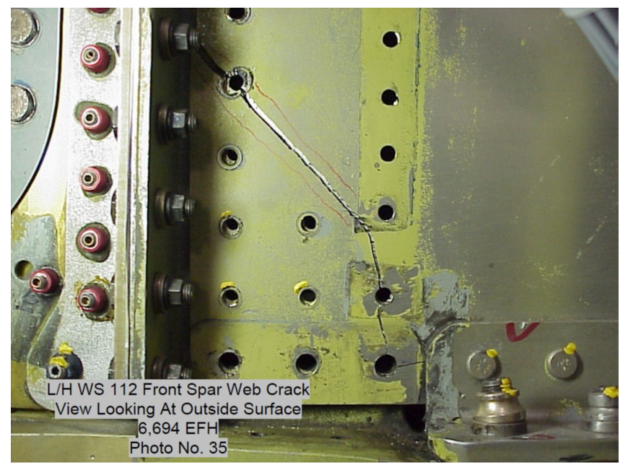
Damage Tolerance Predictions in a Diminishing Stress Field

Presented by: Randal Heller, Principal Engineer, Southwest Research Institute

PROBLEM

Cracks growing in spar webs are not as damage tolerant critical as typically predicted. Test evidence and fleet history suggest that cracks can slow and possibly even arrest because the crack driving force drops as the crack grows toward the beam's neutral axis. In this fiscally austere environment, it is desirable to eliminate any unnecessary inspections and focus efforts on more critical areas. A rigorous program has been undertaken to more accurately characterize the growth of cracks in a diminishing stress field with the goal of eliminating unneeded inspections.



METHOD

Constant amplitude testing was performed on two specimens, one pure tension and one 3-point bending. Crack length vs. cycle count was recorded. 2D StressCheck® models were created to characterize crack paths and from which stress intensity solutions were extracted. These stress intensity solutions were used to generate user-defined beta tables for use in AFGROW. Comparisons were then made between AFGROW's predictions and the crack rates measured during testing. Favorable results suggest that future phases should be pursued.

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EXPERIMENT

Contact Mr. Ken Grube for information about testing at Northrop Grumman
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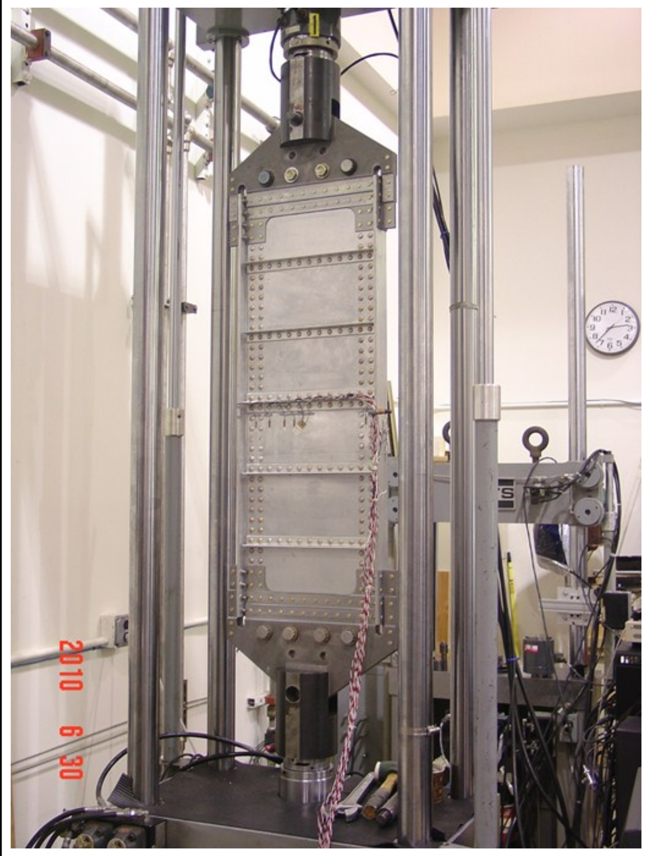
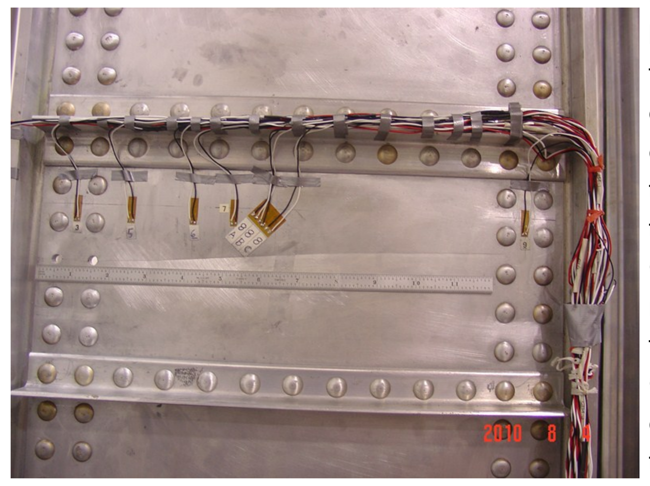
NORTHROP GRUMMAN



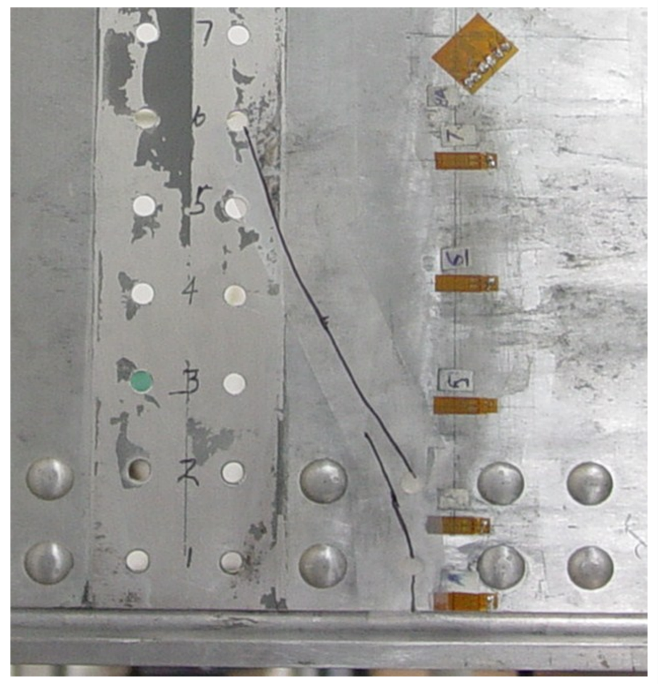
Tension Specimen

Phase I testing consisted of two specimens, one pure tension, and one 3-point bending. Specimens representing typical metallic built-up wing spars were constructed. Strain surveys were taken to verify desired distributions. Razor cuts were used to nucleate cracks from undersized holes. Holes were reamed to 0.25" after crack lengths grew enough that a 0.050" x 0.050" corner crack would remain. Constant amplitude testing was completed at 15 ksi tension peak stress (tension specimen) and 15 ksi bending with 8 ksi shear (bending specimen), a stress ratio of R = 0.05, and a rate of 1.0 - 1.5 Hz. The primary crack grew from the hole to the free edge. Continuing damage cracks were grown between fastener rows, and then into the open web. Crack length measurements were recorded as a function of cycle count. Critical crack lengths and cycles at failure were captured as well as the cracks' paths.

3-Point Bending Specimen

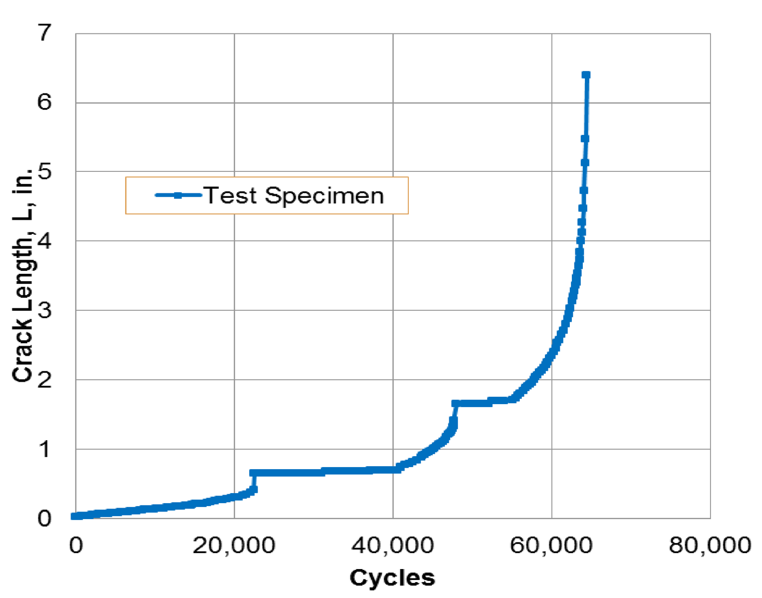


Crack at failure of tension specimen

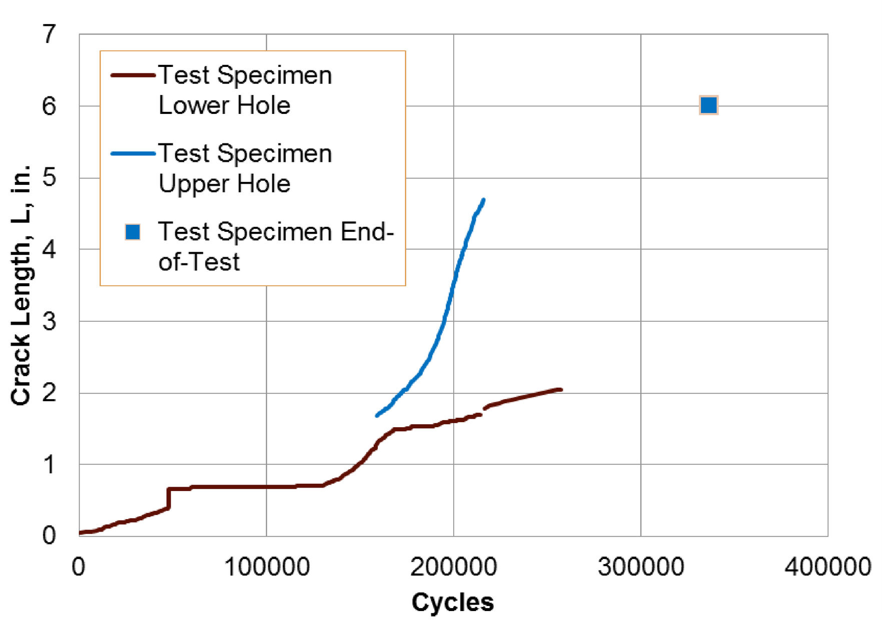


Crack at failure of bending specimen

Crack Growth - Tension Specimen



Crack Growth - Bending Specimen



Test support provided by Mr. Meir Levy,
Northrop Grumman Corporation, Bethpage, NY

CRACK PATH

Contact Mr. Brent Lancaster for information about StressCheck®
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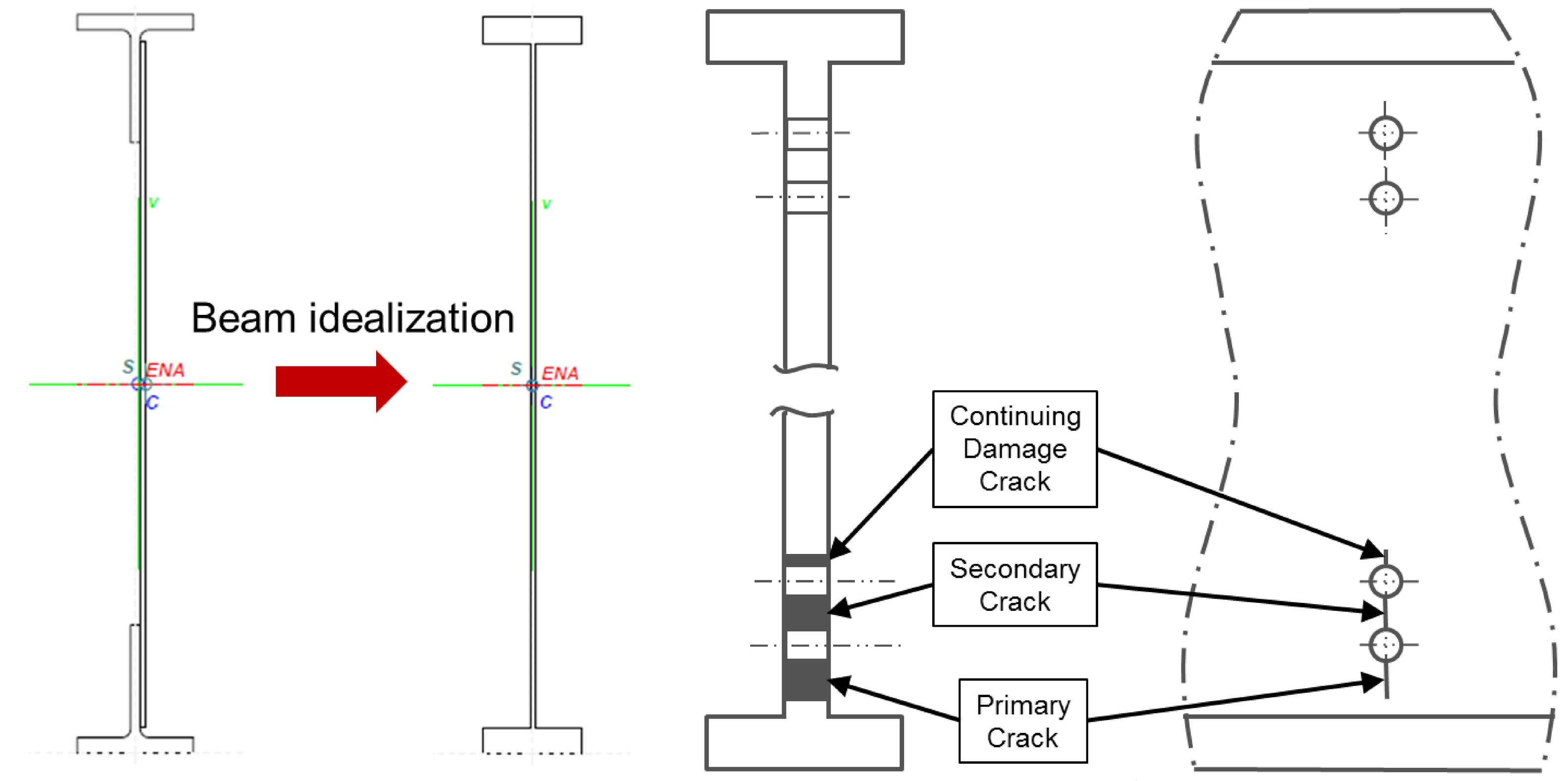
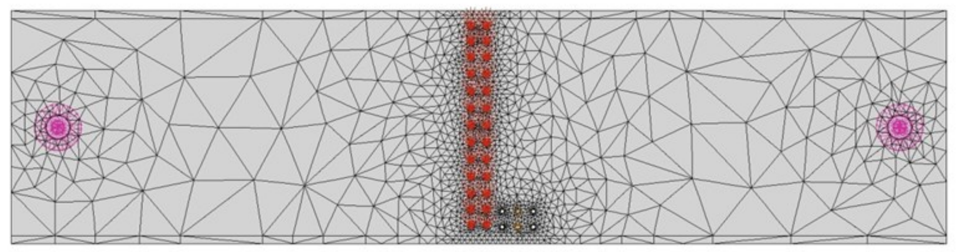
STRESSCHECK esrd





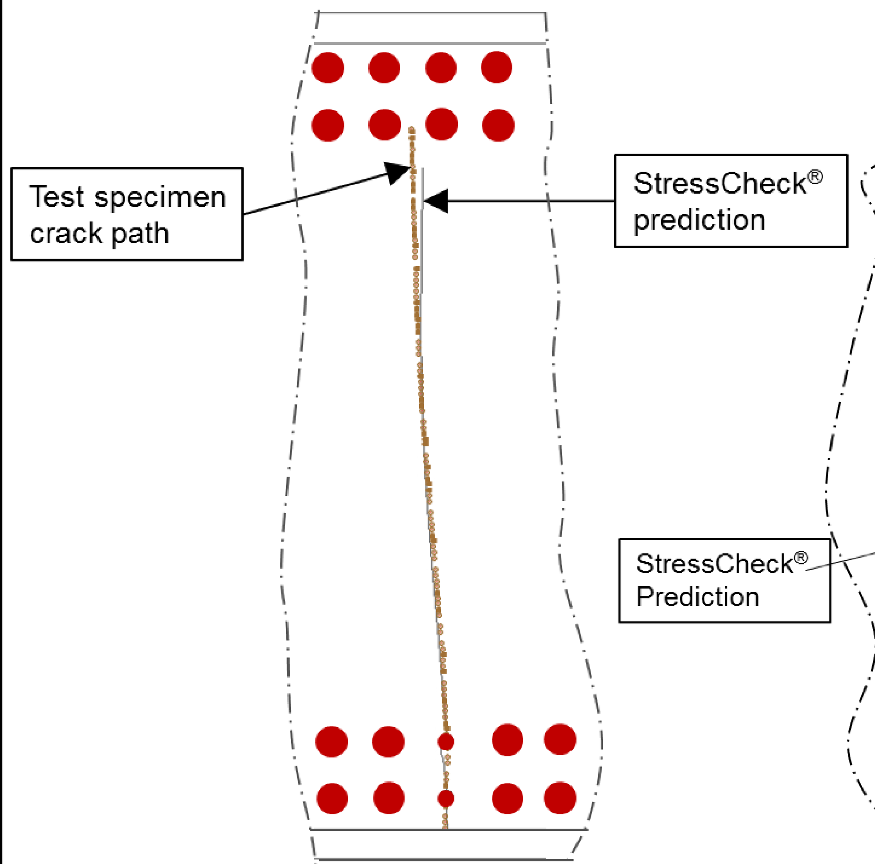
Finite element mesh is automatically regenerated after each crack growth increment. Crack growth increments are user defined.

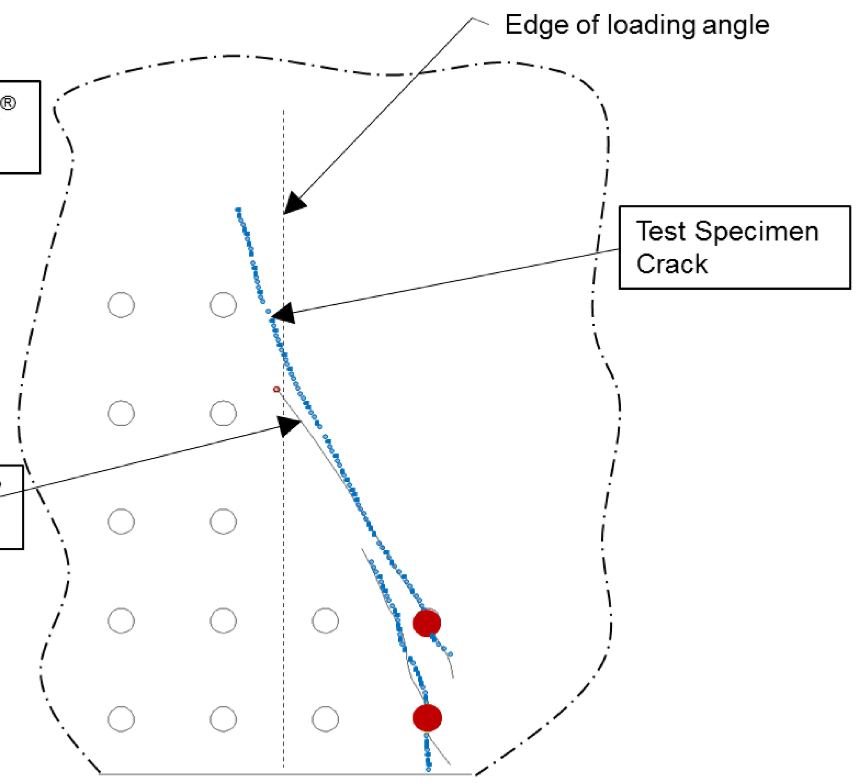
StressCheck® p-version finite element analysis code was used to create single sheet body representations of the test articles. Cracks were grown in the models to replicate the cracking seen in the test specimens. Stress intensities reported by StressCheck® were used, along with the measured crack lengths and stress levels, to generate beta factors according to the formula:

$$\beta = \frac{K}{\sigma\sqrt{\pi * a}}$$

Tabulated beta values were then used for crack growth rate predictions using AFGROW.

Tension specimen crack growth versus StressCheck® prediction.





Bending specimen crack growth versus StressCheck® prediction.

CRACK RATE

Contact Mr. Jim Harter for information about AFGROW
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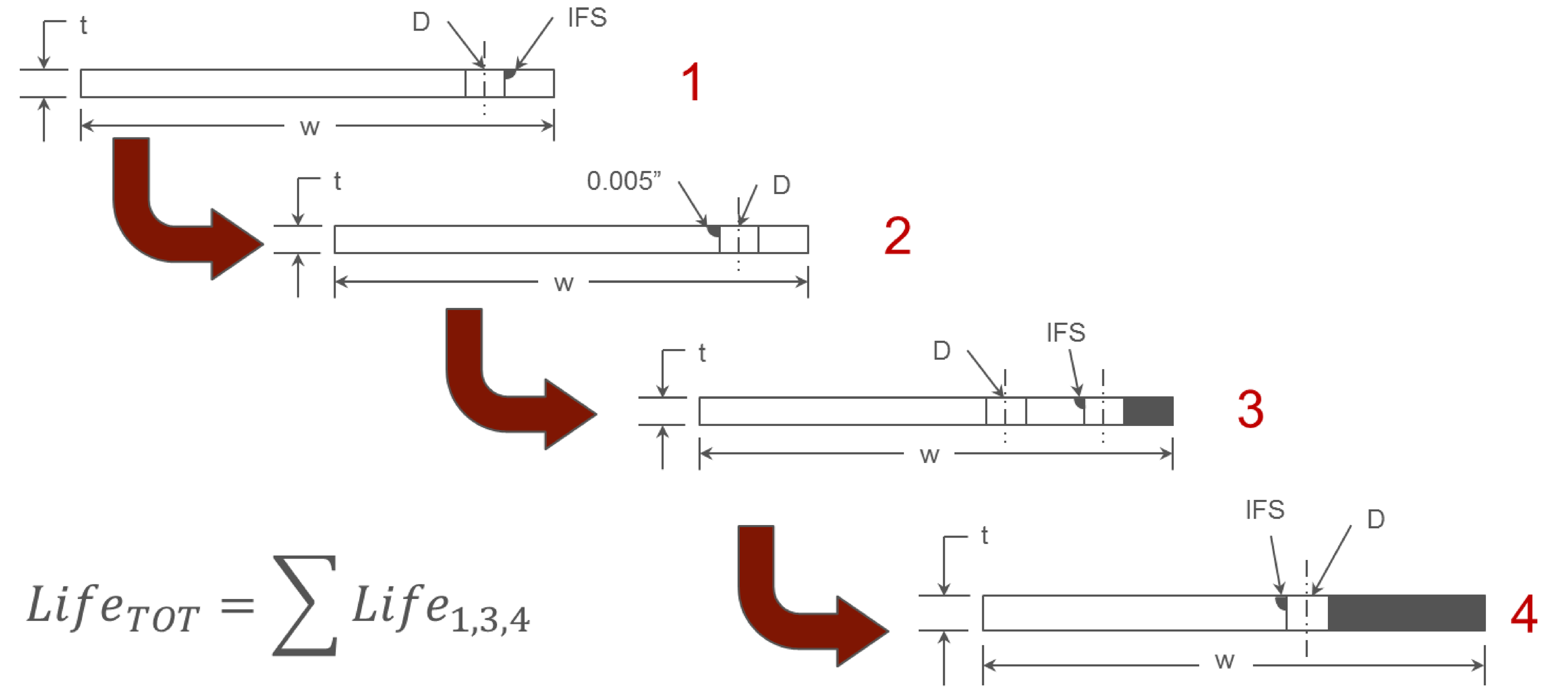
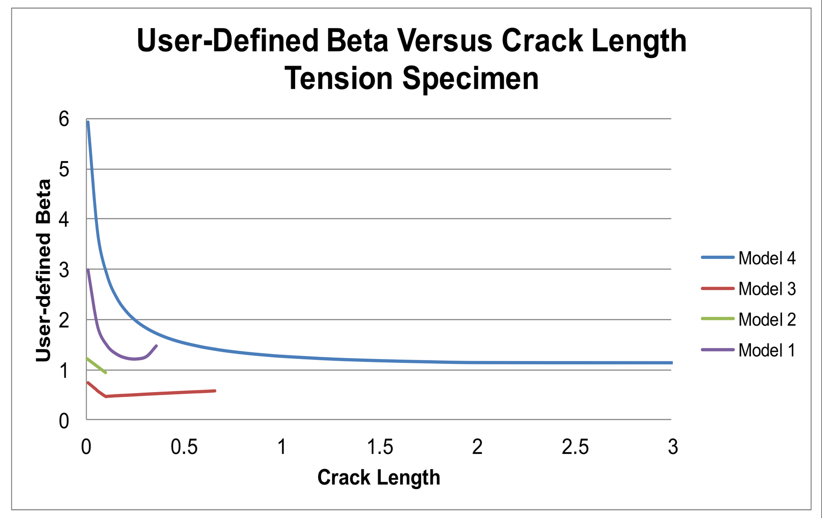
AFGROW LexTech

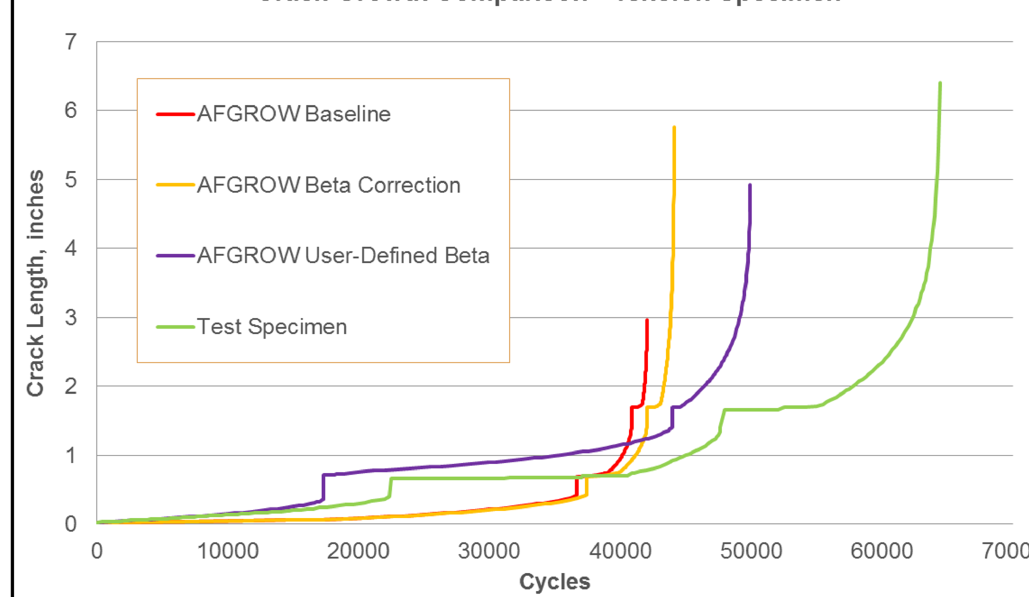


$$Life_{TOT} = \sum Life_{1,3,4}$$

Crack growth predictions were generated three different ways: first, predictions were made reflecting current USAF methodology as used in the A-10 System Program Office; second, a beta correction was investigated that accounted for load shedding with increasing crack length; third, the user-defined beta values generated from the StressCheck® models were used to capture the effect of the changing stress field at the crack tips.

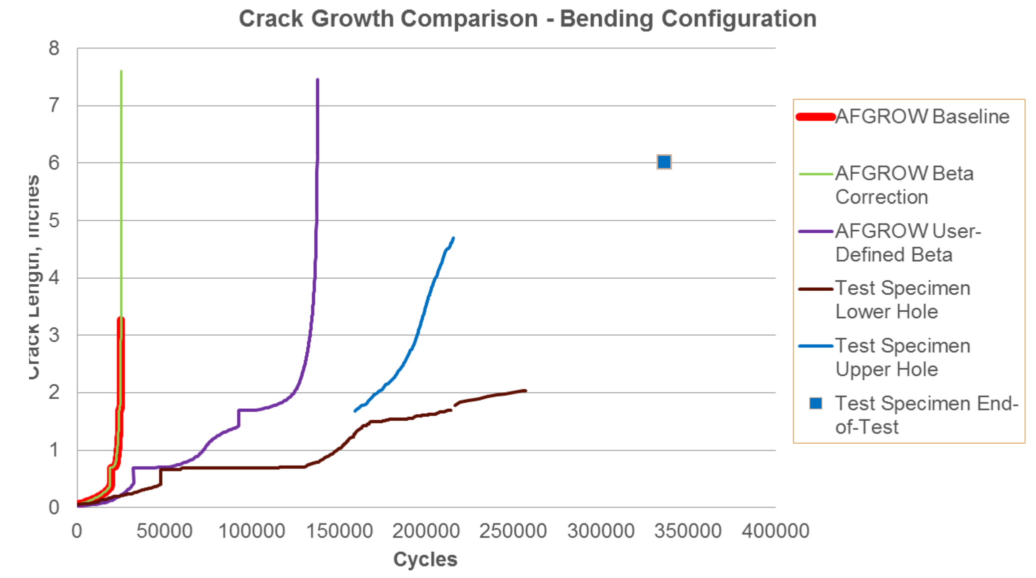
The third case, using the user-defined beta values, best matched the test data for each phase of crack growth.





FUTURE EFFORTS

Future efforts will examine four-point bending (bending without shear) to isolate the shear effect as cracks grow toward the neutral axis. Also, typical fighter-type spectrum loading and possibly the effects of geometric nonlinearities (intermediate diagonal tension effects) will be investigated.



Observe → Characterize → Predict

For more information about this project contact Randal Heller (randal.heller@swri.org)