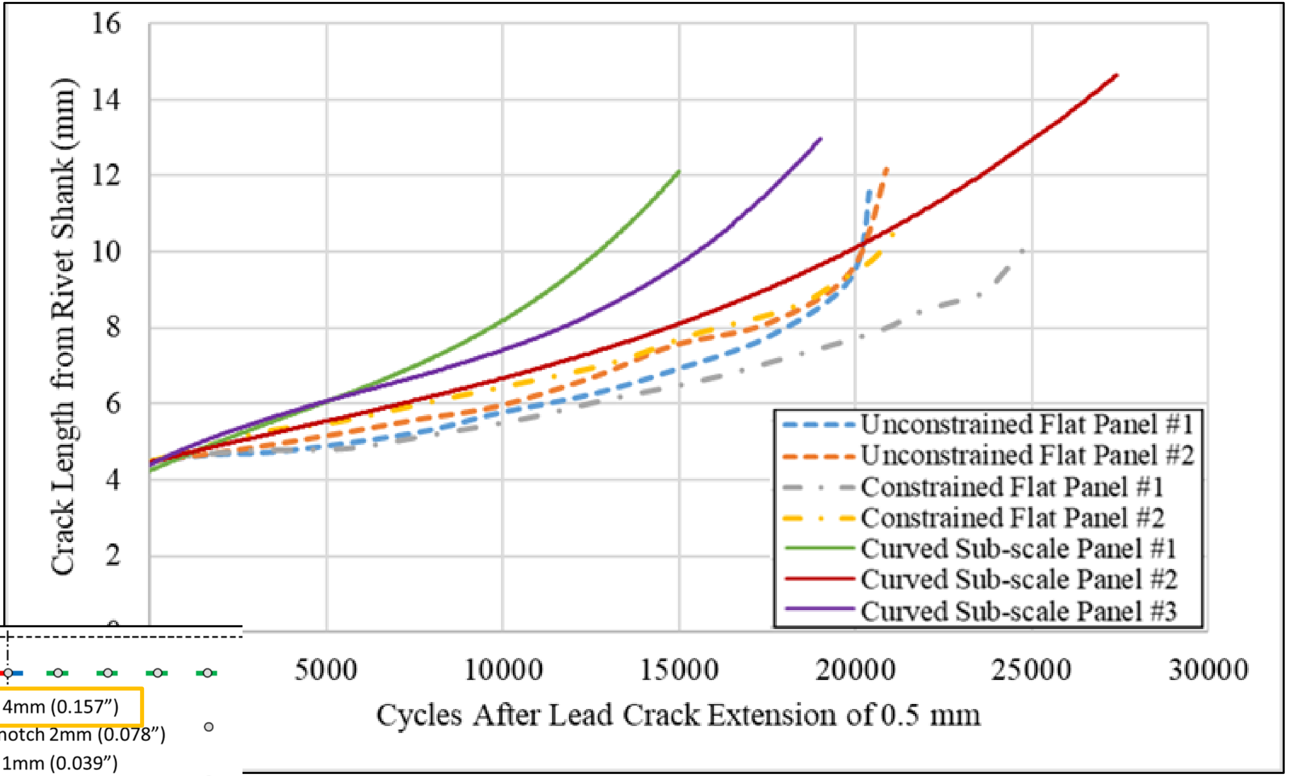


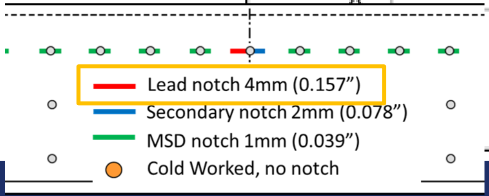


$$Tension = \frac{1}{2}|\varepsilon_1 + \varepsilon_2|$$

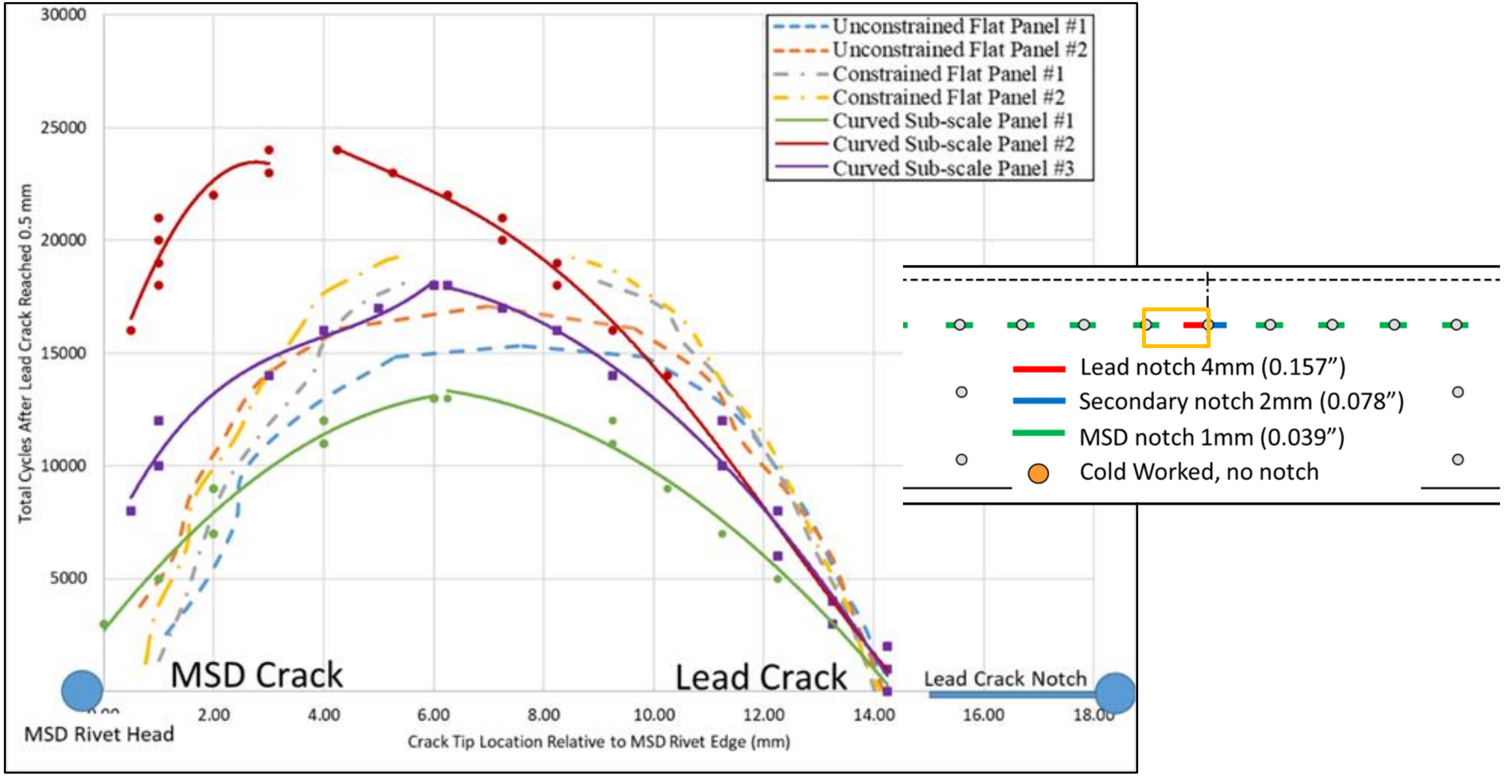
$$Bending = \frac{1}{2}|\varepsilon_1 - \varepsilon_2|$$

Lead Crack Growth Comparison

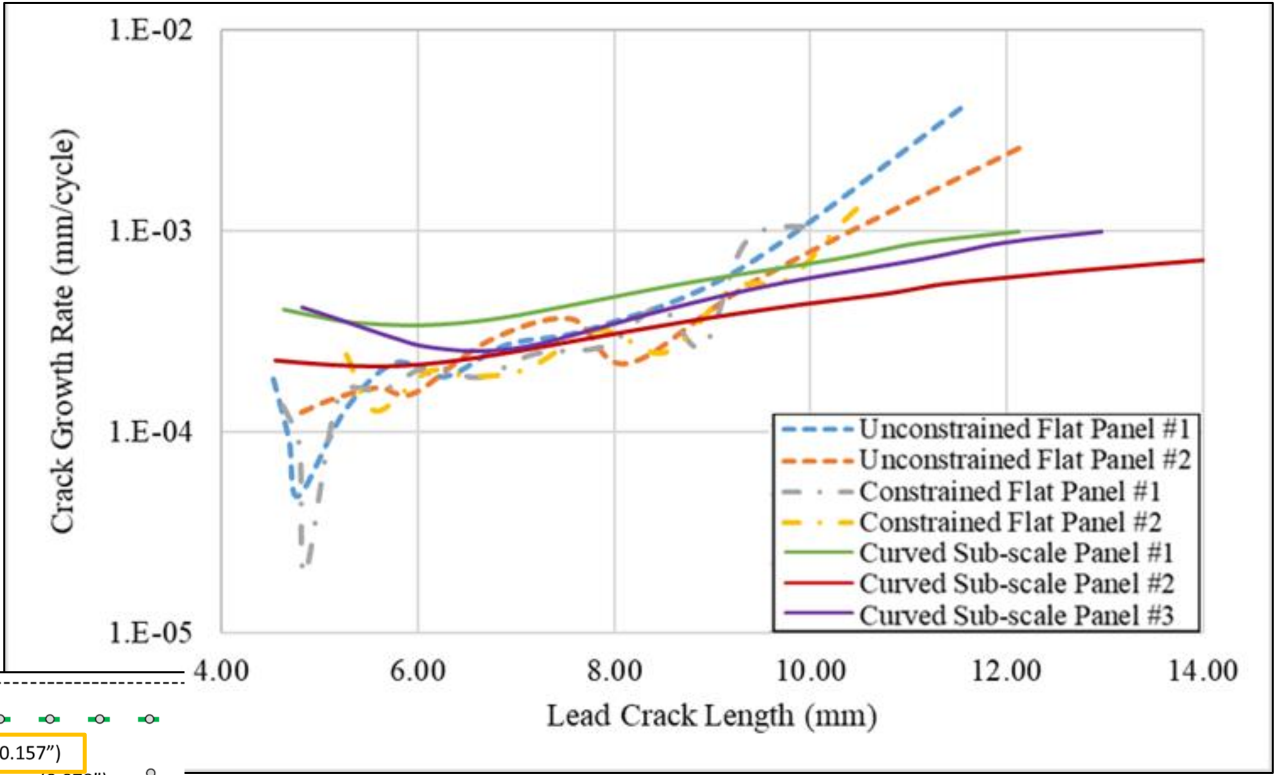


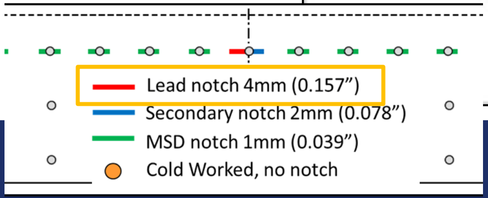


Lead & MSD Crack Tip Position



Lead Crack Growth Rate

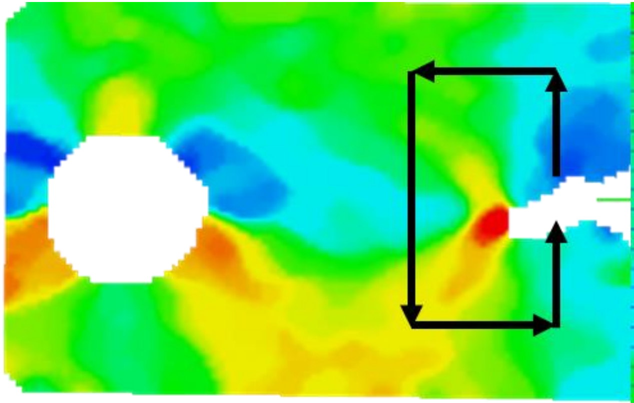


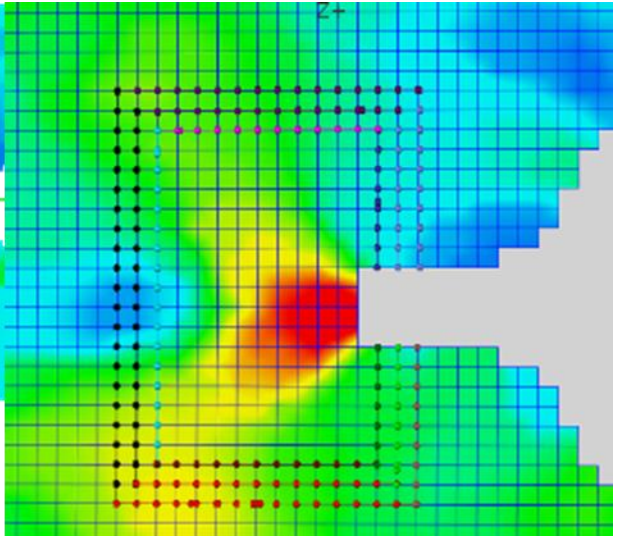


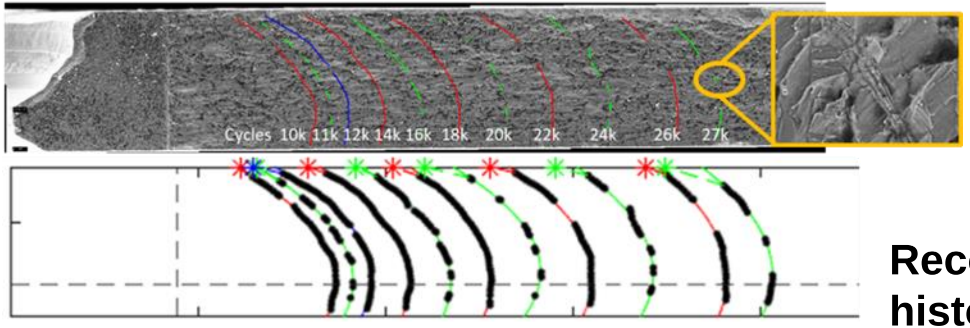
Post-test Analysis

DIC based SIF Calculation

- **Westingaard Equation; Dally & Sanford method**
- **J-integral**







Reconstruction of crack growth history via marker band location

Summary

- Curved sub-scale panels generally exhibited a shorter fatigue life compared to all flat panels. Effects that may influence these results such as the secondary bending, stress biaxiality, and boundary conditions are being investigated
- Comparisons between curved sub-scale and wide flat panels can be considered in three phases
  - Initial crack growth where the curved sub-scale panels had higher crack growth rates
  - Stable crack growth where the curved sub-scale and flat panels showed similar rates
  - Final crack growth where the flat panel crack growth rates rapidly accelerated while the curved sub-scale panels remained relatively consistent
- An anti-bend device installed on a subset of wide flat panels had relatively little impact on the fatigue behavior
- SIF calculation methods using outputs from DIC matched reasonably well with FEM solutions for the panels analyzed
- Post-test fractography using marker bands was able to successfully map crack progression throughout the test

Questions?

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