



U.S. AIR FORCE



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Interference Fit Bushing Durability Life Predictions

Jake Warner



Background, Bushing Installation



■ 1A-10C-3 Typical Instruction

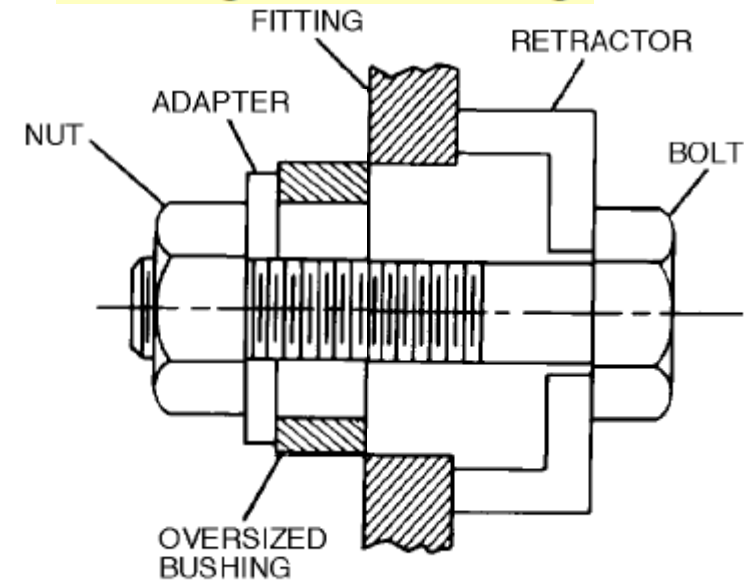
CAUTION

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

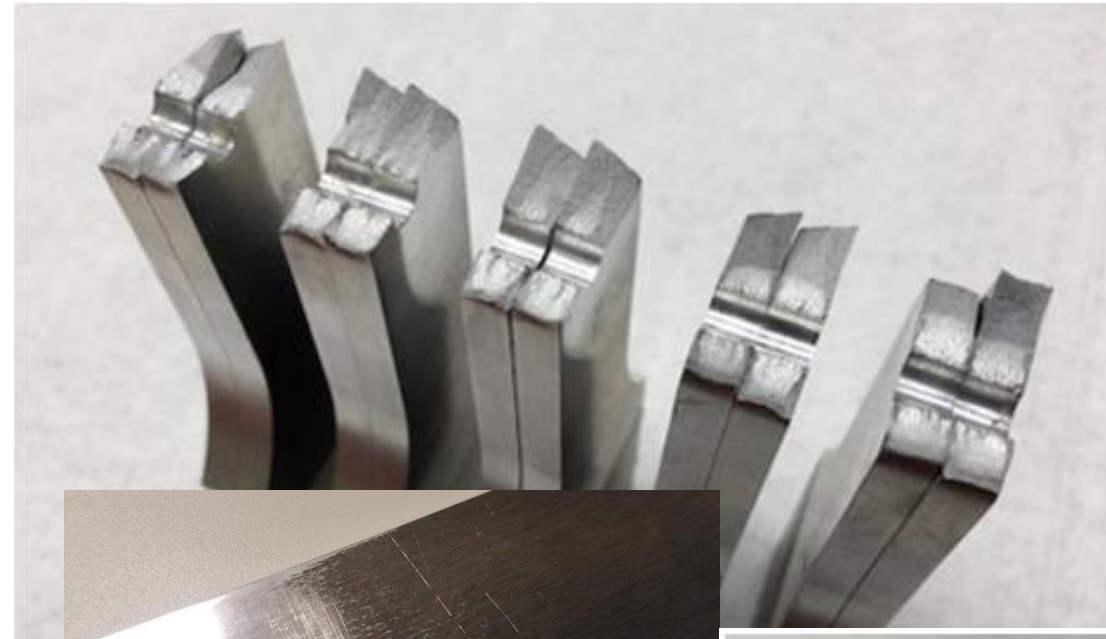




Test Program



- **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, $R=0.1$

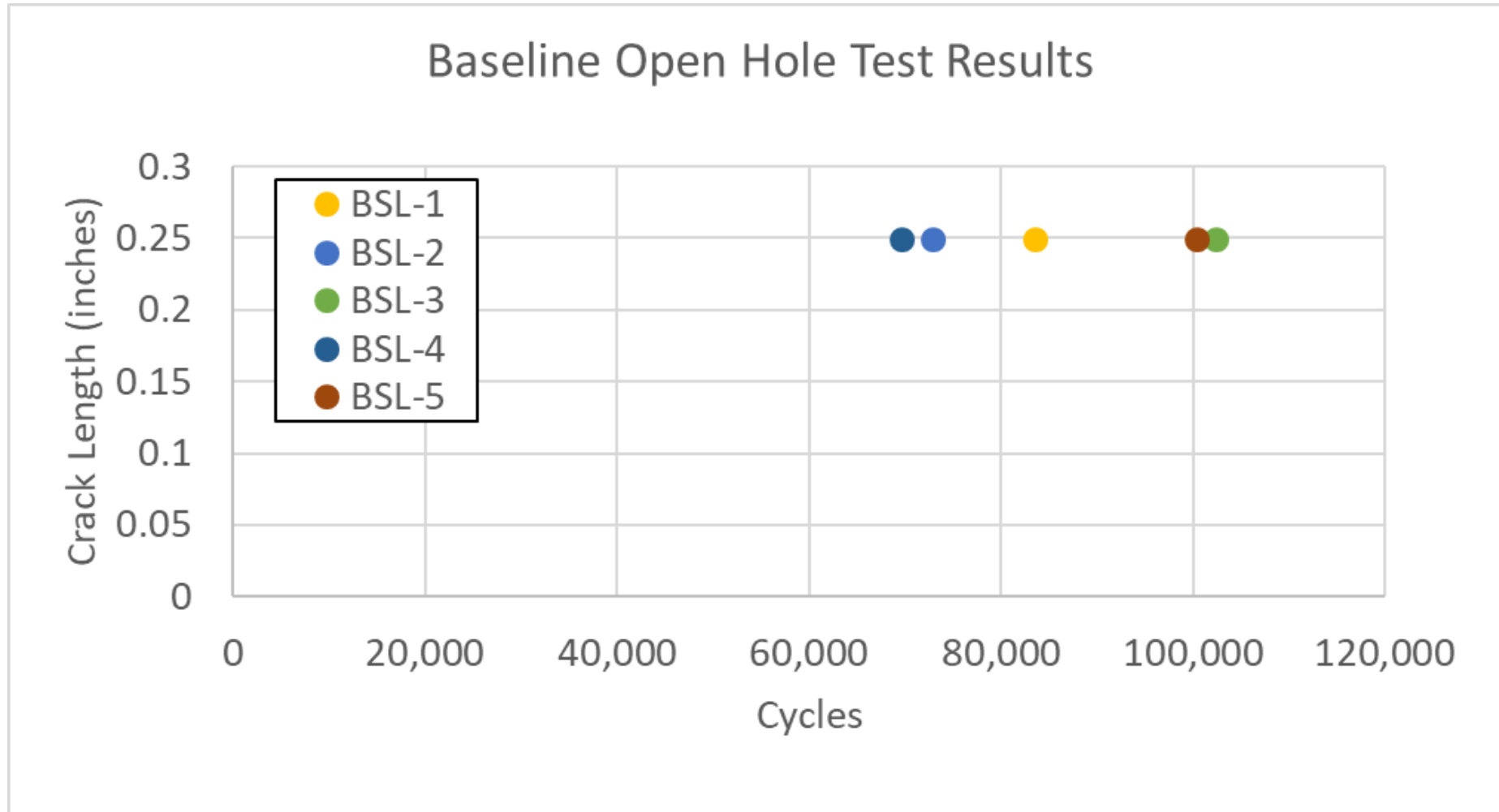




Baseline Test Results



■ Standard Deviation: 15,000 cycles

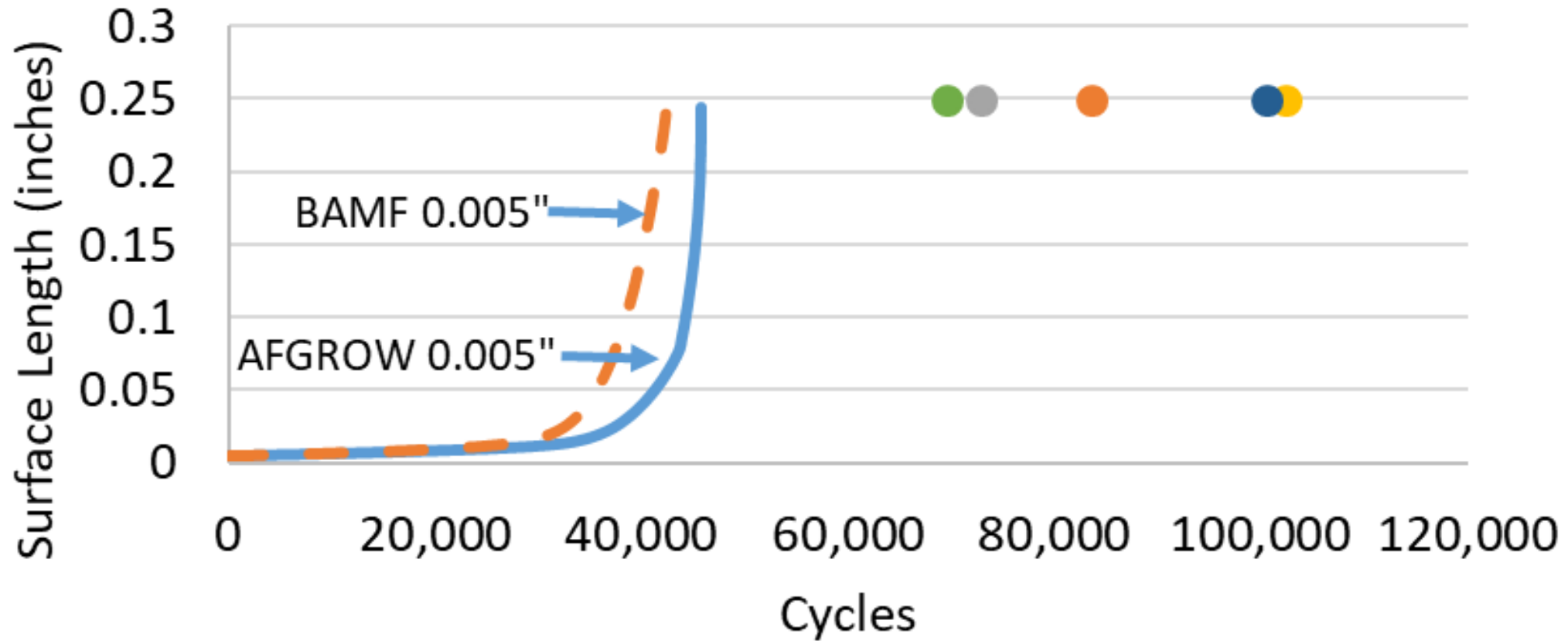




Baseline Prediction 1

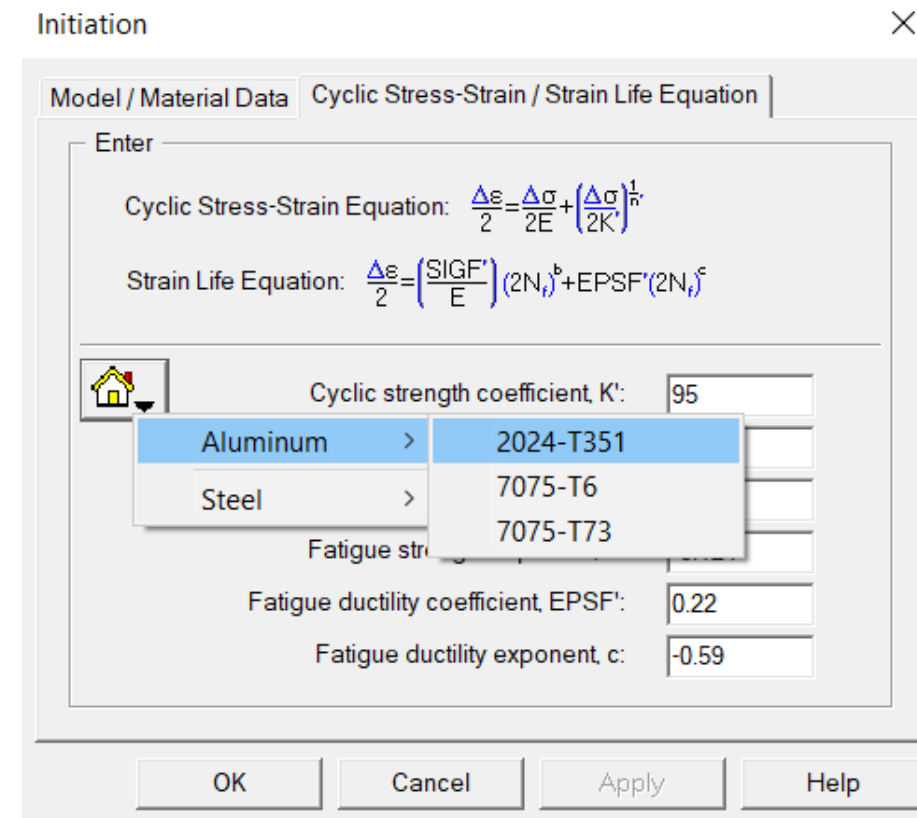
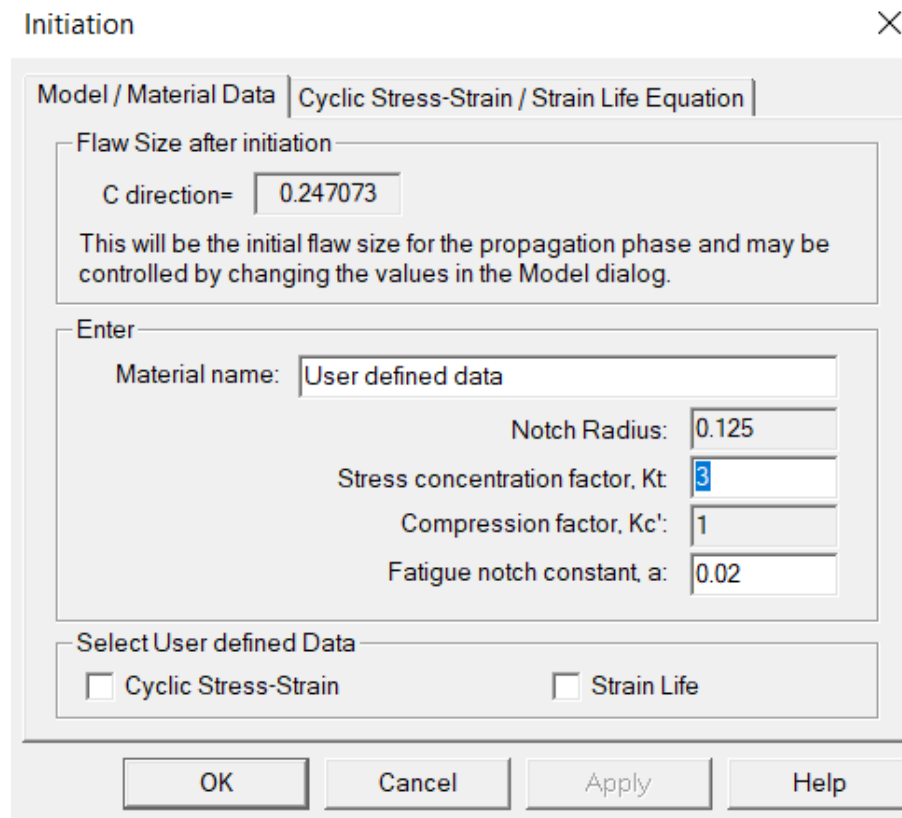
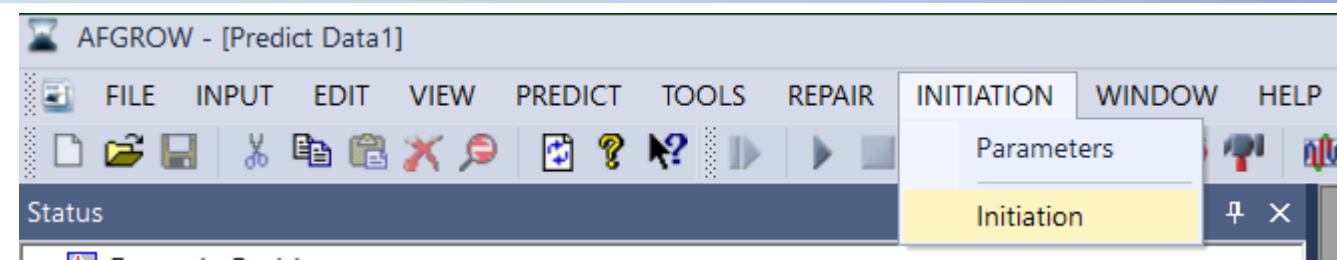


0.005" Initial Flaw Size and Baseline Test





Strain Life Module

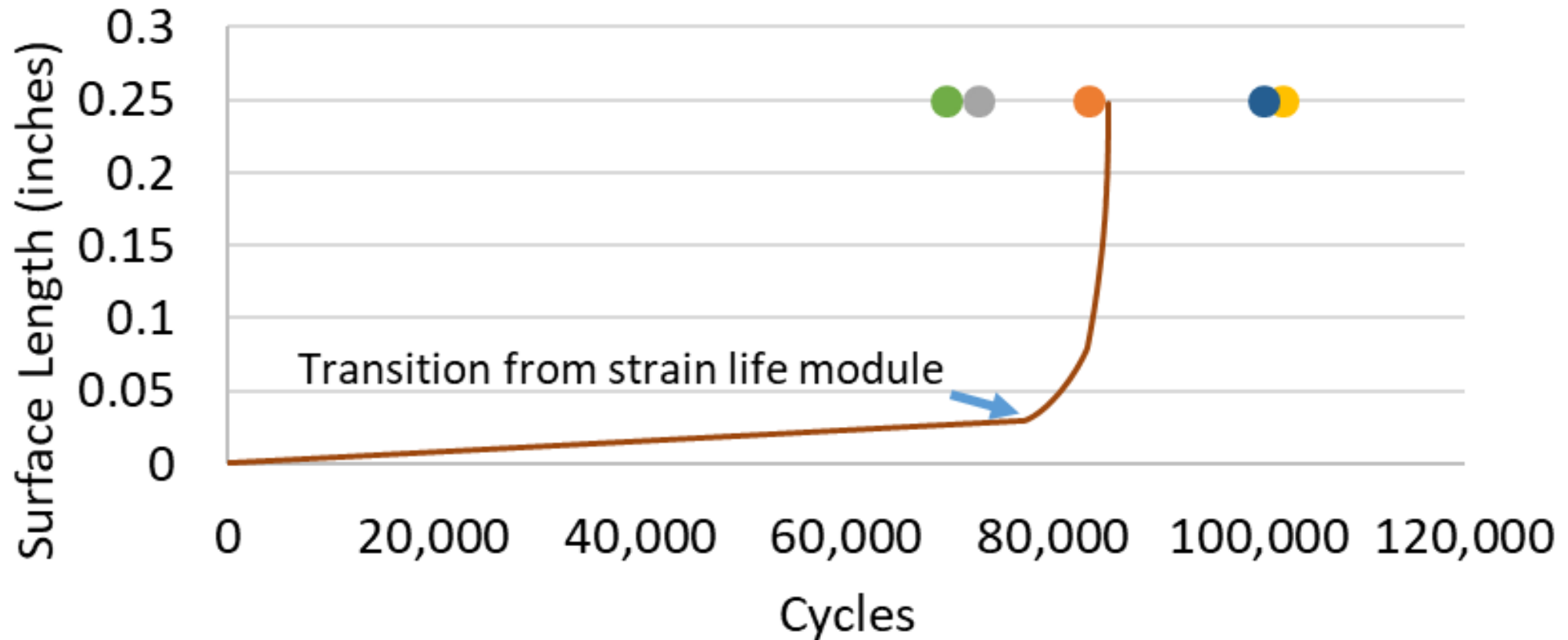




Correlated Baseline Prediction

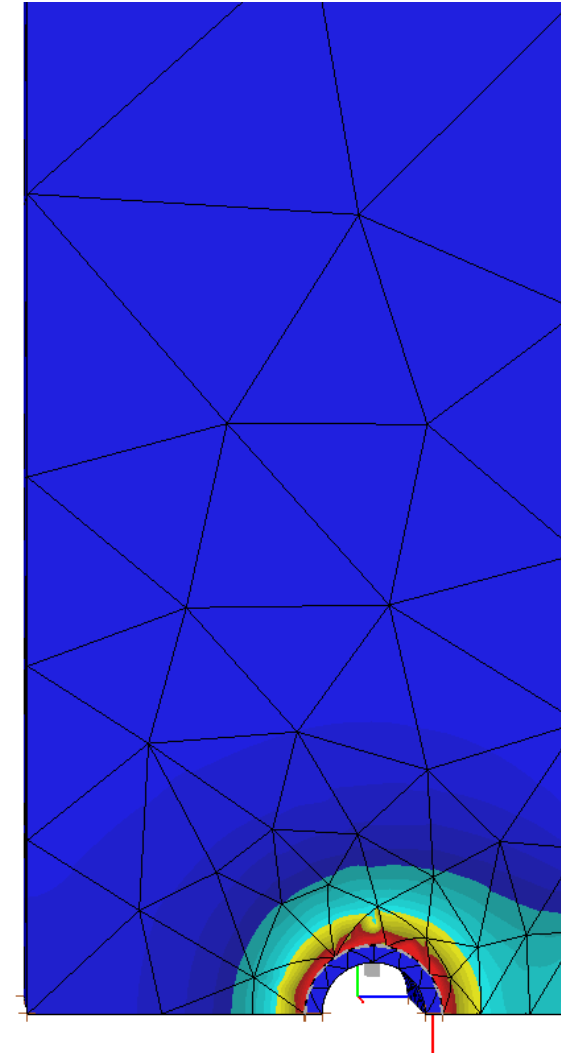
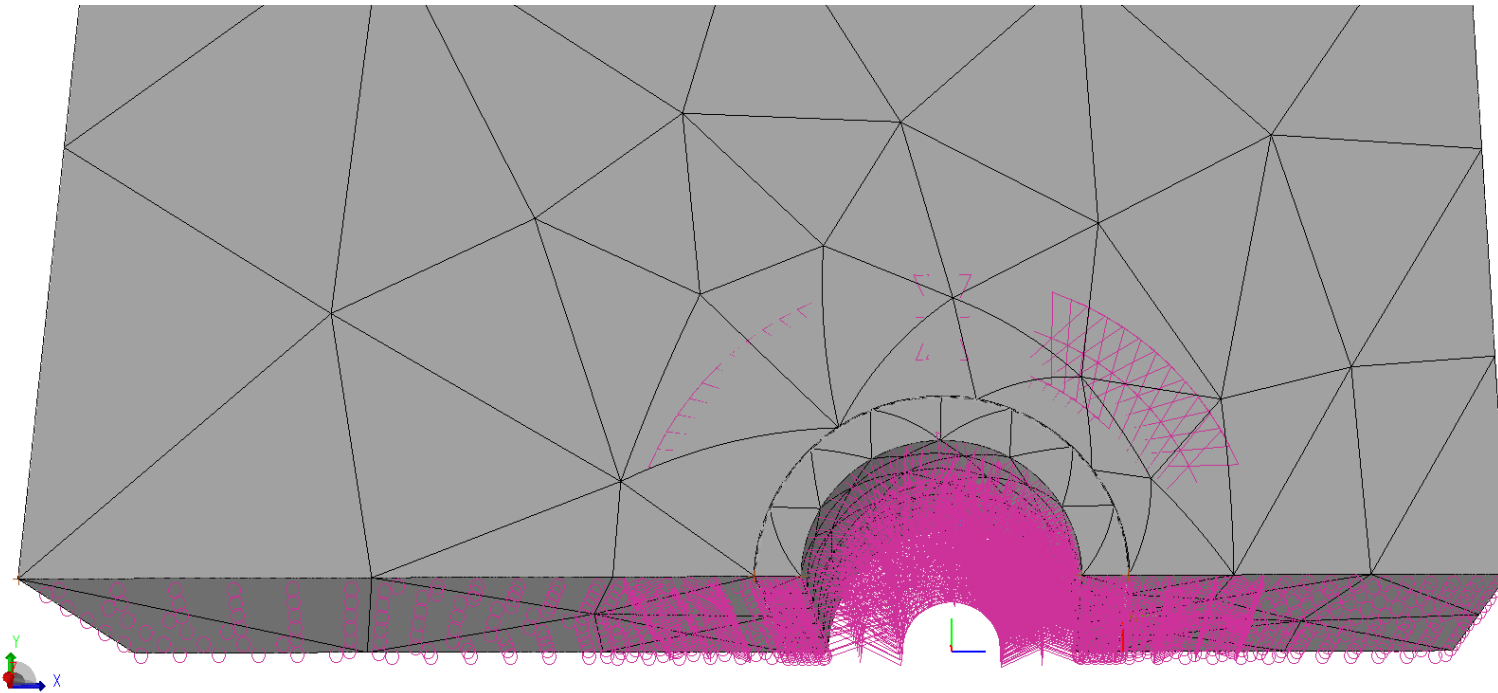


Strain Life and Baseline Test





Bushing Benefit Bureau



StressCheck V10.4
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CONTACT ID=SOL1
Run=1, DOF=59077
Fnc.=S1
Max= 1.063e+005
Min=-2.711e+004



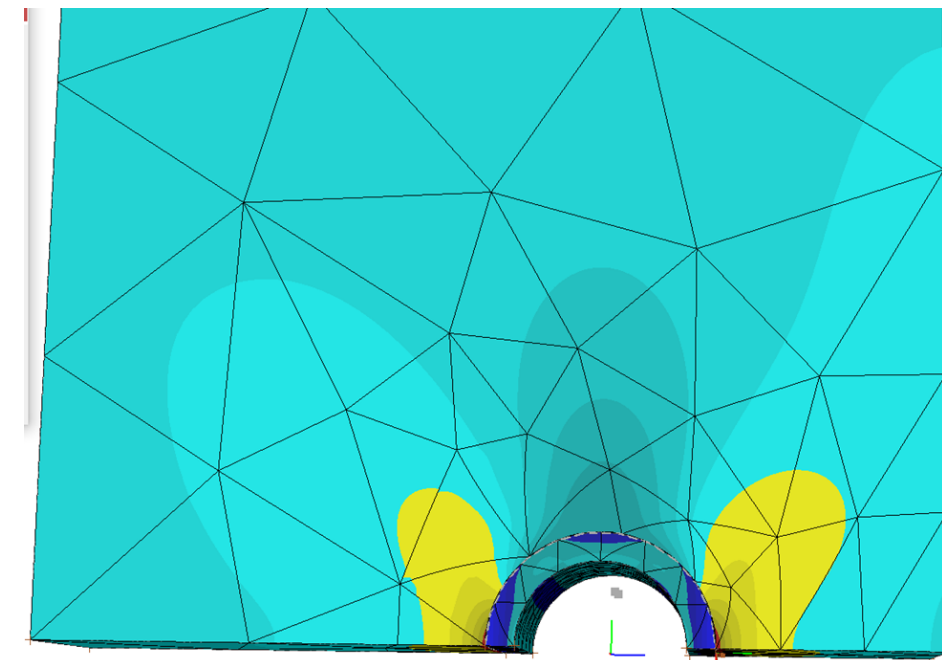
1.000e+004
9.500e+003
9.000e+003
8.500e+003
8.000e+003
7.500e+003
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6.000e+003
5.500e+003
5.000e+003
4.500e+003
4.000e+003
3.500e+003
3.000e+003
2.500e+003
2.000e+003
1.500e+003
1.000e+003
5.000e+002
0.000e+000

- ~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)

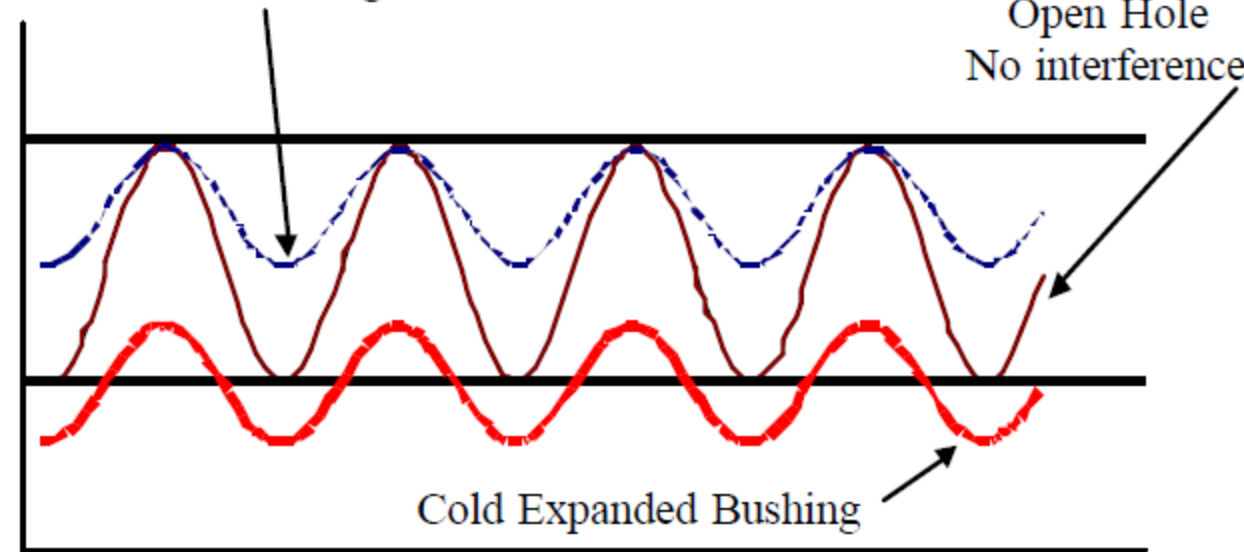


StressCheck V10.4
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CONTACT ID=SOL1
Run=1, DOF=58942
Fnc.=Ey
Max= 1.146e-002
Min=-2.901e-003

8.000e-003
7.455e-003
6.910e-003
6.365e-003
5.820e-003
5.275e-003
4.730e-003
4.185e-003
3.640e-003
3.095e-003
2.550e-003
2.005e-003
1.460e-003
9.150e-004
3.700e-004
-1.750e-004
-7.200e-004
-1.265e-003
-1.810e-003
-2.355e-003
-2.900e-003

Shrink Fit Bushing

Open Hole
No interference



Cold Expanded Bushing



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 ???

Constant Amplitude Loading

Enter

R (Stress Min/Stress Max) :

Select block size

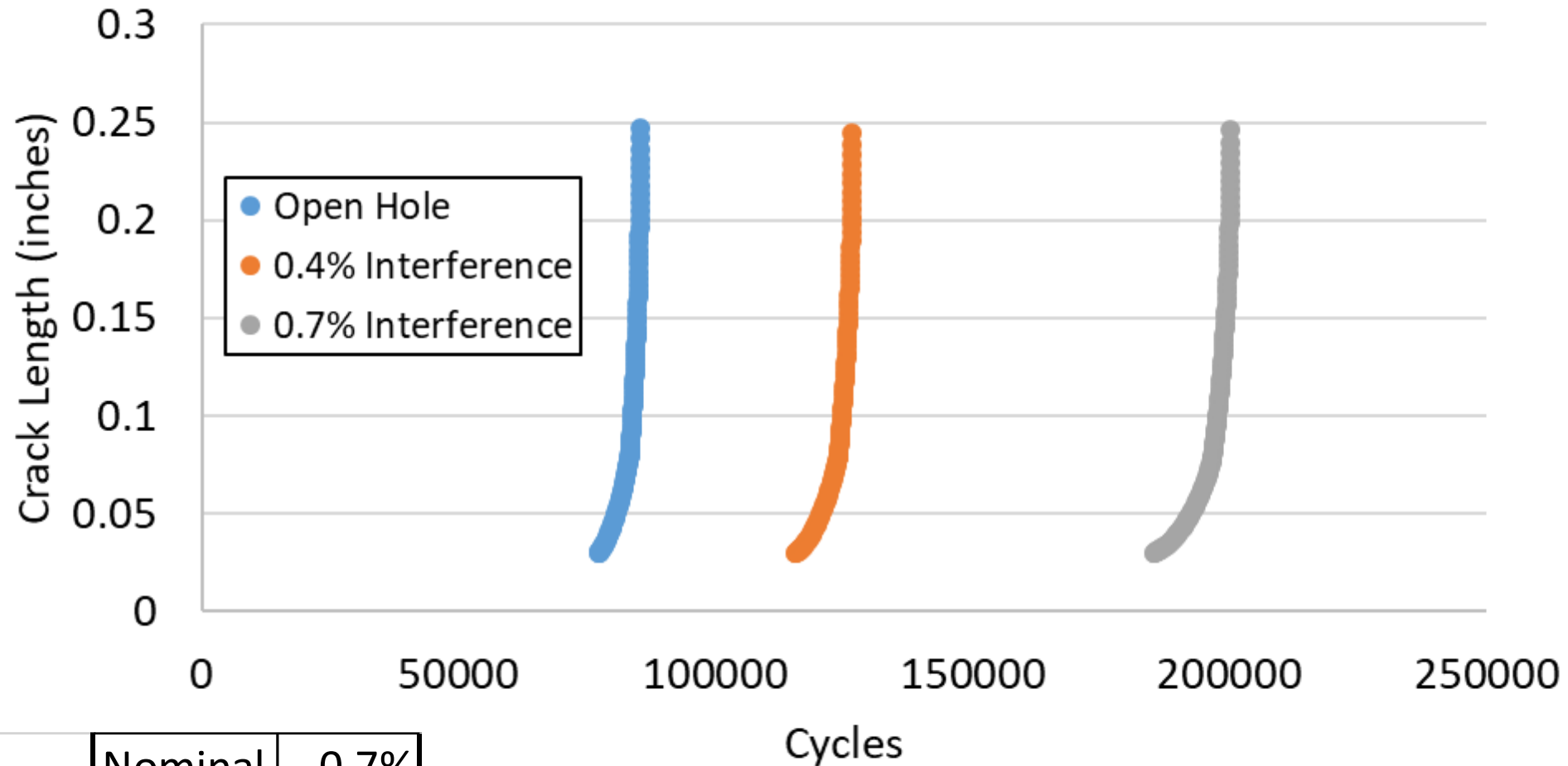
Time Dependent

Duration of the Block:

OK Cancel



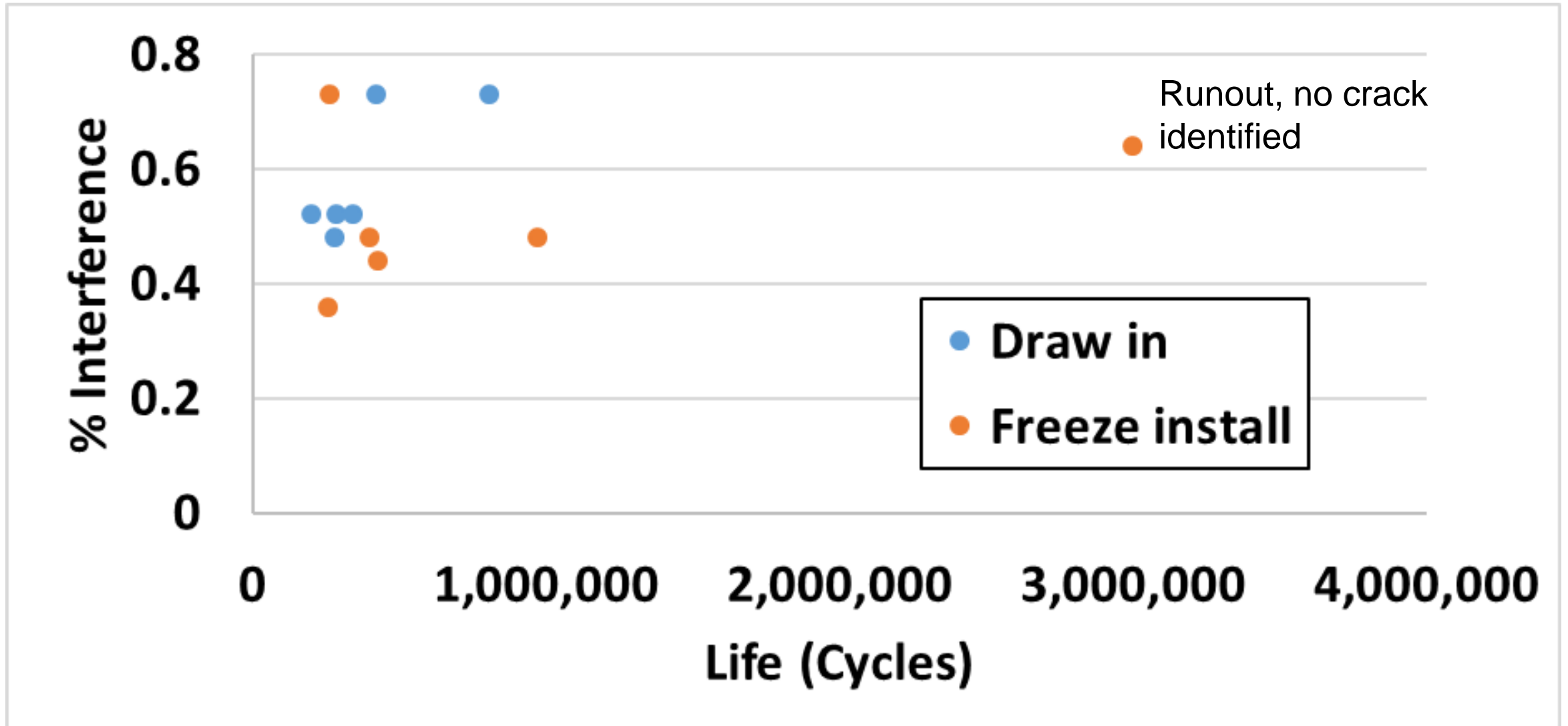
Blind AFGROW Predictions



	Nominal	0.7%
LIF	1.5	2.3

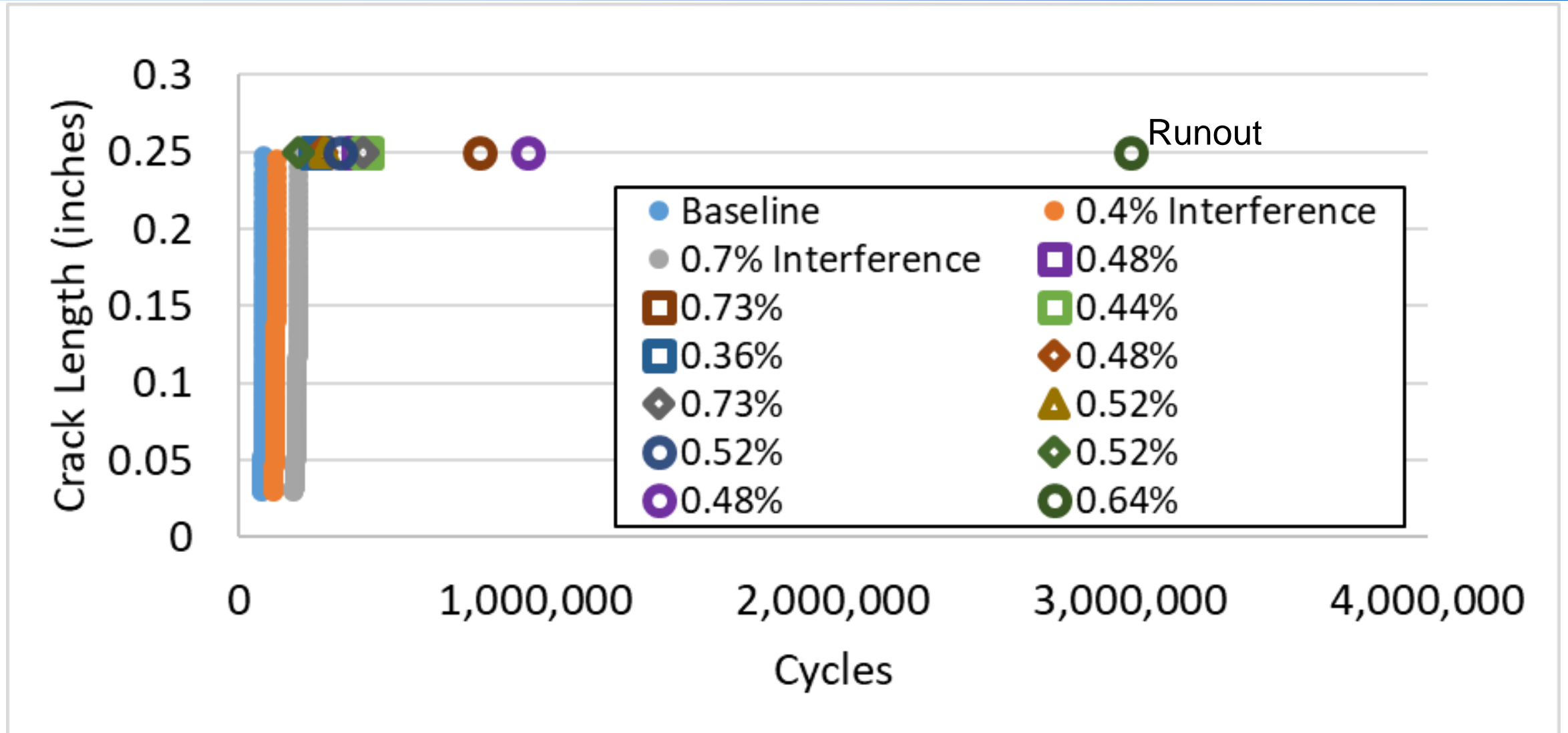


Test Results



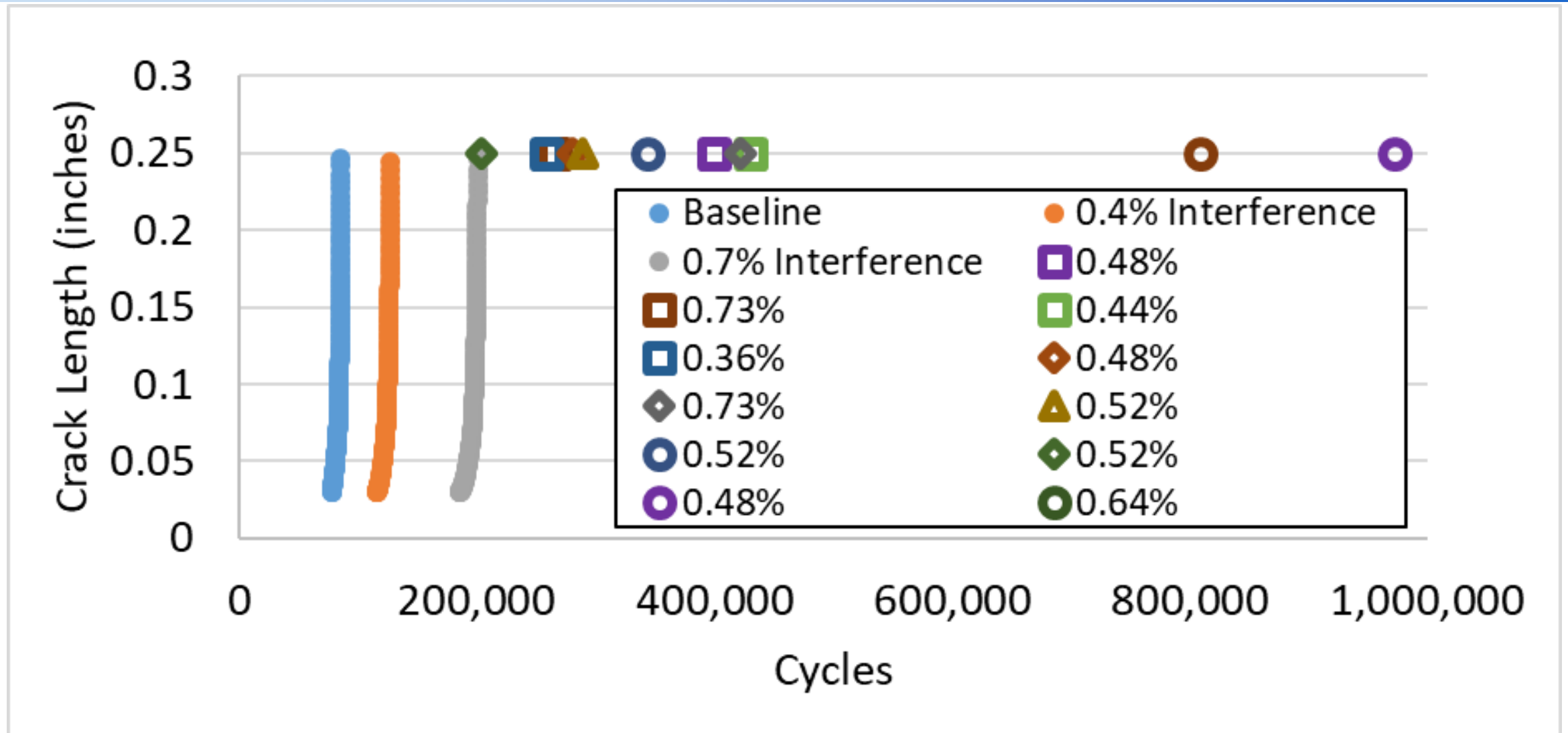


Results and Predictions





Results and Predictions, Runout Removed





Applicability???



**“Even a broken watch is
right twice a day”**



Careride.com



Interference Fastener Dataset



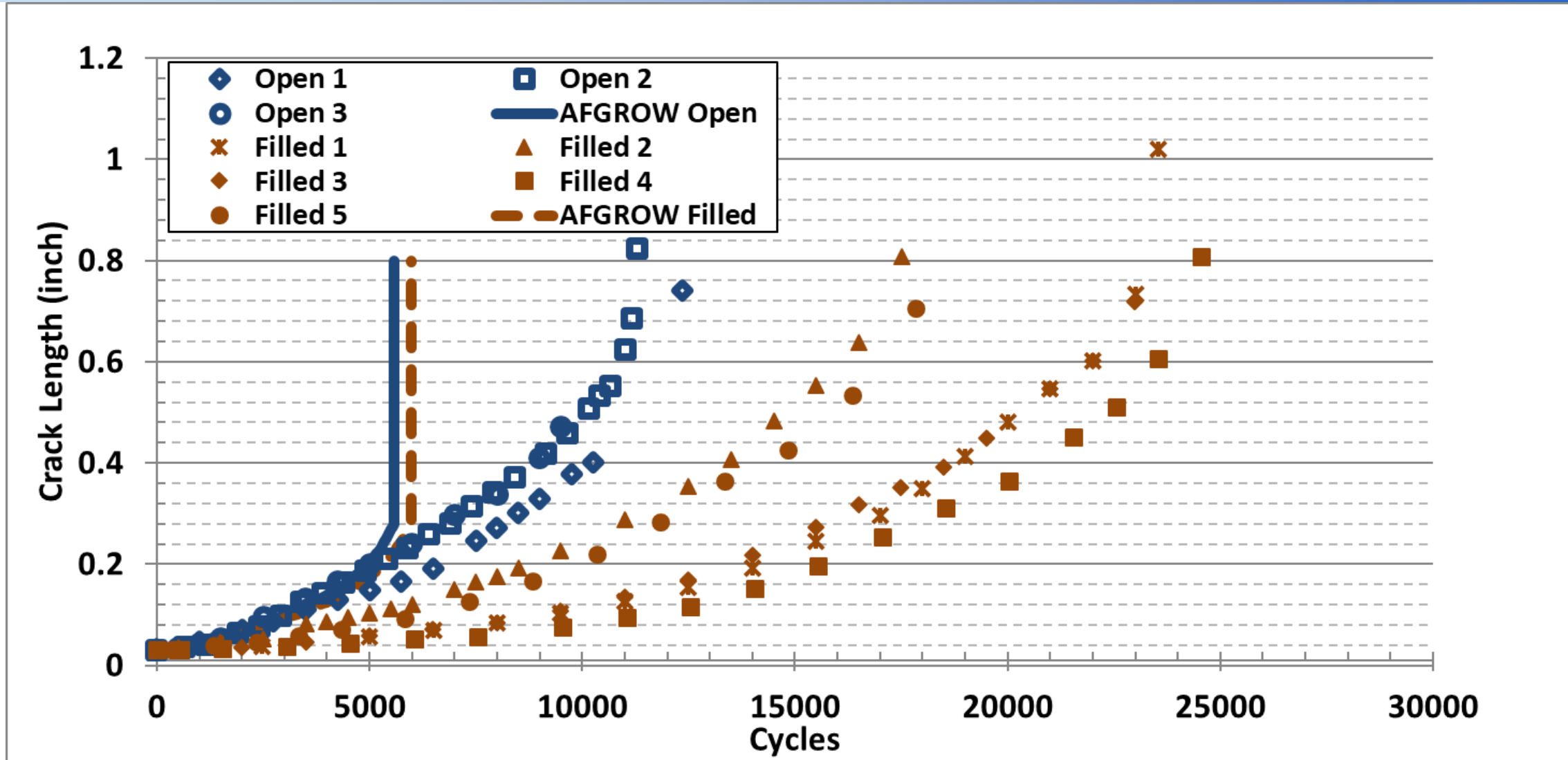
- APES Interference fit fastener test data
- 27.9 ksi, $R = 0.1$
- Center hole specimen
- 7075 parent material, steel fastener
- Fatigue tests from 0.03" precrack



Marylandzoo.org

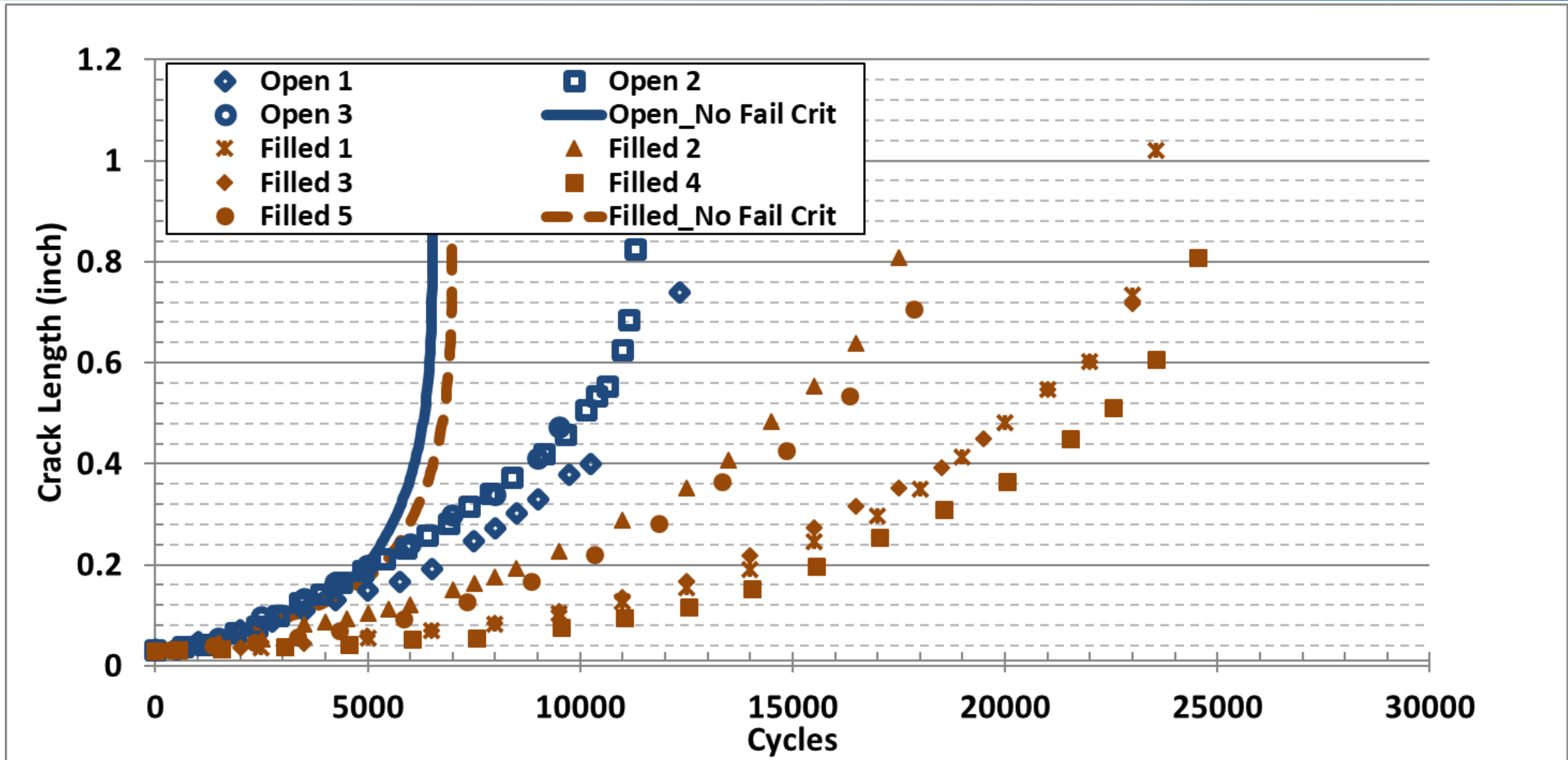


Analytical Model Under Predicts





No Propagation Limits Specified





F-22 Dataset

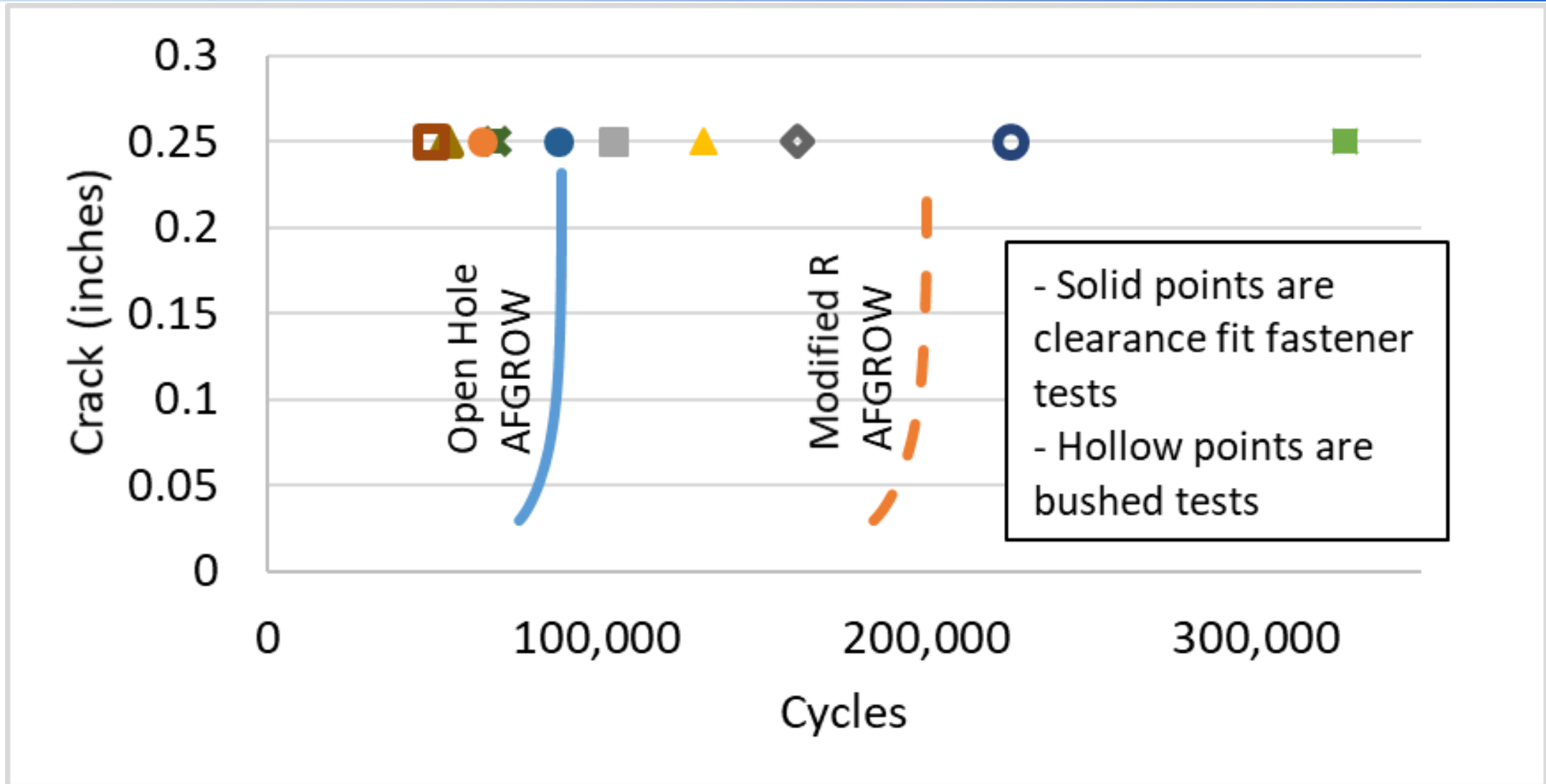


- Durability test, no induced flaw
- 0.76" wide, 0.15" thick, 0.25" hole
- Clearance fit fastener and bushed holes
- Bypass and bearing loads
- 7050-T7451 parent material
- Steel fastener, Ti bushing
- No open hole tests



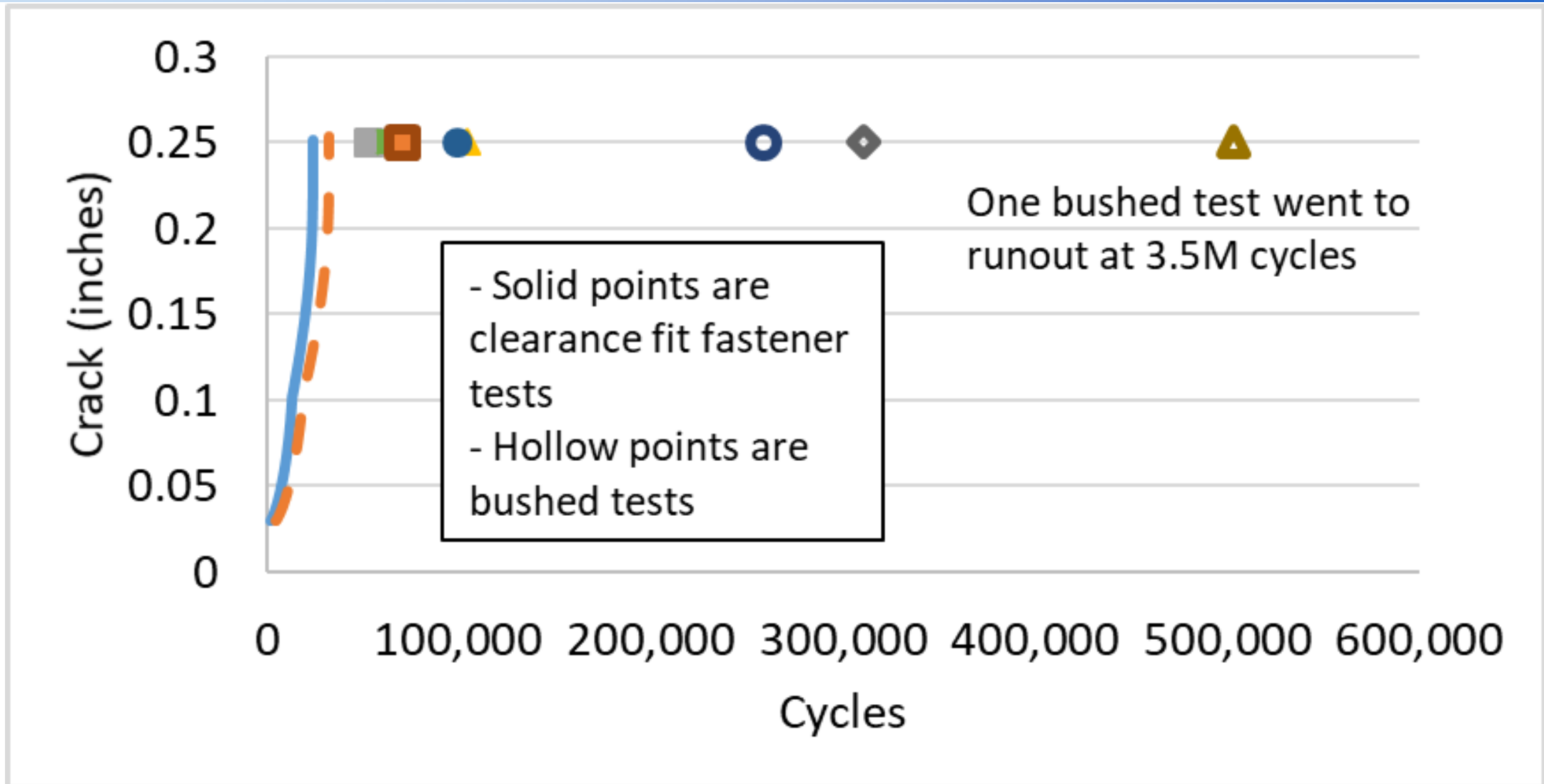


Bypass Loading Results





Bearing Loaded Results

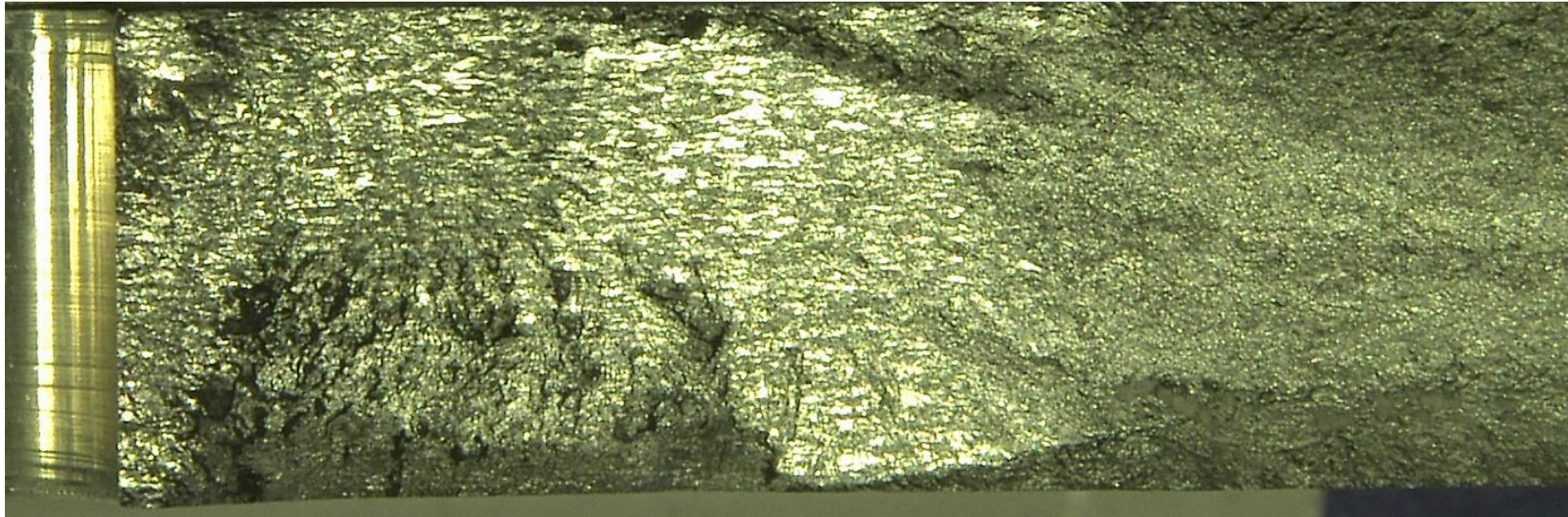




Conclusions



- 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!

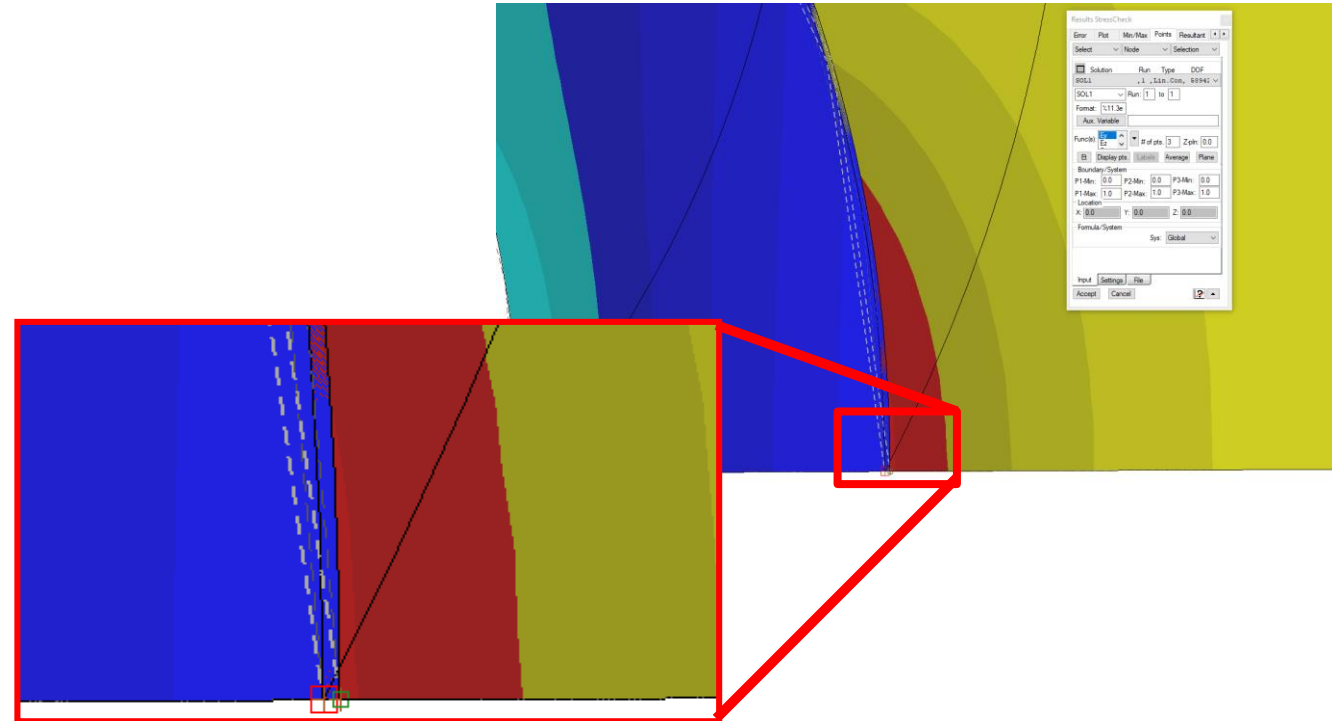
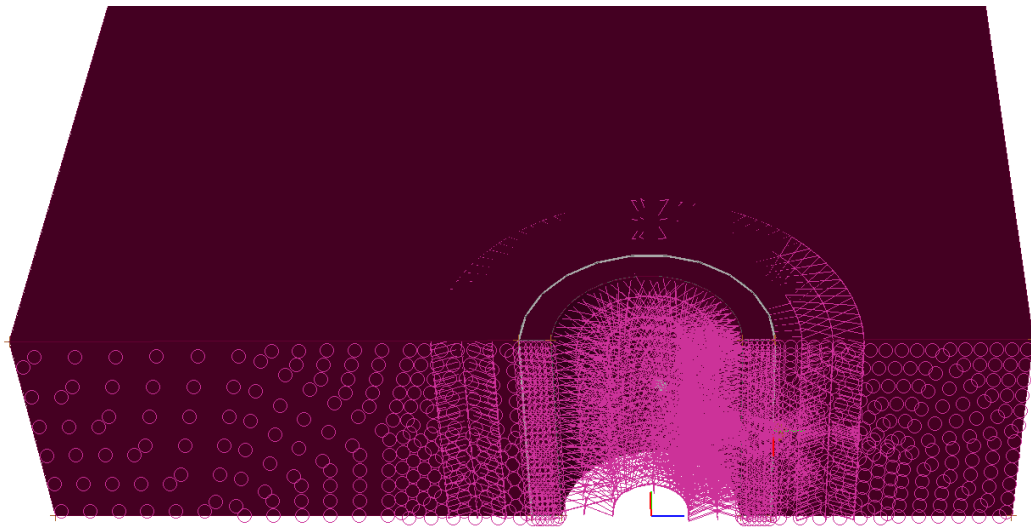




Model Details



- 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

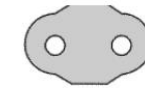




- Use method to run predictions for:
 - F-22 Press fit bushing simulations?
 - Life improvement for a range of interference levels?
 - Test data for some from APES?
 - Literature data?

Attaining Fatigue and Damage Tolerance Life Goals in Helicopter Bushed Assemblies

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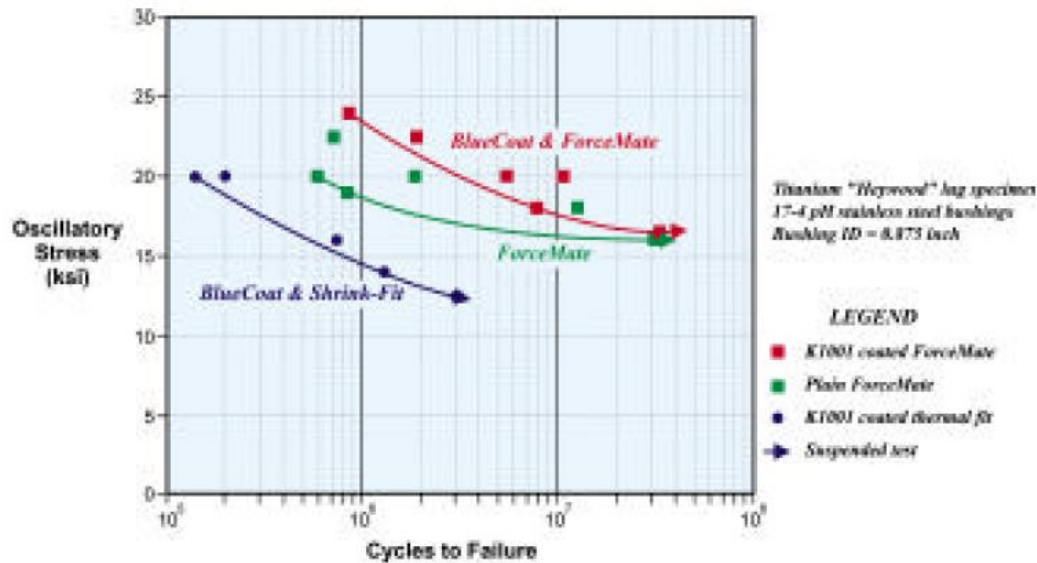


Test Specimen
7075-T651

Load Conditions:
 Constant amplitude
 10 Hz
 R = .05
 Beryllium Copper Bushings

- ForceMate Failure
- × Shrink Fit Failure
- No Failure

Champoux & Landy
 ASTM STP 927
 1987



Maximum Net Section Stress Level (MPa)

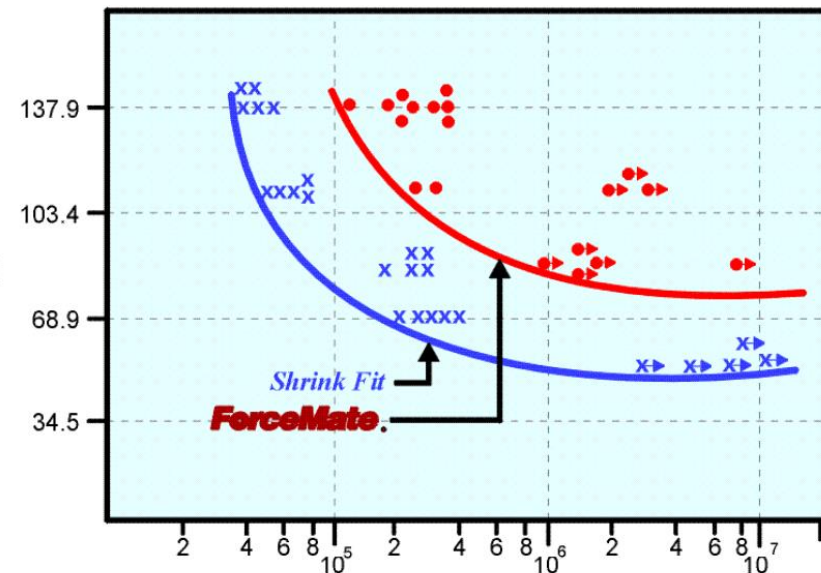


Figure 5. Fatigue Life Comparison of Shrink Fit and ForceMate Bushing Installations



Background, Bushing Installation



■ 1A-10C-3 Typical Instruction

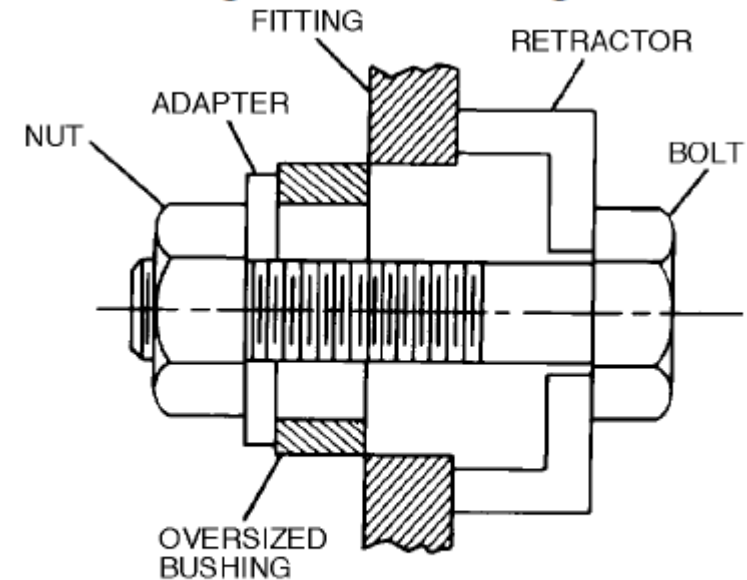
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