# SAE FD&E Spring Meeting
# T-Bar Analysis

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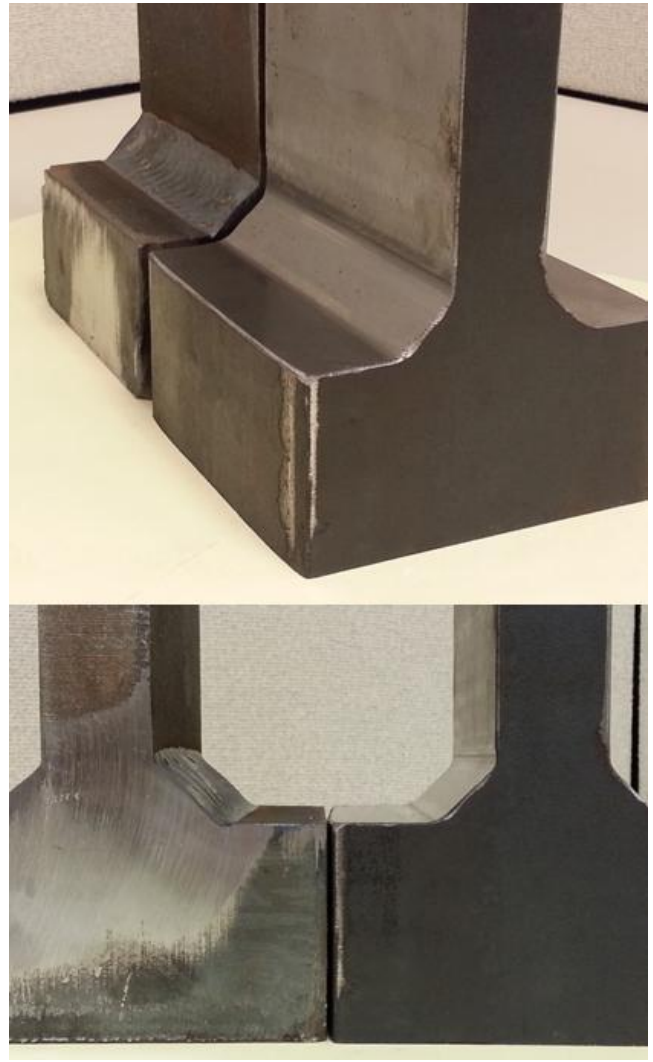
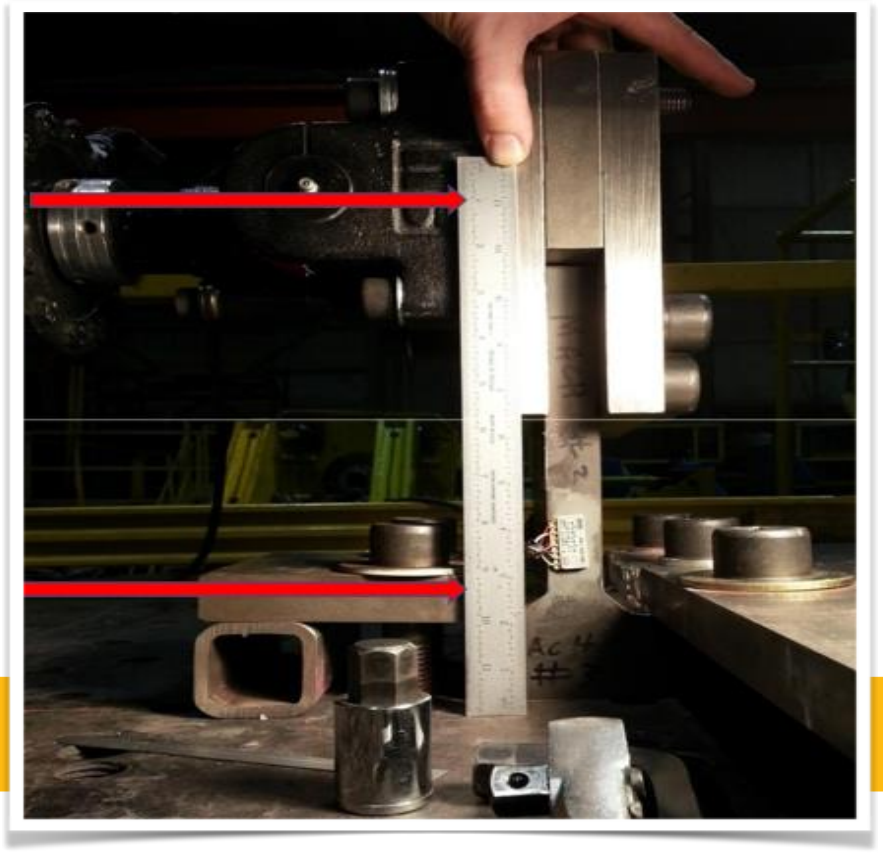
# Project Background

- FD&E Total Life Project
- Welded and machined T-bar specimens fatigue tested to fracture
- Cyclic bending load applied with R values ranging from 0.1 to 0.5
- Residual weld stresses were identified using both analysis and several test methods
- Focus: Welded specimen life

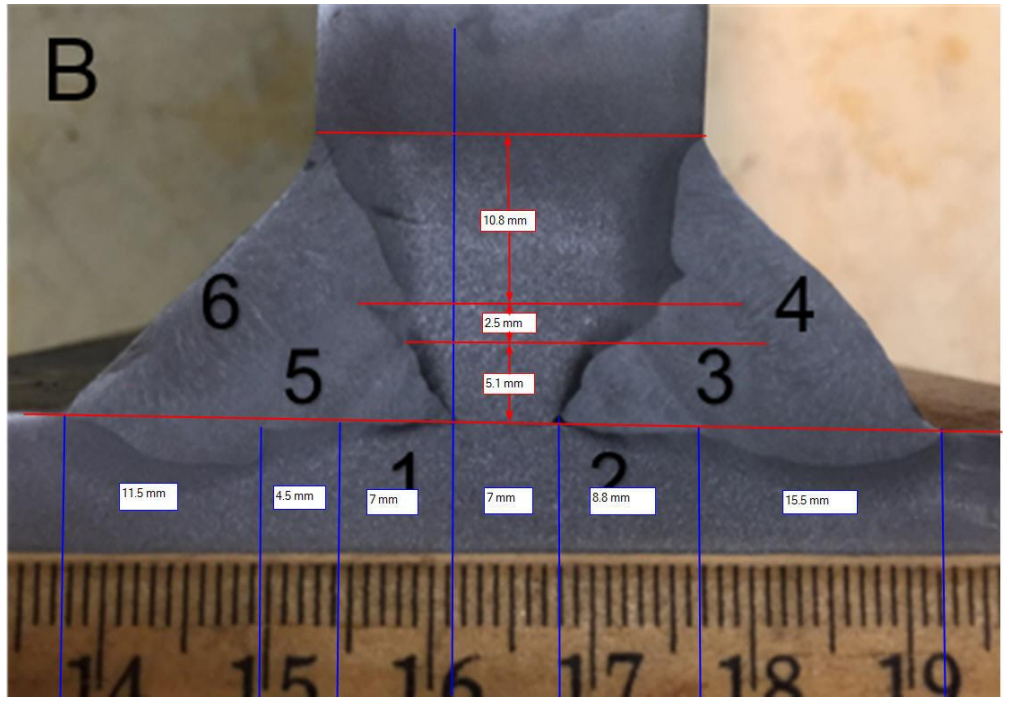




# Objectives

- Compare test life results to common calculation methods
  - Nominal Stress
  - Structural Stress
  - IIW Notch Stress
  - LEFM (with and without Residual Stress)

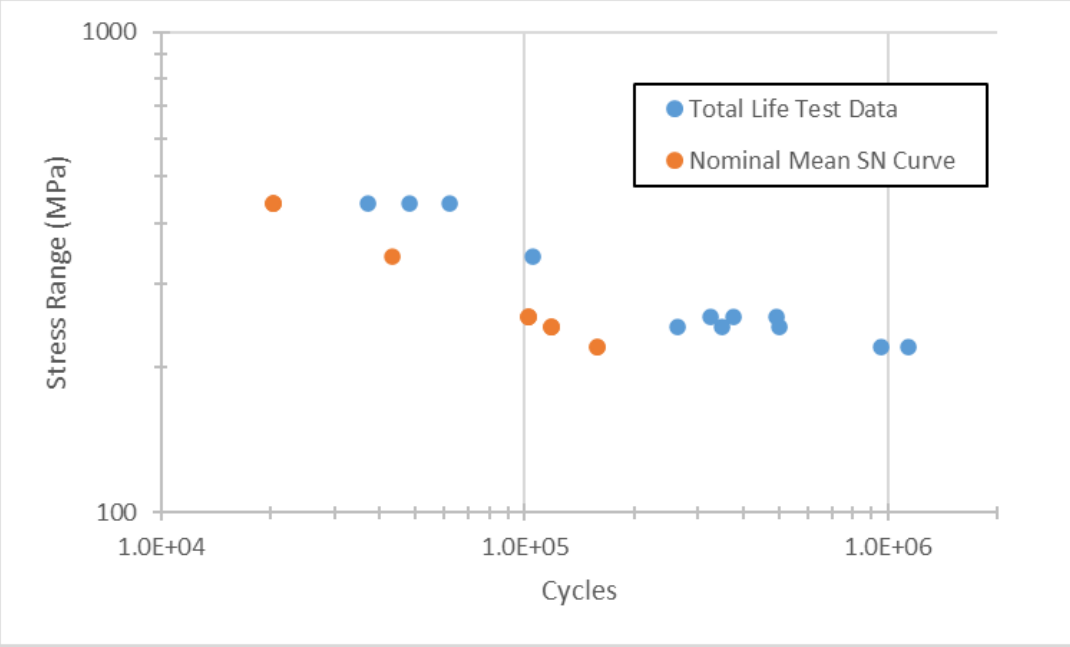
- Study was limited to Constant Amplitude loading only




# Test Results – Total Life

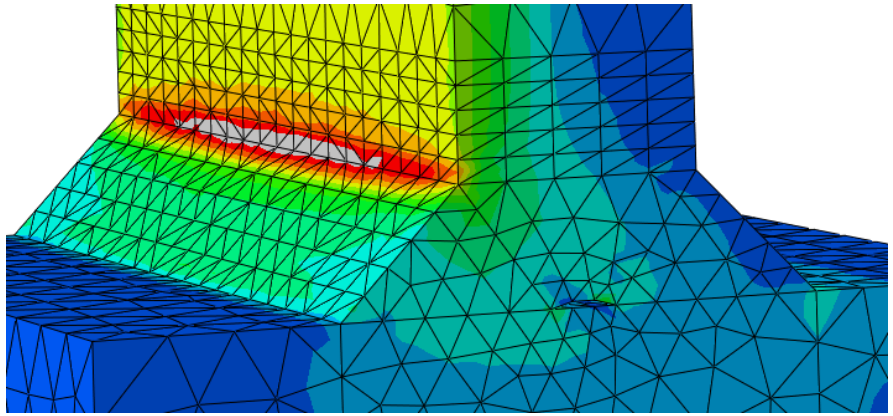
- Constant amplitude loading test results
- Five load ranges: 10.9 – 21.6 kN
- Test lives are generally consistent and the overall trendline is correct
- Total Life exceeds Nominal Mean SN curve at lower stress ranges

| Max Load (kN) | 12.1 | 12.1 | 24 | 24 | 24 | 14 | 14 | 14 | 24 | 24 | 24 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R Ratio | 0.1 | 0.1 | 0.5 | 0.5 | 0.5 | 0.1 | 0.1 | 0.1 | 0.3 | 0.1 | 0.1 | 0.1 |
| Load Range (kN) | 10.9 | 10.9 | 12 | 12 | 12 | 12.6 | 12.6 | 12.6 | 16.8 | 21.6 | 21.6 | 21.6 |
| Stress Range (MPa) | 221 | 221 | 244 | 244 | 244 | 256 | 256 | 256 | 341 | 439 | 439 | 439 |
| Total Life (cycles) | 9.6E+05 | 1.1E+06 | 2.6E+05 | 3.5E+05 | 5.0E+05 | 3.3E+05 | 3.8E+05 | 4.9E+05 | 1.1E+05 | 3.7E+04 | 4.8E+04 | 6.2E+04 |
| Avg Test Cycles | | 1.0E+06 | | | 3.7E+05 | | | 4.0E+05 | 1.1E+05 | | | 4.9E+04 |




# Nominal Stress Life

- Evaluated using standard internal process and SN curve
- 12.1 kN Sample - Crack initiation reported as 6E5 cycles



| Max Load (kN) | 12.1 | 24 | 14 | 24 | 24 |
|---|---|---|---|---|---|
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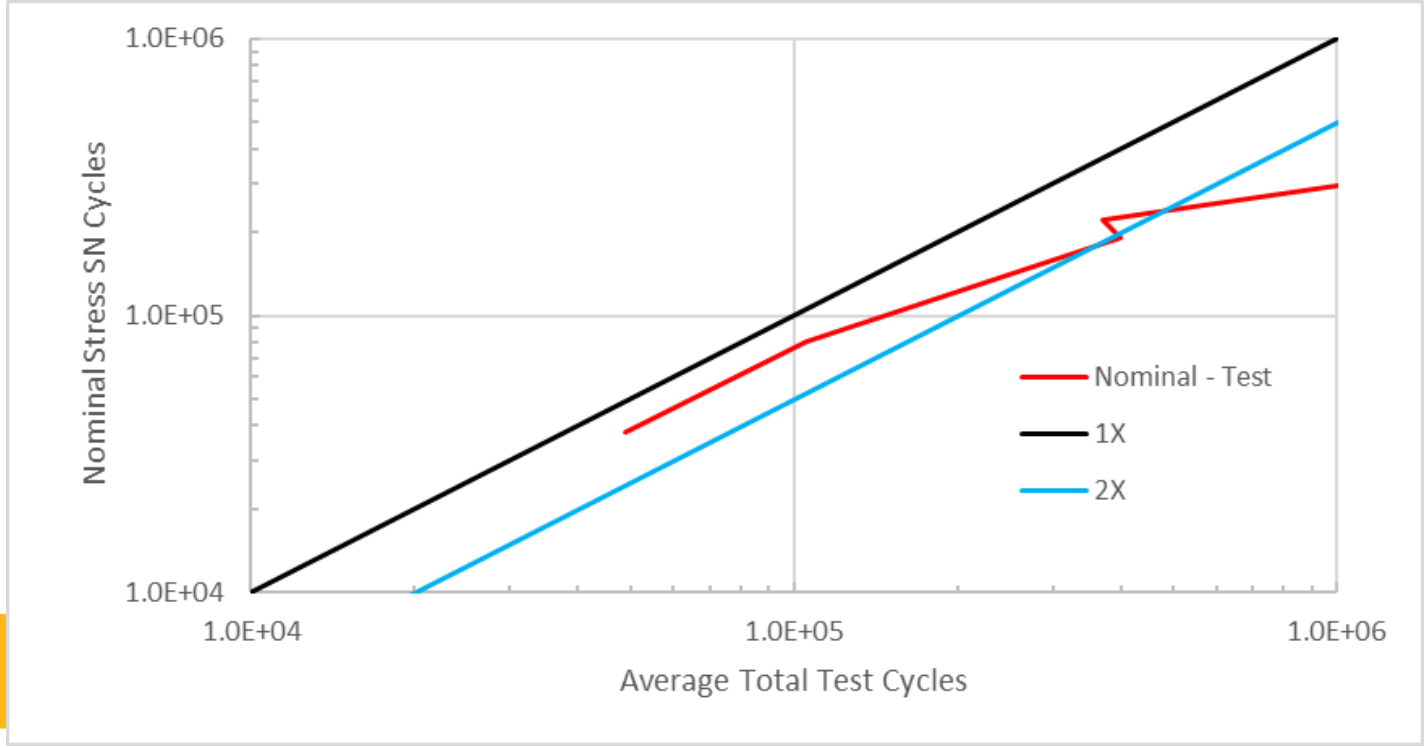
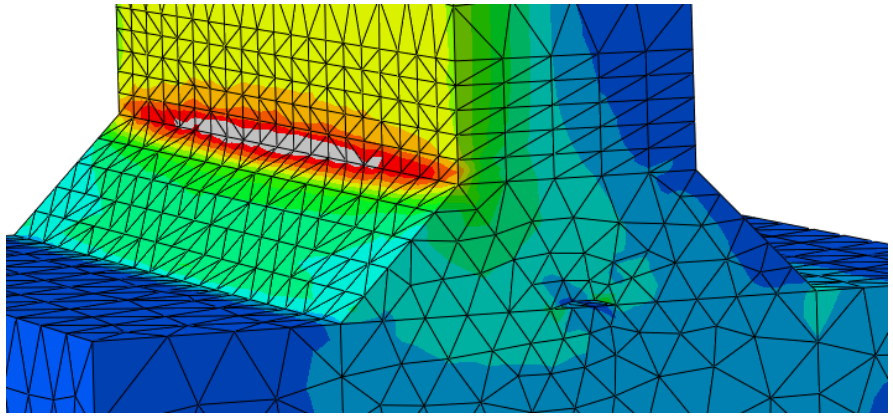
| Load Range (kN) | 10.9 | 12 | 12.6 | 16.8 | 21.6 |
| Stress Range (MPa) | 221 | 244 | 256 | 341 | 439 |
| Avg Test Cycles | 1.0E+06 | 3.7E+05 | 4.0E+05 | 1.1E+05 | 4.9E+04 |



# Structural Stress Life

- Evaluated using standard internal process



| Max Load (kN) | 12.1 | 24 | 14 | 24 | 24 |
|---|---|---|---|---|---|
| R Ratio | 0.1 | 0.5 | 0.1 | 0.3 | 0.1 |
| Load Range (kN) | 10.9 | 12 | 12.6 | 16.8 | 21.6 |
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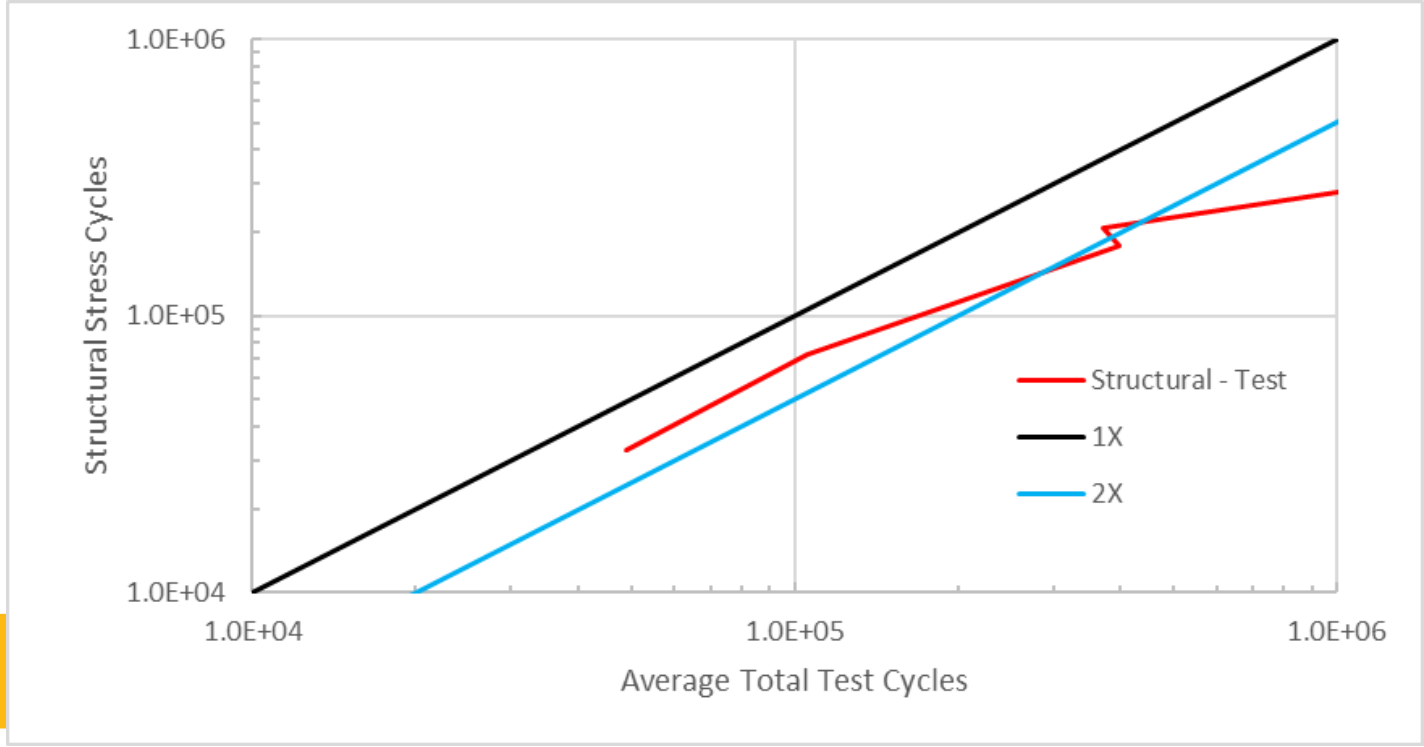
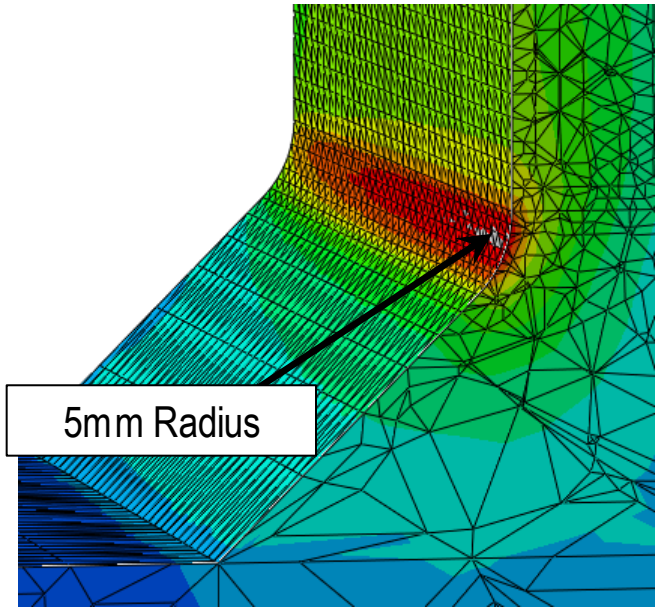
| Avg Test Cycles | 1.0E+06 | 3.7E+05 | 4.0E+05 | 1.1E+05 | 4.9E+04 |

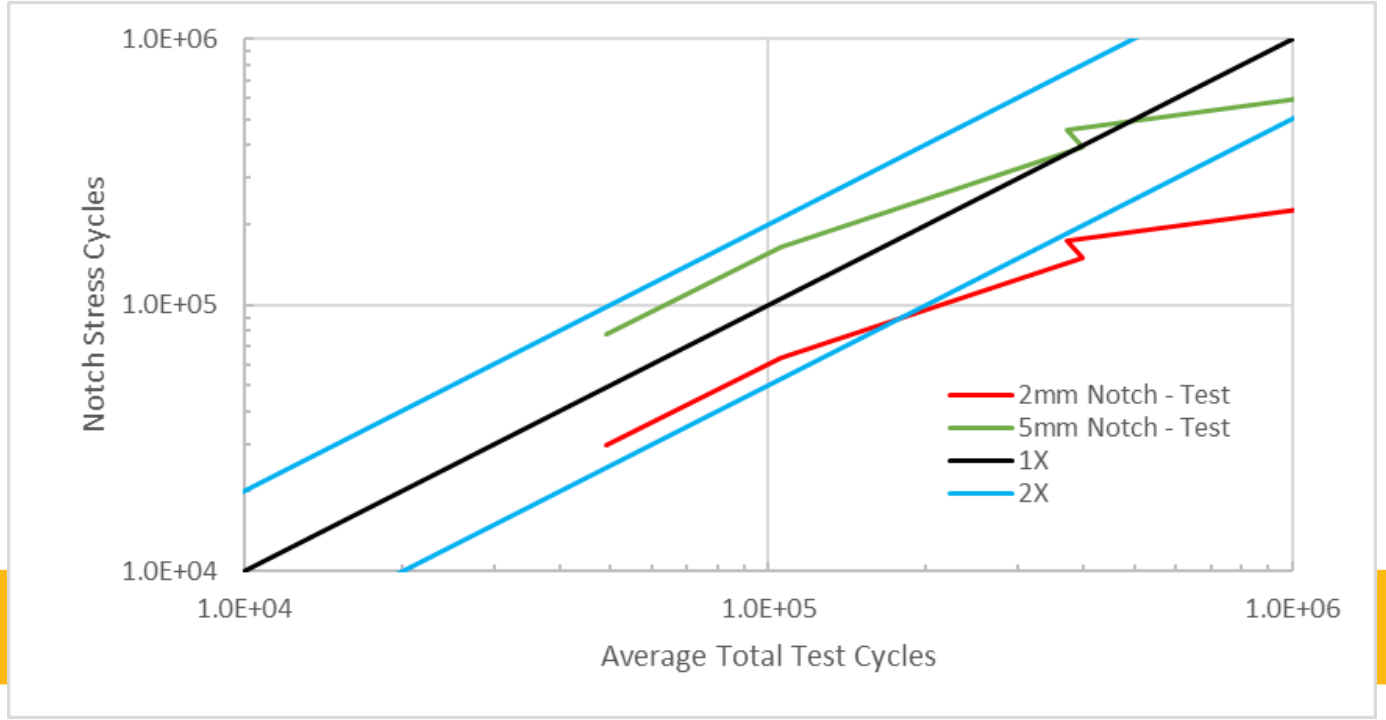


# Notch Stress Life

- Evaluated using IIW Guidelines XIII-2460-13 / XV-1440-13
- Modified for Mean SN Curve
- FEA Toe Radius = 2 and 5 mm
- 12.1 kN Sample - Crack initiation reported as 6E5 cycles

| Max Load (kN) | 12.1 | 24 | 14 | 24 | 24 |
|---|---|---|---|---|---|
| R Ratio | 0.1 | 0.5 | 0.1 | 0.3 | 0.1 |
| Load Range (kN) | 10.9 | 12 | 12.6 | 16.8 | 21.6 |
| Stress Range (MPa) | 221 | 244 | 256 | 341 | 439 |
| Avg Test Cycles | 1.0E+06 | 3.7E+05 | 4.0E+05 | 1.1E+05 | 4.9E+04 |

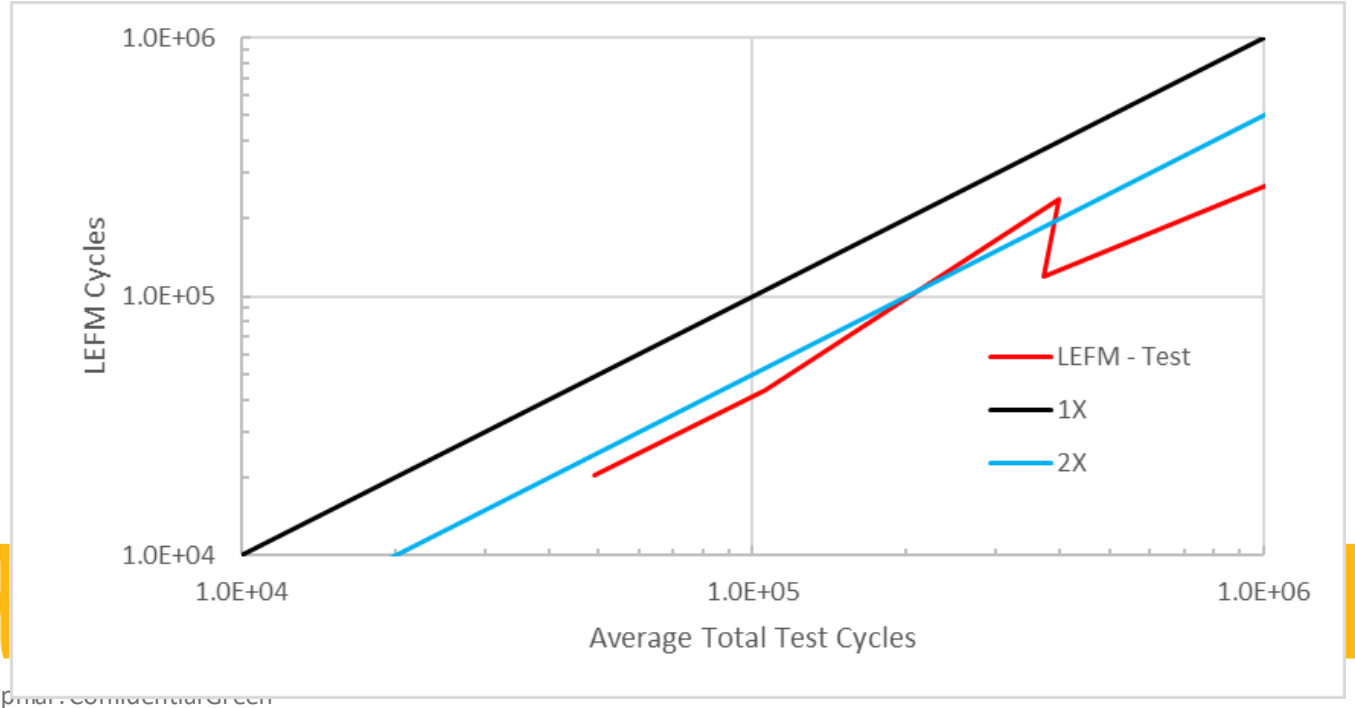


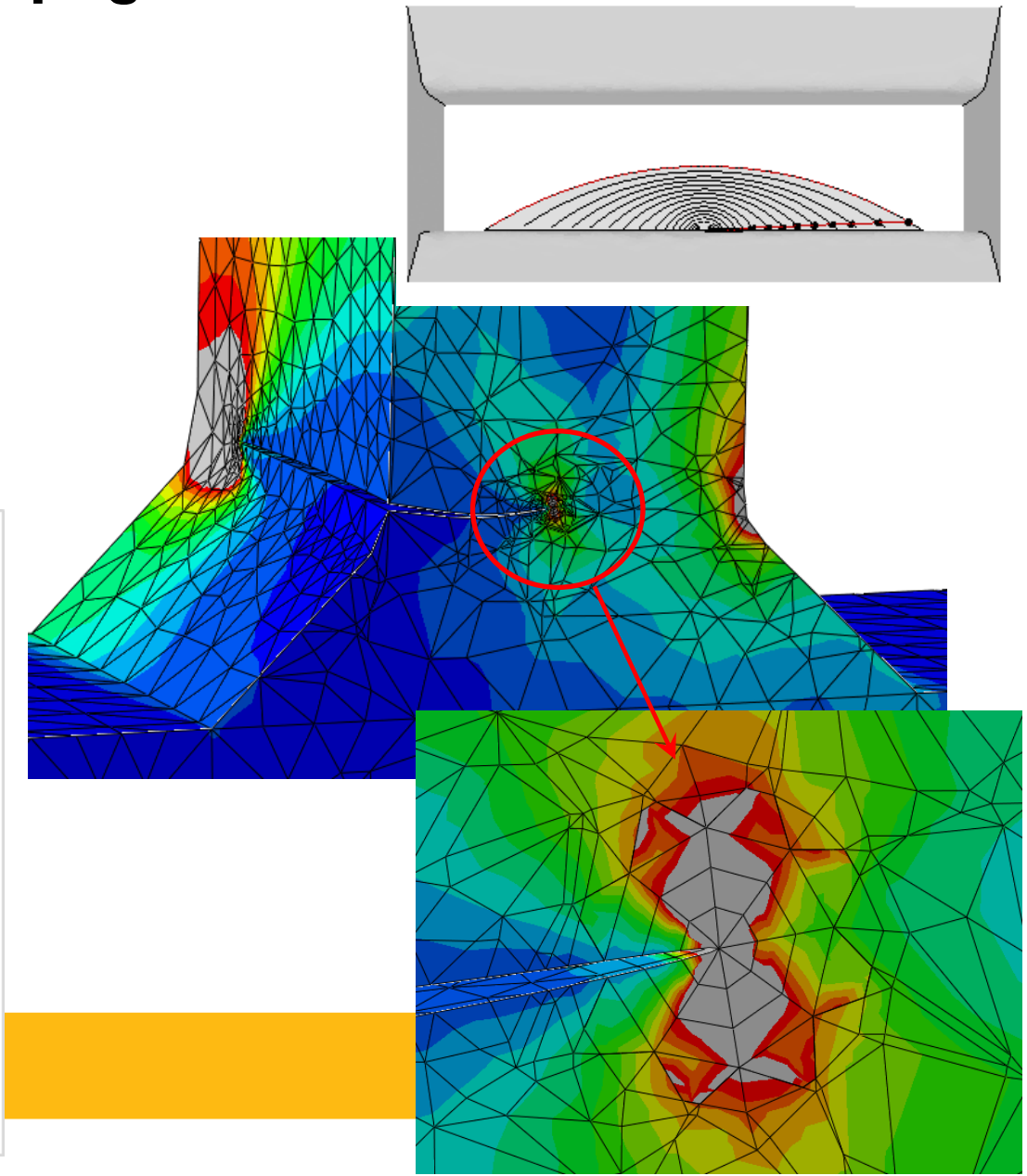



# Linear Elastic Fracture Mechanics Propagation Life

- Evaluated using Franc3D/Abaqus
- Simulation based on IIW Guidelines XIII-2460-13 / XV-1440-13
- Final crack size based on internal guideline for $K_{IC}$

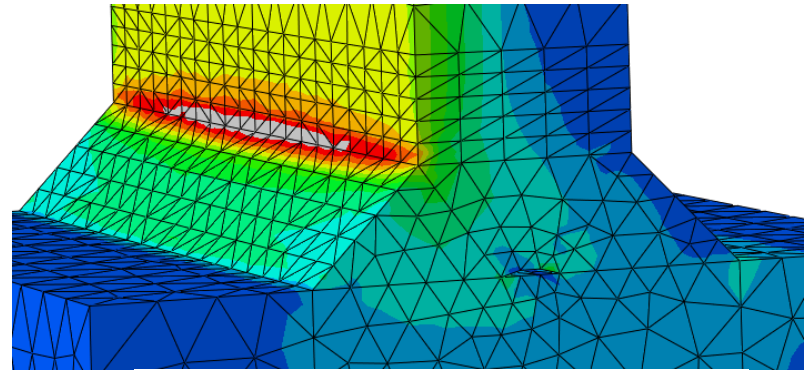
| Max Load (kN) | 12.1 | 24 | 14 | 24 | 24 |
|---|---|---|---|---|---|
| R Ratio | 0.1 | 0.5 | 0.1 | 0.3 | 0.1 |
| Load Range (kN) | 10.9 | 12 | 12.6 | 16.8 | 21.6 |
| Stress Range (MPa) | 221 | 244 | 256 | 341 | 439 |
| Avg Test Cycles | 1.0E+06 | 3.7E+05 | 4.0E+05 | 1.1E+05 | 4.9E+04 |

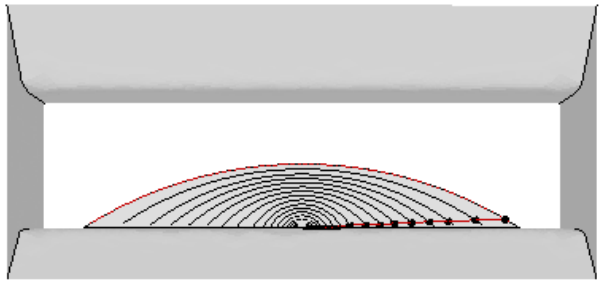


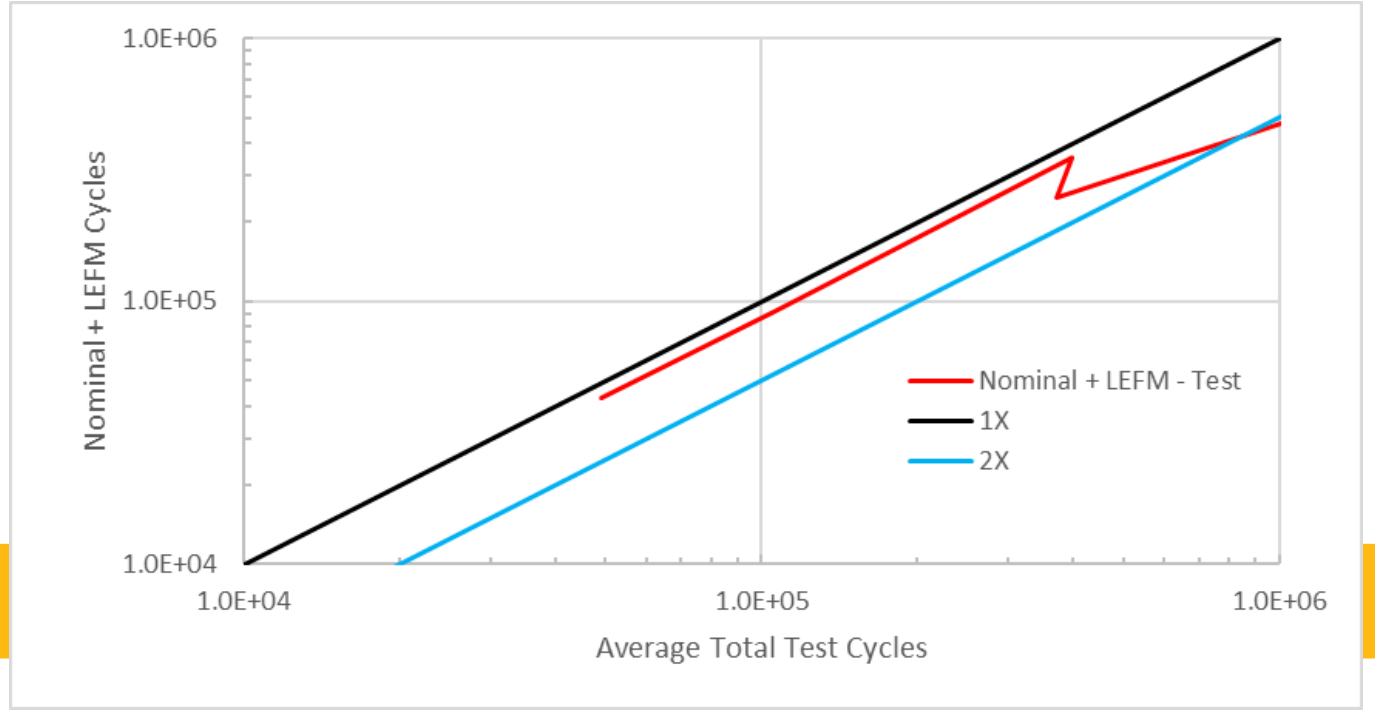
# Nominal + LEFM Life

- Combined method for estimating Total Life
- Crack Growth based on IIW Guidelines XIII-2460-13 / XV-1440-13
- Final crack size based on internal guideline for $K_{IC}$



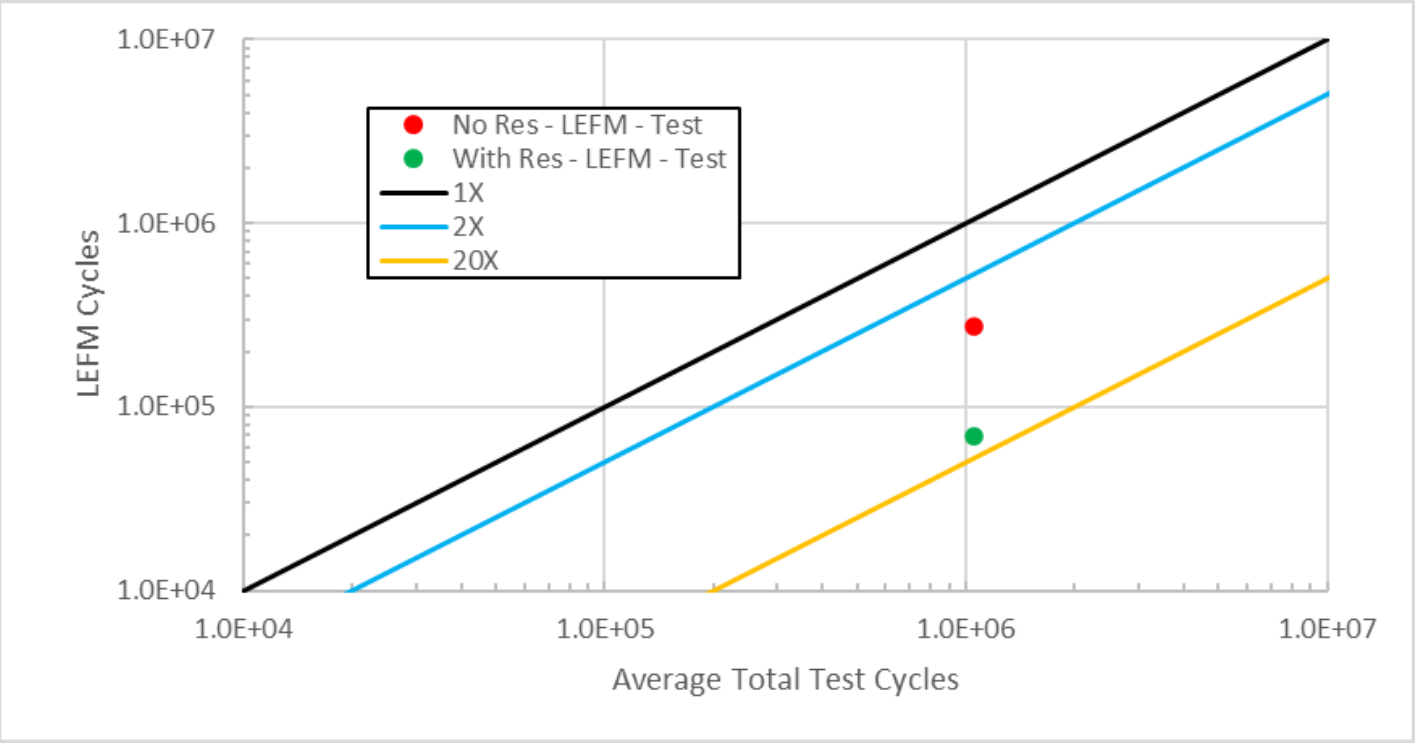


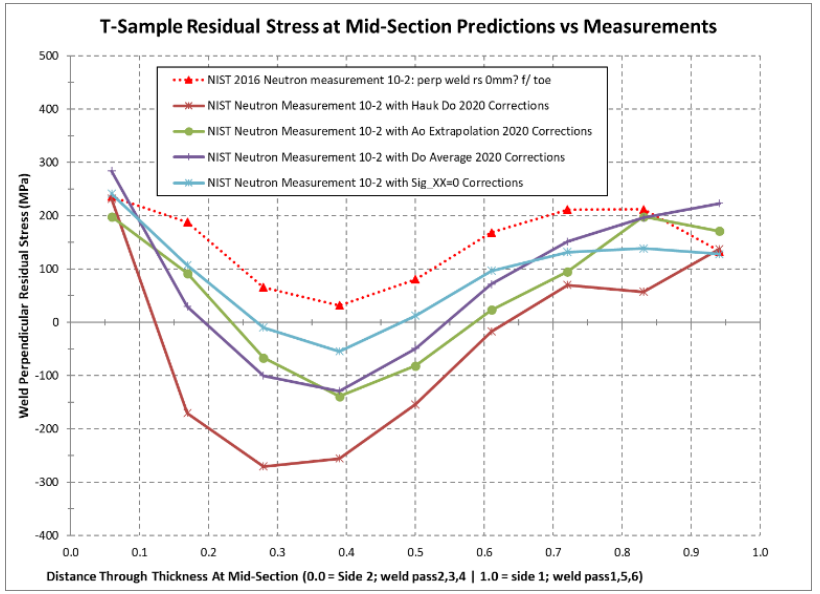
| Max Load (kN) | 12.1 | 24 | 14 | 24 | 24 |
|---|---|---|---|---|---|
| R Ratio | 0.1 | 0.5 | 0.1 | 0.3 | 0.1 |
| Load Range (kN) | 10.9 | 12 | 12.6 | 16.8 | 21.6 |
| Stress Range (MPa) | 221 | 244 | 256 | 341 | 439 |
| Avg Test Cycles | 1.0E+06 | 3.7E+05 | 4.0E+05 | 1.1E+05 | 4.9E+04 |

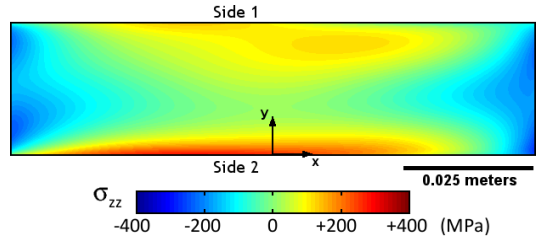


# LEFM Life with Residual Stress

- Residual stress field applied in Franc3D
- Residual stress estimated from prior analytical and test results
- Original LEFM underpredicted Life
- Tensile residual of ~125 MPa accelerates crack growth
- Only evaluated 12.1 kN Loading

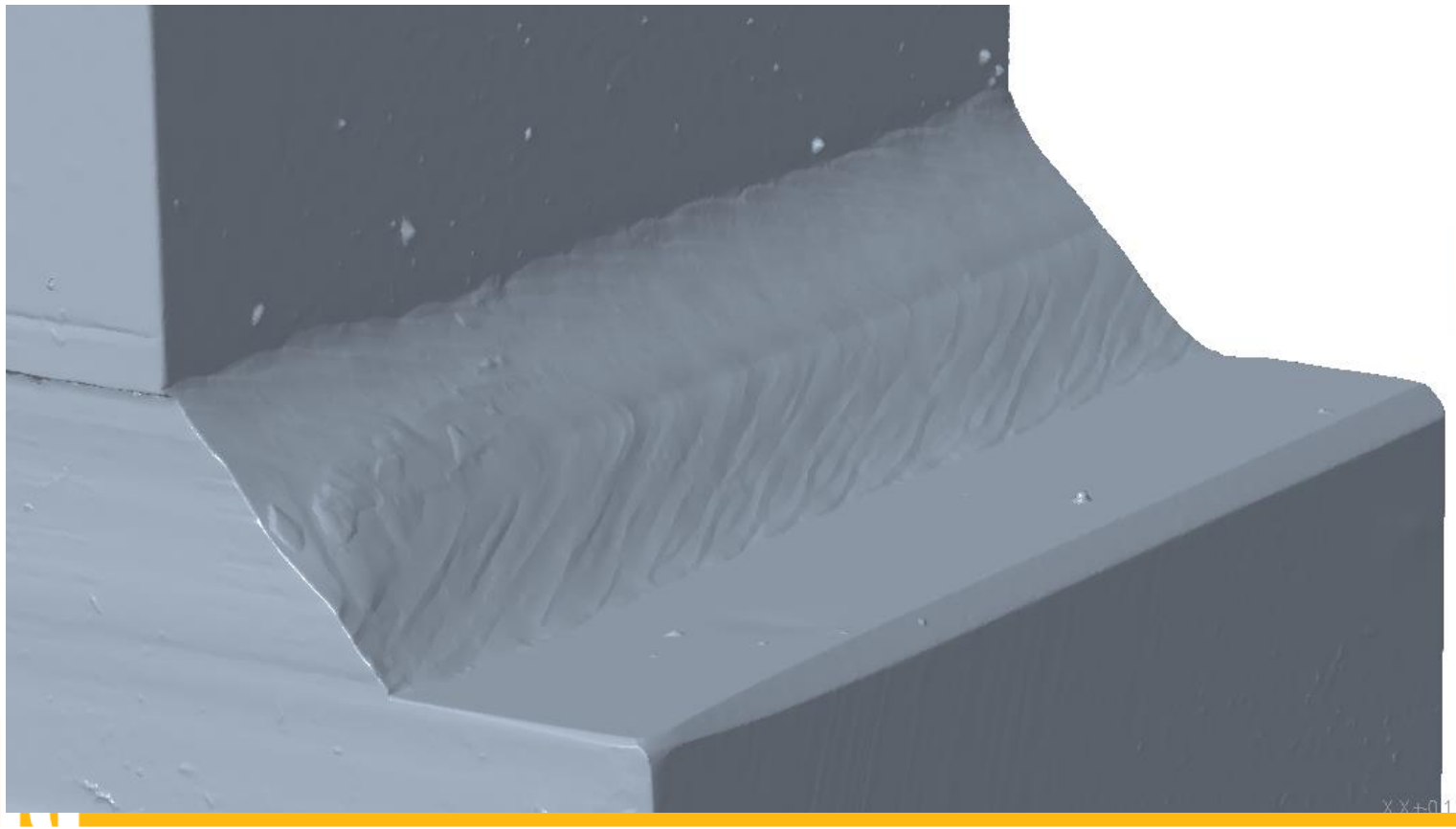


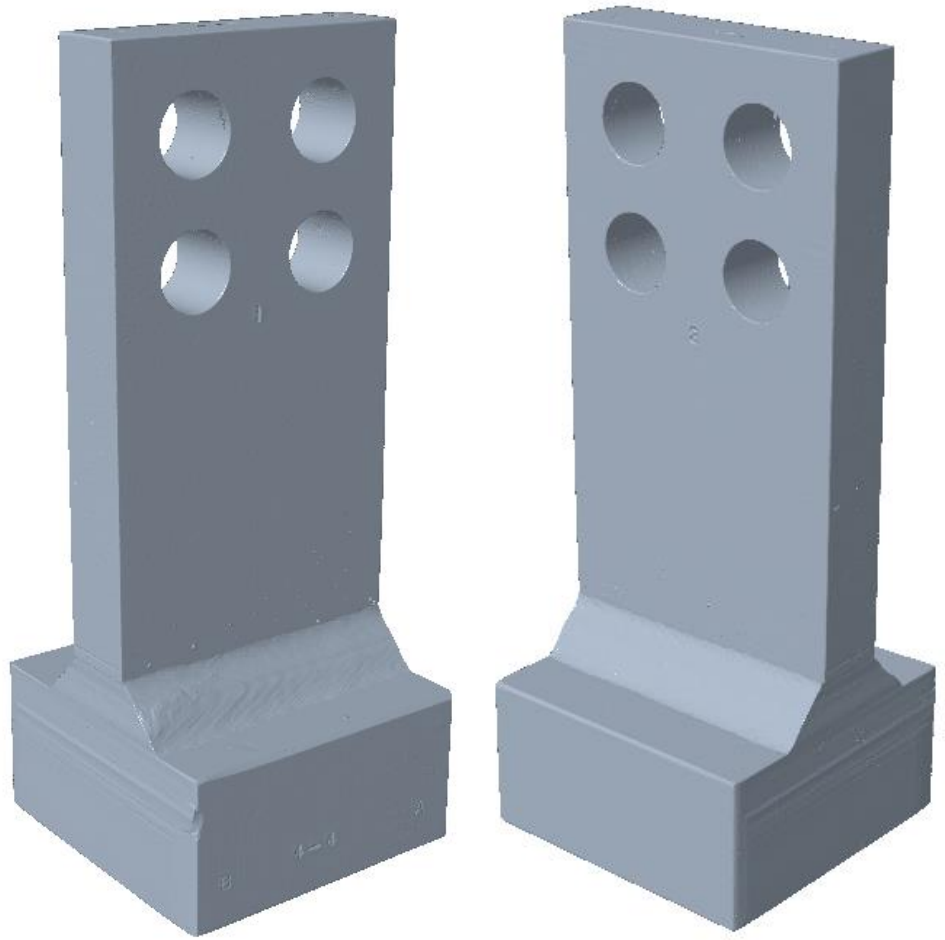




# Welded T-bar - 3D Scan

- STL file that can be imported to CAD
- Next Steps
  - Calculate weld life using actual geometry
  - Compare to fatigue test life for this specimen





# Summary

- Most analysis methods return reasonable life results for Load Range > 12 kN (Cycles < 4E5)
- Notch Stress shows promise for better correlation, but result are dependent on toe geometry
- Combining Nominal Stress and LEFM returned the best geometry independent correlation
- Including Tensile residual stress field to LEFM did not improve correlation
- Next Step: Focus on refined analysis of scanned geometry