Development of Crack Screening Guidelines for Coke Drums

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Motivation

- During turnarounds, engineers face the possibility of discovering too many cracks in coke drums to repair during the planned shutdown.
- While it is preferred to repair all cracks, it is desirable to have guidelines that can be used to prioritize the need for repairing cracks of various depths, lengths, and locations.
- In addition recognized crack acceptance has a risk associated with it as a result of the uncertainty of stresses encountered during quenching operations and the location of these peak stresses.

Equipment Description

- 6 drums C-1/2Mo built in 1967
- 2 drums 1Cr-1/2Mo built in 1981
- 26’ ID
- 66.5’ T-T
- 7 courses
- Variable thickness range 0.64” to 1”

Challenges

Crack propagation studies in coke drums are challenging because:

- Thermo-mechanical loads in coke drums are unpredictable in their randomness, asymmetry, and highly-localized nature.
- Materials may degrade after years of service.
- The process of conducting variable-load Monte-Carlo simulation for numerous cracks is prohibitively time-consuming.

Scope

The scope of this phase of the study covers:

- The most common surface circumferential cracks in the shell.
- Both C-Mo and Cr-Mo drums.
- Cracks on the inside and outside surfaces of the wall.
- Cracks in the base metal, weld, and HAZ.
- The effects of structural discontinuities such as nozzles, shell-to-head and shell-to-skirt junctions and wall-thickness changes are not included.

Approach

- Conservative loading: Primary membrane stress plus secondary residual stress from welding plus cyclic loading from the most conservative measured histogram.
- Material properties:
  - Measured strength properties from retired coke drum C-Mo plate are applied to both C-Mo and Cr-Mo drums.
  - Fatigue properties:
    - Standard / published values (conservative), or
    - Measurements from retired coke drum C-Mo plates.
- Outside and inside cracks produce comparable results. The slightly more conservative outside cracks are analyzed.
- Cracks in the weld and HAZ zone are treated the same.

Assumptions

- Cracks are too far apart to interact with each other.
- The wall is free of other types of defects such as corrosion, creep damage, fire damage, etc.
- The effects of the following parameters are not included:
  - Weld overlays
  - Internal clad
  - Bulging plasticity

Model Overview

- Analysis type: Crack growth assessment
- Crack Growth Mechanism: Fatigue
- Load Type: Variable amplitude
  - Method: Cumulative damage summation
- Analysis Option: Calculate life
- End point: Grow to failure
- Report Fatigue Life: Cycles
- Type of Fracture Analysis: Initiation/ brittle fracture
- FAD Type: API 579-1/ASME FFS-1 of 2007 Level 2

Material Strength

Properties obtained from Suncor's Fatigue Test program adjusted for temperature.

- Young's modulus
- Yield strength
- Tensile strength

Fracture Toughness

Two values are used for two types of models:

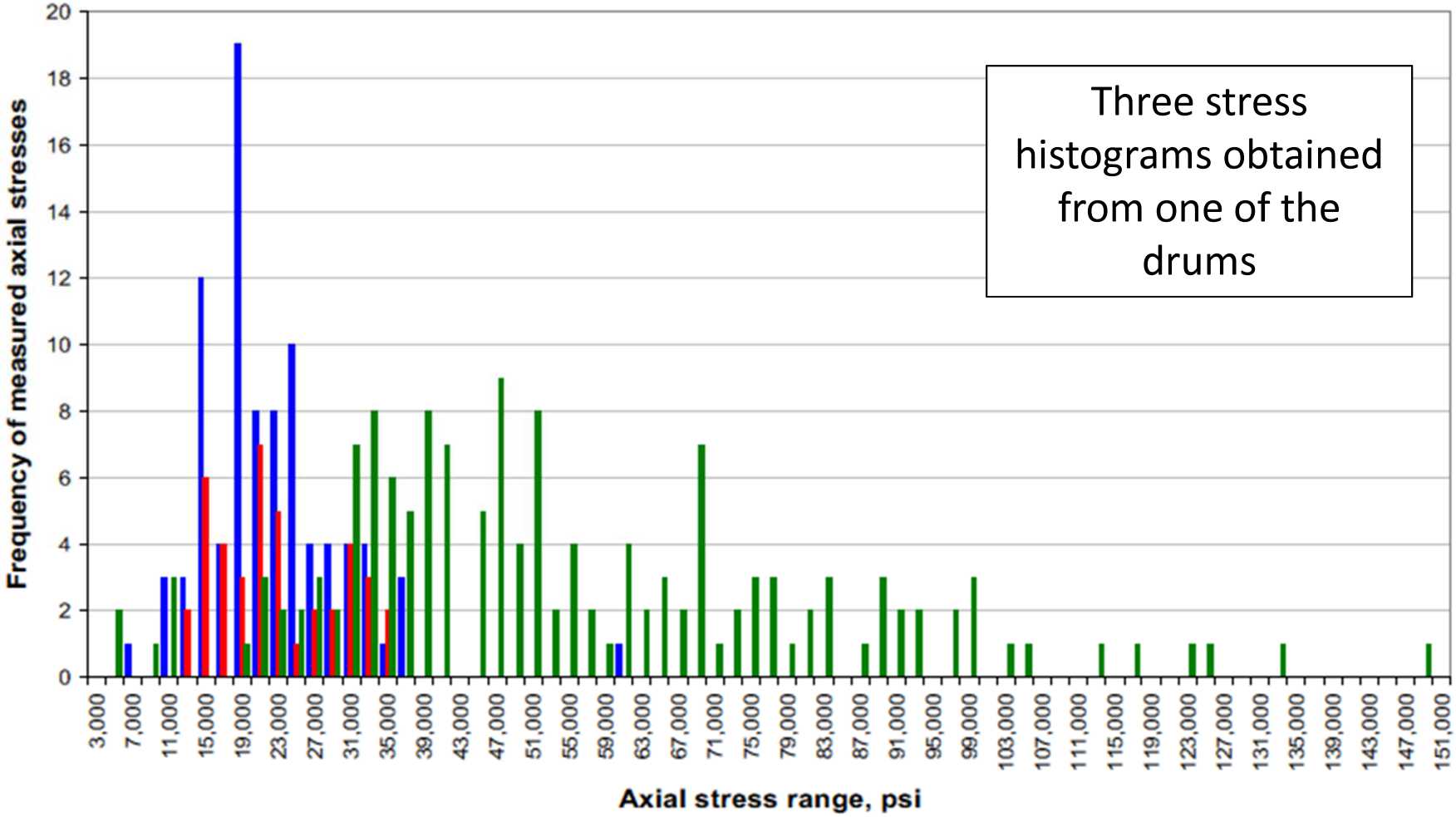
- Textbook (more conservative)
- Measured from Suncor's Fatigue Test program

Crack Propagation Model

Simple power law (Paris) is utilized for both models:

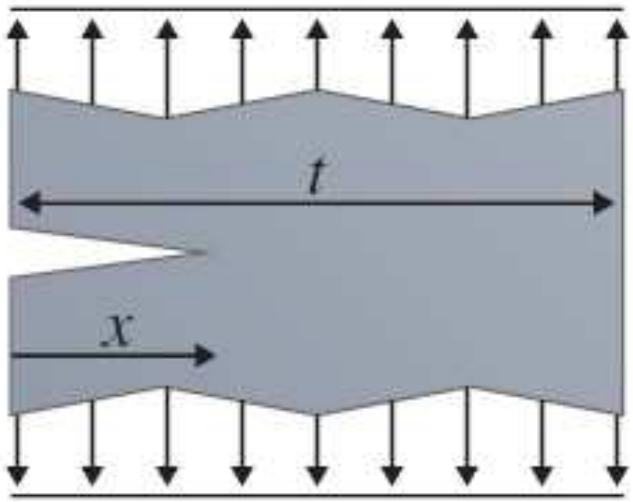
- Textbook: (conservative)
- Measured (Suncor's Fatigue test program)

Measured Histograms



Primary Load

- Uniform membrane stress.
- This primary load is used to check against the Failure Assessment Diagram (FAD).



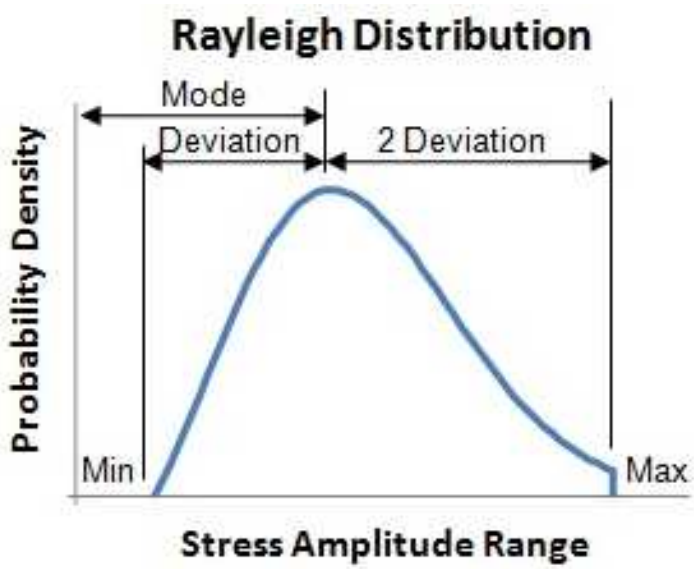
Secondary Load

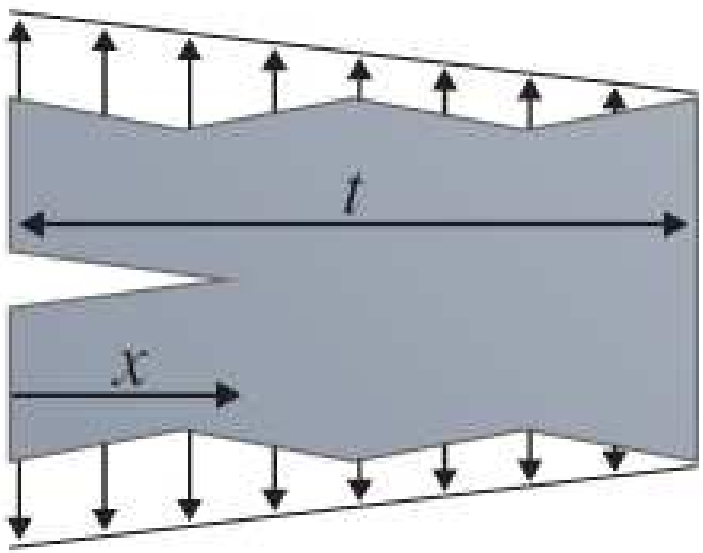
Secondary load at weld is equal to residual stresses after PWHT per API 579-1/ASME FFS-1 of 2007.

Cyclic Load

The most conservative stress histogram was used to grow cracks:

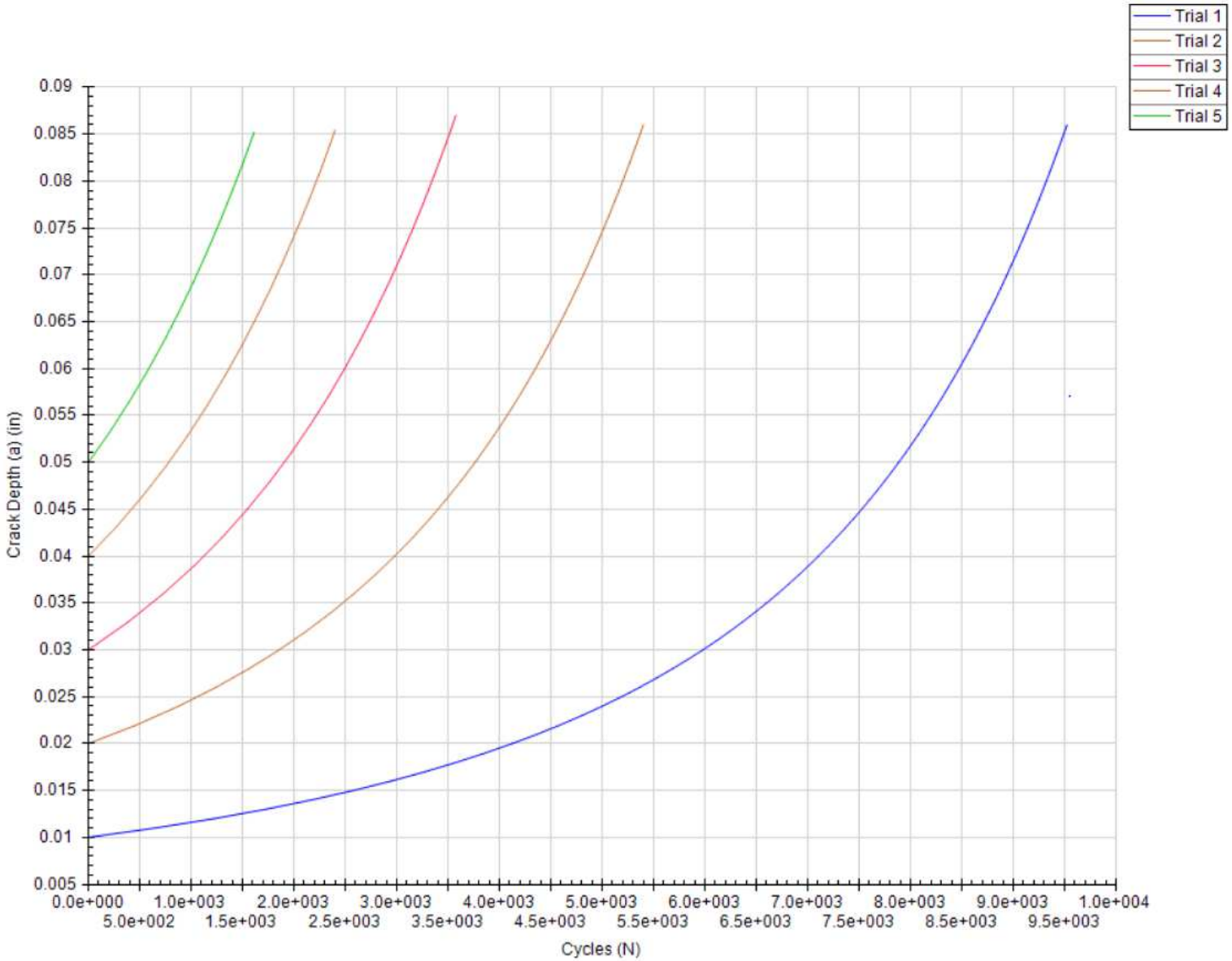
- Bending stress.
- Rayleigh distribution.





Example Results

Axisymmetric Cracks of Various Depths in Weld/HAZ of 0.64” Thick Wall



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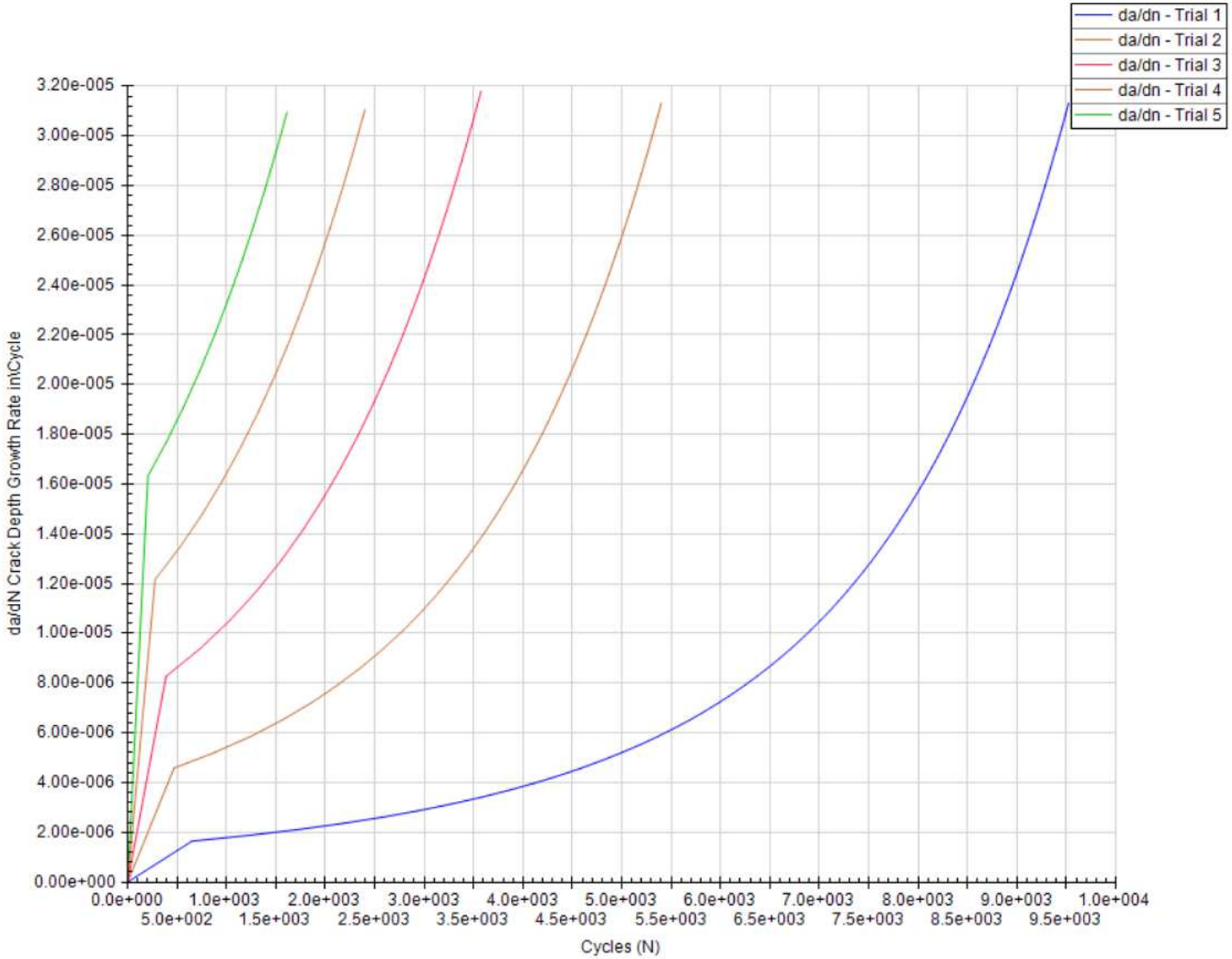

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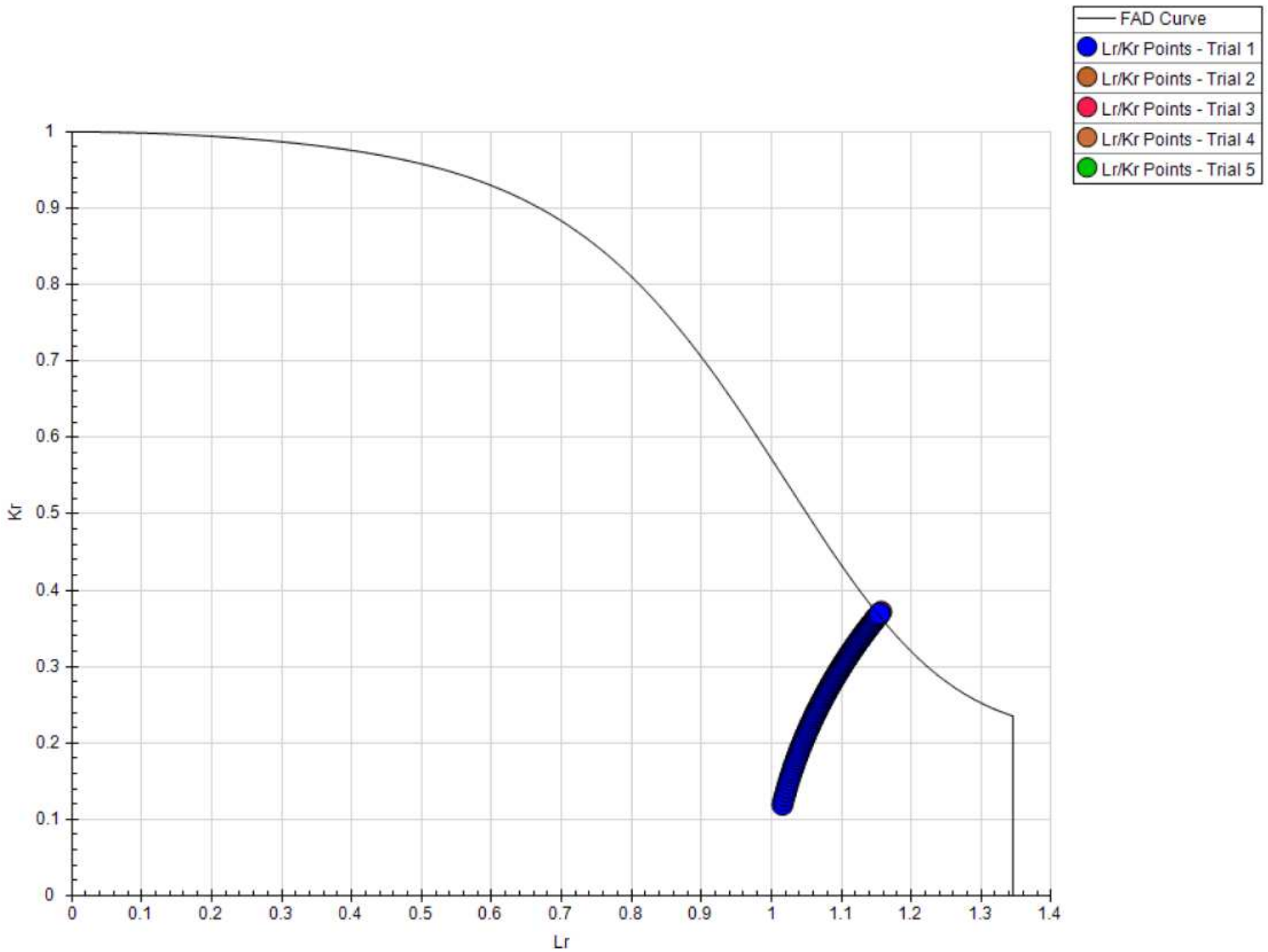
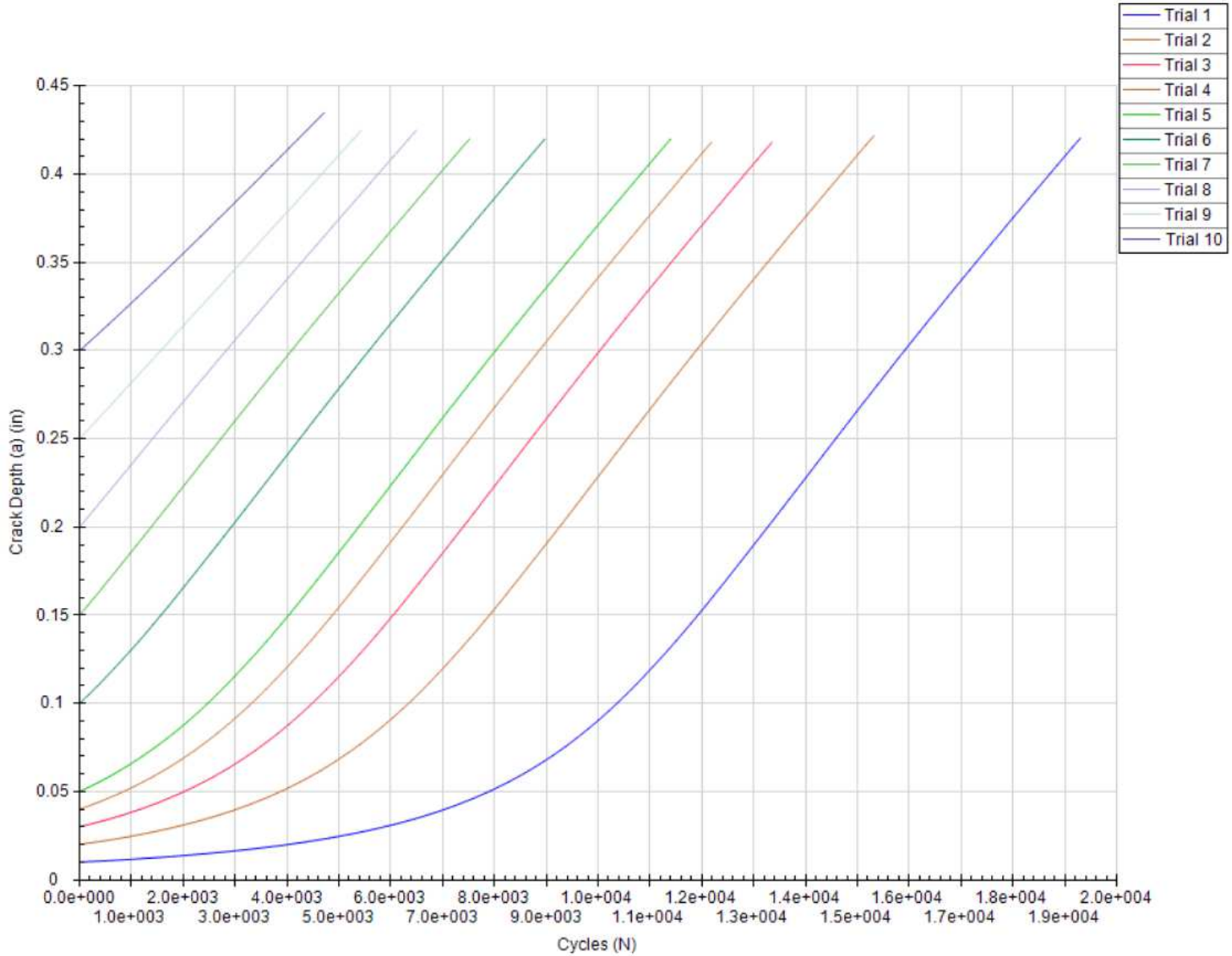


1” Long Crack of Various Depths in Base Metal of 1” Thick Wall



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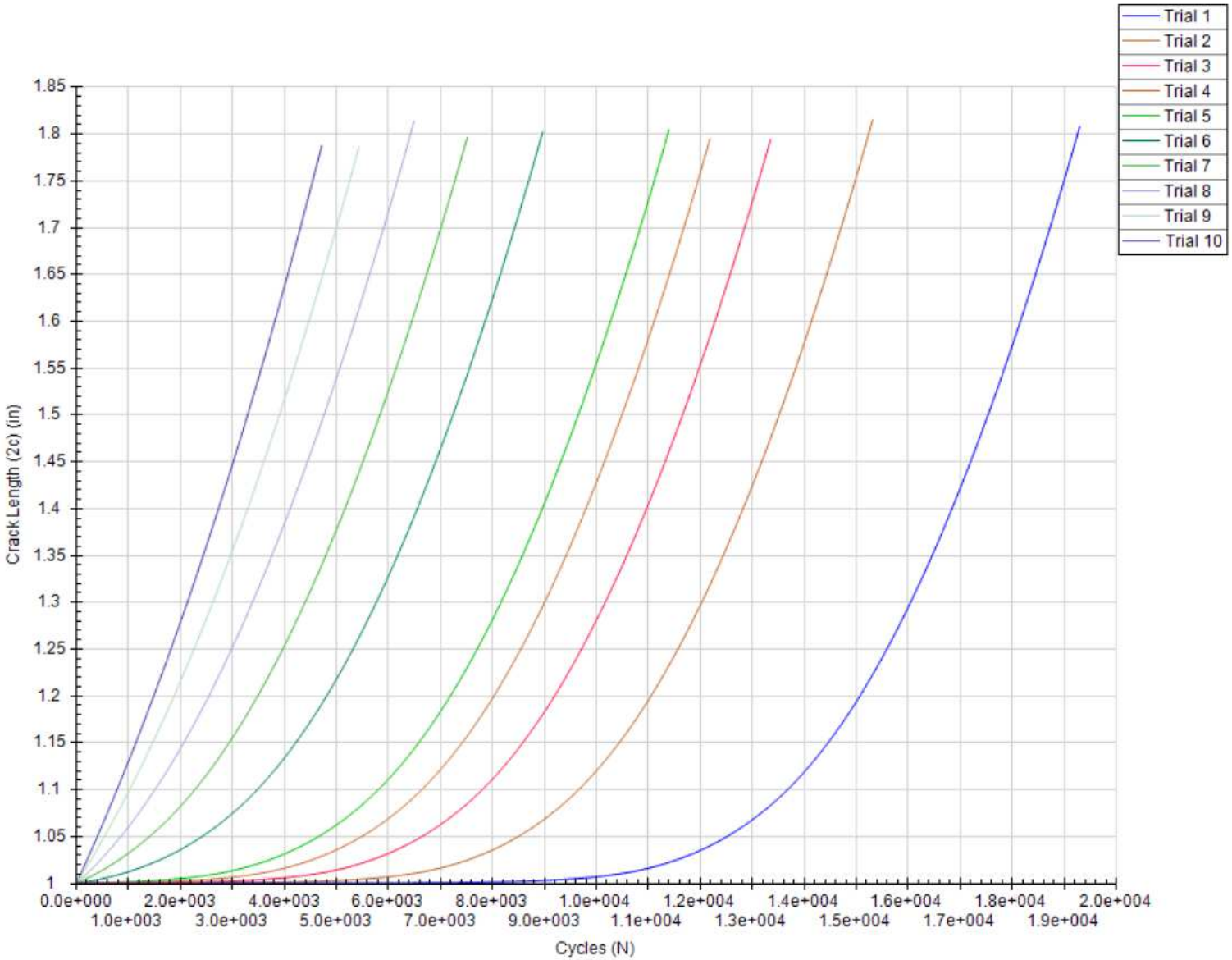

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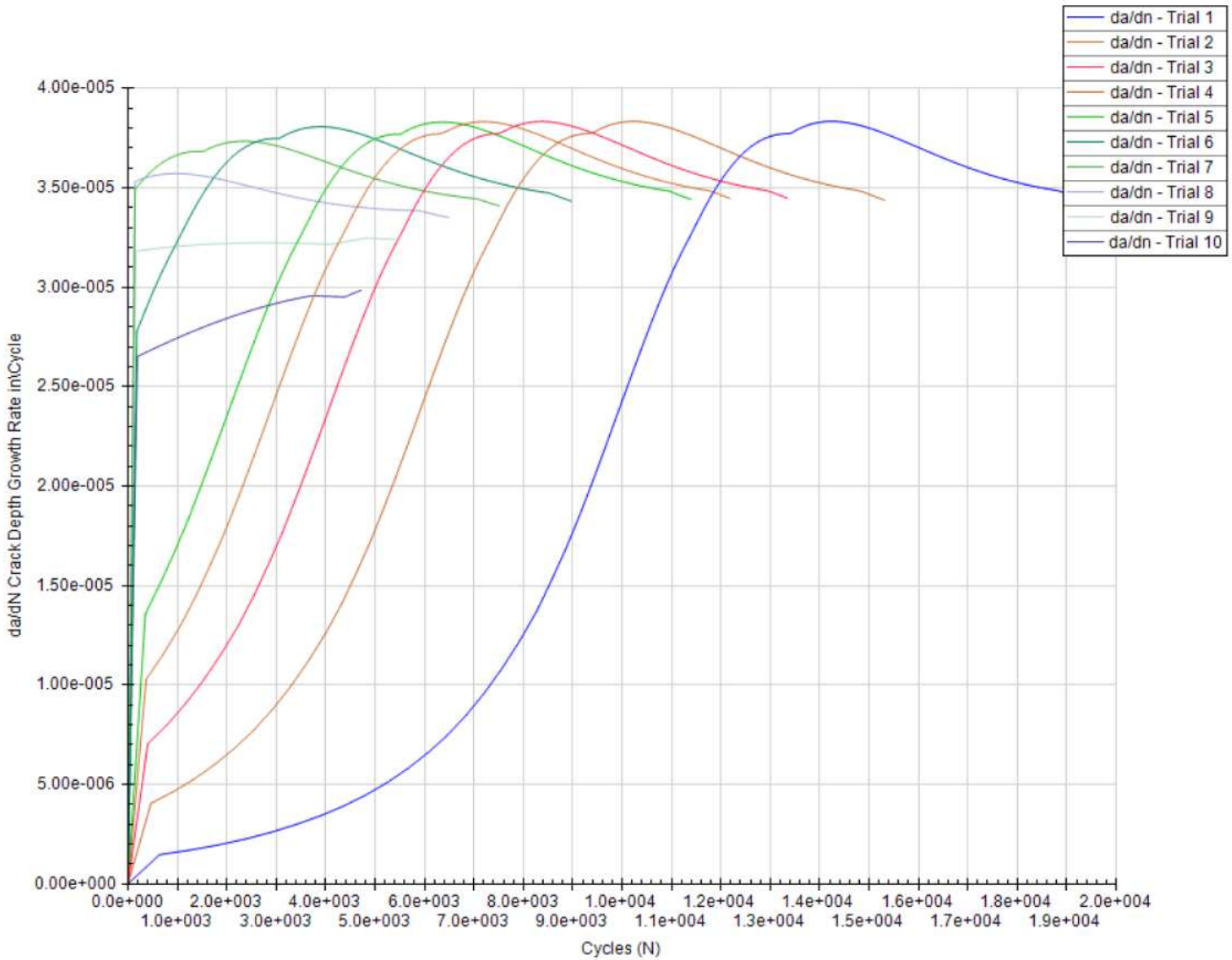

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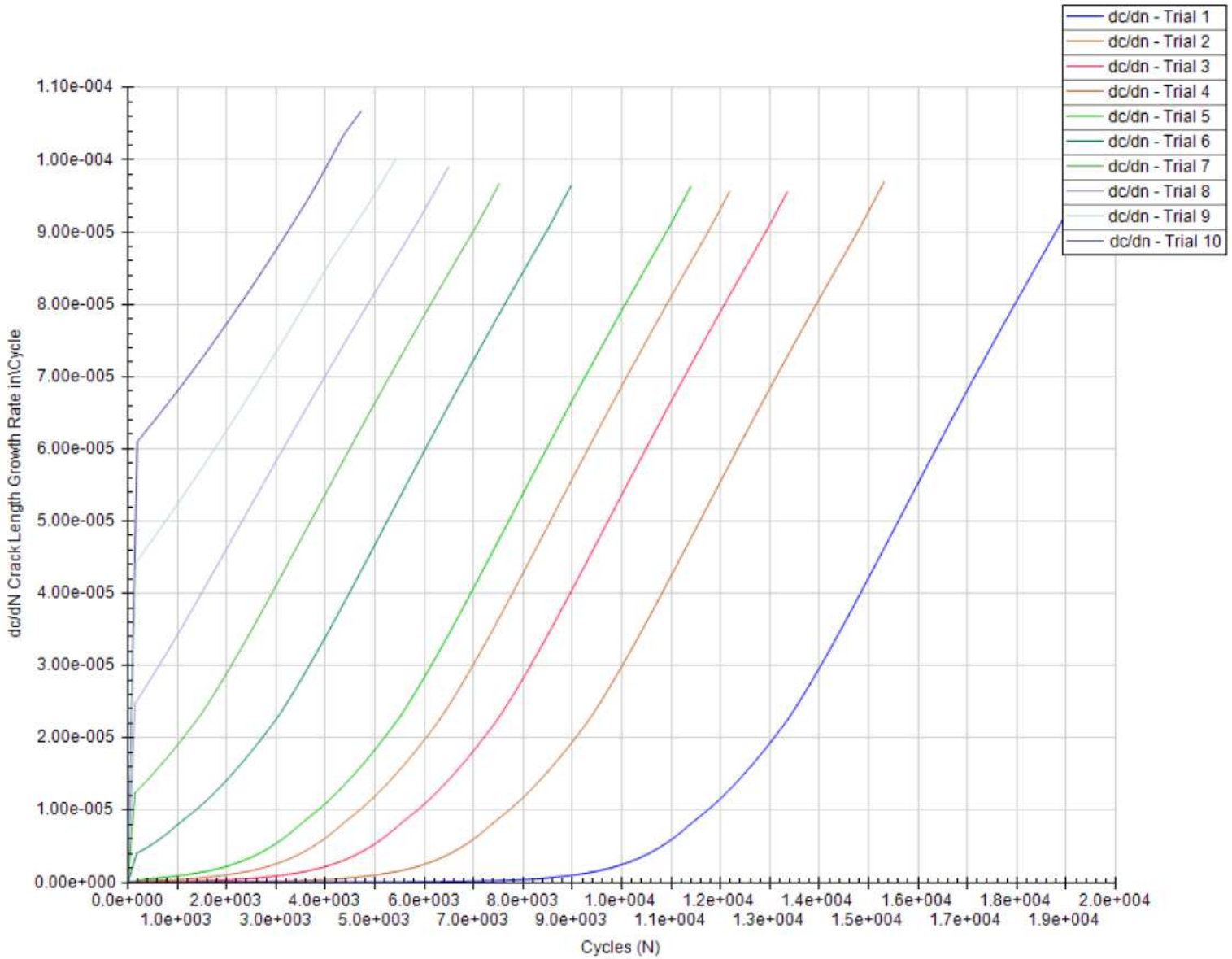

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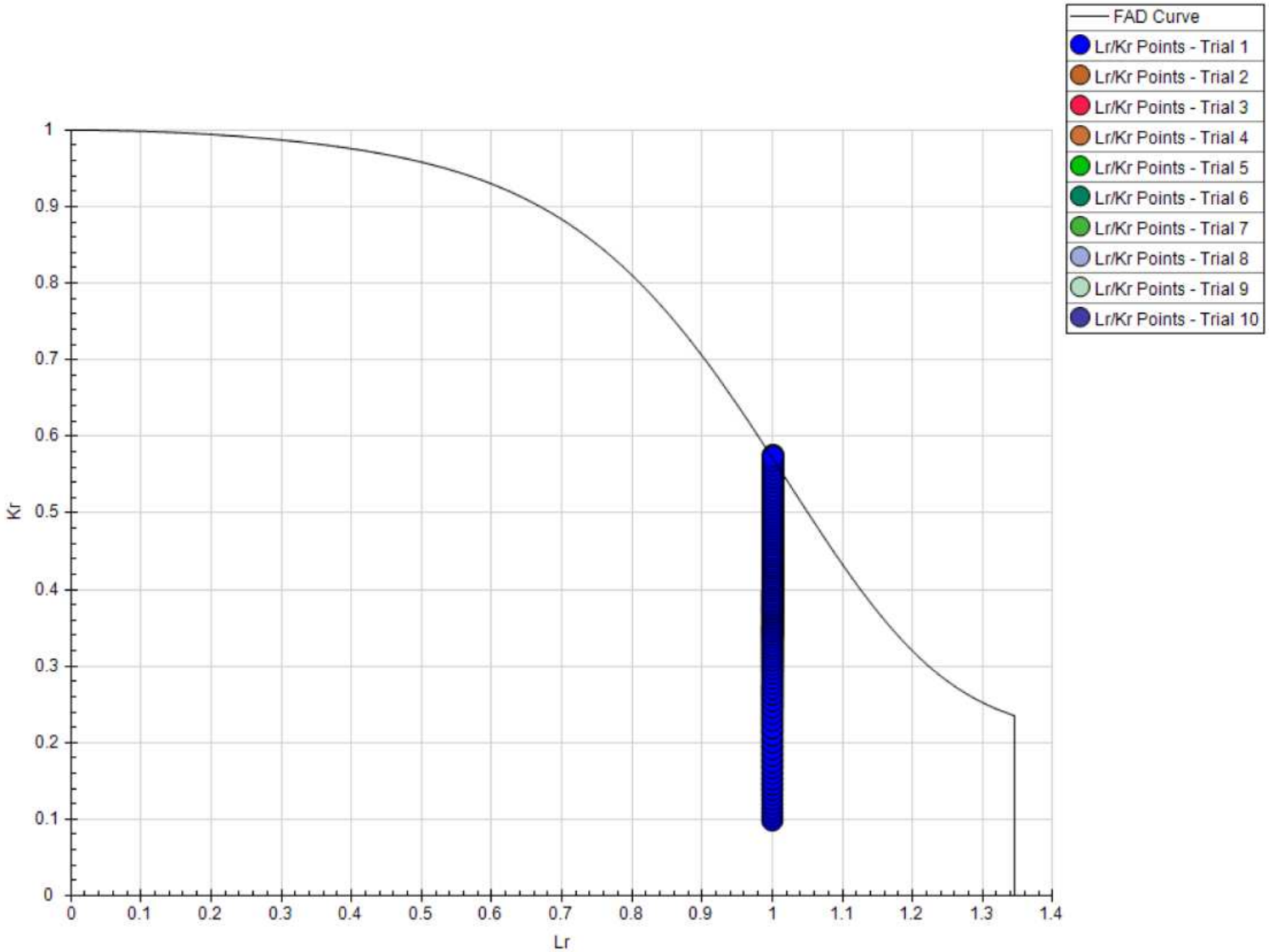
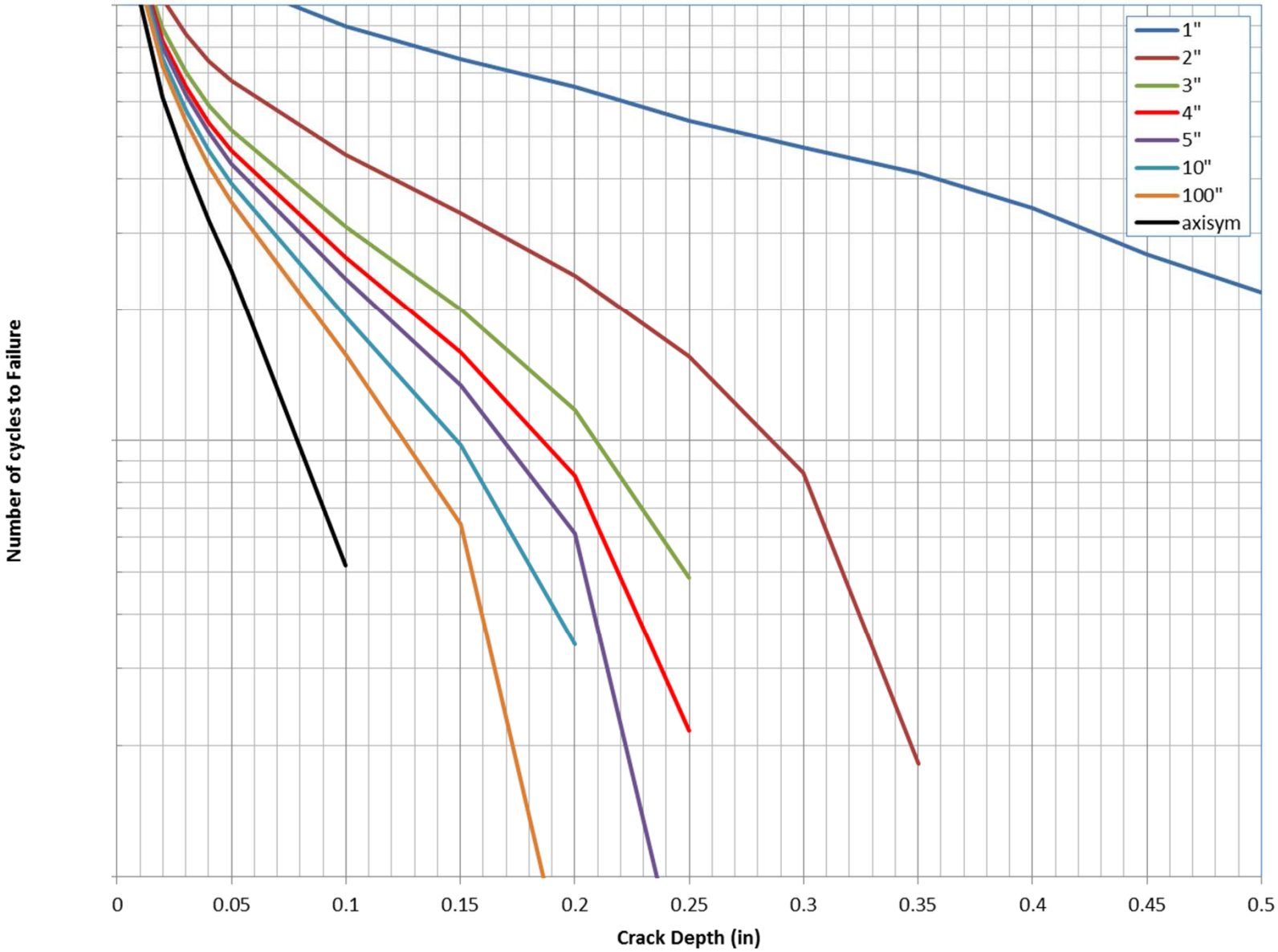
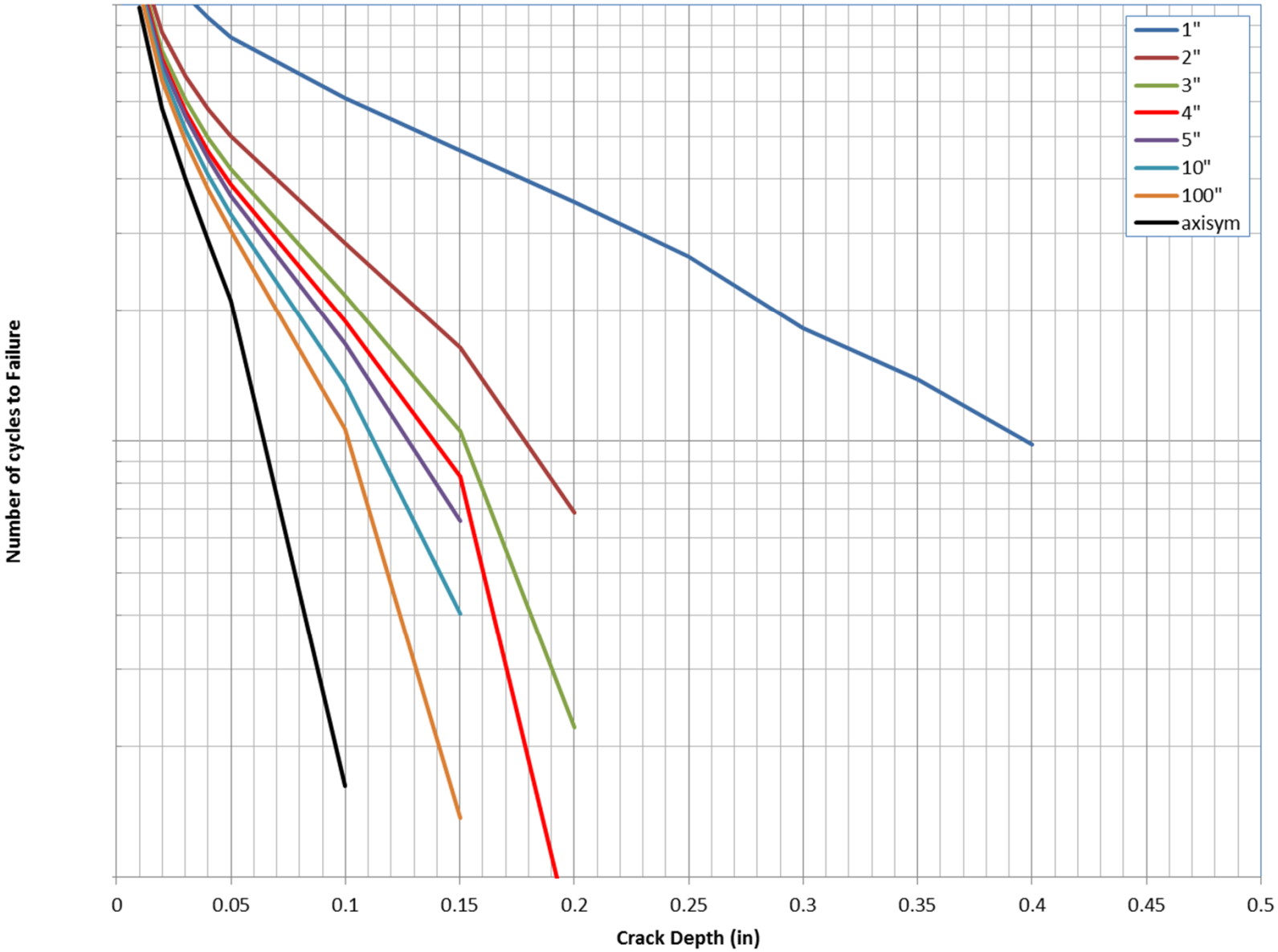


External circumferential cracks in 1” base metal



External circumferential cracks in 1” weld/HAZ metal



SUMMARY

To help understand and predict the behavior of the most common types of shell cracks in a set of coke drums, crack propagation assessment procedures from API 579-1/ ASME FFS-1 of 2007 were used along with measured strains and material properties to generate a set of conservative easy-to-use remaining-life charts that can be used as a basis for crack repair guidelines.