Natural PWSCC Crack Growth in Dissimilar Metal Welds With Inlay

David L. Rudland

RES/DE/CIB

David.Rudland@nrc.gov

F. W. (Bud) Brust, DJ Shim, Ed Punch, S Kalyanam

Engineering Mechanics Corporation

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Introduction

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- Investigated PWSCC growth predictions for an initial defect in an Alloy 52 inlay.
- This presentation focuses on the effects of natural flaw growth and its comparison to idealized flaw growth in inlay flaw evaluations.
- Natural flaw growth is defined as Advanced Finite Element Analyses (AFEA) flaw growth, i.e. local K-driven crack growth along crack front
- Inlay work fully documented in NRC report – ML101260548 (report – ML101260554)

Inlay Geometry and Mesh

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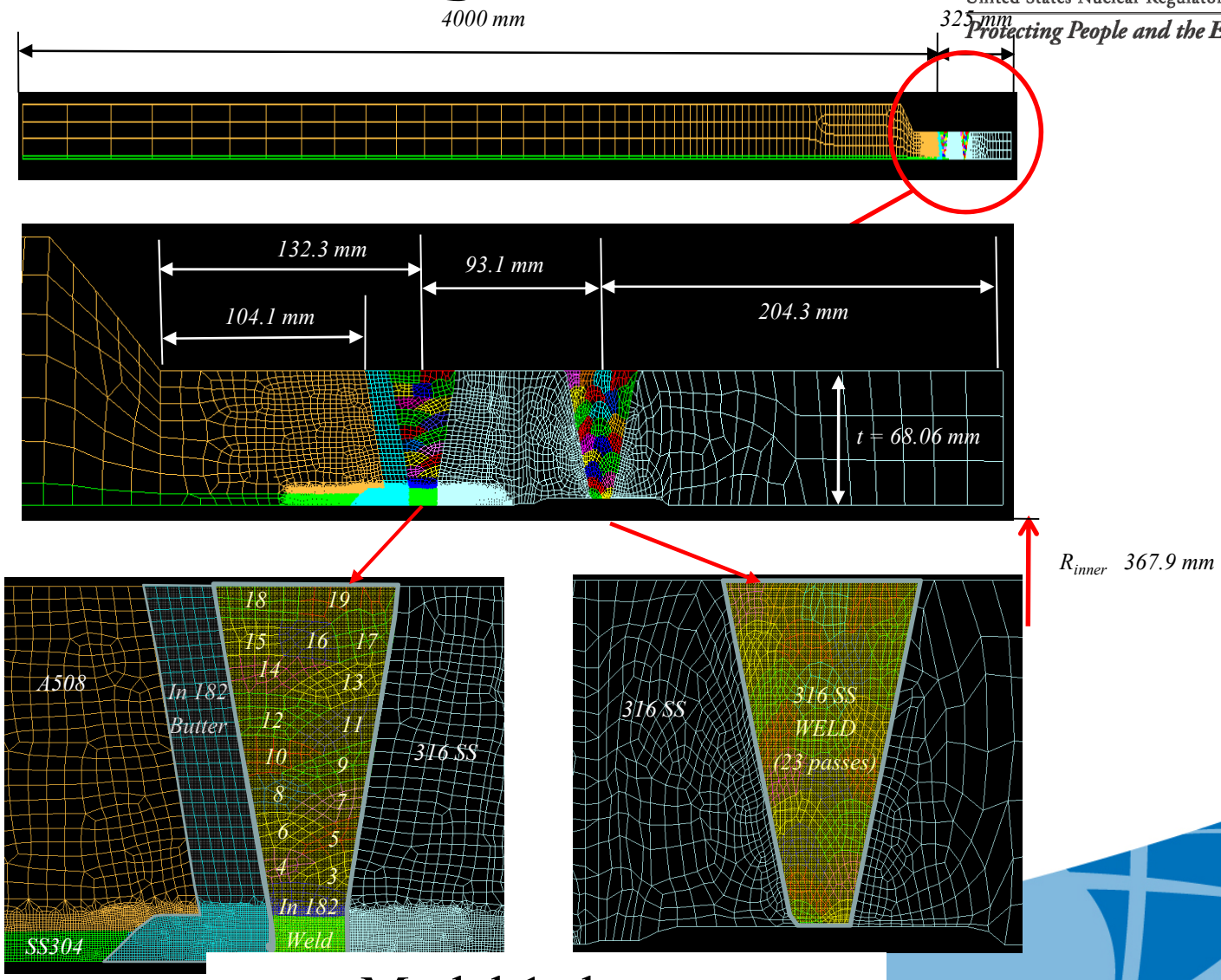

Model 1 shown,
Model 2 similar but t=80mm

Inlay Modeling

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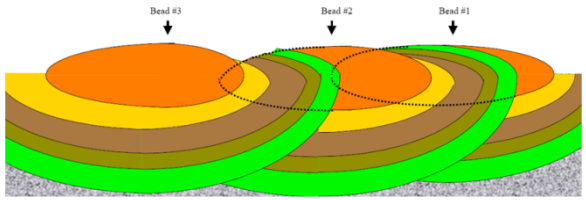
- Per Code Case N-766, 3mm thick inlay
- Temper bead procedure
  - Process to control HAZ Micro-structure
  - Subsequent passes 'temper' the prior bead HAZ
  - Low Heat input (In general)
  - For Two Dimensional Modeling – Attempt to Keep Weld Melt Zone to 10% (maximum) beyond molten deposited metal



- 1.5 mm x 1.5 mm weld bead size
- Three layers (137 weld passes) applied, removed final 1.5 mm thick layer
- Inlay is 4.4% of wall thickness in this study

WRS Result - example

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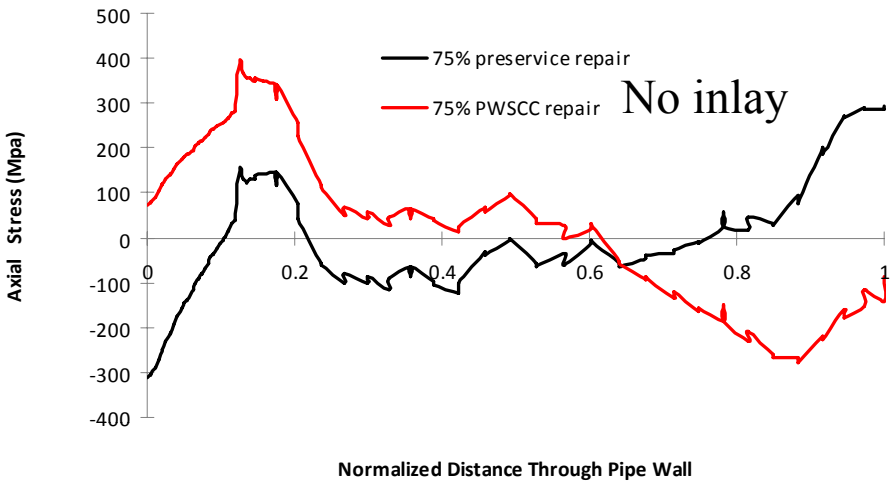

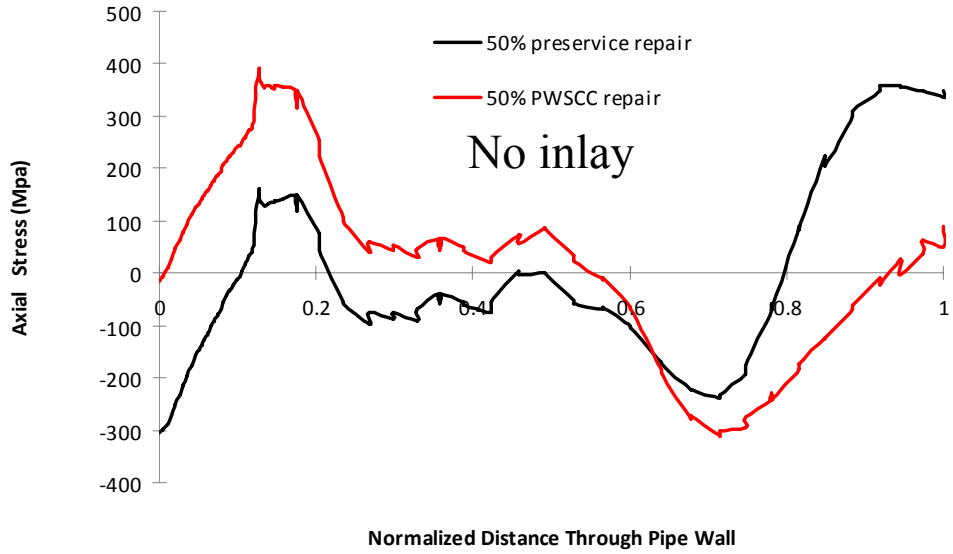

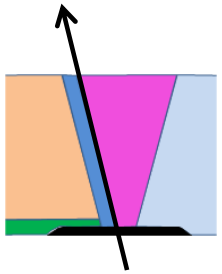

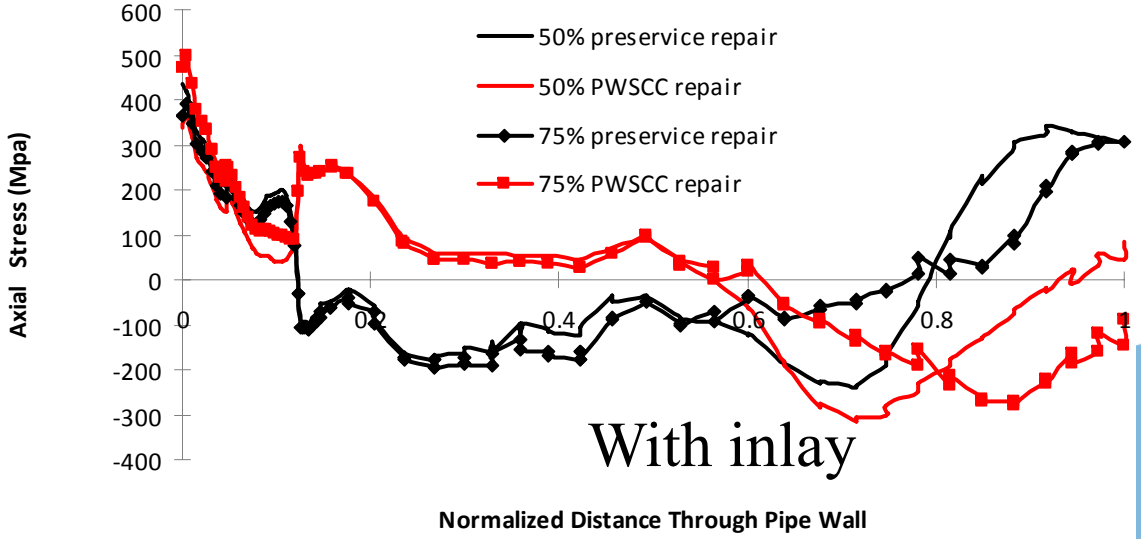

Detailed results in ML101260554

Idealized Flaw Growth Analyses

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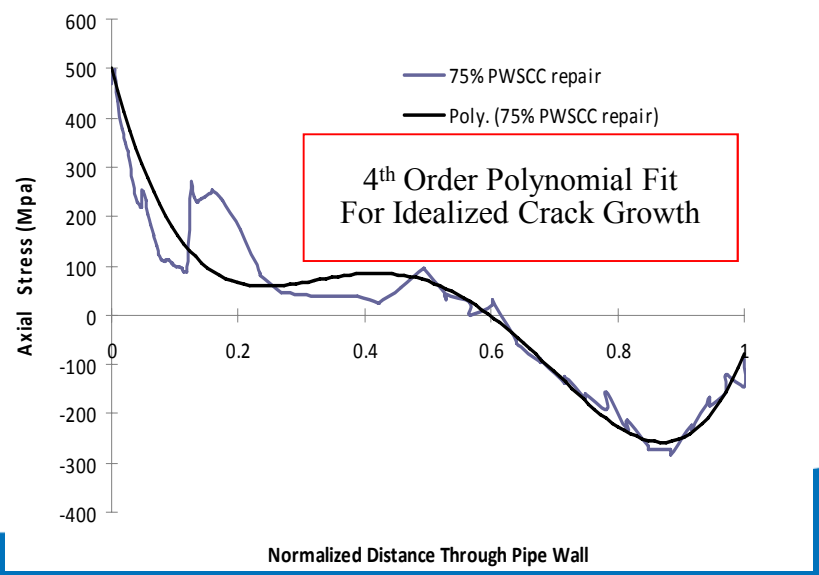
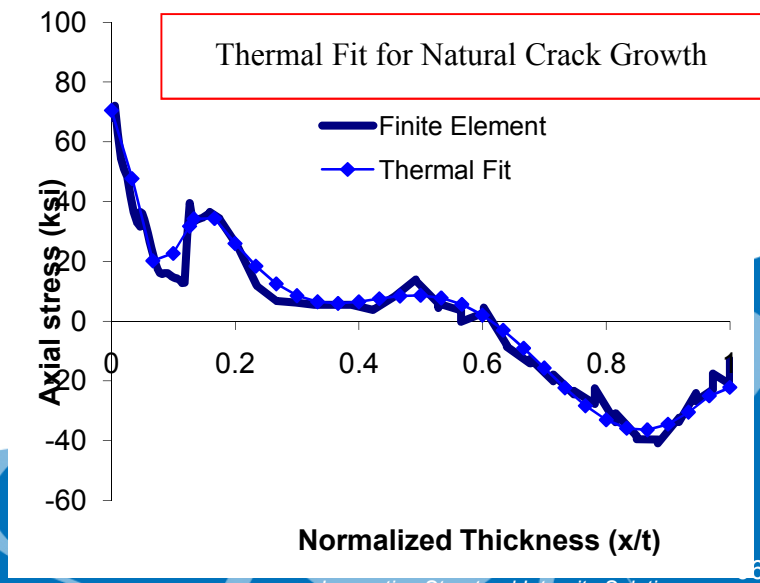
- Hot leg geometry – OD = 872 mm (34.3 inch), t = 68 mm (2.7 inch)
- 1.5mm deep by 10 mm long semi-elliptical defect – (varied in sensitivity study)
  - Anderson and Chapuliot influence functions for circumferential cracks
  - Anderson for axial cracks (linearly extrapolate for a/t<0.2)
- A182 growth = 75th percentile (MRP-115) – A52 growth assumed factor on A182 growth (varied in sensitivity study)
- TWC idealized – growth per weighted average A182/A52
- Flaw stability controlled by SS, and Z-factor

Assumed Loads

- Bending stress = 96.5 MPa (14 ksi) (varied in sensitivity analysis)
- Axial stress = 38.6 MPa (5.6 ksi), Pressure = 15.5 MPa (2250 psi), Temp = 326 C (620F). Temperature varied in sensitivity study
- Effects of crack face pressure included
- WRS fit to 4th order polynomial for idealized flaw analyses





A52/152 Growth Rates

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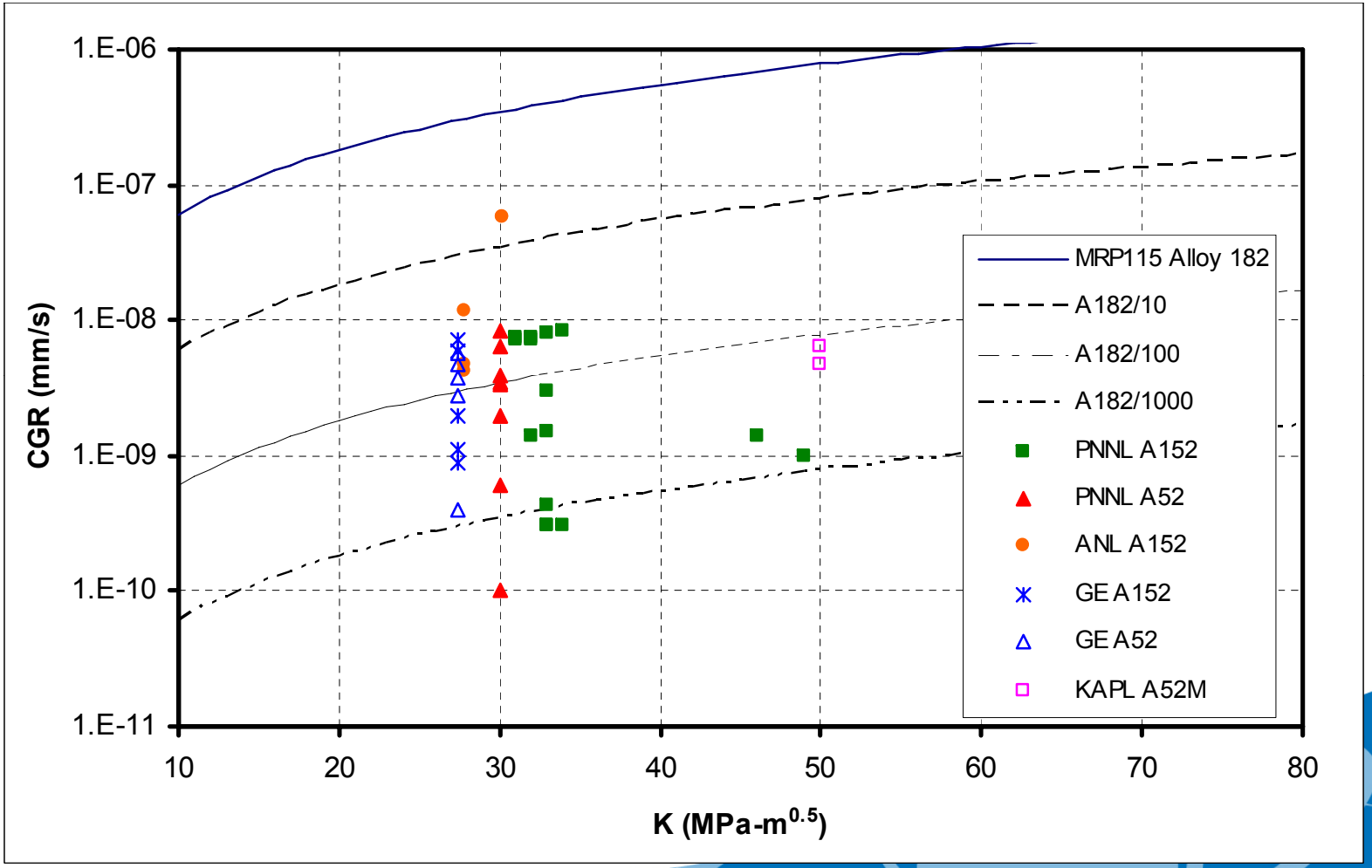

Innovative Structural Integrity Solutions

Effect of WRS - Idealized Flaw Growth Analyses

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Flaw Analysis Case #	WRS case	Model #	Inlay depth	Time, years		
				Inlay	Through-wall	Rupture
1	50% pre-service repair	1	3mm	9.7	25.1	33.7
2	50% PWSCC repair,	1	3mm	10.9	15.9	24.8
3	75% pre-service repair,	1	3mm	10.1	31.0	39.7
4	75%PWSCC repair	1	3mm	7.5	12.1	23.3
5	50%preservice-75%PWSCC repair	1	3mm	10.3	15.1	24.0
6	50% pre-service repair	1	6mm	23.6	38.8	46.0
7	50% PWSCC repair	1	6mm	28.5	33.4	40.6
8	12% pre-service repair	2	3mm	10.0	>100	>100
9	50% PWSCC repair	2	3mm	10.3	16.1	23.7

*A52 growth = A182/100

Case 4 – 62% of the time to leakage (through-wall) is spent in 4% of wall thickness

Natural Flaw Growth

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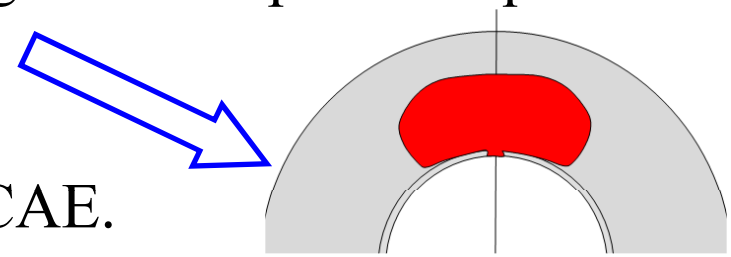
- Initial flaw shape was semi-elliptical
- Challenging to model because crack growth shape is unique (like 'balloon')



- Semi-Automated Growth - PipeFracCAE.
- As crack grew deep, large meshes Required
  - 150,000 to 200,000 element meshes
- Mesh transitions have been verified through spreadsheet calculations – similar verification done in Wolf Creek/MRP-216 effort

Natural Flaw Growth

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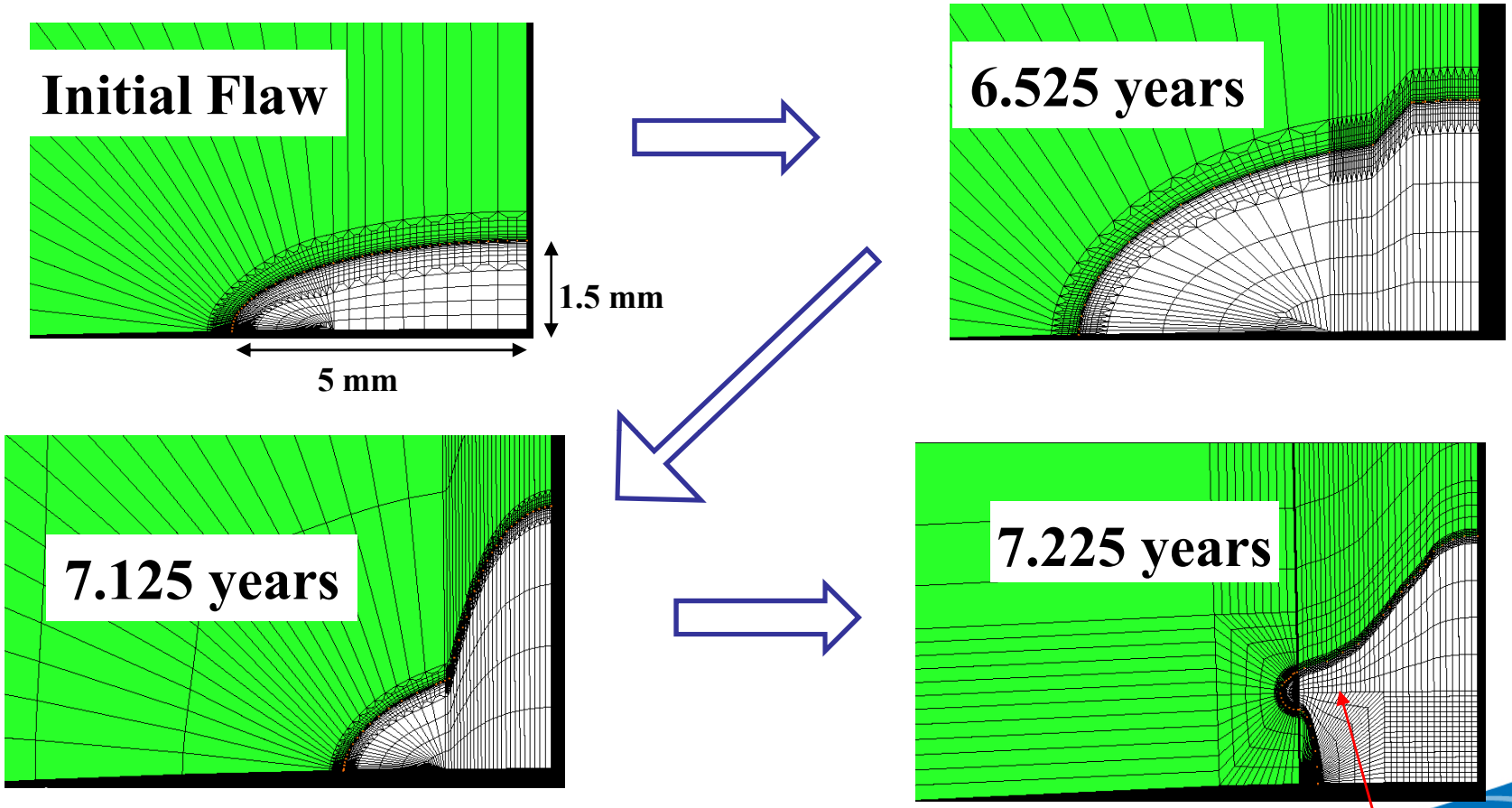
Case 4: Crack Growth



Crack growth in horizontal direction applied while making a 0.1 year step increment

First balloon

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Natural Flaw Growth

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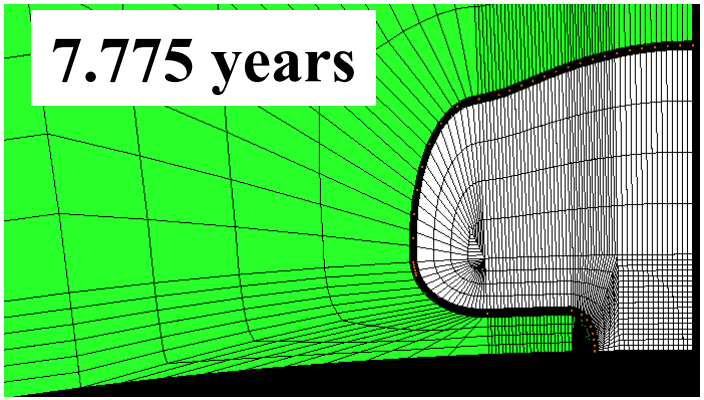
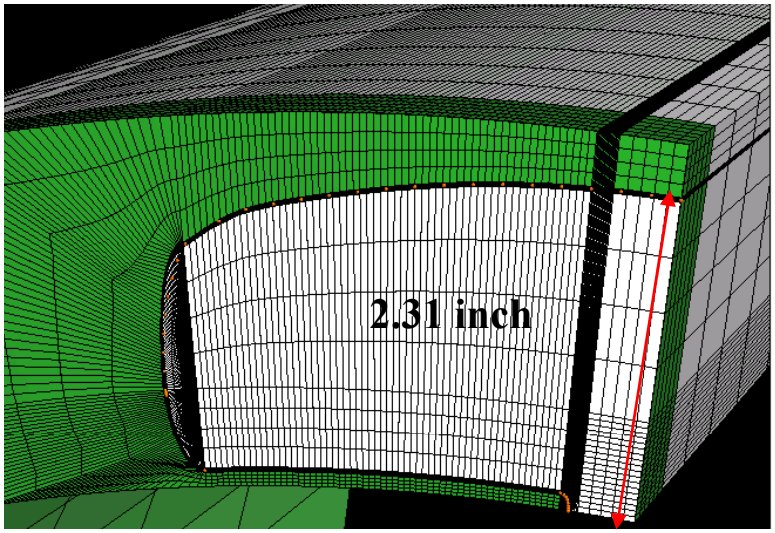
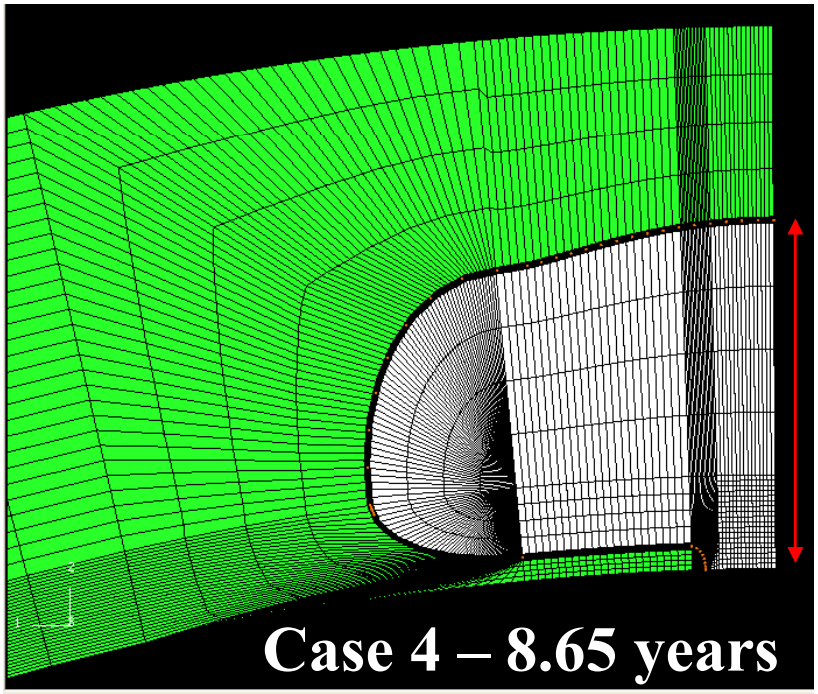




9.6 years, 189972 nodes
171521 elements



1.73 inch

Case 4: Crack Growth

Natural Flaw Growth: Different Cases

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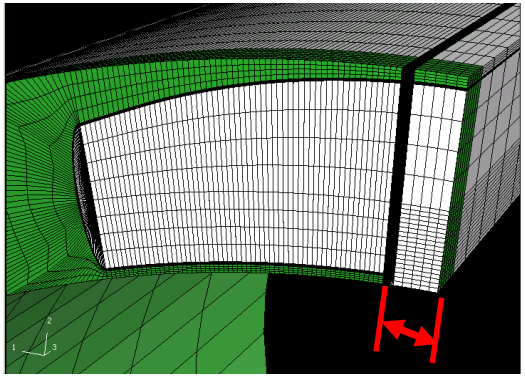
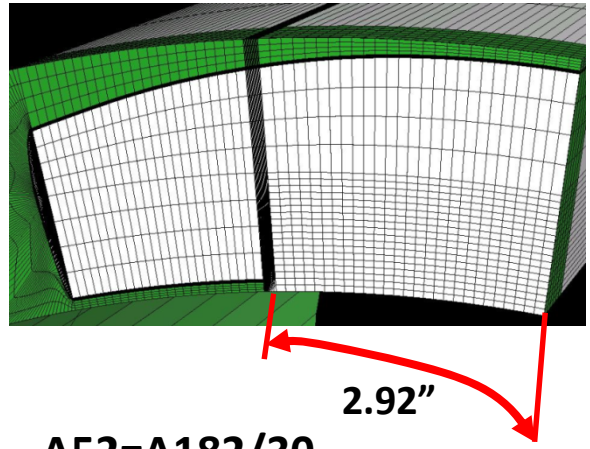
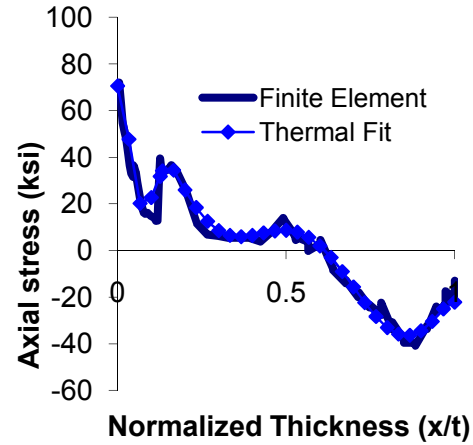
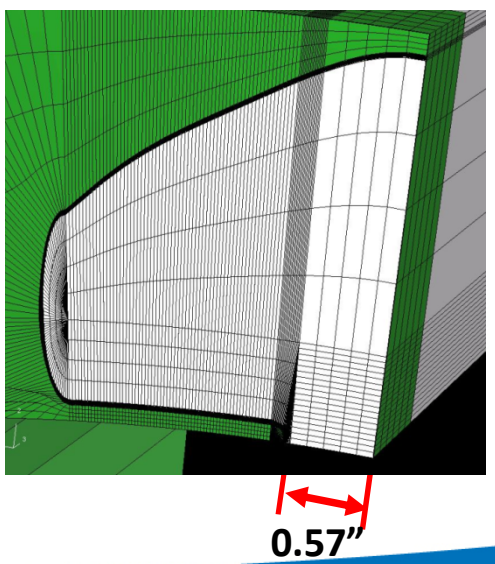


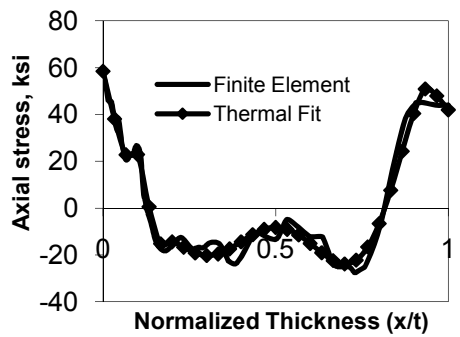
Case 4
A52=A182/100



A52=A182/30







Case 1
A52=A182/100

Result Comparison

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Case #	WRS case	Total time, years (Idealized Growth)			Total time, years (Natural Growth)		
		Inlay	TWC	Rupture	Inlay	TWC	Rupture
1	Case 1 50% pre-service repair	9.7	25.1	33.7	11.9	31.5	37.4
2	Case 2 50% PWSCC repair	10.9	15.9	24.8	8.5	15.1	19.3
4	Case 4 75% PWSCC repair	7.5	12.1	23.3	6.5	11.1	13.2
4	Case 4 Modified 75% PWSCC repair (A52=1/30(A182))	3.4	8.4	16	1.7	5.2	6.8
4	Case 4 Modified 75% PWSCC repair (Larger Bending Moment)	6.9	10.2	17.5	6.0	9.5	11.5

Summary

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- Purpose of natural flaw growth analyses was to determine if idealized flaw assumptions were appropriate in flaw evaluations for inlayed DM welds.
- The unusual flaw shapes did not highly impact the time through the inlay and to leakage calculated using the idealized flaw assumption.
- Natural crack growth slightly faster than idealized growth, but not large impact on growth times
- Work fully documented in NRC report – ML101260548 (report – ML101260554)