2010 USAF AFGROW Workshop

Title:

Converting Experimentally Derived Data into AFGROW Beta (β) Corrections

by

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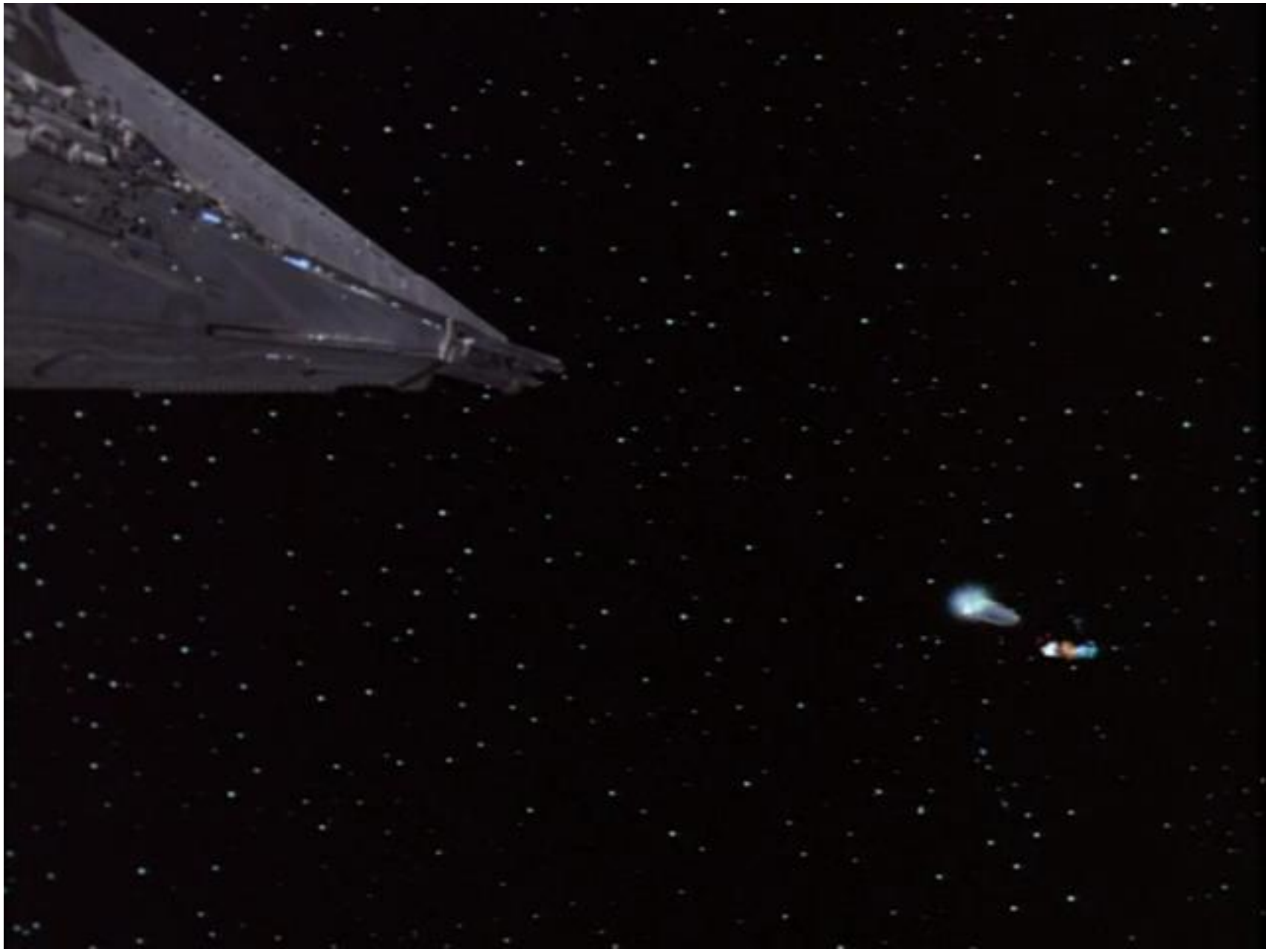


AGENDA FOR PRESENTATION

1. Beta Corrections in LEFM
2. Fatigue Testing Set-up
3. Fractography for Accurate Modeling/Predictions
4. Fatigue Testing Data
5. Crack Growth Data Processing
6. Results
7. Discussion

APPLICATION OF β CORRECTIONS

- β corrections are currently used for:
  - Geometric Corrections
  - Loading Conditions
  - Crack Interactions

$$K = \sigma\sqrt{\pi a}$$

$$K = \sigma\sqrt{\pi a}\,\beta$$

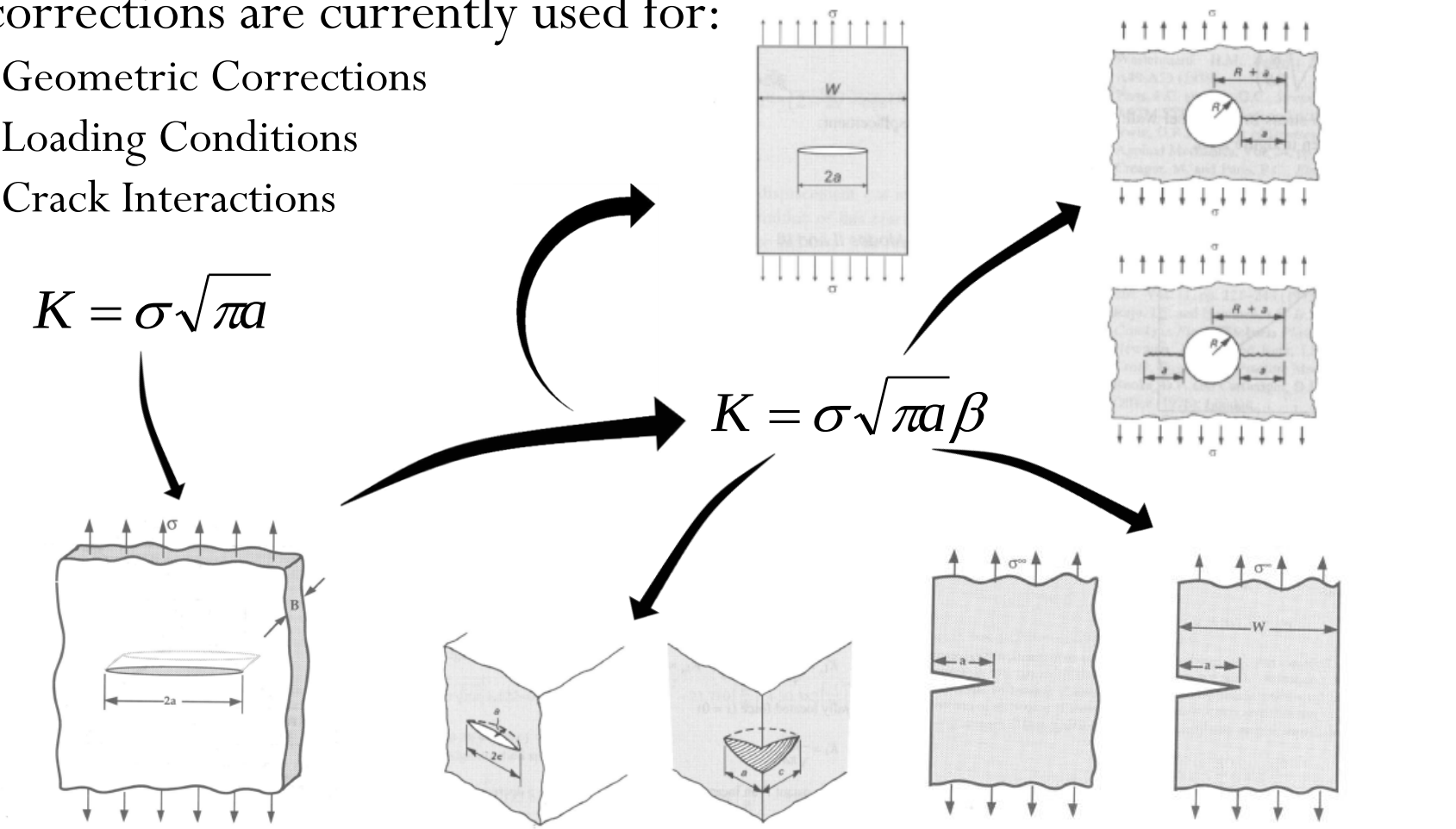


Fig. 1 Use of β corrections in LEFM.

FATIGUE TESTING SPECIMENS

- Materials Tested
  - 2024-T351 & 7075-T651 Aluminum Alloys
- Constant Amplitude Spectrum
  - Stress Ratio = 0.1
  - Max Spectrum Stress = 25, 20 and 12 ksi
- Specimens Tested (Each Material)
  - 2 - ASTM E 647 Specimens – Middle Tension M(T)
    - Verification of Test Setup & Results
  - 4 - Non Cold Expanded Specimens
    - Baseline Crack Growth Behavior
    - 0.50" Diameter Open Hole, EDM Corner Notch
  - 19 – Cold Expanded Specimens
    - Tested Configuration
    - 0.50" Diameter Open Hole, EDM Corner Notch
    - Processed by FTI's Split Sleeve Cold Expansion™

Fig. 2 Final specimen preparation for cold expanded specimens.

FATIGUE TESTING SET-UP

- Hill AFB Materials Testing Laboratory
  - Interlaken 55 kip fatigue machine
  - MTS 55 kip hydraulic wedge grips
  - Instron Fast Track 8800 controller
  - Visual crack measurements with Gaertner traveling microscope

Fig. 3 MTS grip set-up with traveling microscopes.

Fig. 4 Interlaken 55 kip fatigue machine at Hill AFB.

FRACTOGRAPHY - MACRO

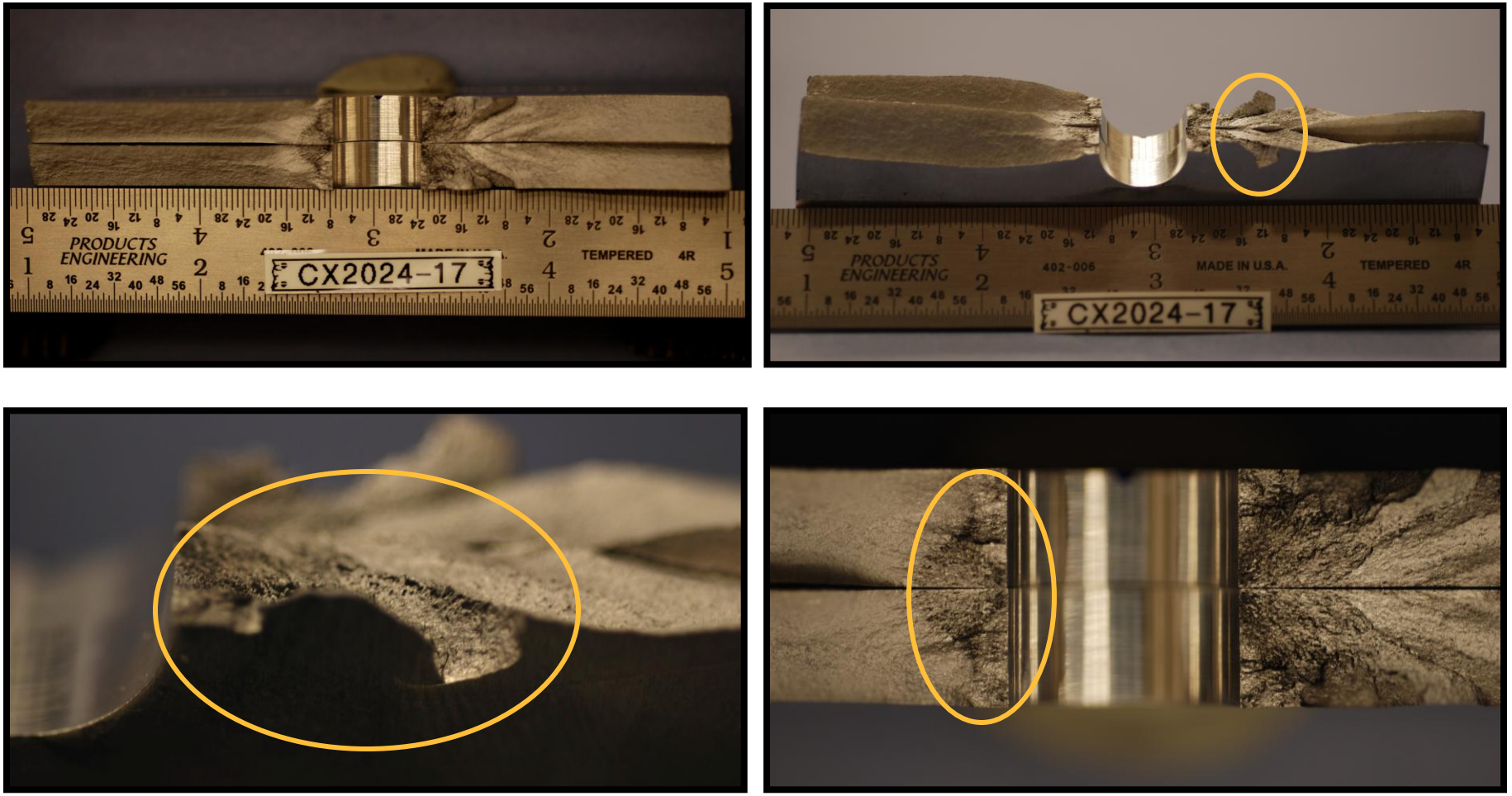


Fig. 5 Fracture surface images of CX 2024-17. Image taken with a Nikon digital SLR camera with a Nikkor 60 mm lens.

DATA COLLECTION & PROCESSING

- Visual Crack Measurements
- da/dN Calculated Using the Secant Method
- Stress Intensities Determined Using StressCheck® FEA Models
  - Crack Front Geometry Determined Using Marker Band Sequence
  - StressCheck Models Developed Based on Observed Geometries
  - Stress Intensities Validated with AFGROW

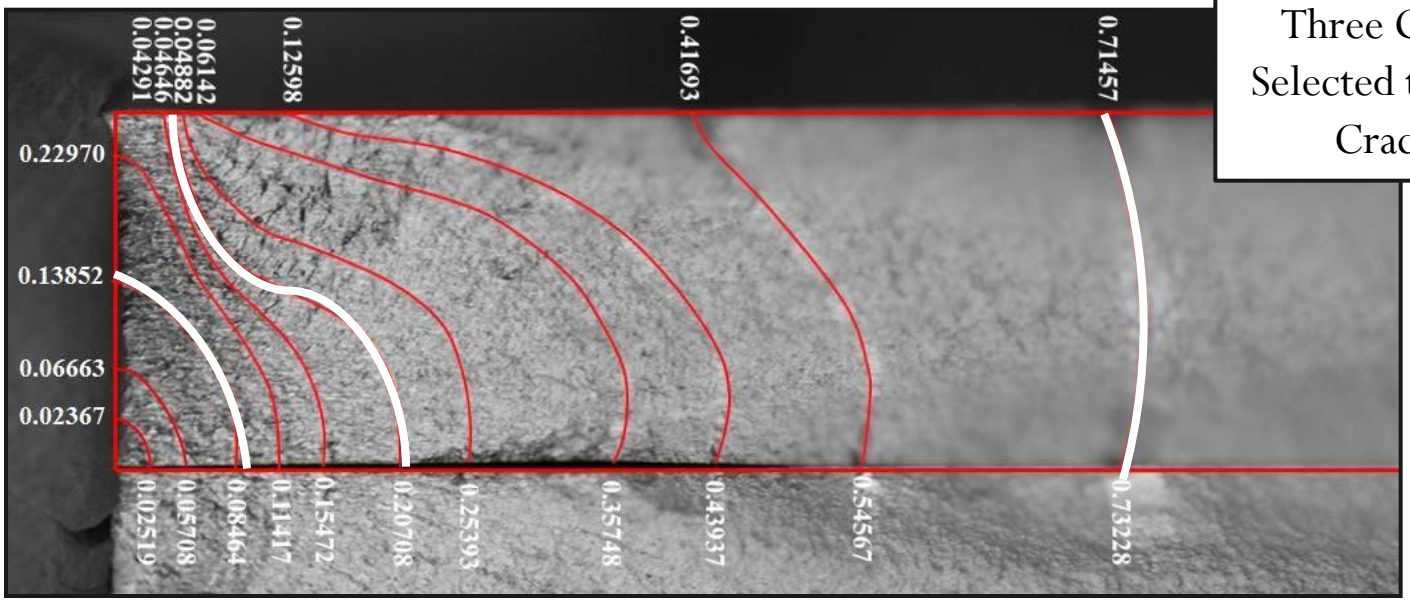
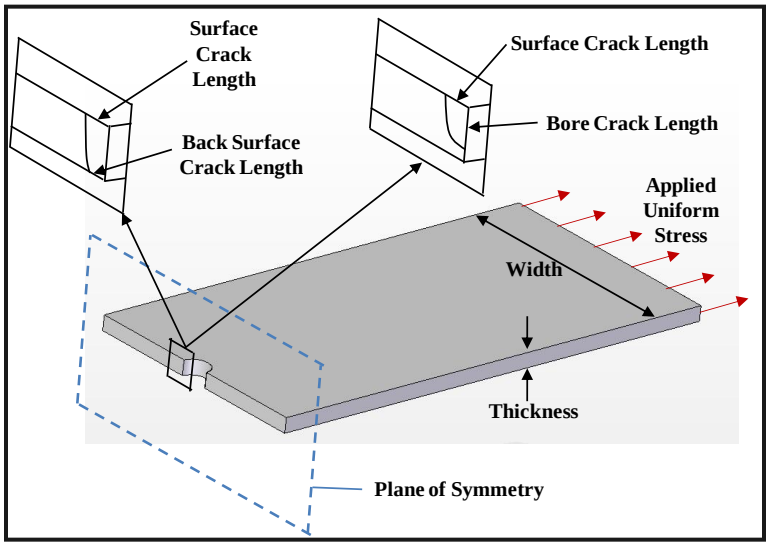


Fig. 6 Marker banding of 7075-T651 aluminum alloy.

STRESS INTENSITY DEVELOPMENT

- StressCheck® Modeling
  - Extract Stress Intensities at Crack Front
    - Mesh refinement at crack front
    - Contour integral used
    - Stress intensities at surface – Develop ΔK



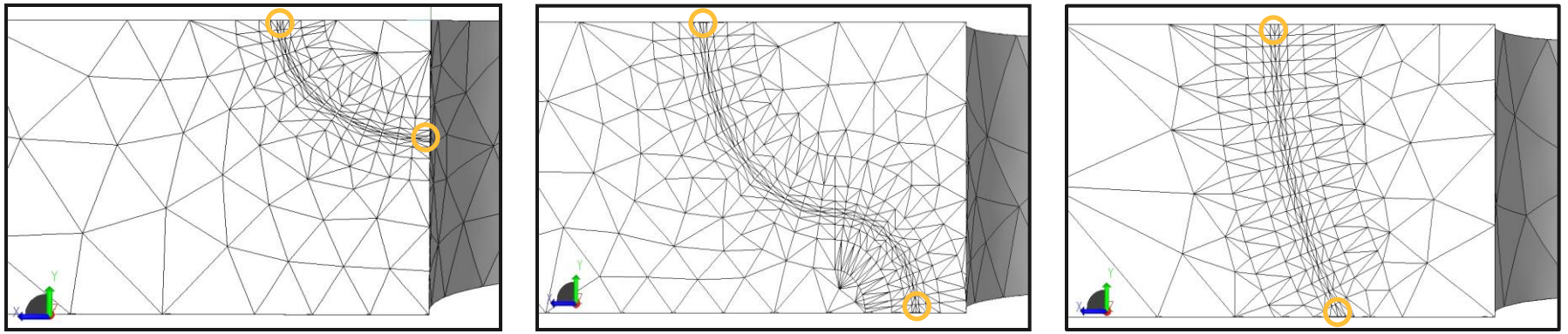


Fig. 7 StressCheck® FEA Models. Left – corner elliptical; Middle – through thickness P-shaped; Right – through thickness elliptical.

DATA COLLECTION & PROCESSING

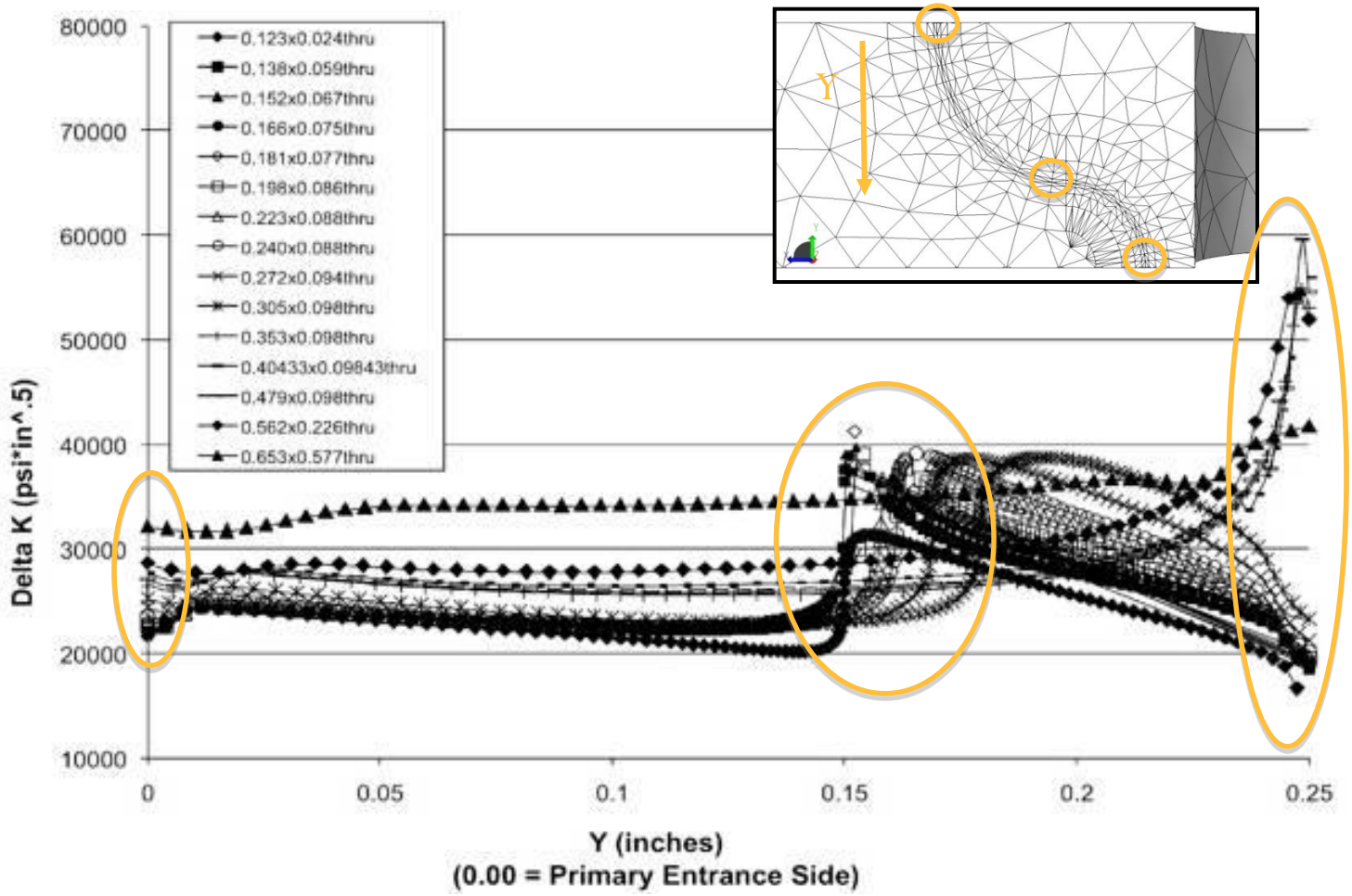


Fig. 8 Stress intensities for thru cracks from StressCheck for CX 2024-04.

DATA COLLECTION & PROCESSING

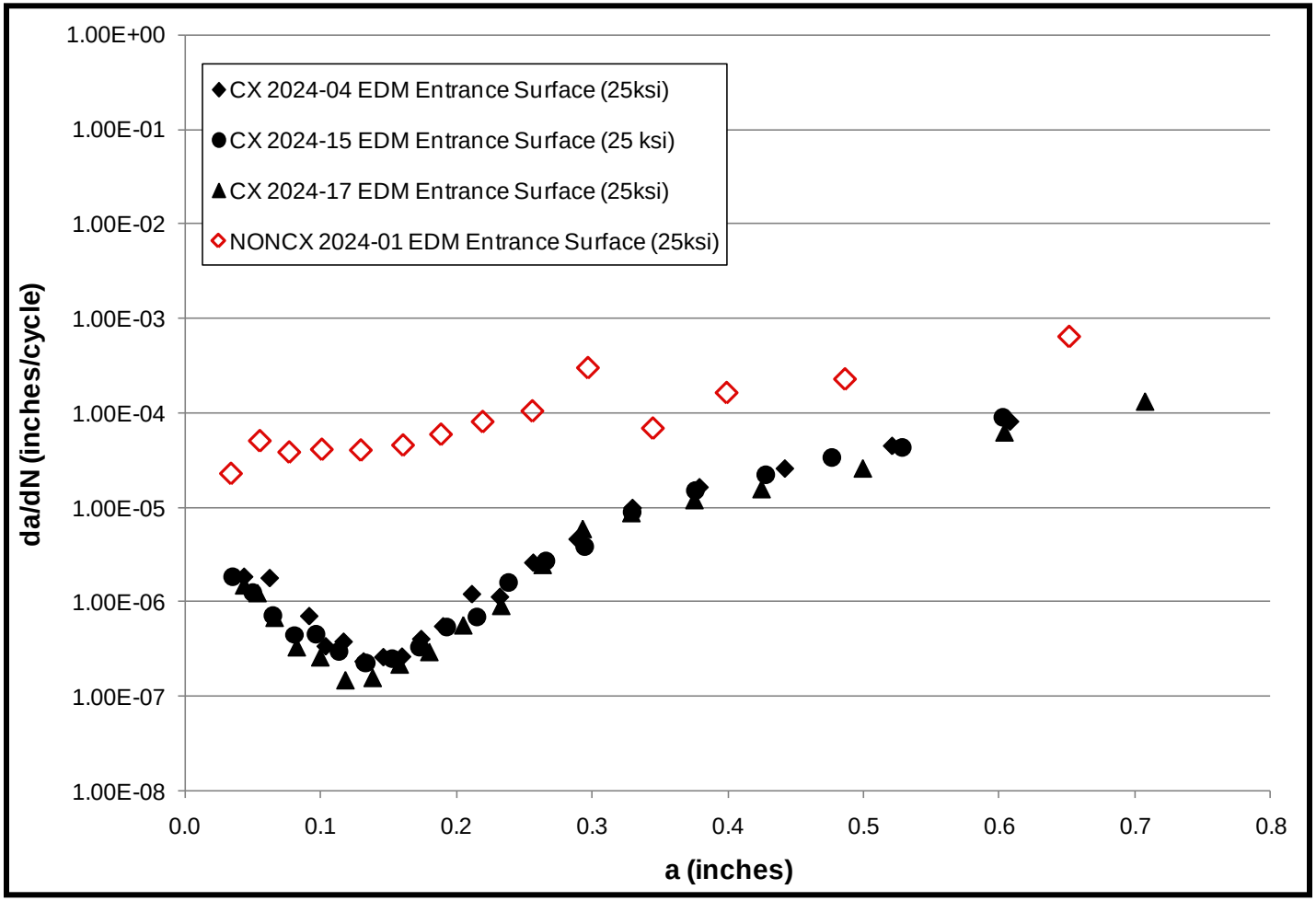


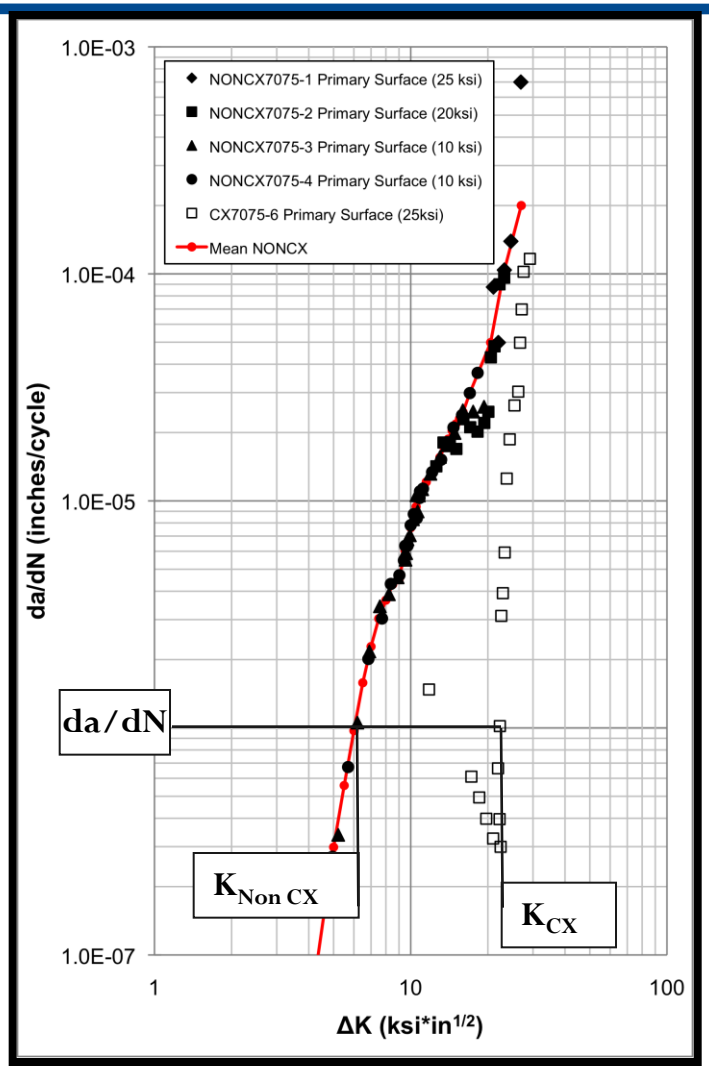
Fig. 9 Crack growth rate (da/dN) vs. crack length (a) curve.

β CORRECTION CALC. PROCESS

- Compare Stress Intensities for Non Cold and Cold Expanded Specimens at Given Crack Growth Rates, da/dN

$$\beta = \frac{K_{NonCX}}{K_{CX}}$$

- Based on the Similitude Principle
  - "At the same crack growth rate, da/dN, the same ΔK applies to the standard specimens and the configuration being considered."



2024 & 7075 β CORRECTION PLOT

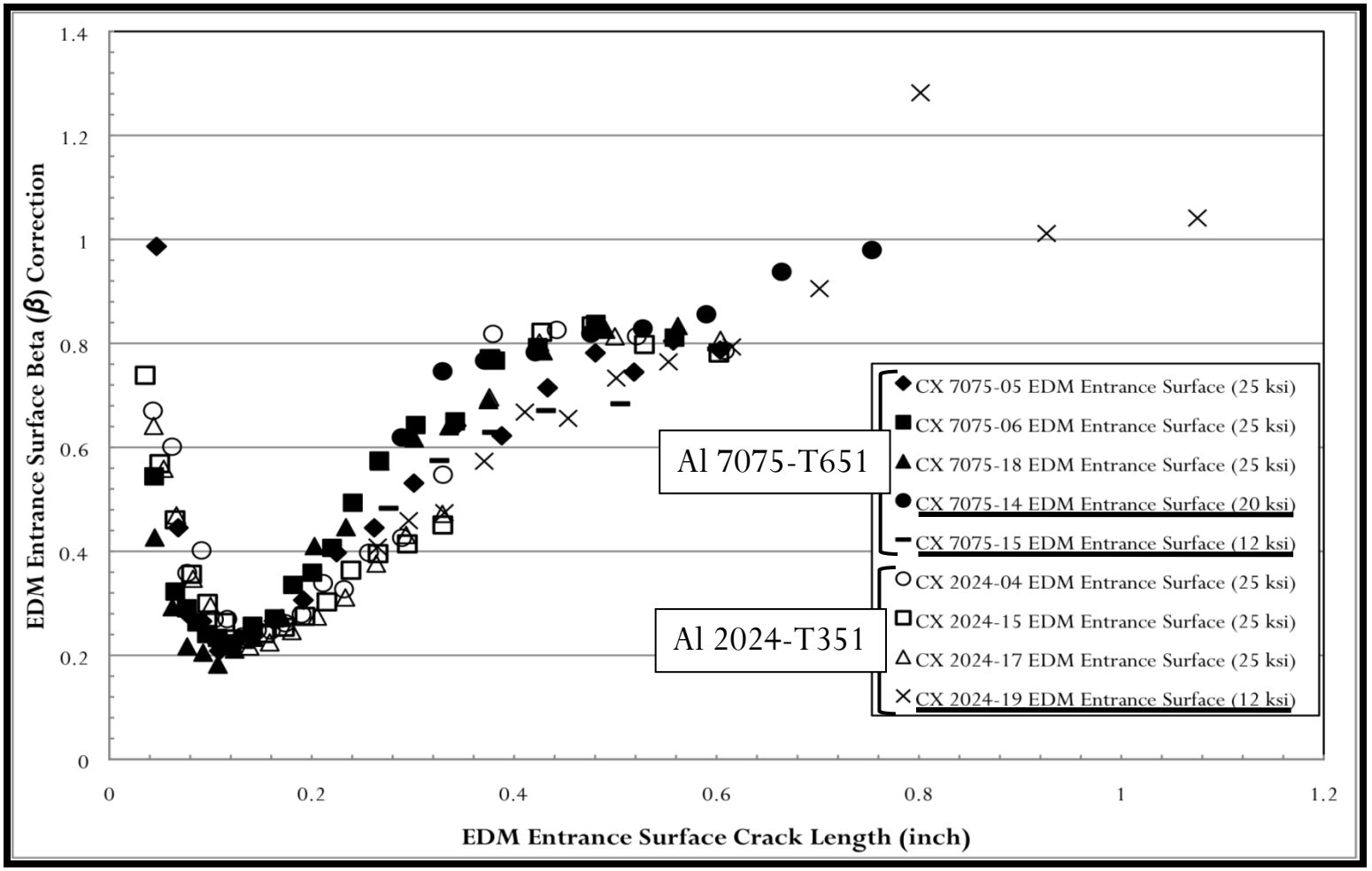


Fig. 10 EDM entrance surface β correction vs. crack length with highlighted areas of interest.

FATIGUE LIFE PREDICTIONS

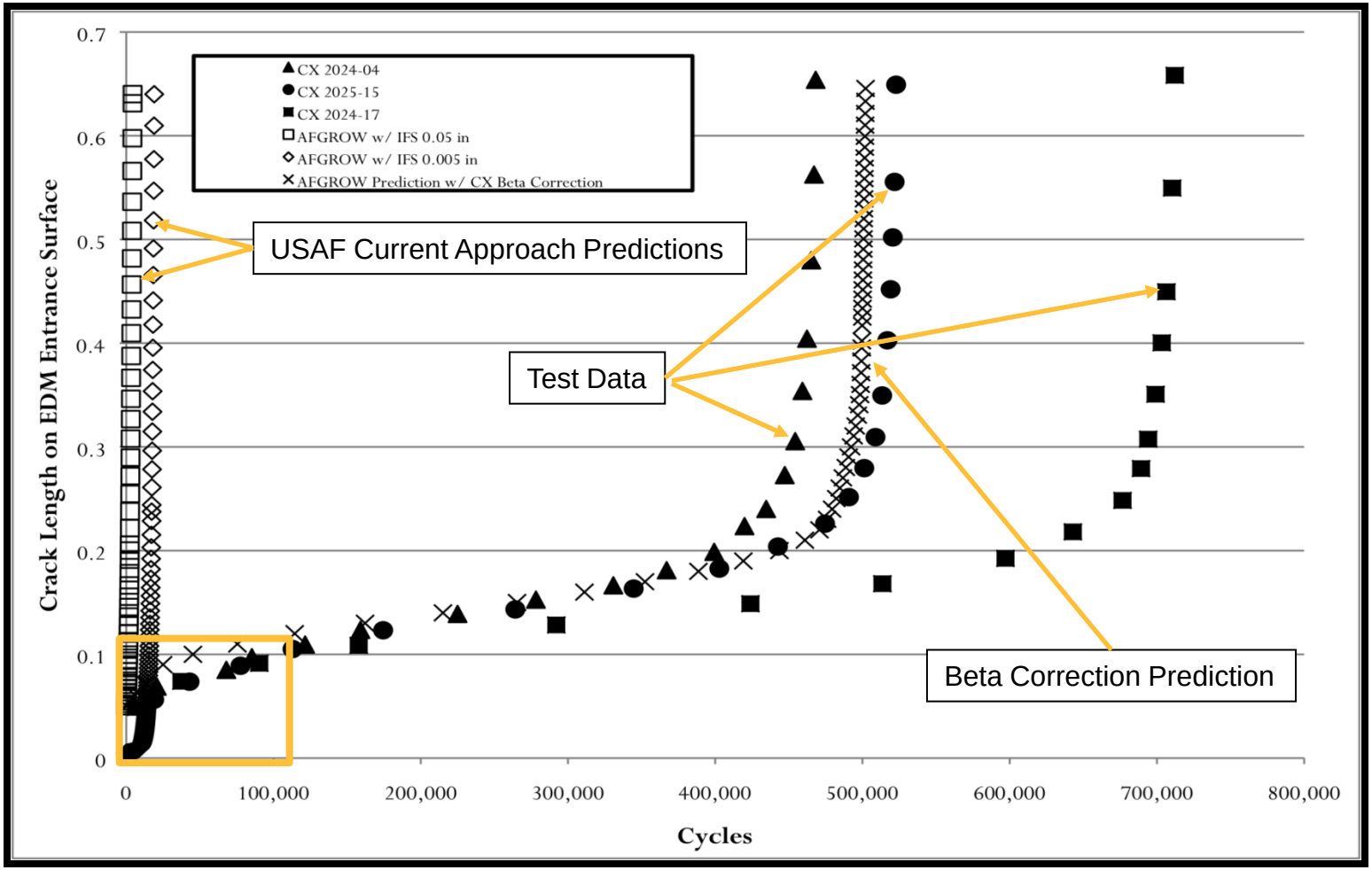


Fig. 11 Fatigue life prediction using AFGROW with varying initial flaw sizes to account for cold expansion

FATIGUE LIFE PREDICTIONS

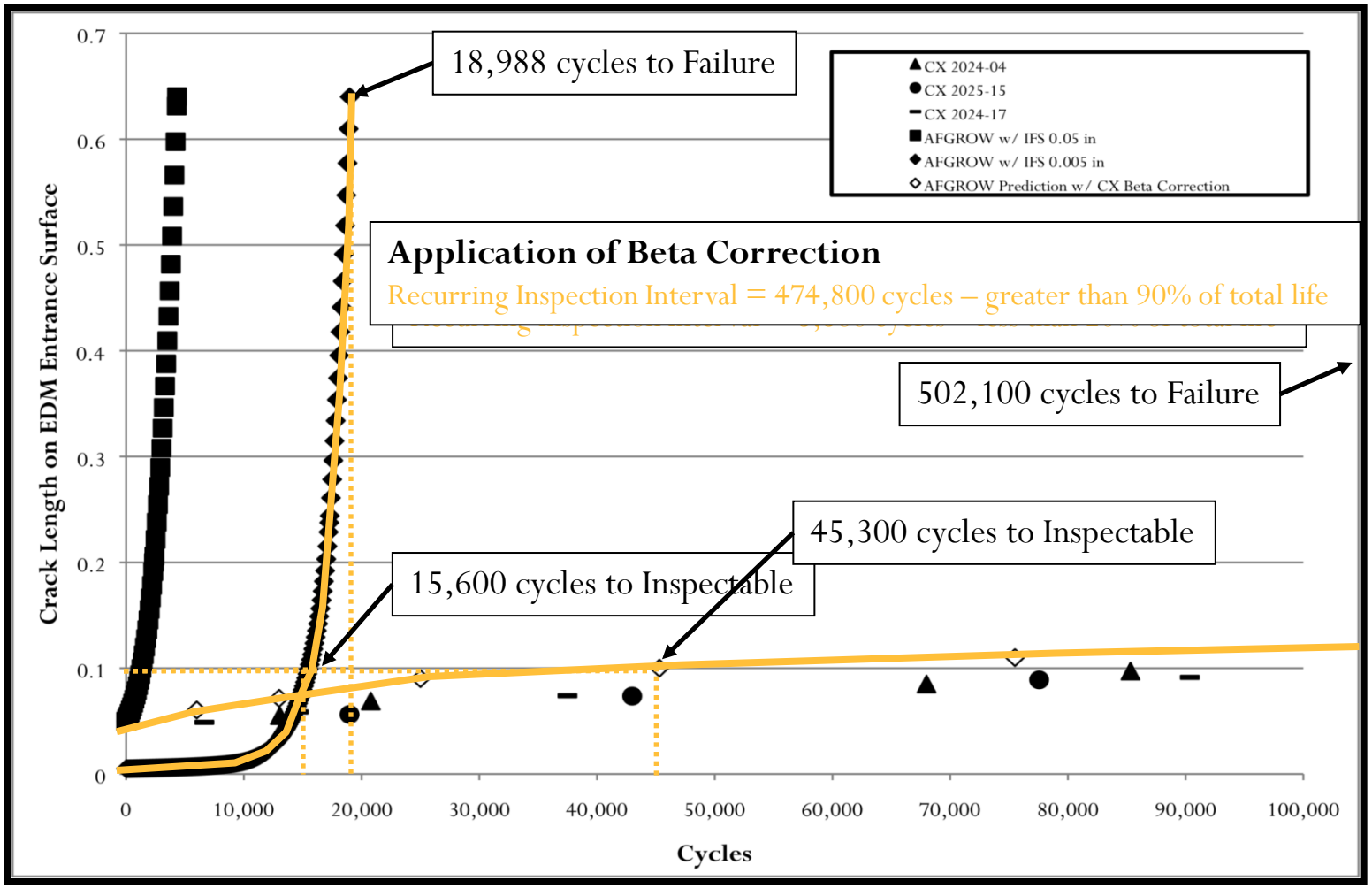


Fig. 12 Zoomed in view of fatigue crack growth behavior comparison of AFGROW with varying IFS and testing data

DISCUSSION

- Need for More Accurate Crack Growth Predictions
  - Increased confidence in prediction = reduced risk
  - Possibility to increase time between inspection = $ Savings
- Data Provided for Constant Amplitude Loading
  - Working on spectrum loading derivation
- Testing for Cold Expansion β Corrections
  - Other processes have need to be modeled and corrections produced

QUESTIONS?