Improved Probabilistic Remaining Useful Life Estimation in Structures: Modeling Multi-site Fatigue Cracking in Oil and Gas Service Structures

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Objective
• Investigate the effect of fatigue in presence of neighboring cracks
• Integrate the failure data into a life prediction model that could be used to predict the life of engineering structures
• Develop a method of accounting for applicable and realistic cracks interaction, validated with acceptable modeling error

Methodology
• Investigating the interactions of neighboring adjacent cracks under cyclic loading using both:
  ✓ Experiments:
    ➢ Output: surface crack growth, crack depth growth, associated number of cycles
    ➢ Reasoning: develop a life prediction model that estimates the number of cycles required to achieve failure in presence of neighboring cracks
  ✓ Simulation:
    ➢ Output: stress intensity factor around the crack
    ➢ Reasoning: justify the crack development behavior under different fatigue and geometrical conditions

Approach

Step 1: Experimental data collection
- Shows the different fatigue tests performed under different uni-axial stresses for different neighboring cracks geometries.

Step 2: Stress intensity factor simulation
- Explains the physics of failure aspect
- Focuses on the stress intensity factor (SIF) around the cracks and how it changes around the crack as it propagates in presence of neighboring cracks.

Step 3: Model development
- Shows different statistical tools and analysis used to develop the life prediction model. Bayesian analyses will be the core of the modeling efforts.

Step 4: Model validation and uncertainty characterization

Results

- Surface crack length:
- Crack depth:

Probabilistic Modeling

- Data scatter development
- General model development
  \[ a_i \sim N(\mu_i, \sigma_i) \]
  \[ \mu_i = f(N_i, SR_i | \alpha_1, \alpha_2, \ldots) \]
  \[ \sigma_i = f(N_i, SR_i | \gamma_1, \gamma_2, \ldots) \]

Where N is the number of cycles and SR is the neighboring cracks size ratio

\[ p(\theta | data) = \frac{p(data | \theta), p(\theta)}{p(data)} \]
\[ \theta = \{\alpha_1, \alpha_2, \ldots, \gamma_1, \gamma_2, \ldots\} \]

(Azarkhail & Modarres, 2007)