U.S. AIR FORCE

U.S. AIR FORCE

Interference Fit Bushing Durability Life Predictions

Jake Warner

Background, Bushing Installation

1A-10C-3 Typical Instruction

CAUTION

Bushing and plug installations are designed with an interference-fit. To avoid damage on installation it is necessary to shrink bushing/plug by subjecting it to low temperature. It may also be necessary to heat the surrounding material to expand the hole. Heating is limited to 200°F. Heating above 150°F is limited to 30 minutes.

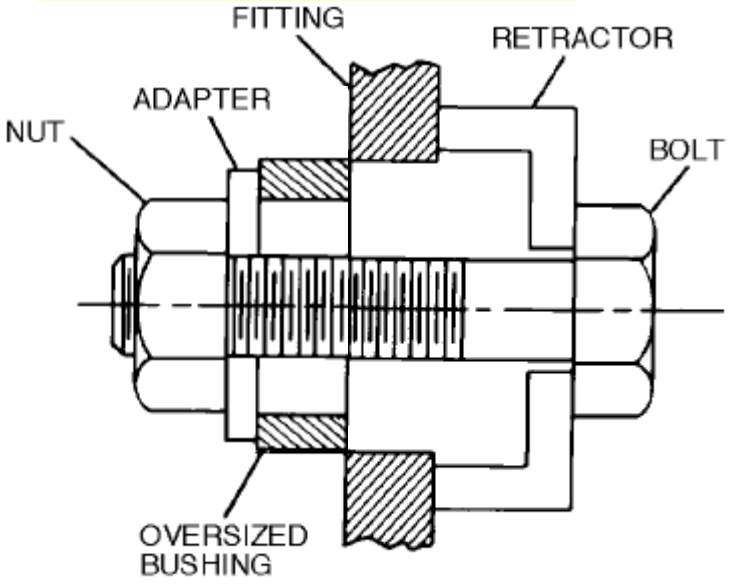
(2) If bushing expands before it can be fully inserted, remove the bushing IAW Paragraph 3.8 REMOVAL OF INTERFERENCE-FIT BUSHINGS and re-install using an installation tool that is large enough to keep the bushing from expanding before it is installed. The tool and bushing may need to be frozen for longer than 20 minutes.

1A-10C-3 Case Specific Instruction

c. Install oversize bushing in wing attachment fitting as follows:

(1) Assemble bolt, nut, adapter, and retractor as shown on Figure 8-11.

(2) Tighten bolt until oversize bushing has migrated into wing attachment fitting.



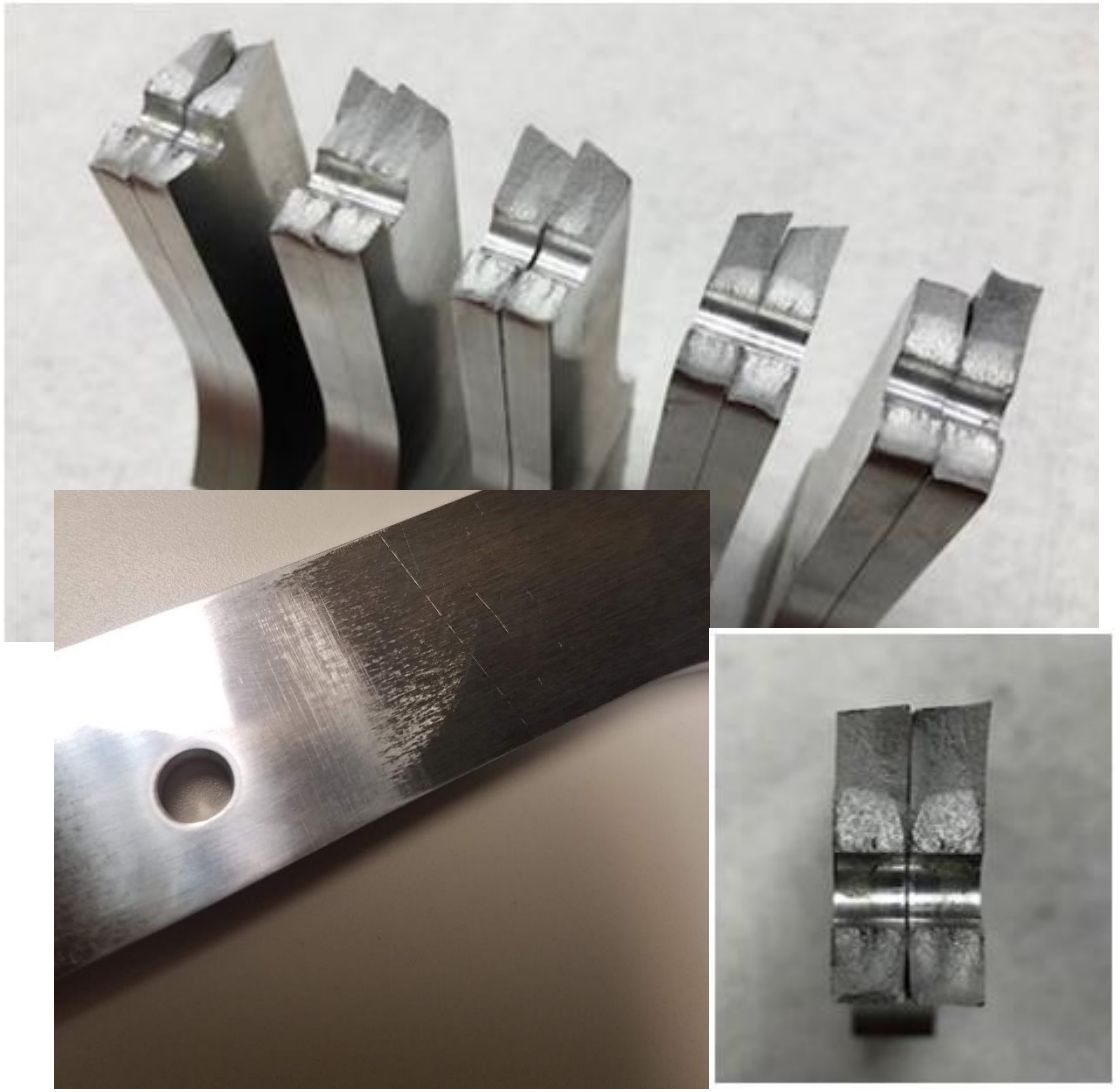
TYPICAL TOOL APPLICATION FOR BUSHING INSTALLATION

Devil is in the Details

- 202 request to use alternative bushing installation method
- Alternative method uses a bolted assembly to pull the bushing into the hole
- TO method freezes bushing with liquid nitrogen
- Technician explains that alternative method has been used for years

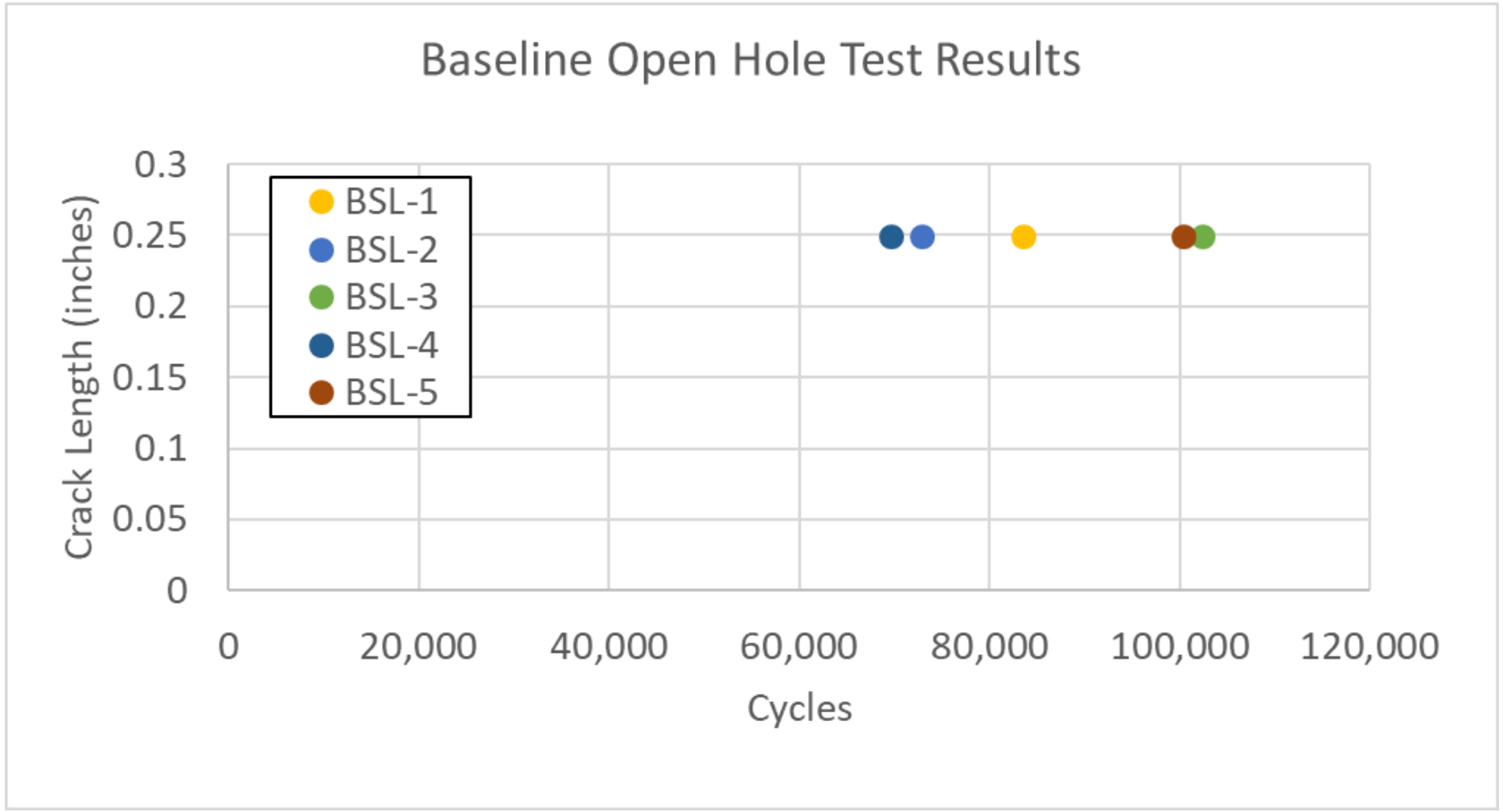
Test Program

- **Goals:**
  - Quantify fatigue benefit for
    - •Freeze install bushing
    - •Drawn in bushing
- **3 Coupon sets (e/D=1.5, D=t=.25)**
  - Baseline, open hole
  - Freeze install bushing
  - Drawn in bushing
  - 2024-T351 with 7075-T6 bushing
- **Durability test (no induced flaw)**
  - Max stress: 20 ksi, R=0.1

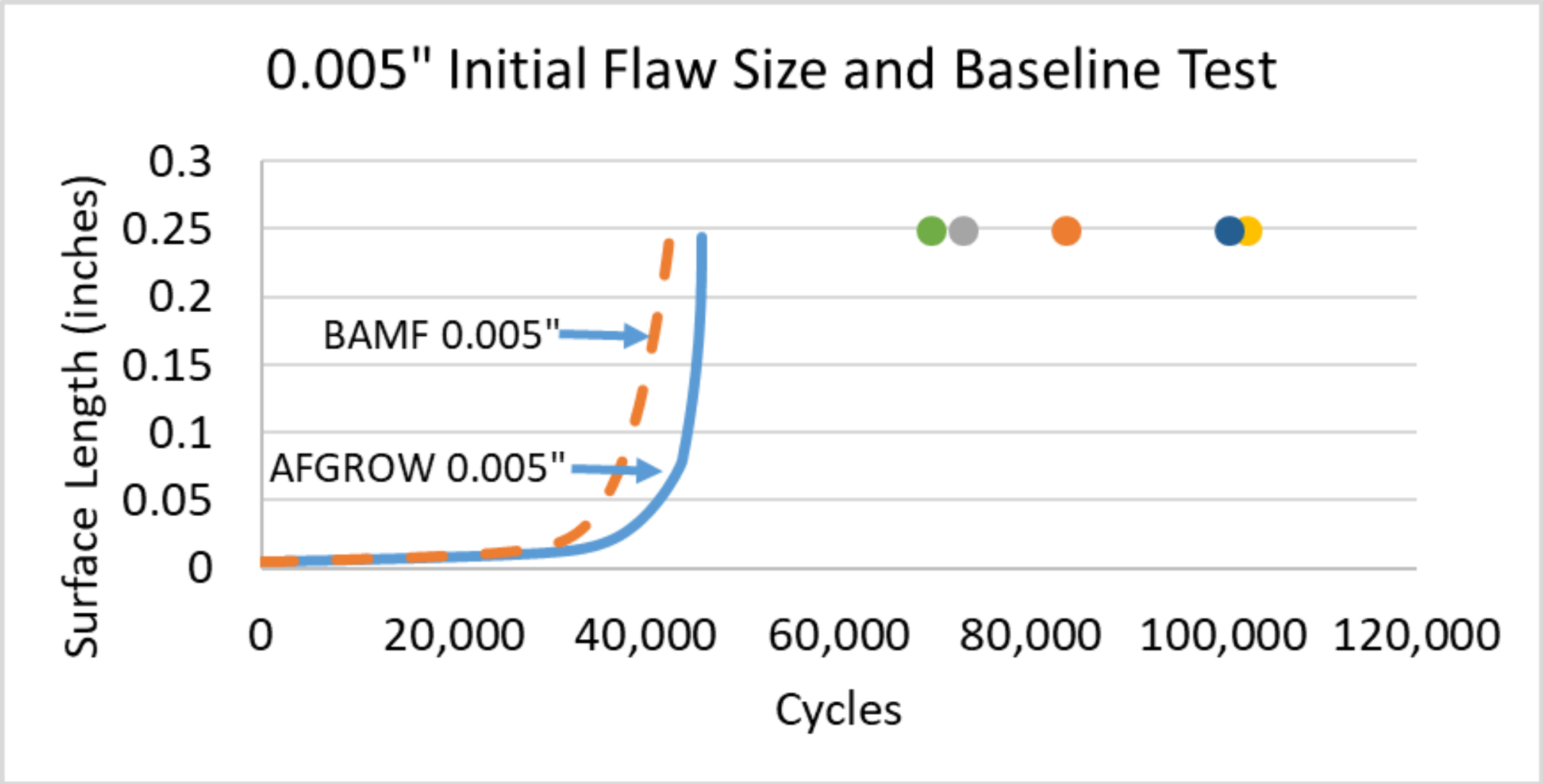


Baseline Test Results

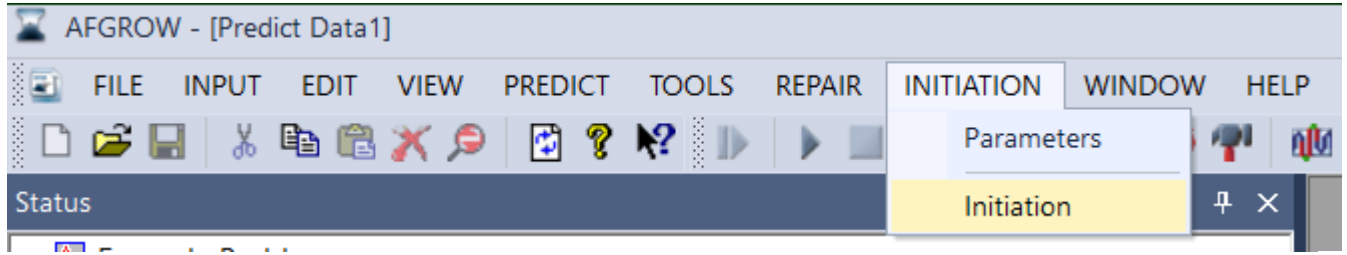
- **Standard Deviation: 15,000 cycles**

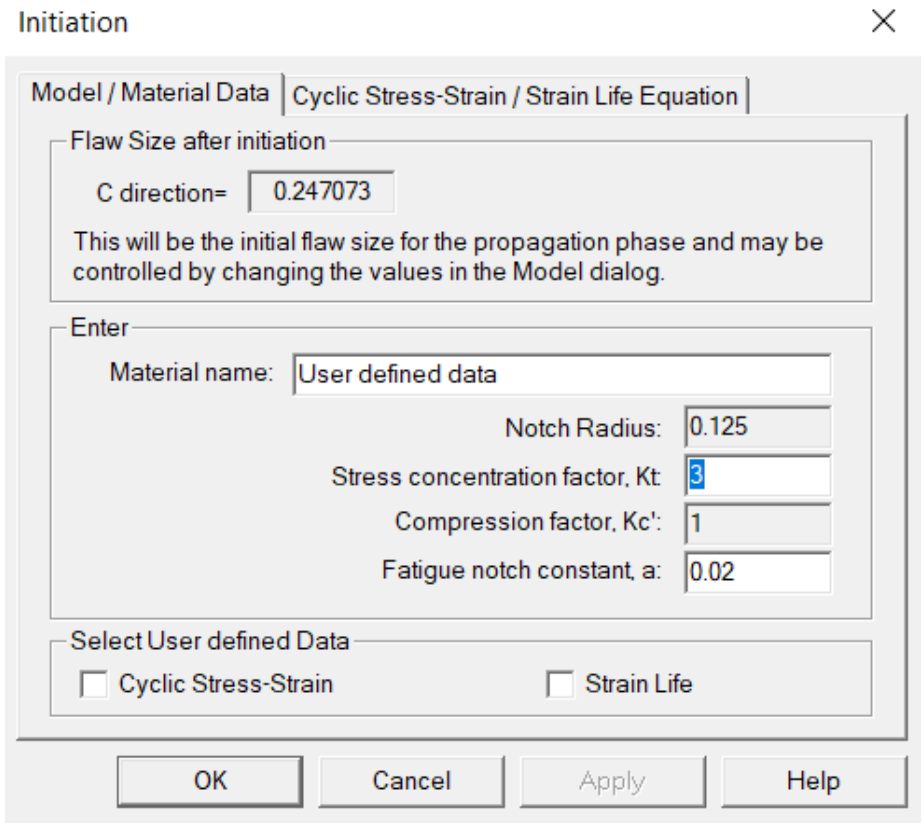


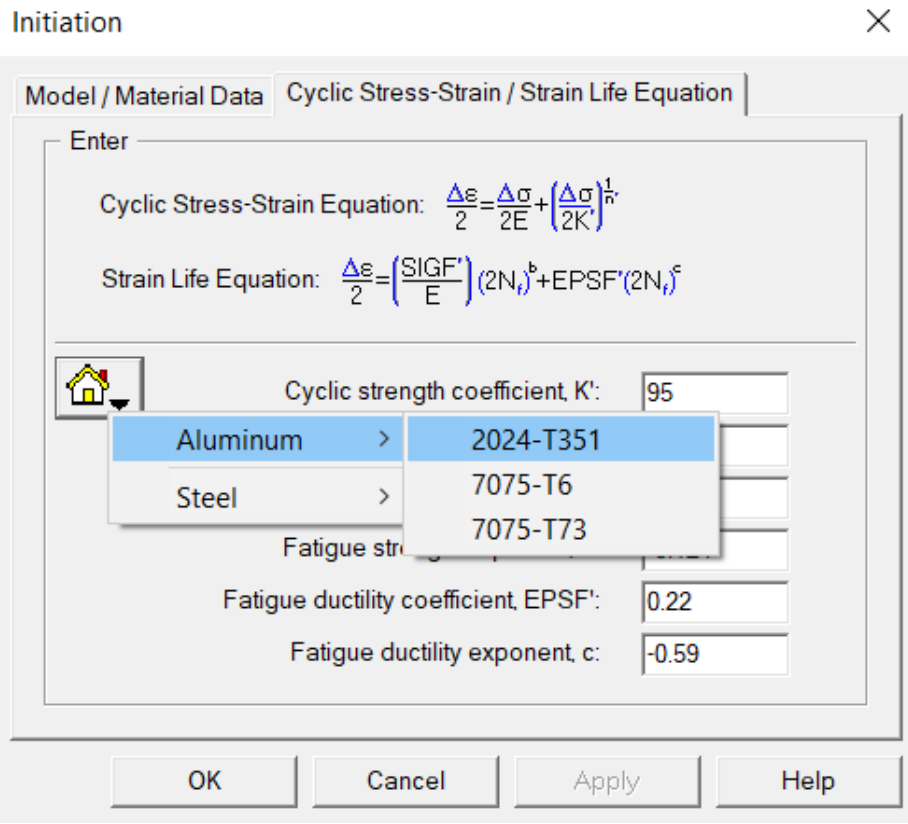
Baseline Prediction 1



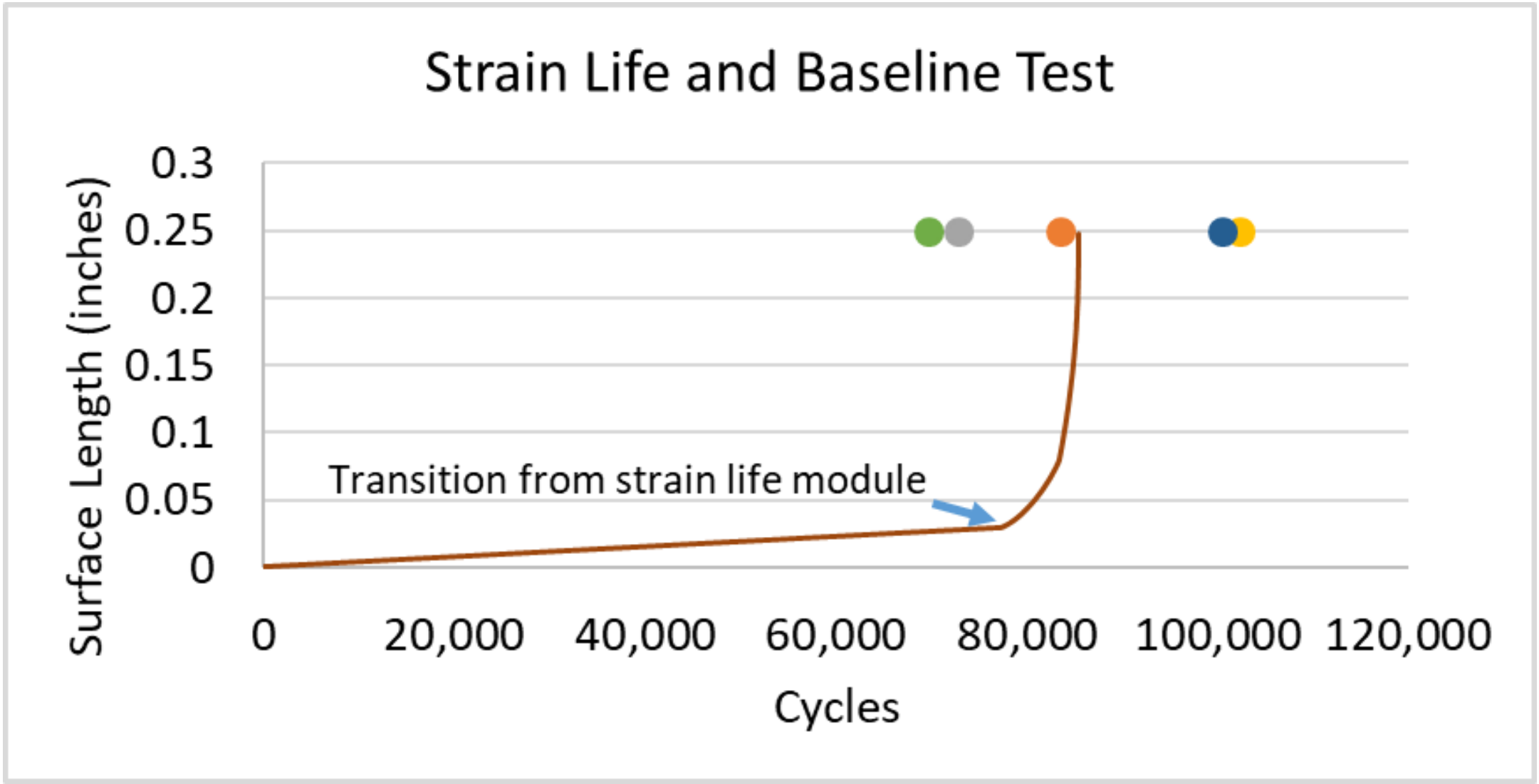
Strain Life Module



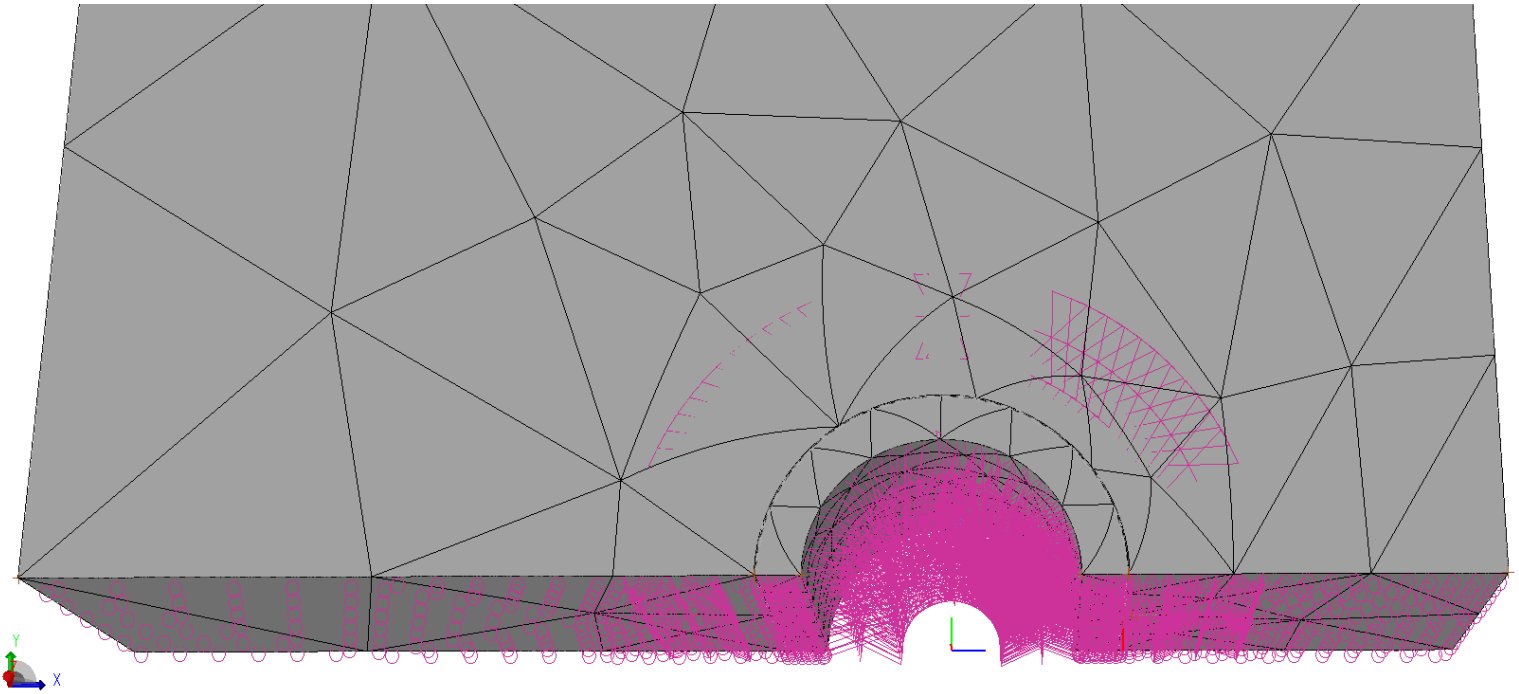


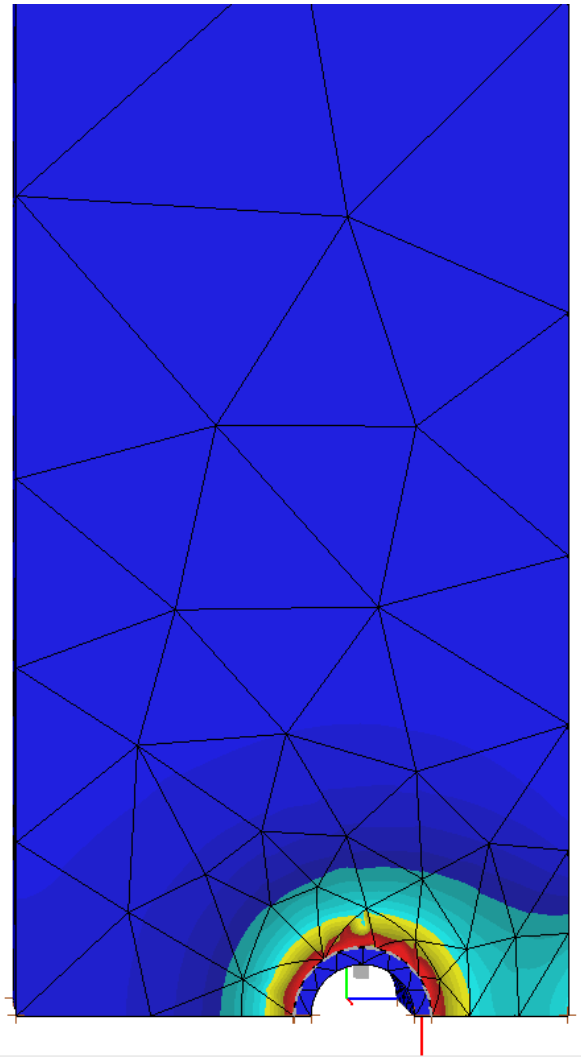


Correlated Baseline Prediction



Bushing Benefit Bureau

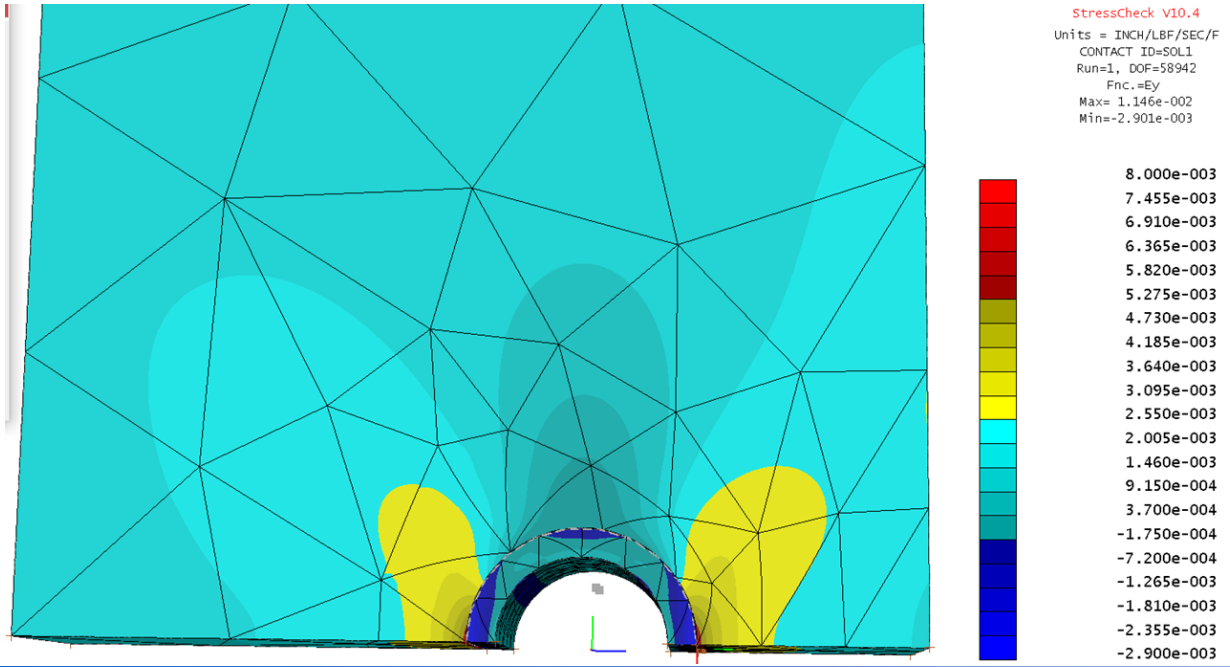


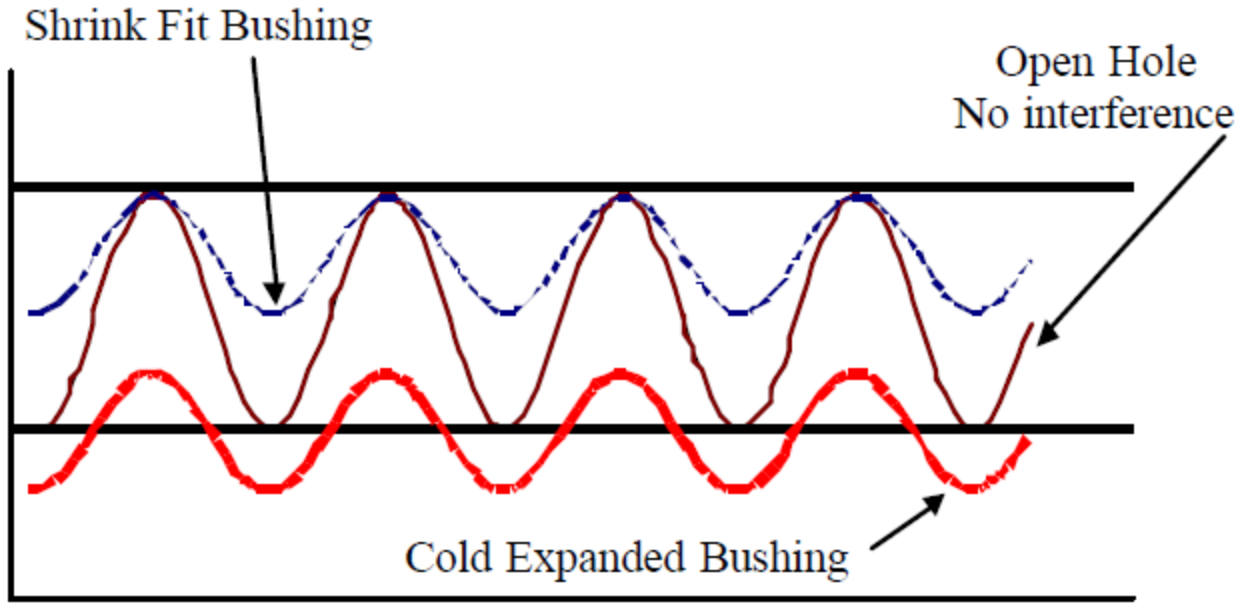


- ~10 ksi tensile load from bushing alone
- Bushings/interference fit fasteners do not create beneficial stresses

Defining a Bushing Benefit

- **Fatigue benefit comes in the increased stiffness at the hole**
  - **Increased stiffness decreases strain deformation**
  - **Limited strain deformation decreases effective delta K of each load cycle, effectively changing the stress ratio**
- **FEA used to determine strain at max and min loads (elastic model only)**



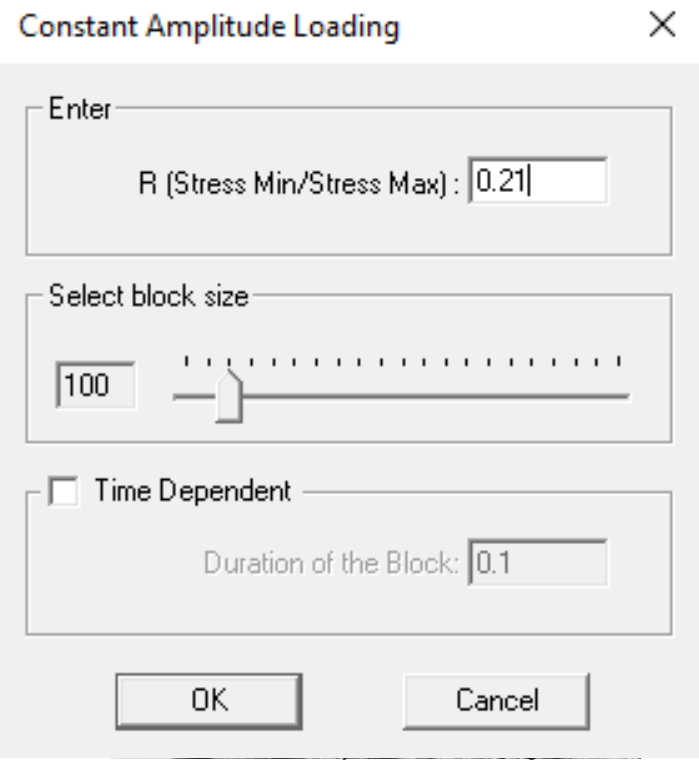


Strain Results

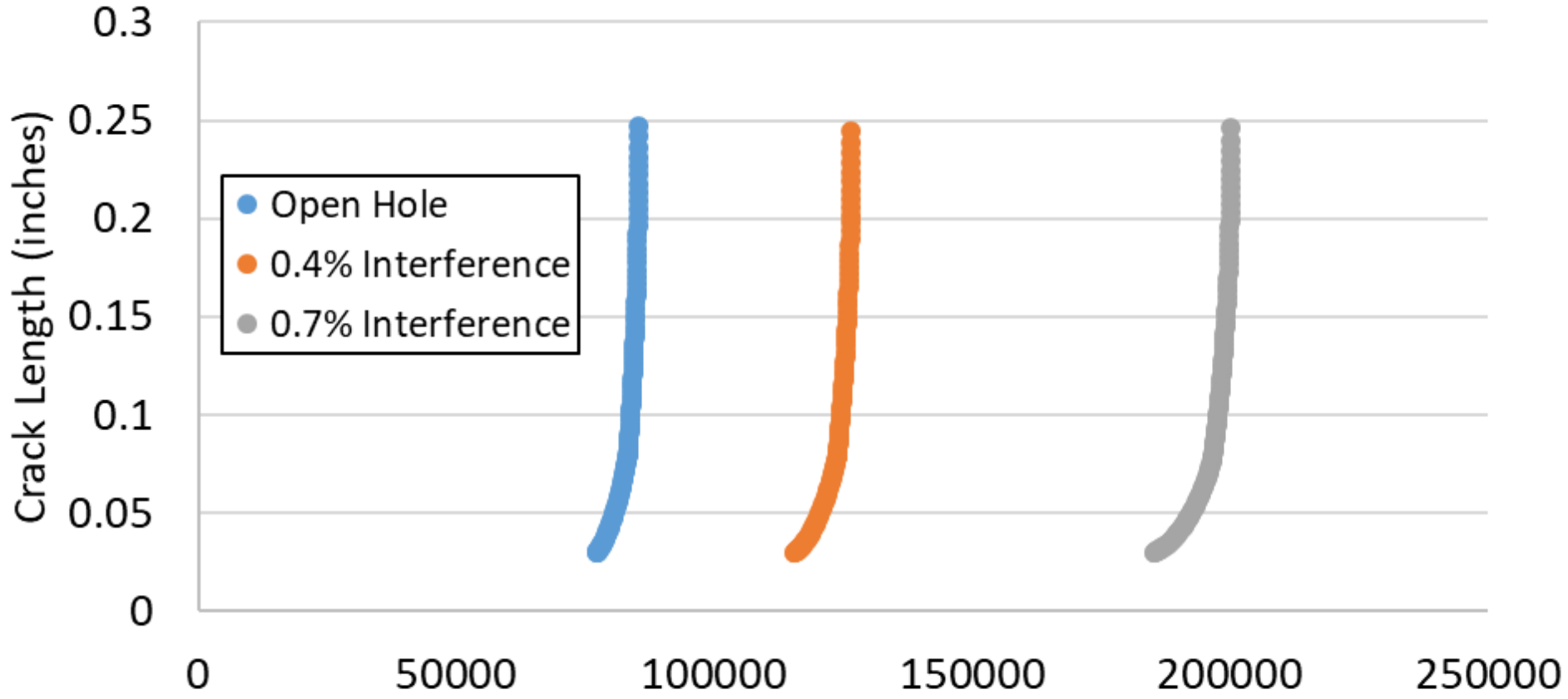
- **0.4% interference gives *strain* ratio of 0.21**
- **0.7% interference bushing gives strain ratio of 0.3**

Load	Open Hole Strain	0.4% Interference Strain	0.7% Interference Strain
2 ksi	0.0005686	0.001321	0.001987
20 ksi	0.005686	0.00643	0.006675
Delta	0.0051174	0.0051	0.004688
Strain R	0.1	0.21	0.30

Strain ratio = Stress ratio ???

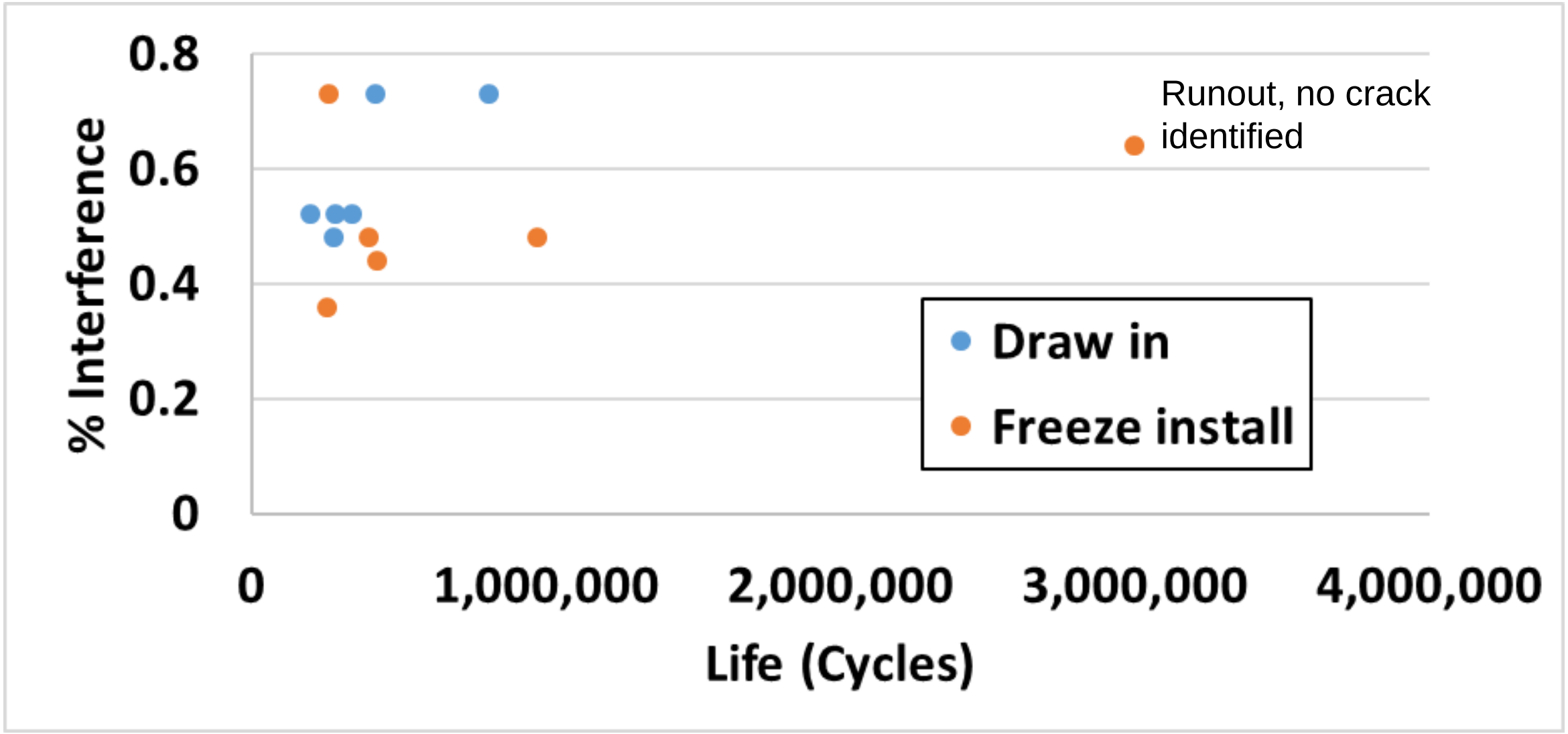


Blind AFGROW Predictions

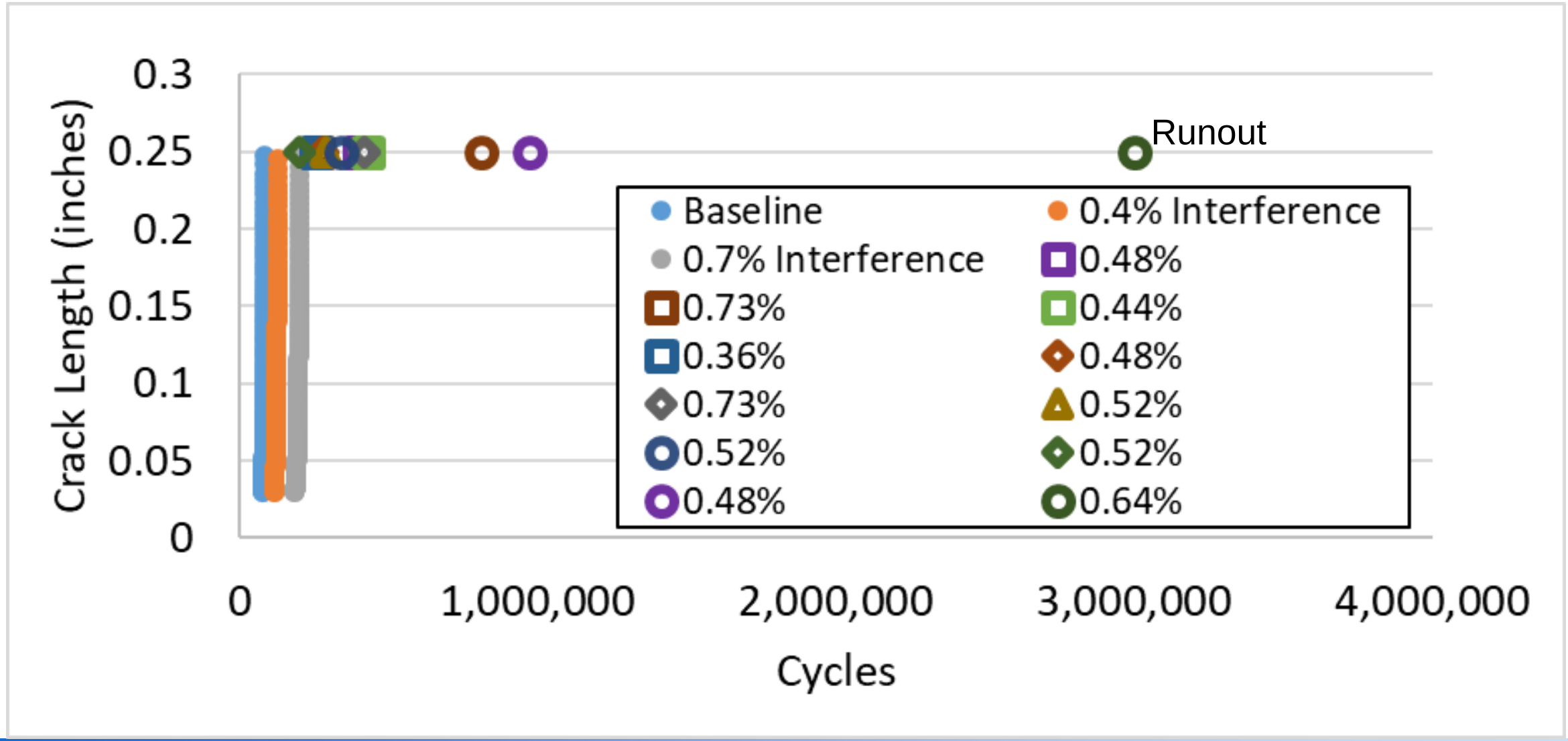


	Nominal	0.7%
LIF	1.5	2.3

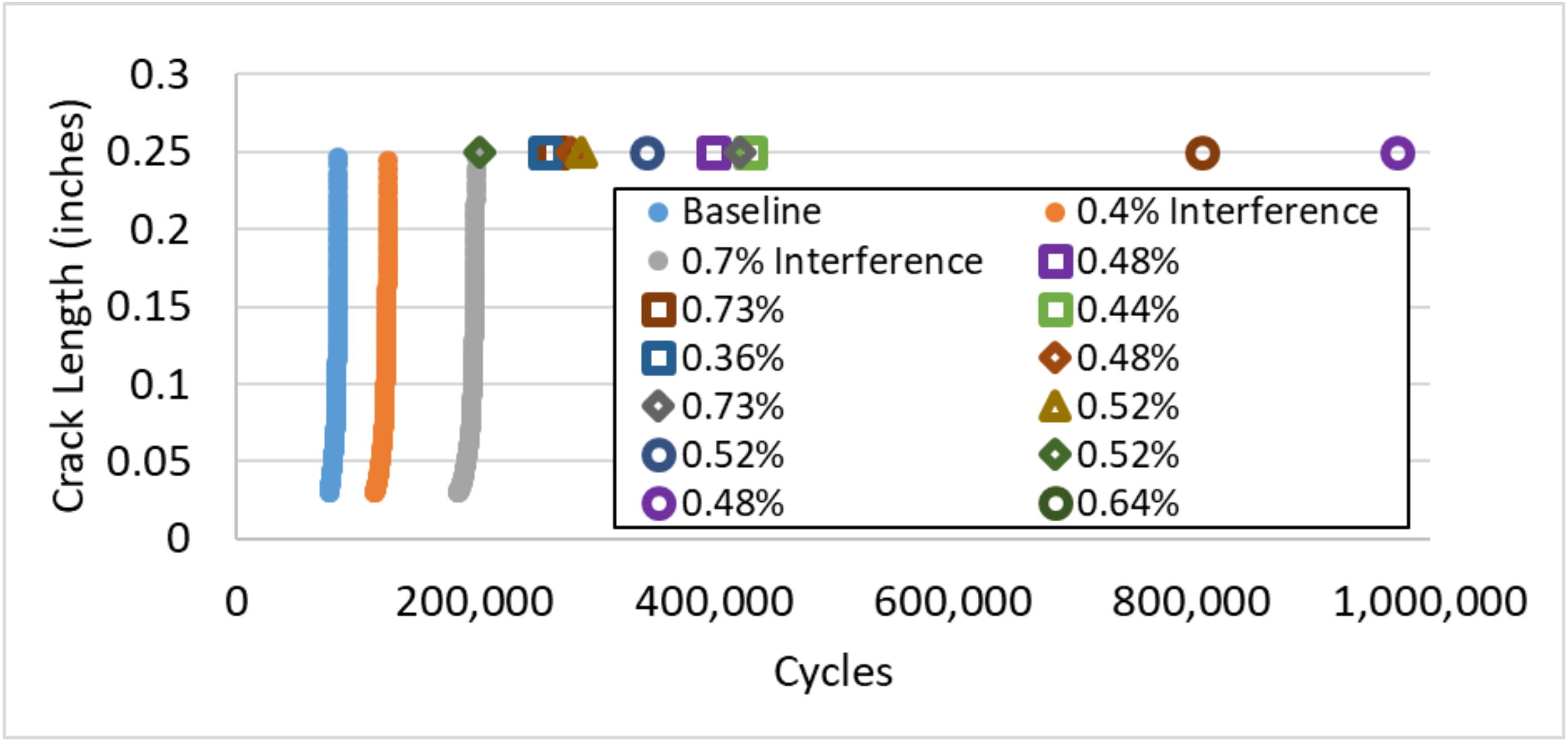
Test Results



Results and Predictions



Results and Predictions, Runout Removed



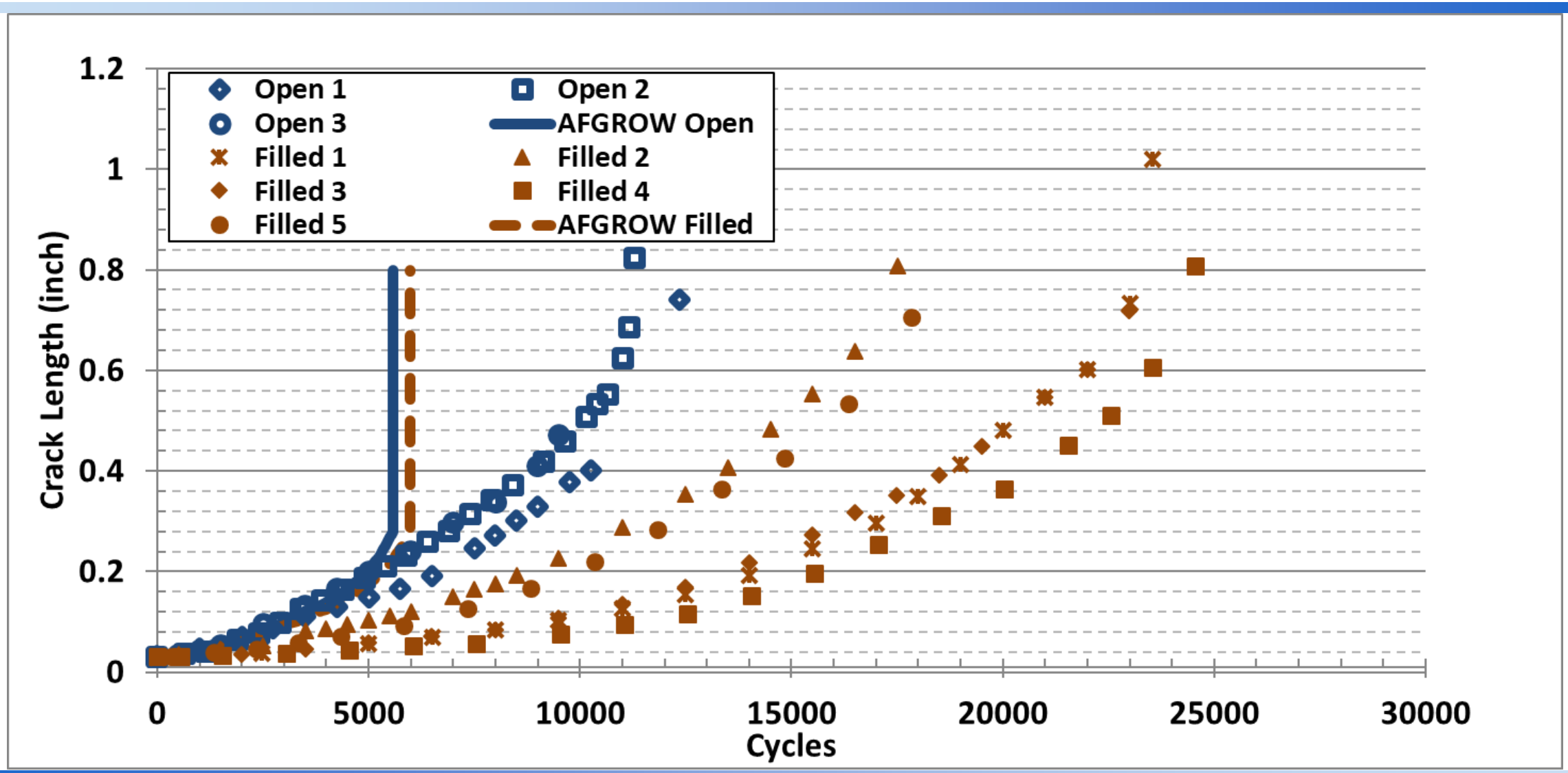
Applicability???

"Even a broken watch is right twice a day"

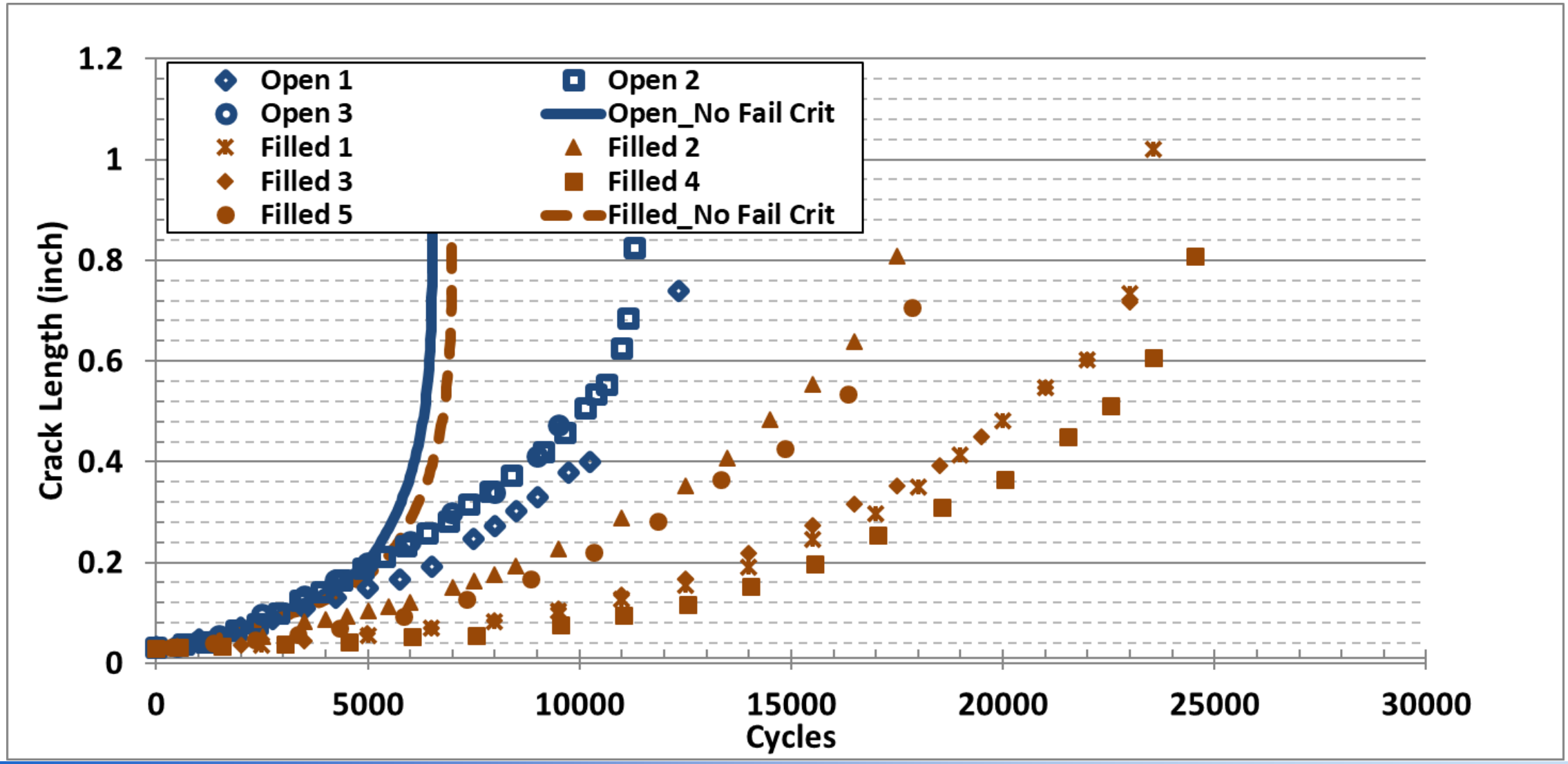
Interference Fastener Dataset

- APES Interference fit fastener test data
- 27.9 ksi, R = 0.1
- Center hole specimen
- 7075 parent material, steel fastener
- Fatigue tests from 0.03” precrack

Analytical Model Under Predicts



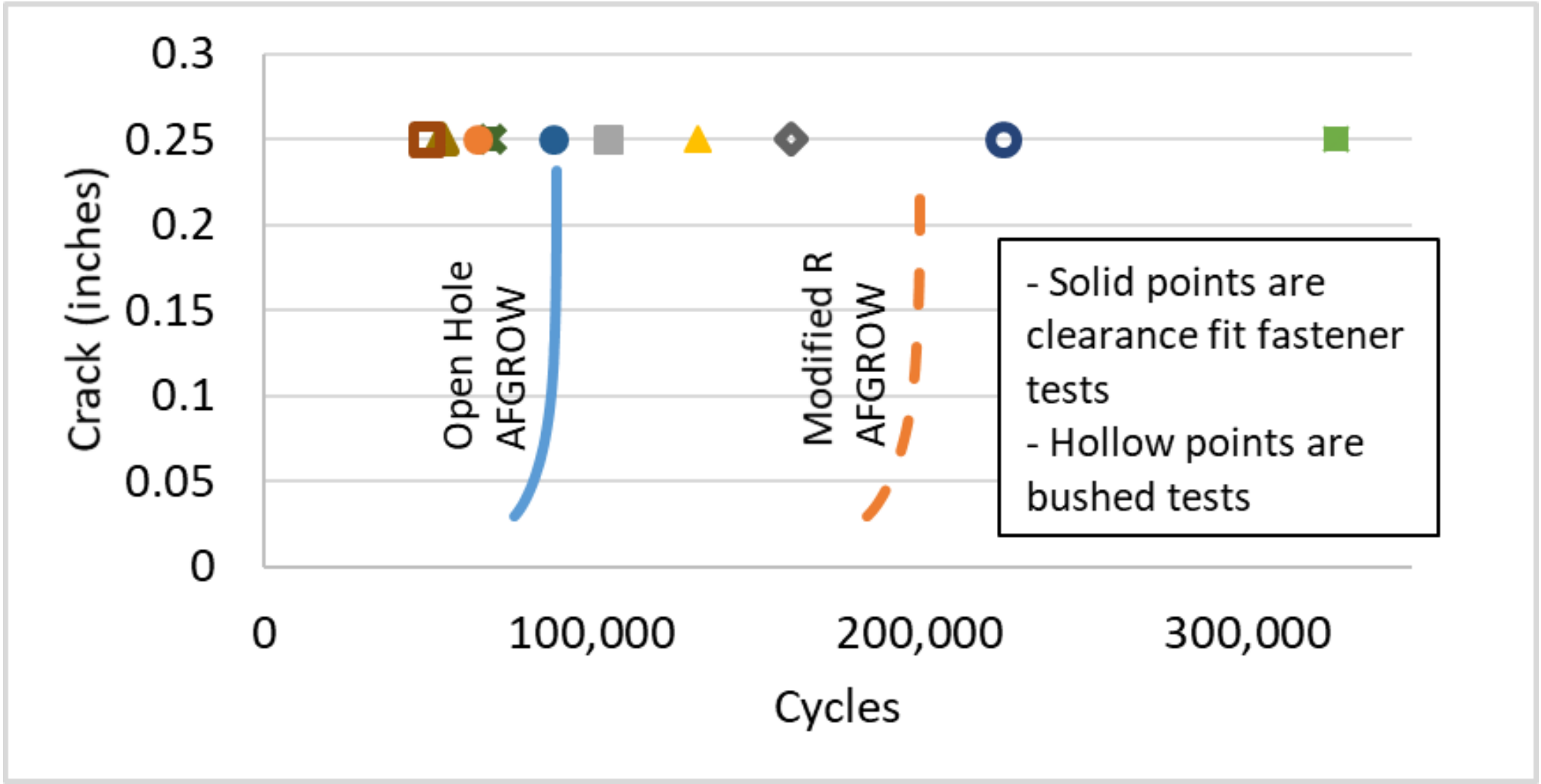
No Propagation Limits Specified



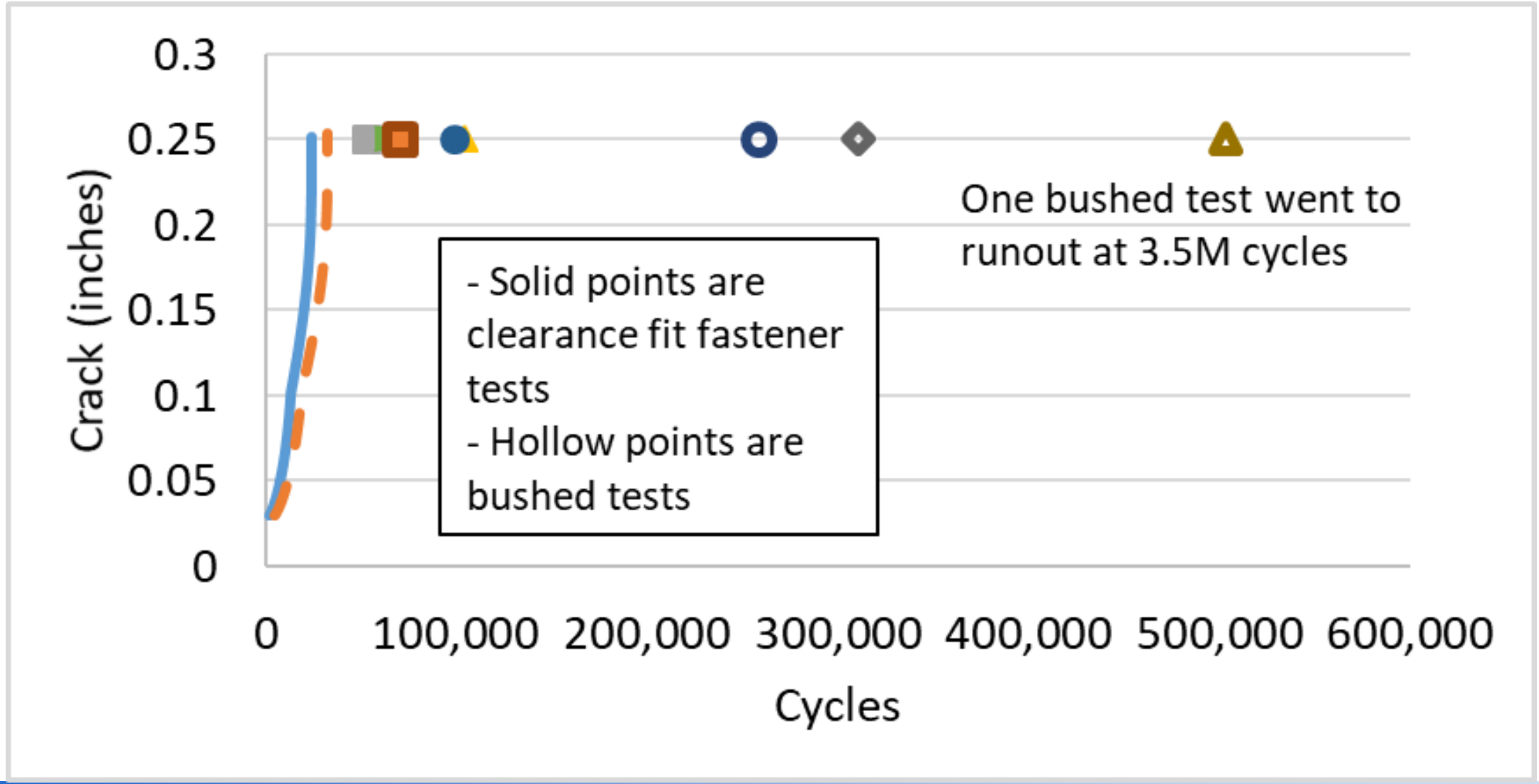
F-22 Dataset

- Durability test, no induced flaw
- 0.76” wide, 0.15” thick, 0.25” hole
- Clearance fit fastener and bushed holes
- Bypass and bearing loads
- 7050-T7451 parent material
- Steel fastener, Ti bushing
- No open hole tests

Bypass Loading Results

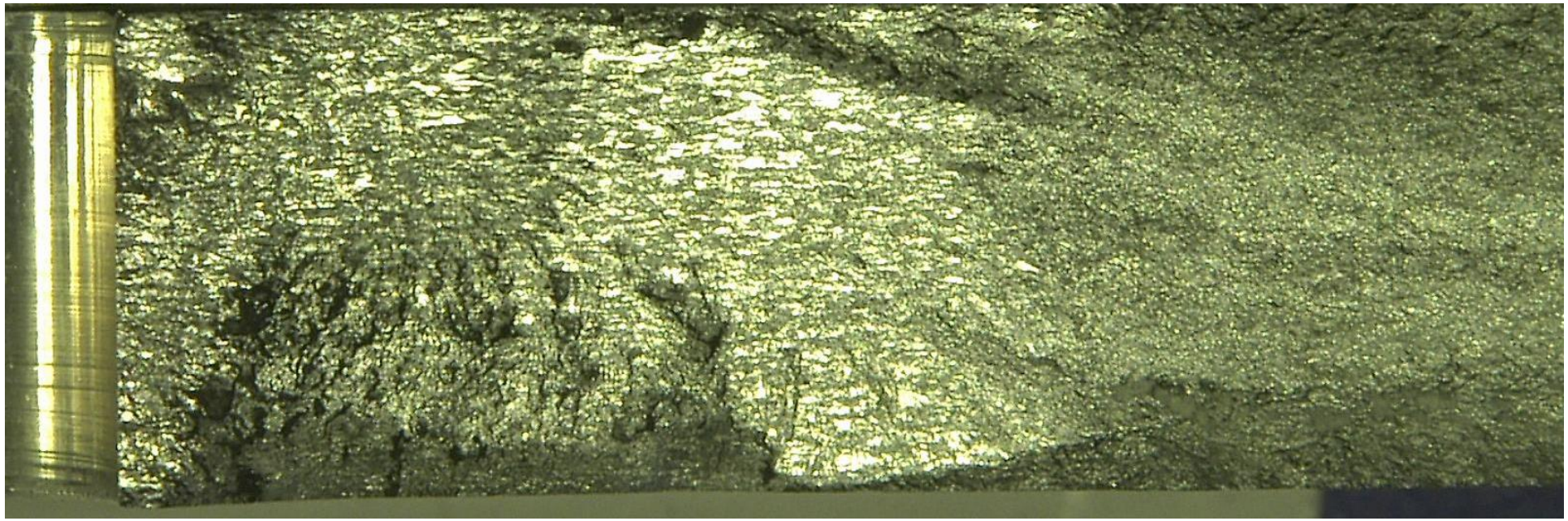


Bearing Loaded Results



Conclusions

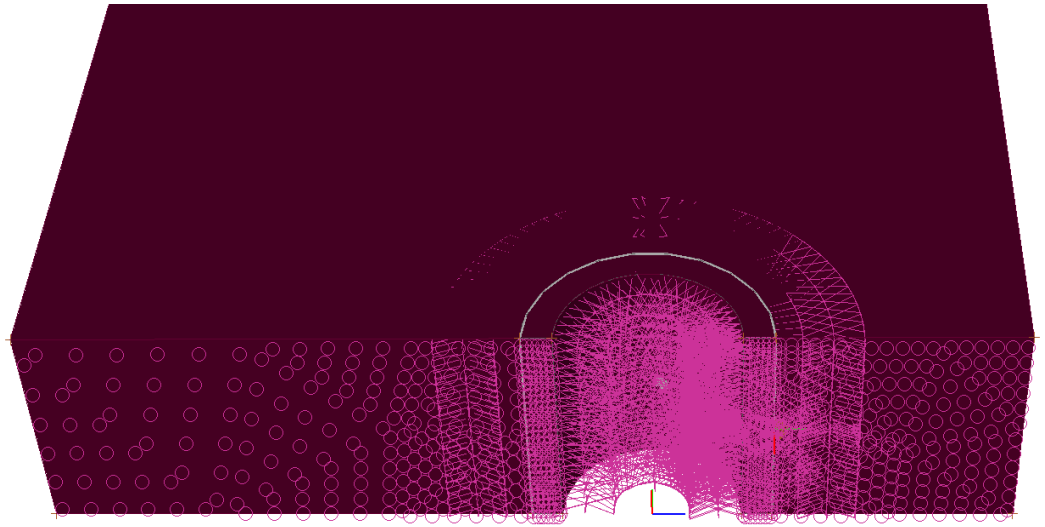
- Interference bushings/fasteners do not create residual stresses
- Modified stress ratio approach doesn't appear to be widely applicable
  - Promising correlation may have been primarily in the strain life prediction
- No strong correlation between percent interference and life improvement in datasets presented

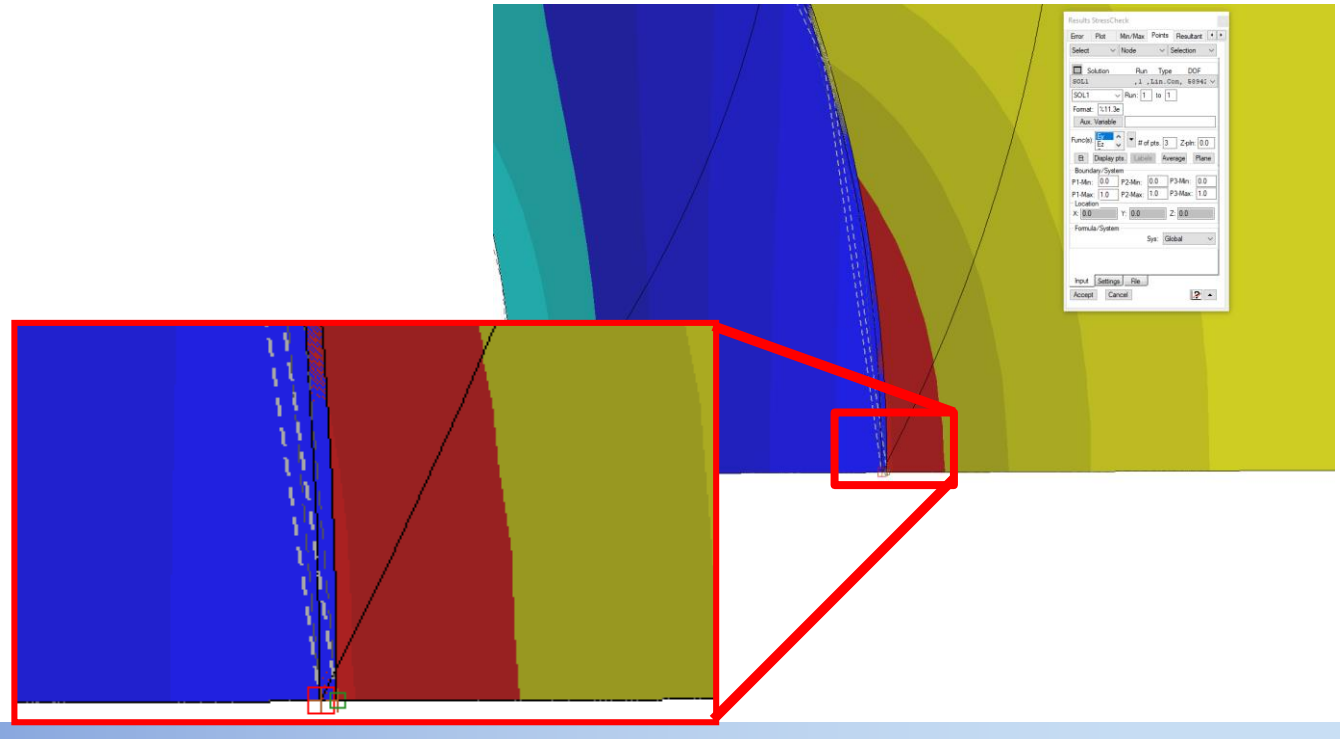


Thanks!

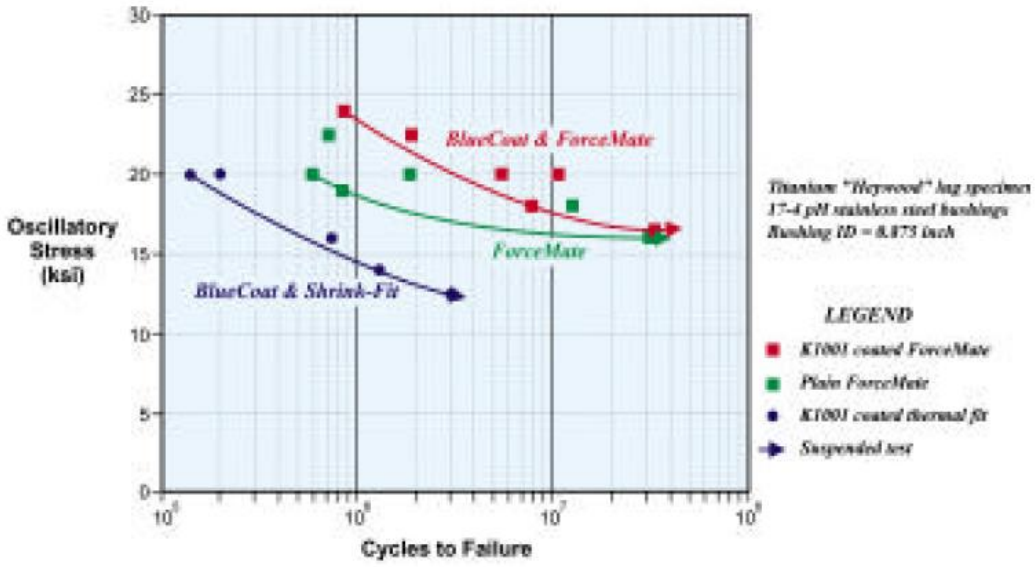
Model Details

- Bushing interference modeled statically with contact, permitting bushing to deform as well as parent material
- 20 contact iterations for convergence, ~3% StressCheck estimated error
- Strain pulled from parent material node at symmetry face and hole bore





- **Use method to run predictions for:**
  - **F-22 Press fit bushing simulations?**
  - **Life improvement for a range of interference levels?**
    - **Test data for some from APES?**
  - **Literature data?**



Attaining Fatigue and Damage Tolerance Life Goals in Helicopter Bushed Assemblies

Len Reid
Vice President, Engineering
lreid@fatiguetech.com
Fatigue Technology Inc., Seattle, Washington 98188-2868

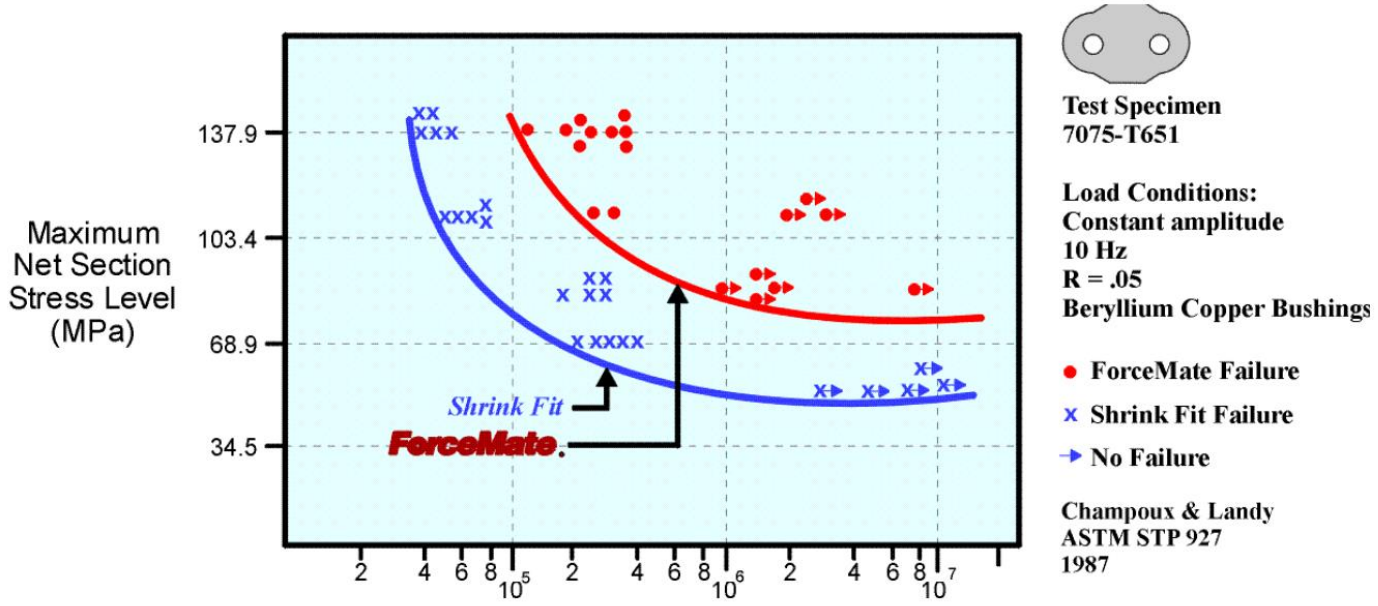


Figure 5. Fatigue Life Comparison of Shrink Fit and ForceMate Bushing Installations

Background, Bushing Installation

1A-10C-3 Typical Instruction

CAUTION

Bushing and plug installations are designed with an interference-fit. To avoid damage on installation it is necessary to shrink bushing/plug by subjecting it to low temperature. It may also be necessary to heat the surrounding material to expand the hole. Heating is limited to 200°F. Heating above 150°F is limited to 30 minutes.

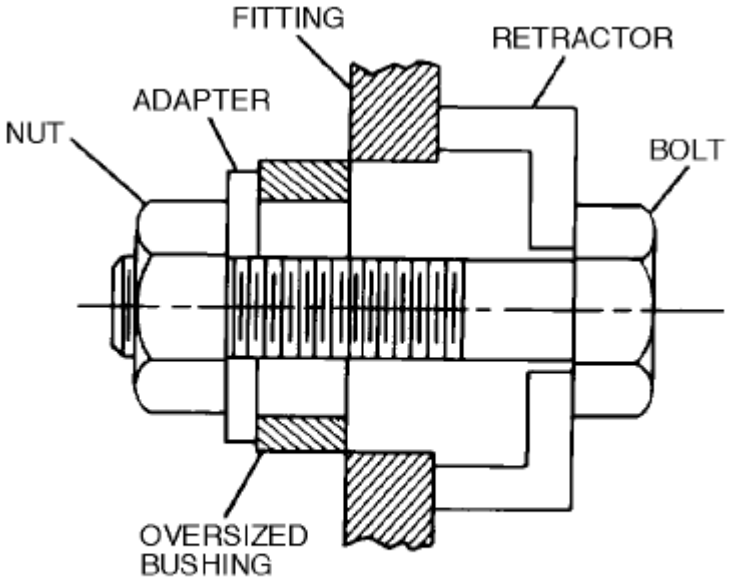
(2) If bushing expands before it can be fully inserted, remove the bushing IAW Paragraph 3.8 REMOVAL OF INTERFERENCE-FIT BUSHINGS and re-install using an installation tool that is large enough to keep the bushing from expanding before it is installed. The tool and bushing may need to be frozen for longer than 20 minutes.

1A-10C-3 Case Specific Instruction

c. Install oversize bushing in wing attachment fitting as follows:

(1) Assemble bolt, nut, adapter, and retractor as shown on Figure 8-11.

(2) Tighten bolt until oversize bushing has migrated into wing attachment fitting.



TYPICAL TOOL APPLICATION FOR BUSHING INSTALLATION