Kt Free CX Tests

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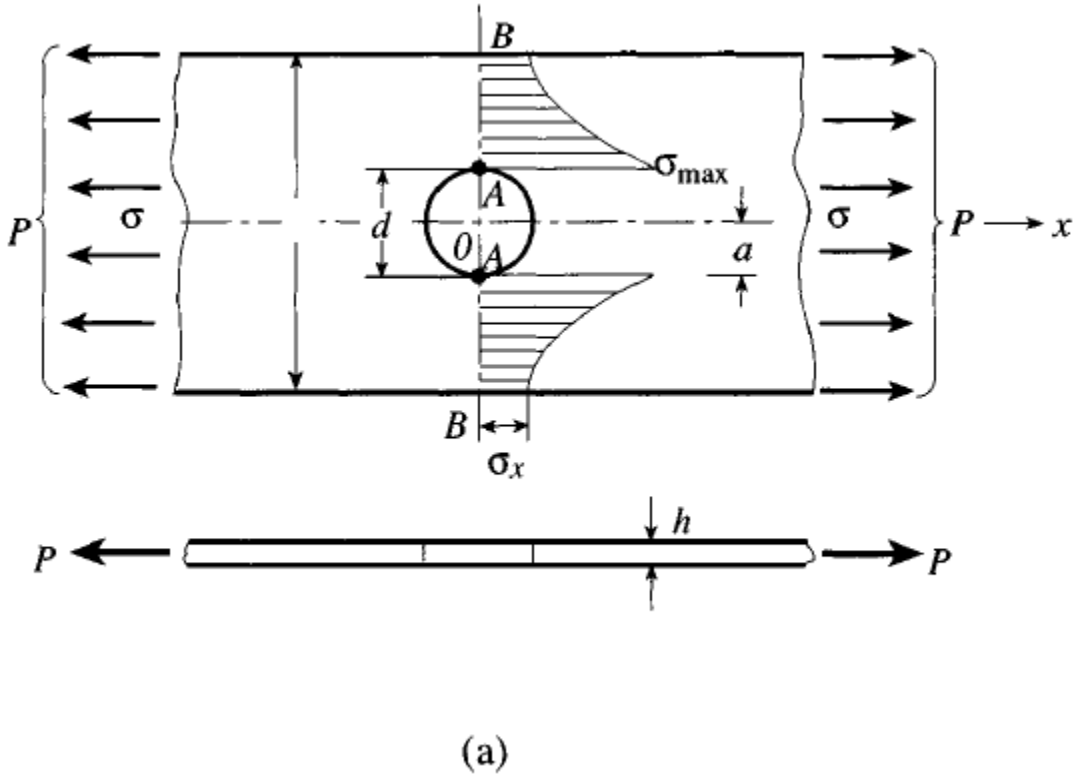
AFGROW 2021

Acknowledgements

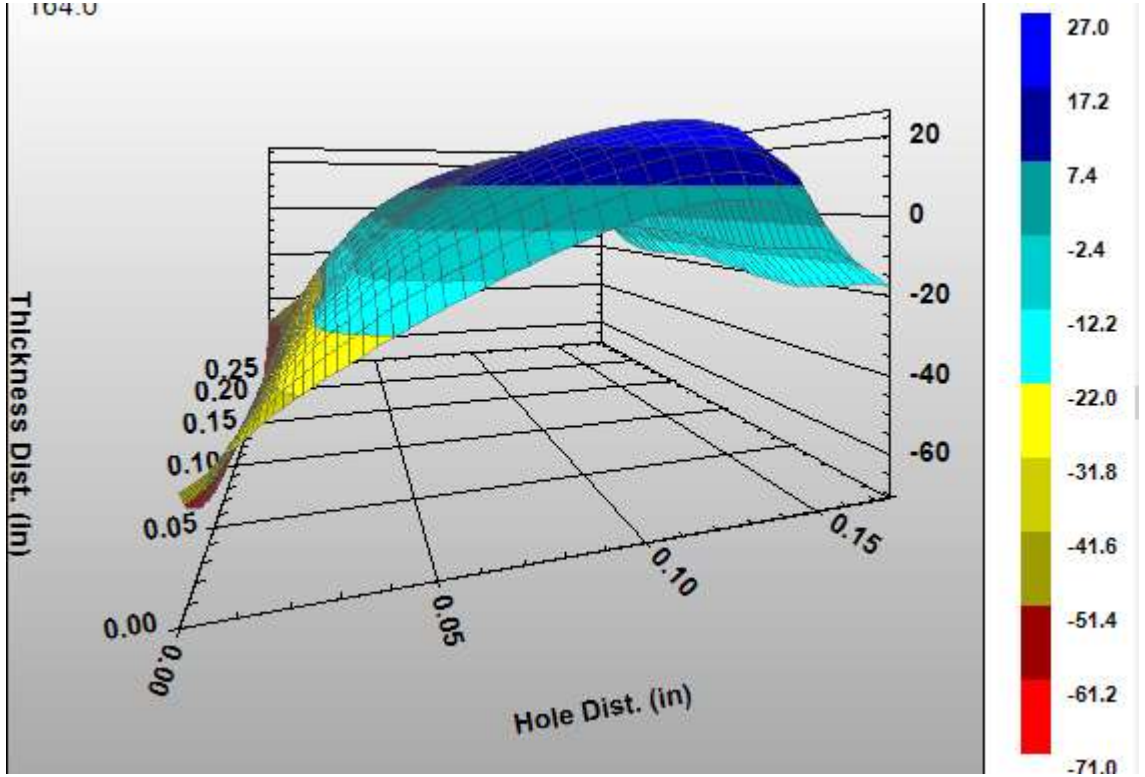
- A-10 ASIP and Analysis
- AP/ES – Scott Prost-Domasky
- CAStLE – Jim Greer
- Dallen Andrew and Evan Ross thesis work
- Family and Faith
- Hill Engineering – Josh Hodges
- LexTech team, Jim Harter, Alex Litvinov
- SwRI – Lucky Smith, Marcus Stanfield

The Problem

- **Residual Stress (RS) analysis has compounding steep stress gradients**
  - **Kt from the hole**
  - **Cold Expansion RS field**



Peterson's Stress Concentration Factors, 2nd Edition

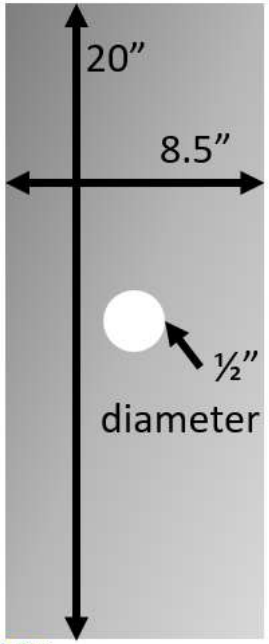


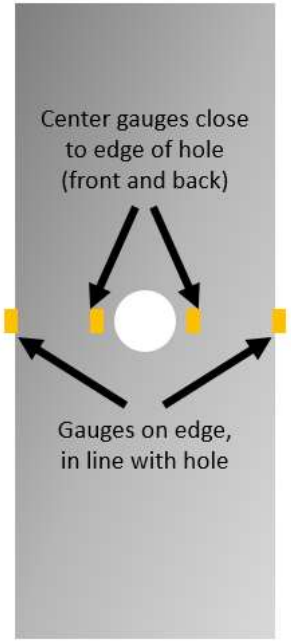
Kt Free Specimens

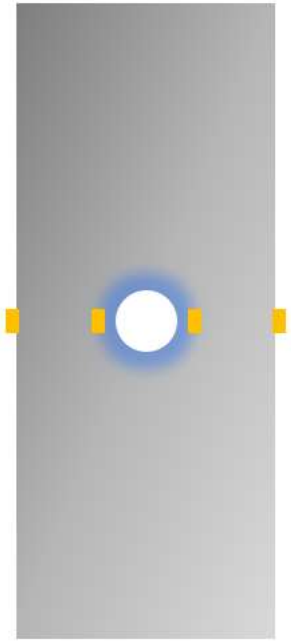
Coupon Development

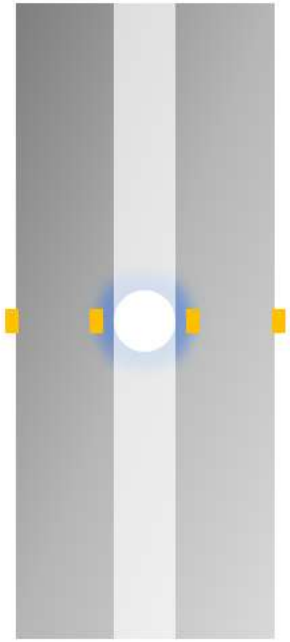
- Objective: Eliminate the effect of the hole K_t while preserving the RS field created by Cx

1. Machine ¼" thick Specimen
2. Install Strain Gauges (6)
3. CX Hole (record strain from CX) and final ream
4. Cut Specimen into two bars (measure strain to determine stress relaxation – next slide)









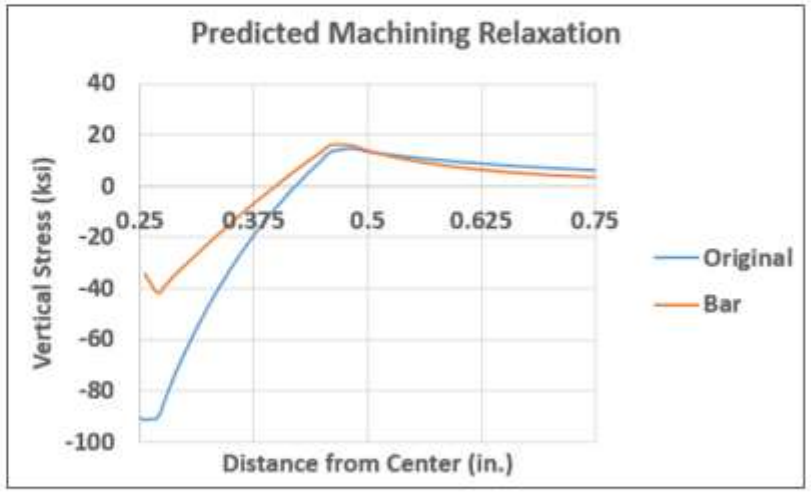
ERSI

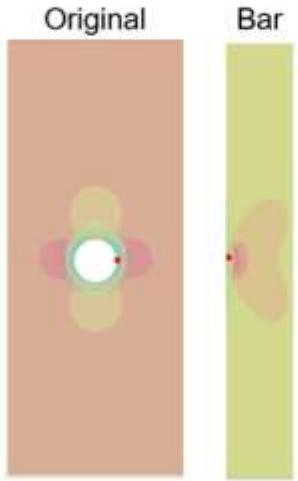
Expected Impacts to RS

- **Thanks to Marcus Stanfield for FEA**

Summary

- FEA prediction indicates specimen with hole removed ("bar") has an RS stress field with the same characteristic shape as the specimen with the Cx hole.
  - Will be verified with RS analysis.
- Fatigue crack growth (FCG) behavior will be compared to existing FCG data for Cx hole coupons.



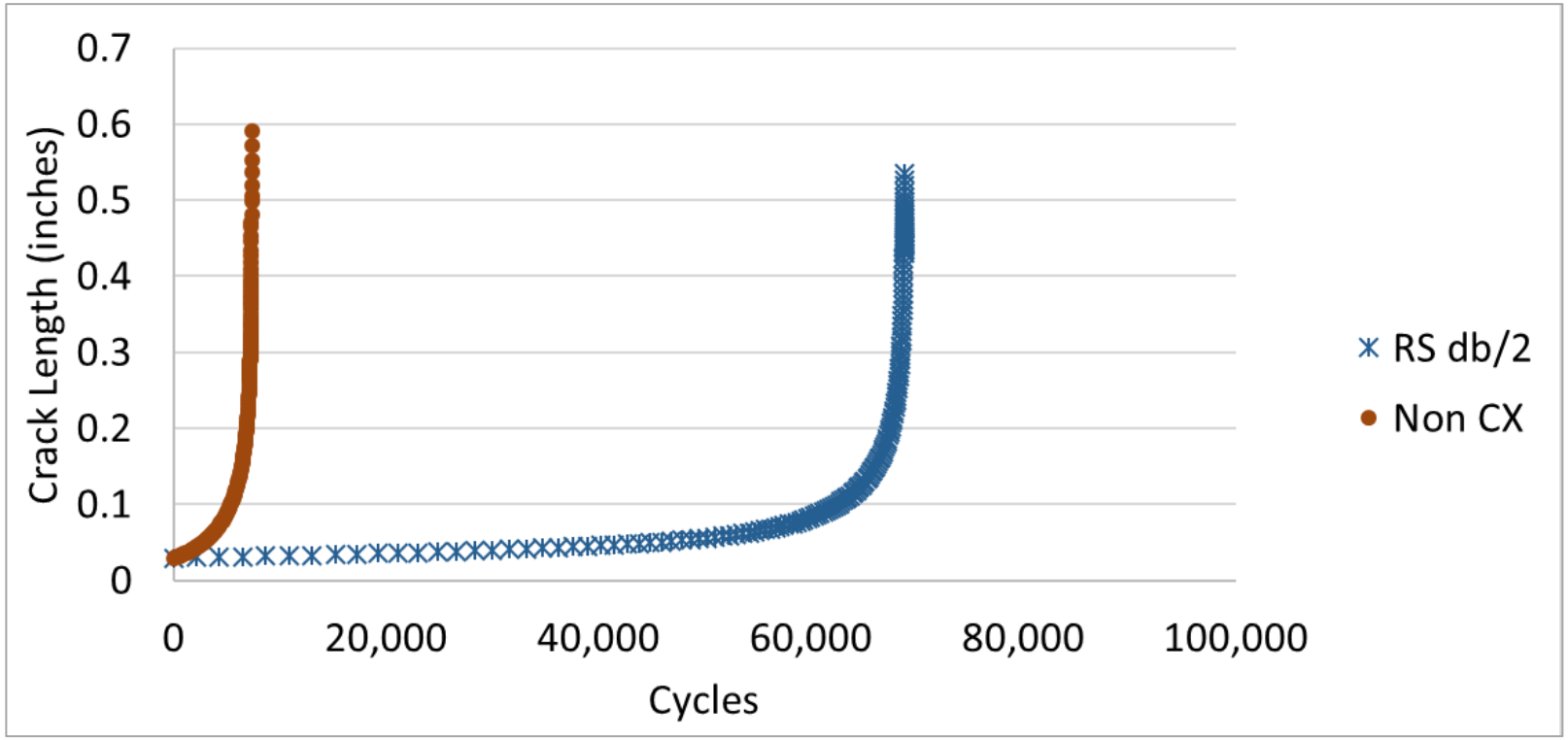


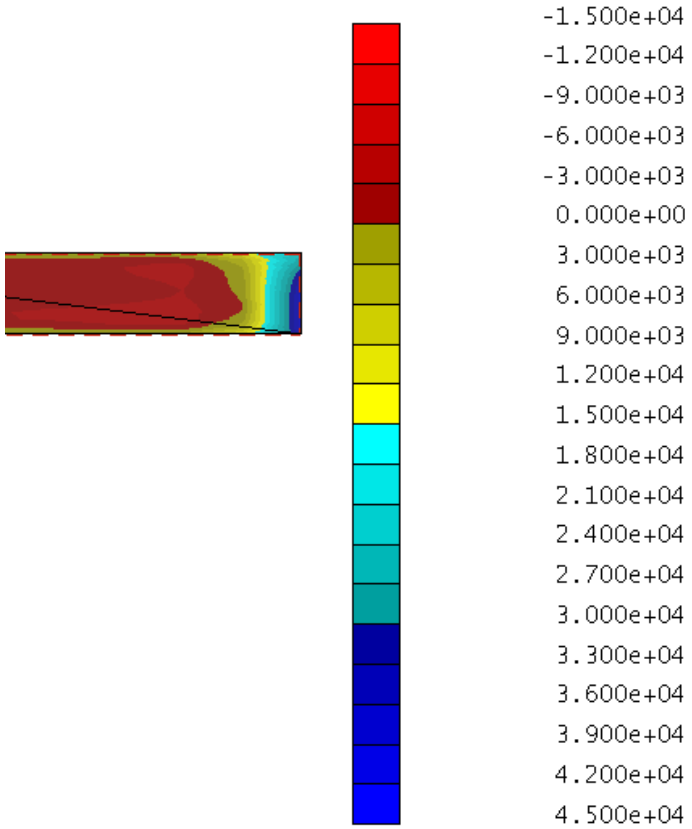
- Status
  - Specimen preparation complete
  - Testing of FCG specimens (x6) and RS analysis specimens (x2) to follow

ERSI

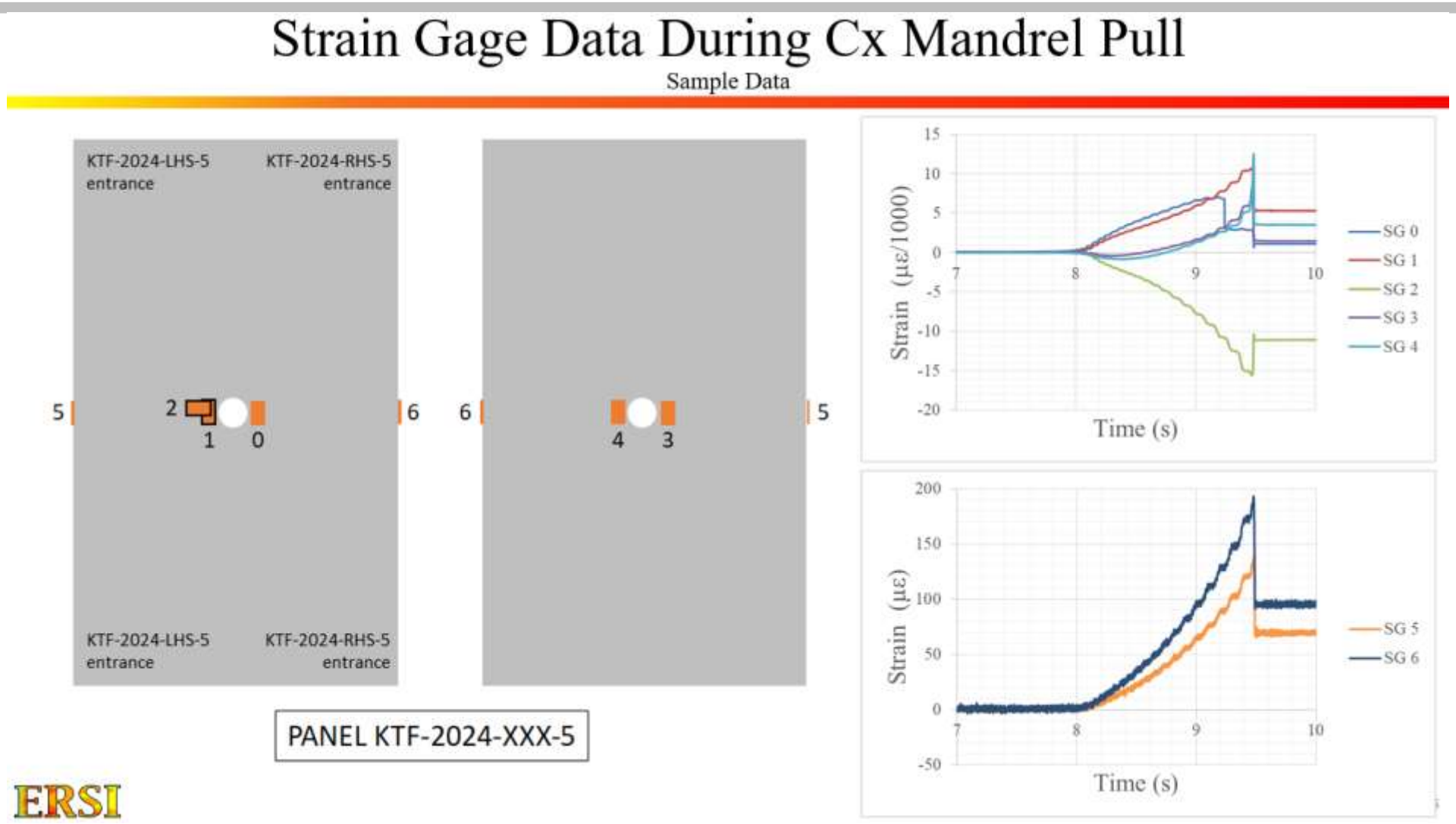
Initial Prediction

- RS field approximated from Marcus FEA, RS database output divided by 2
- Without Kt from hole, higher stress needed, 45 ksi
- BAMpF prediction to substantiate test stress



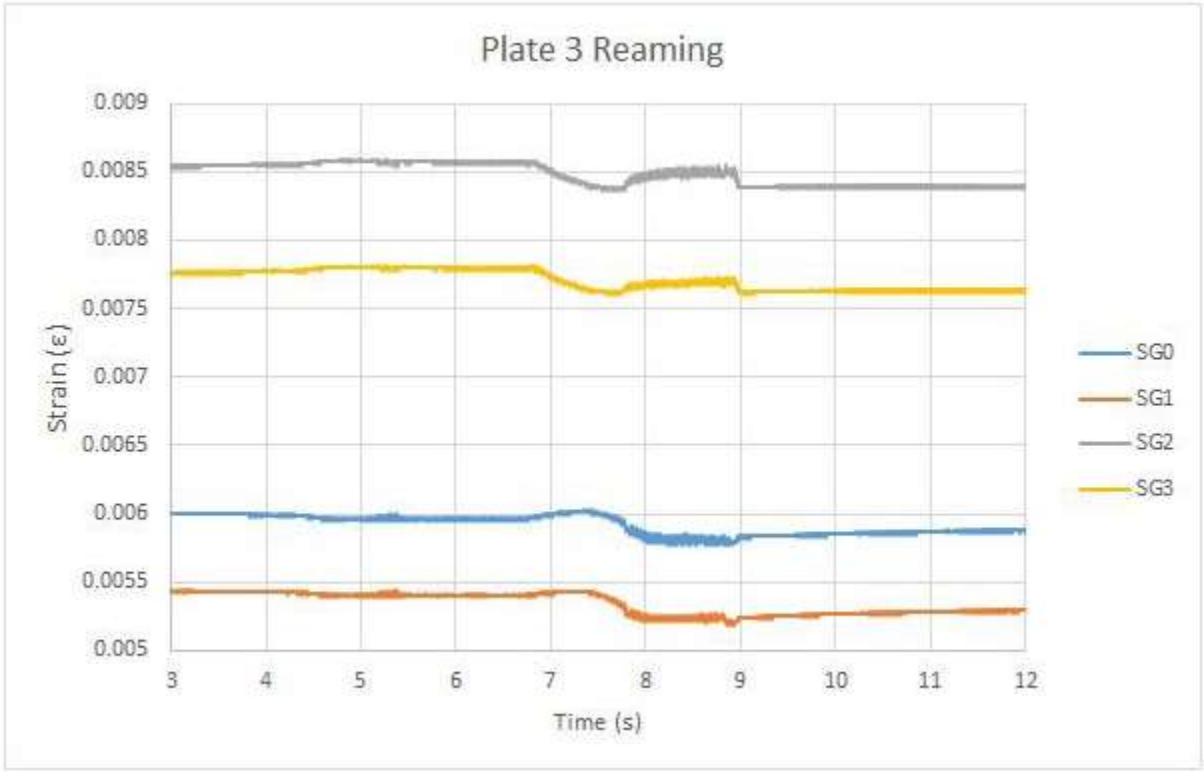


Specimen Fabrication

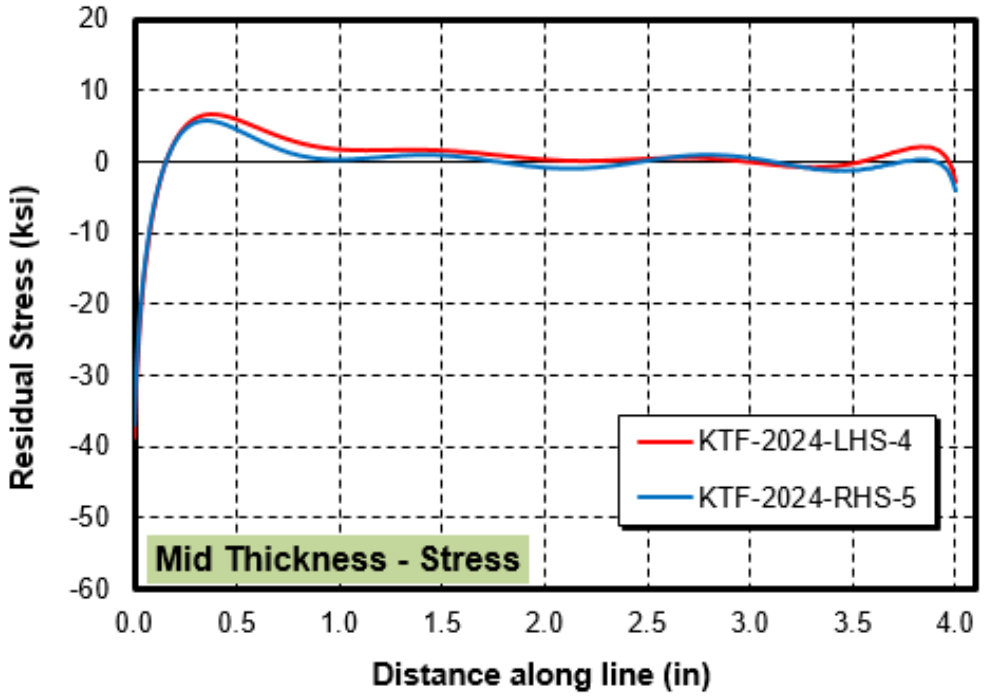


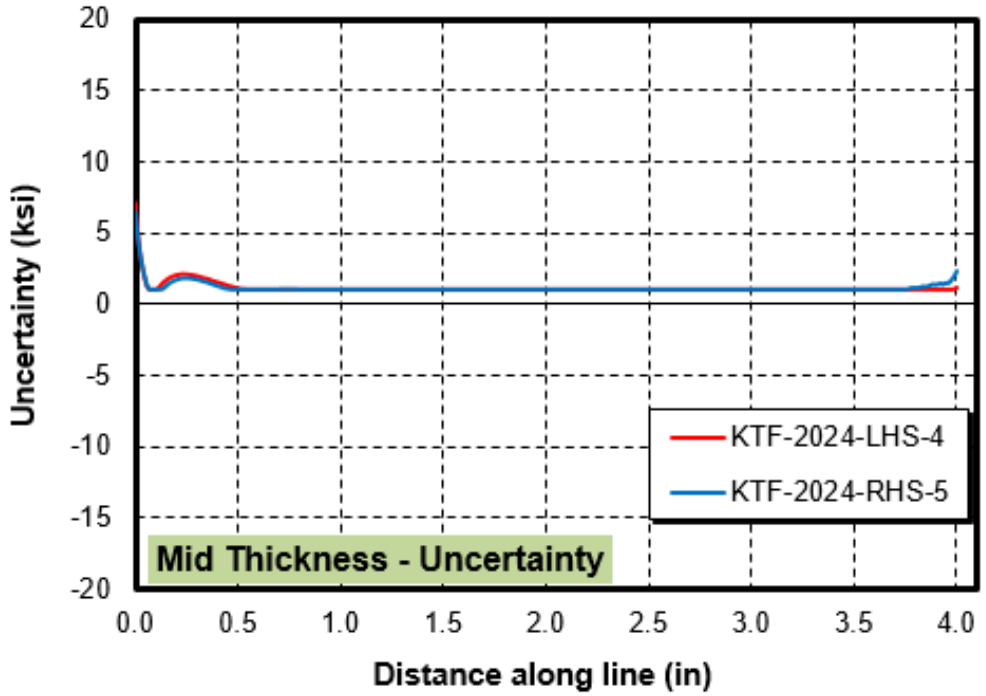
Strain Gauge Derived RS Field

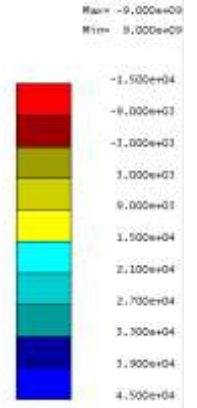
- RS field estimated from contour results of standard configuration, modified according to strain gauge readings during machining processes
- Thanks to Jim Greer and AF Academy for specimen fabrication



Direct Contour Results of Final Specimen

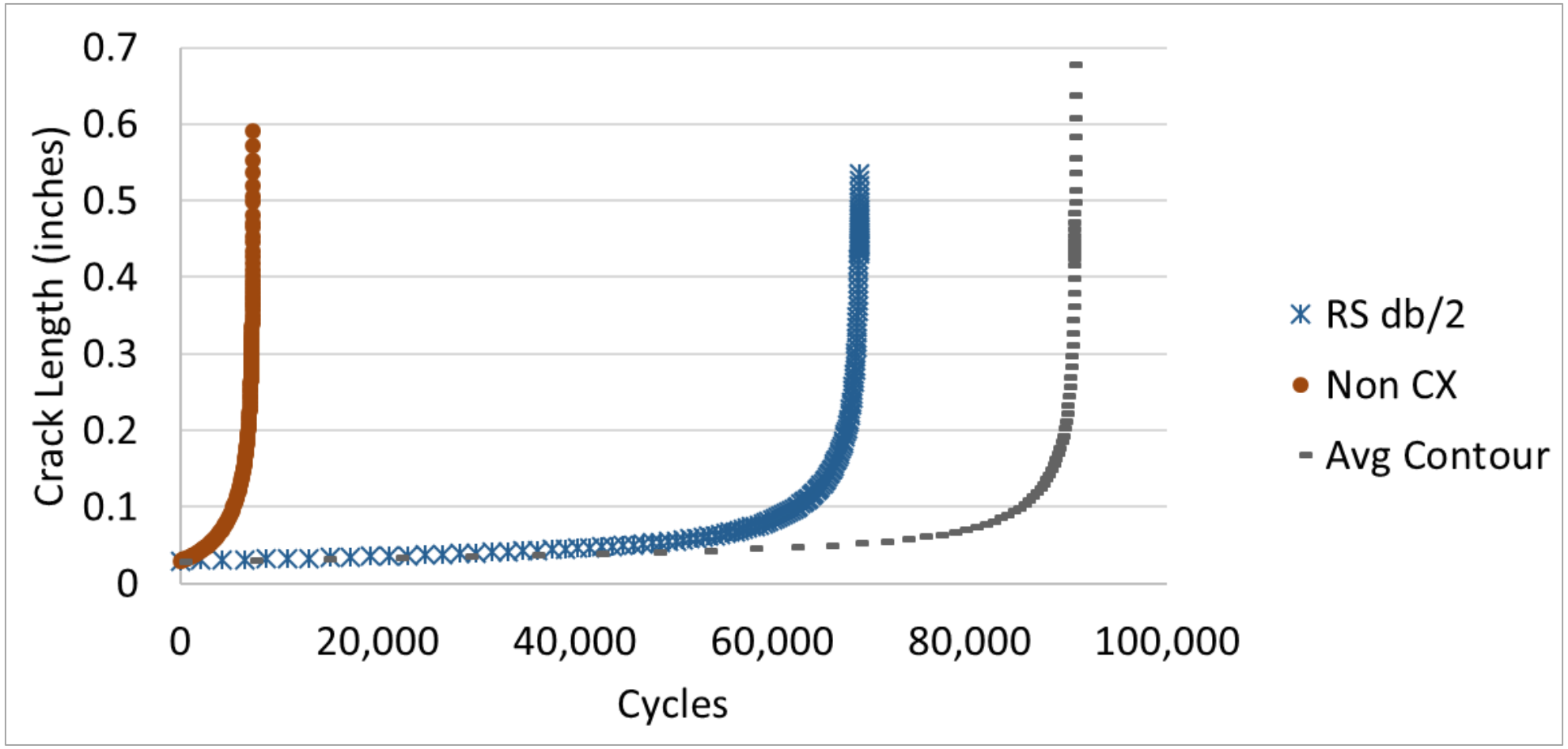






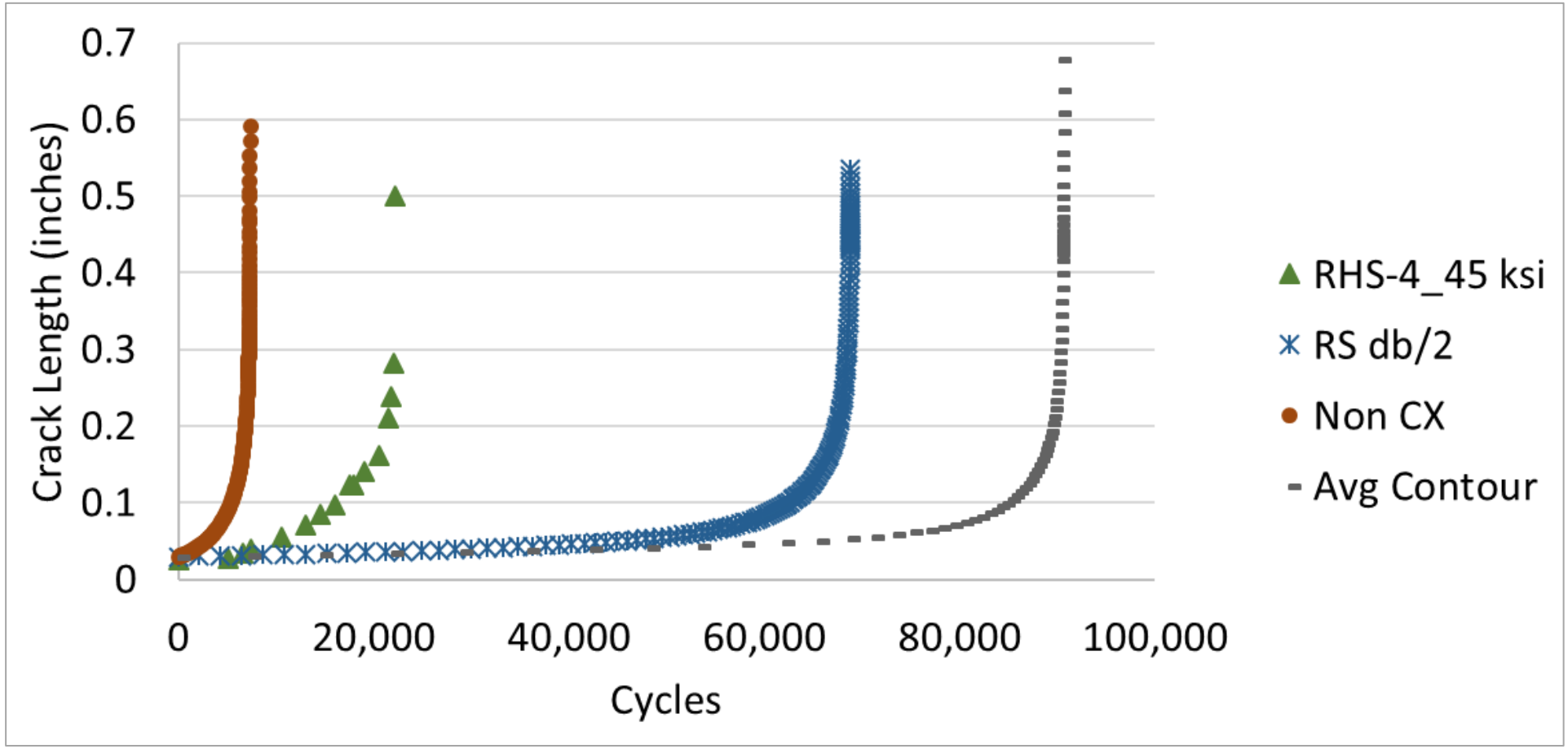
Contour Prediction

- Contour method performed on 2 samples
- BAMpF repeated with average RS surface, extended life at 45 ksi



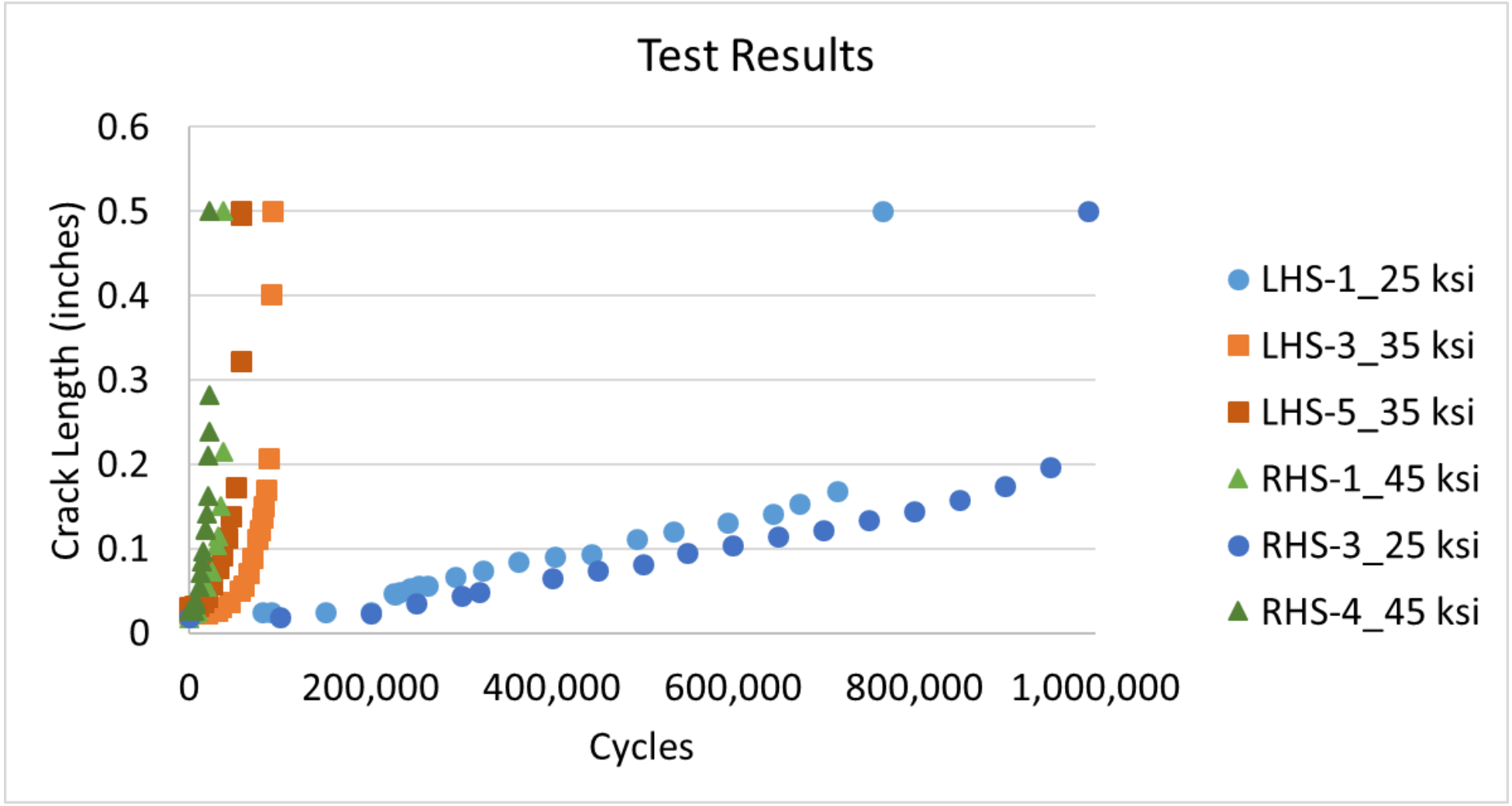
Initial Test Result

- 45 ksi, R=0.1
- Test results much shorter than prediction
- 6 total samples
- Decide to test at three stresses
  - 45 ksi
  - 35 ksi
  - 25 ksi



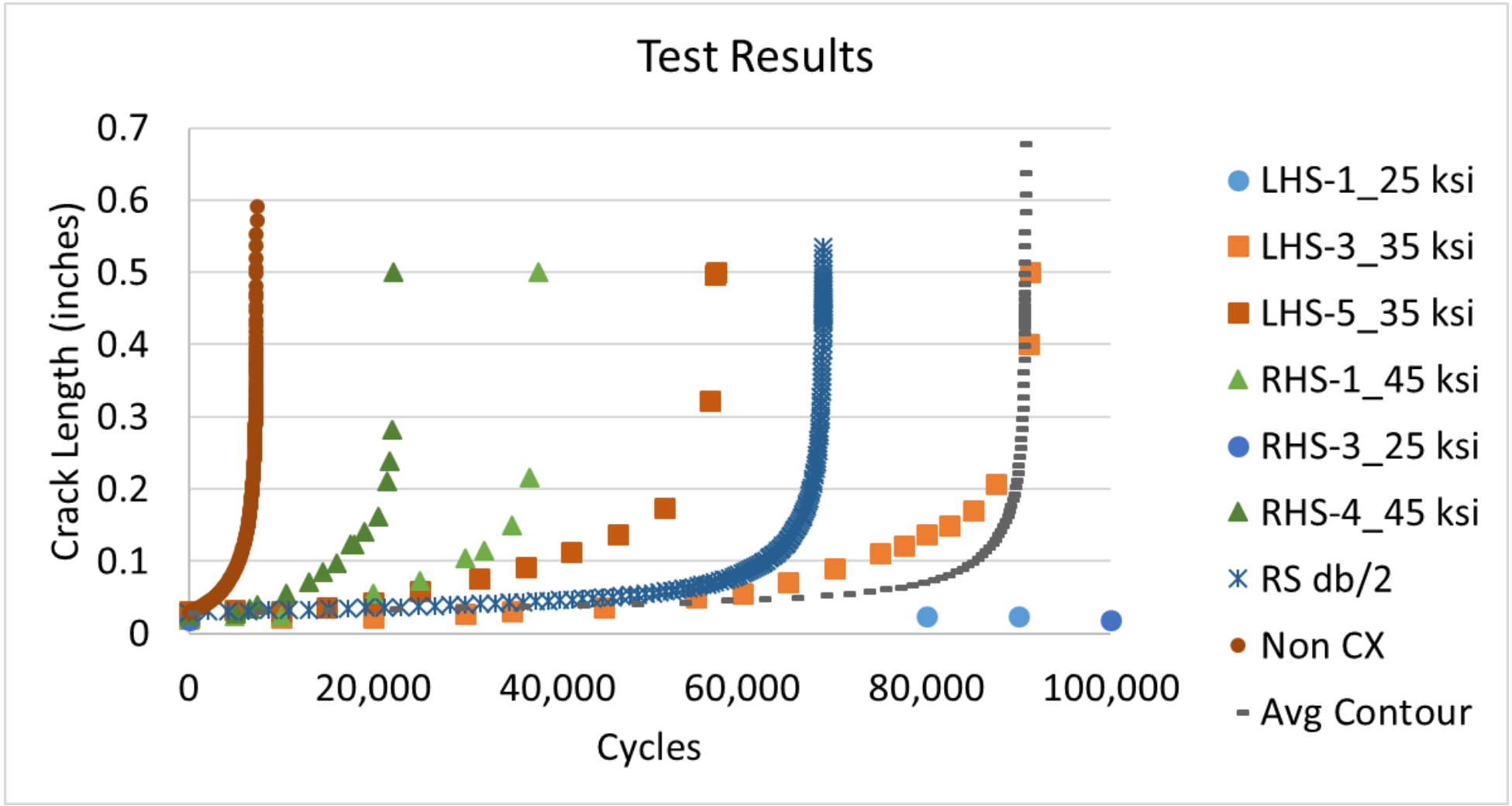
All Test Results

- Circles = 25 ksi, Square = 35 ksi, Triangles = 45 ksi



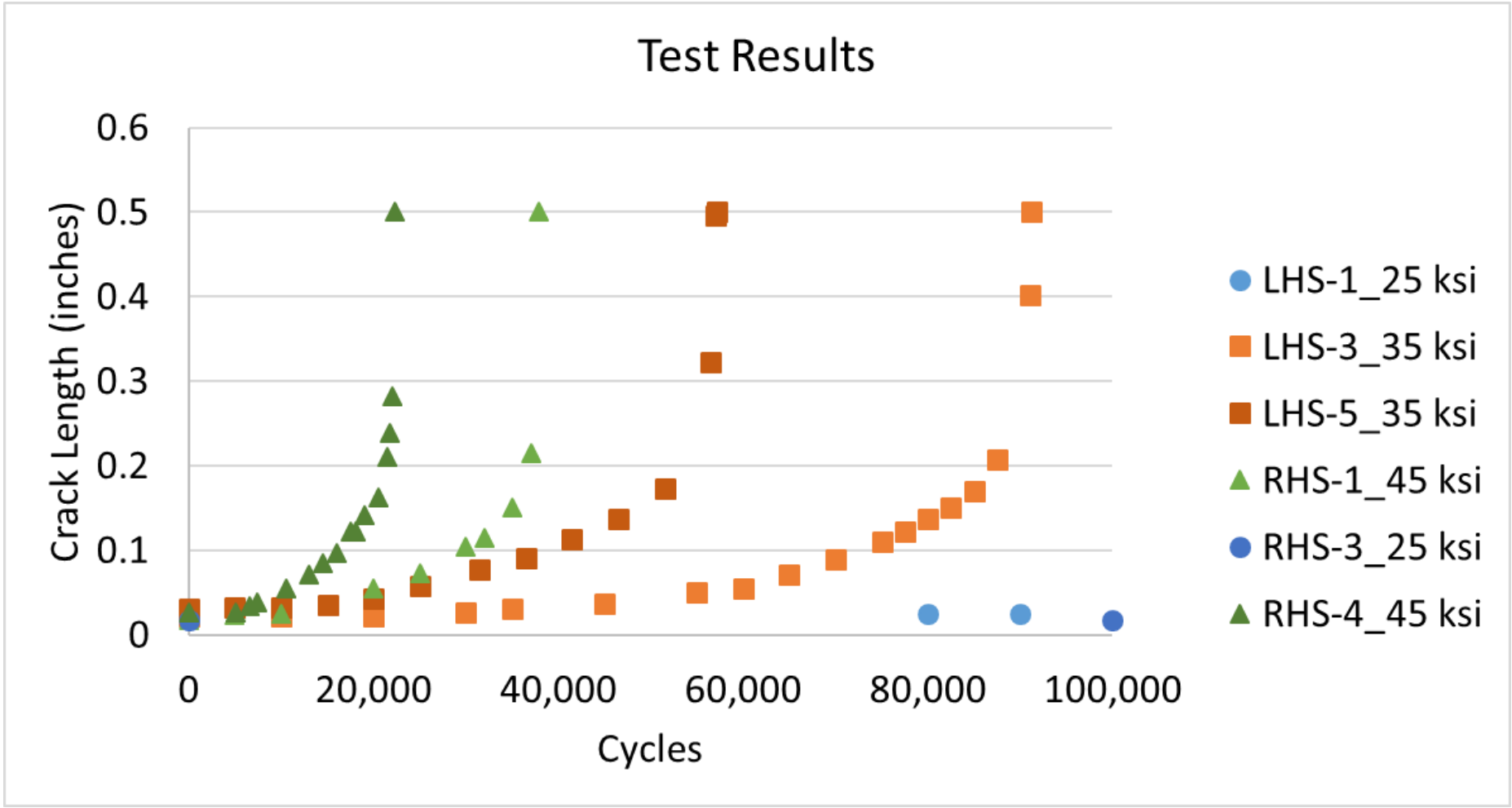
All Test Results – First 100K Cycles

- Circles = 25 ksi, Square = 35 ksi, Triangles = 45 ksi



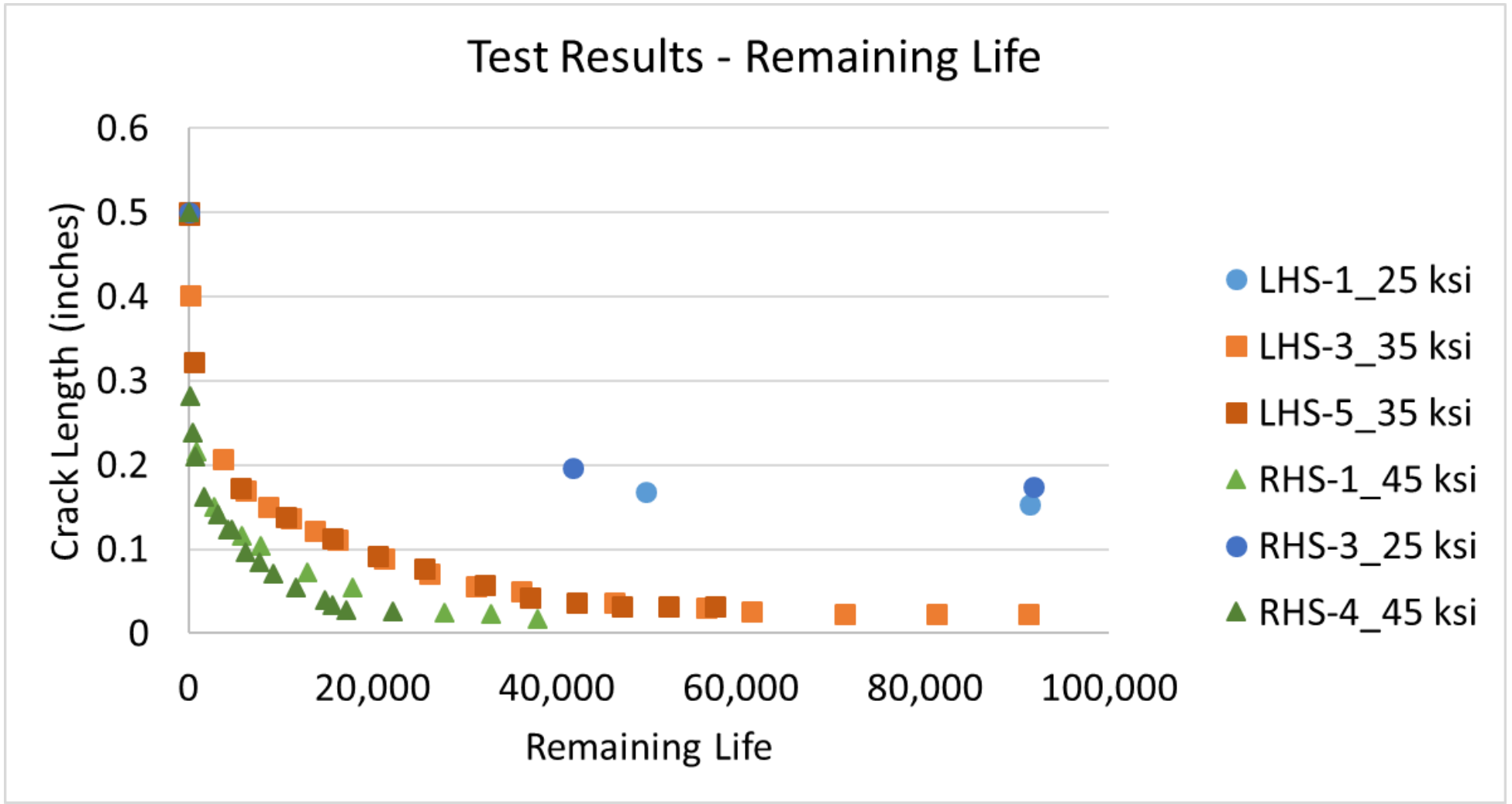
Data Spread

- Significant spread between results of the same stress
- RHS-1 specimen was short, initially tested at 25 ksi but had a failure in the grip section



Understanding Data Spread

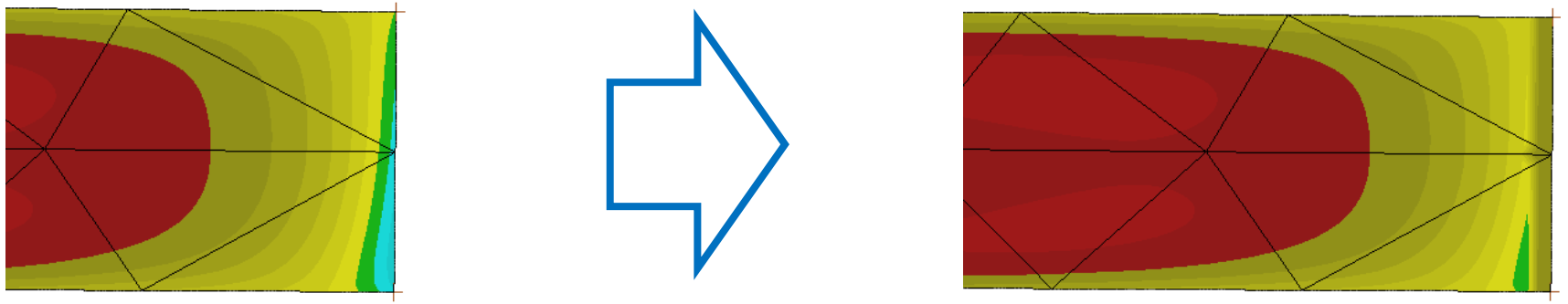
- Remaining life plot shows that 35 ksi life difference is result of initial crack length
- LHS-3, .023”
- LHS-5, .031”
- RHS-1, .018”
  - Short height
- RHS-4, .026”



Understanding Test Results

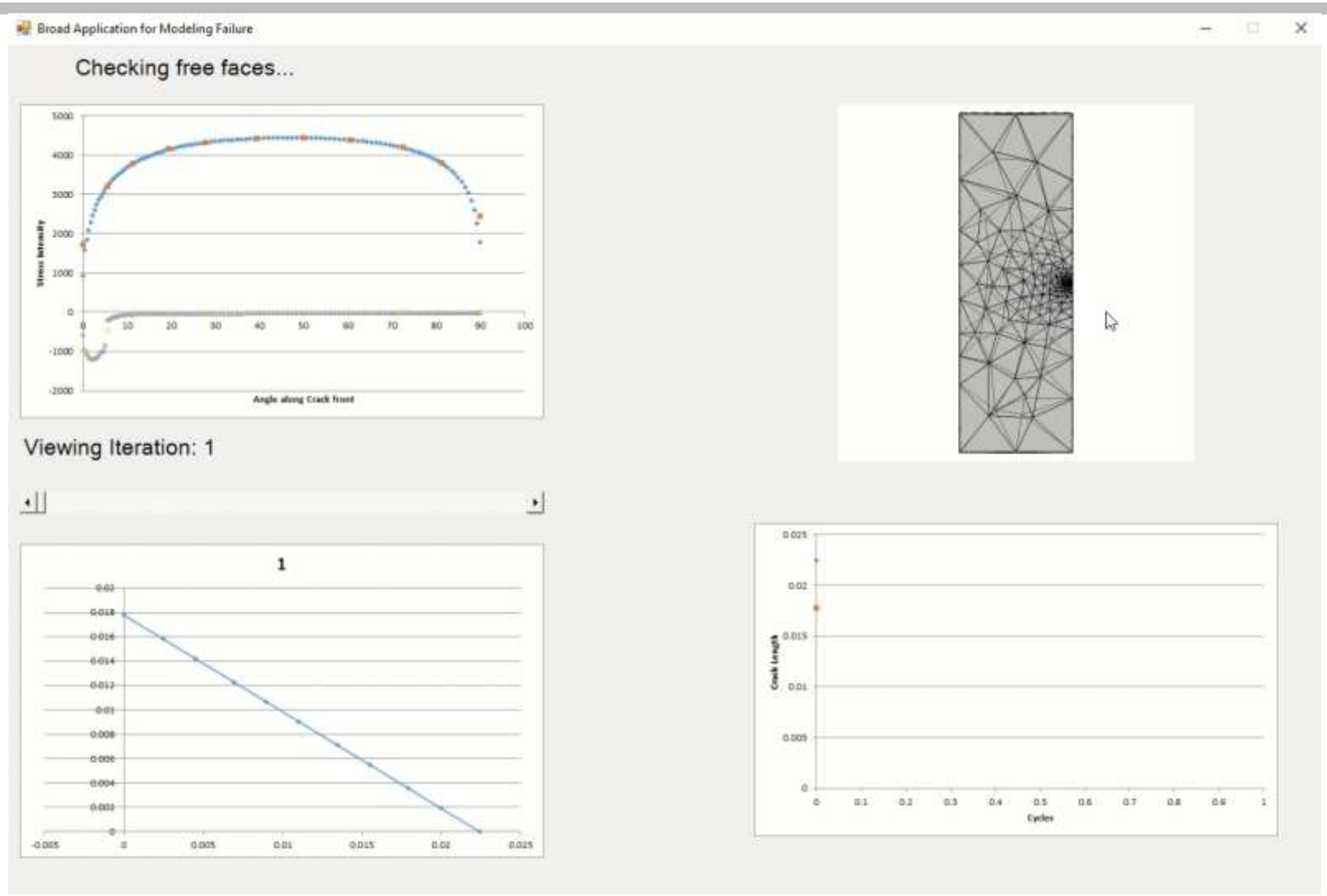
- BAMpF runs at 35 ksi and 25 ksi predicting crack arrest
- 45 ksi results over predicted life
  - Both points above indicate too much benefit from RS

- What if RS minimized until crack grew 0.02” into the part?



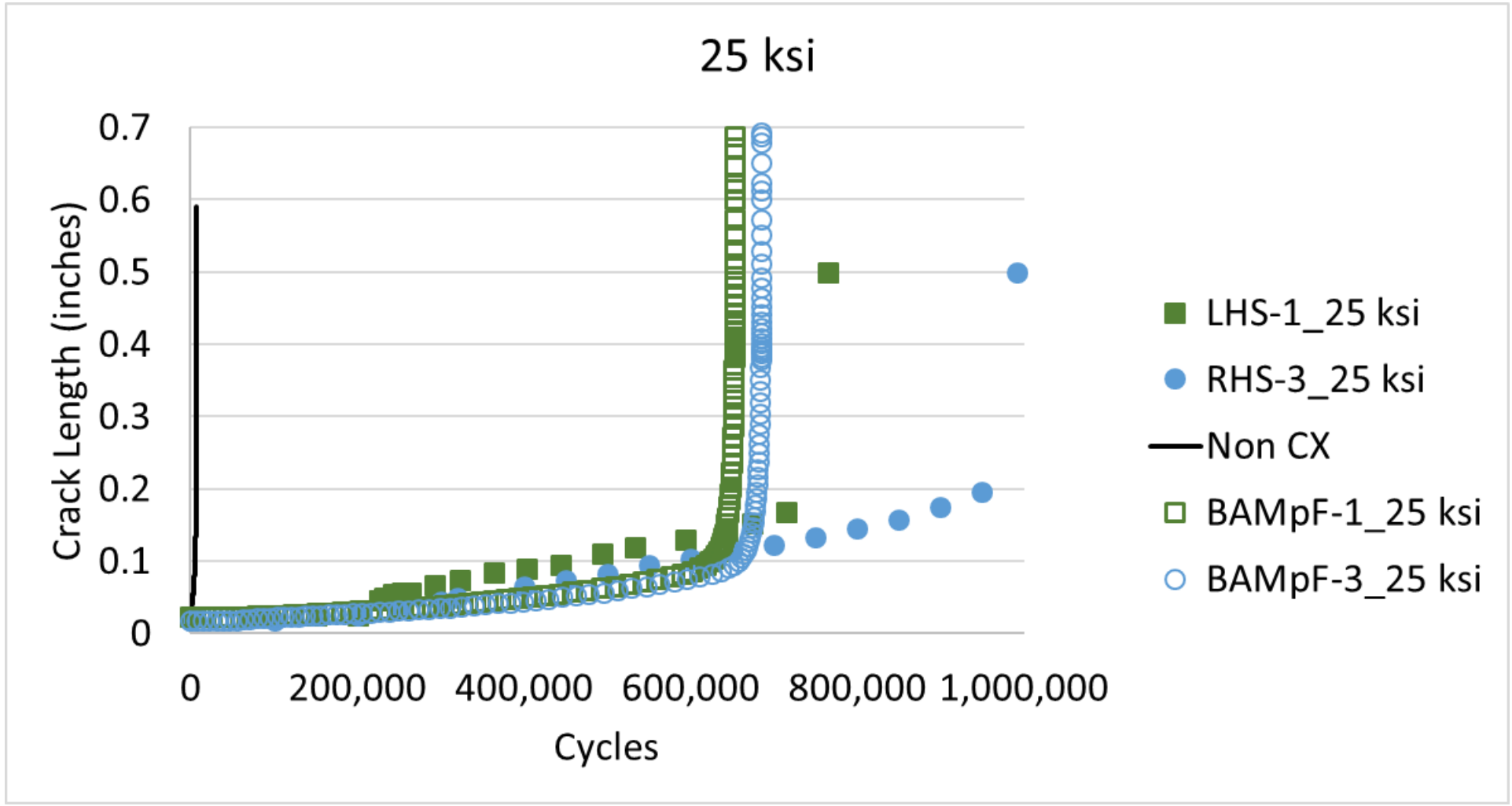
```
FUNCTION      if(x<0.02;{TENSILE};{RS})
RS            1000*(-((-2.8033505934e+01)+(2
TENSILE       100
```

Video of tensile at bore to avoid crack arrest



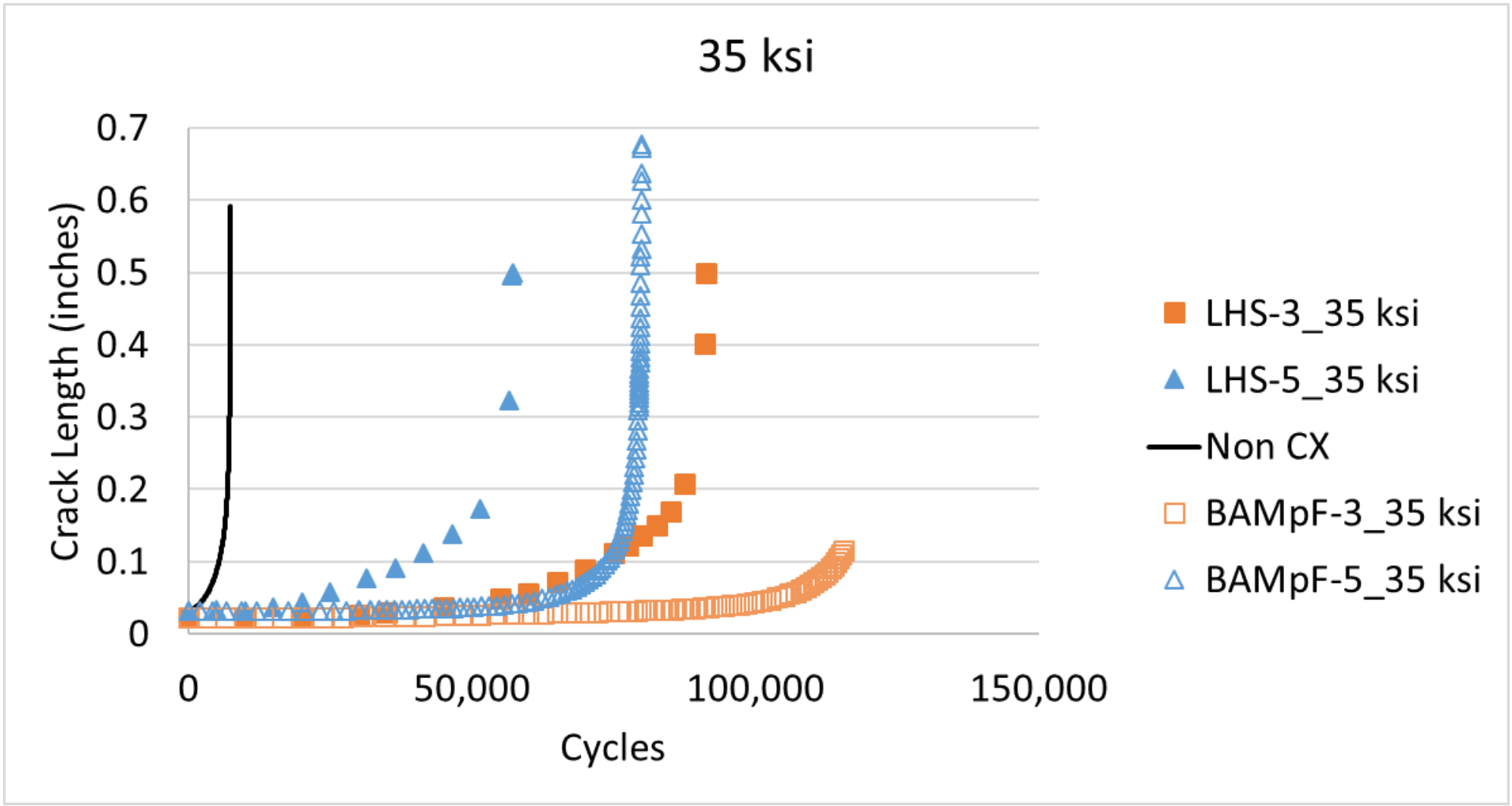
25 ksi Results

- With minimal RS until 0.02” into the part, BAMpF results correlate very well



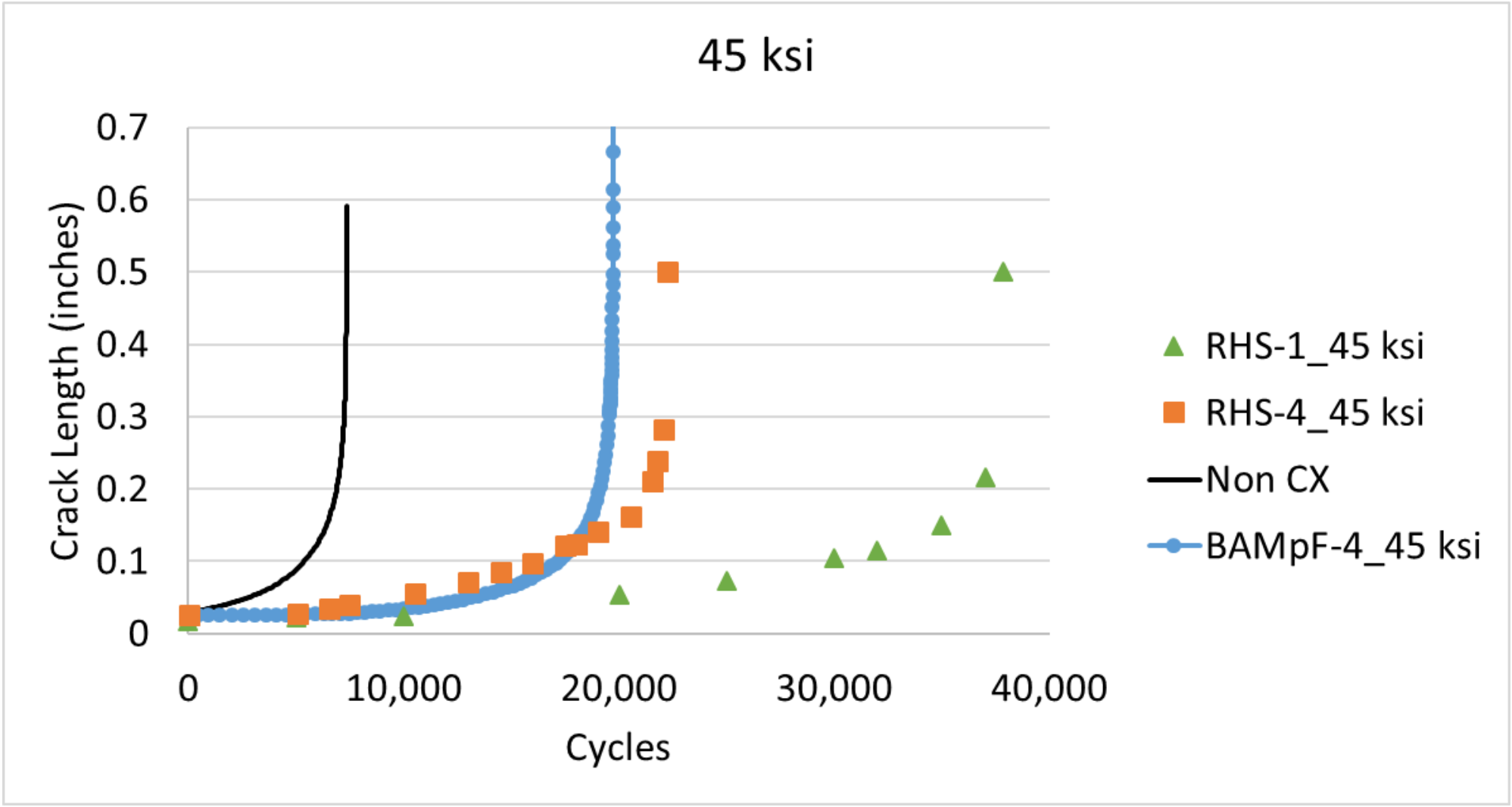
35 ksi Results

- Minimal RS for first 0.02” over predicts



45 ksi Results

- Model correlates well for .02” minimal RS approach



Conclusions/Questions

- Tests ran shorter than initially predicted
- For analysis to correlate with prediction RS field needed to be changed

- Why did blind predictions not correlate well?
- How does thru thickness growth rate of Kt free tests compare to standard CX hole tests?
- How does surface growth compare to standard CX hole tests?
- How does aspect ratio compare to cracks from a standard CX hole?
- Can strain data from machining operations inform better predictions?

Questions?