Environmentally Assisted Fatigue

EPRI Overview

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NRC Meeting on Fatigue Research and Related ASME Activities
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Background

- Nuclear plants designed in accordance with ASME Section III are required to address fatigue usage
  - Cumulative usage factor (CUF) must be less than 1.0
  - CUF is calculated using ASME Code S-N curves which are based on testing in air
- Since 1999, plants applying for license renewal have been required to address environmentally assisted fatigue (EAF)
  - Fatigue specimen testing in water environments has shown reduced cyclic life
  - Consideration of EAF has typically been accomplished through the application of an environmental factor, F_{en}
  - Demonstrating that CUF_{en} is less than 1.0 has been a significant challenge for the industry
- High calculated CUF_{en} values have not been substantiated by actual plant service experience

Meeting Objectives

- Provide NRC staff with an overview of EPRI's EAF efforts
- Obtain critical early feedback on current and planned ASME Code initiatives
- Identify areas for additional research or evaluation
- Identify opportunities for collaboration

Current EPRI Perspective on EAF

License Renewal

- No urgent need for improved methods; most plants have submitted applications and received NRC approval
- Locations not meeting regulatory criteria using current analytical methods can be addressed by elastic plastic analysis (EP) or monitoring (both expensive)

Second License Renewal

- Introduce an appropriate level of conservatism in analysis and test data that will likely be required for 80 years

New Plants

- No significant issues with current licensing period
- Introducing an appropriate level of conservatism will be useful for longer-term operation
- Alternative EAF analysis methodologies have been submitted for consideration and need NRC approval

Flexible Operations

- Some plants have used a reduced number of design cycles based on base-loading to satisfy cumulative usage requirements
- Load following operation may exceed cumulative usage factor requirements

Overview of EPRI EAF Effort

Objective

Ensure that EAF can be addressed in both current & new plants in a consistent manner that meets nuclear safety objectives while assuring appropriate level of conservatism

Applicability

Better understanding leads to increased accuracy of environmental fatigue curves and more accurate fatigue crack growth rates that can then be used to optimize the fatigue licensing basis.

Data are expected to be available to support some of the later license renewal applicants, applicants for extended operation (60-80 years), flexible operation considerations, and new plant applicants.

Results Implementation

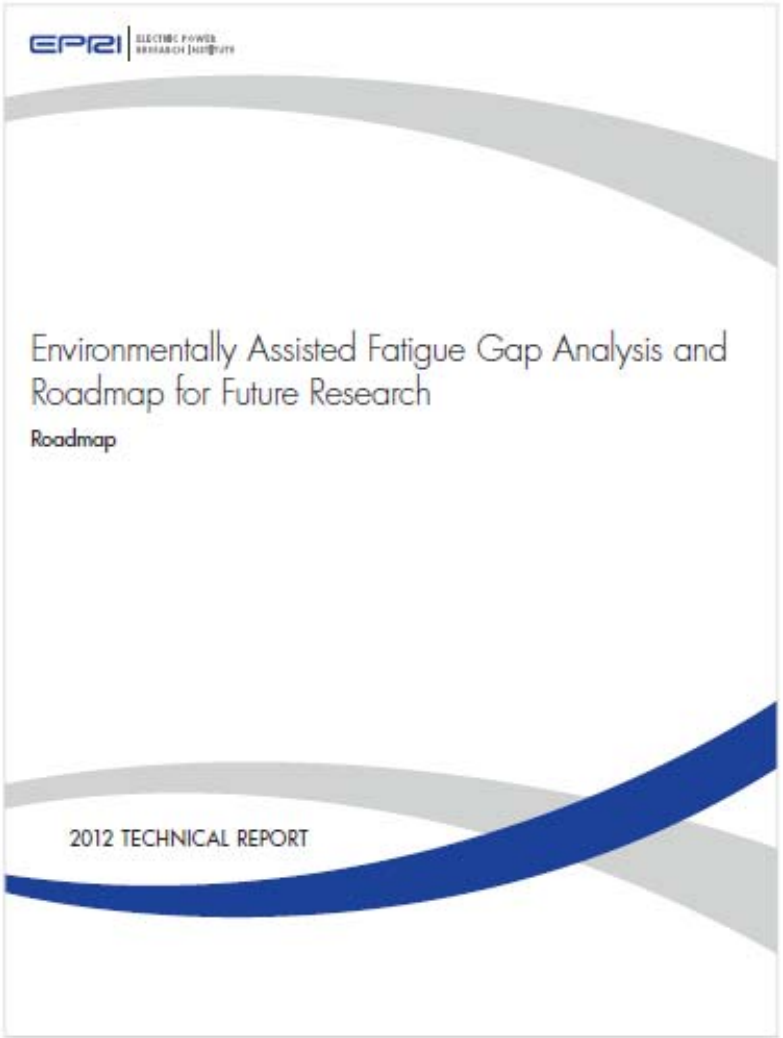
Develop the technical basis for ASME Code modifications and Code Cases that support refined procedures for assessing fatigue environmental factors

Promote consistent procedures for use by vendors, construction firms, and utilities

Support ASME Section III and XI Code revisions that explicitly incorporate EAF procedures

Environmentally Assisted Fatigue Roadmap

- *Environmentally Assisted Fatigue Gap Analysis and Roadmap for Future Research*
  (Dec 2012, Report ID 1026724)
  - Gap prioritization performed by industry expert panel
  - 21 gaps identified as high priority
  - 7 hypotheses proposed to explain the apparent discrepancy between test data and field experience



Environmentally Assisted Fatigue
Sponsorship & Organization

- EPRI Programs funding EAF Activities
  - Materials Reliability Program (MRP)
  - Boiling Water Reactors Vessel Integrity Program (BWRVIP)
  - Advanced Nuclear Technology (ANT)
  - Primary Systems Corrosion Research (PSCR)

- Overall Coordination - David Steininger (dsteinin@epri.com)

- 'Short-Term' or Analytical Committee led by Nathan Palm of BWRVIP (npalm@epri.com)
  - Address knowledge gaps pertaining to conservatisms in analytical methodologies
  - Develop the technical basis for ASME Code modifications and Code Cases that support refined procedures for assessing fatigue environmental factors

- 'Long-Term' or Experimental Committee led by David Steininger (dsteinin@epri.com)
  - Address knowledge gaps pertaining to mechanistic understanding of EAF
  - Resolve perceived discrepancies between EAF methodology, existing test data, and industry operating experience
  - Chair, International EAF committee coordinating EAF testing world wide. Committee spear heading testing of full, prototypical test fixture.

Analytical Committee Activities
Existing EPRI Guidance Documents

Selection of Locations for EAF Evaluation

- *Environmentally-Assisted Fatigue Screening, Process, and Technical Basis for Identifying EAF Limiting Locations*
  - Issued September 2012
  - Product ID: 1024995

Calculate CUF

- *Stress-Based Fatigue Monitoring Methodology for Fatigue Monitoring of Class 1 Nuclear Components in a Reactor Water Environment* (FatiguePro Basis)
  - Issued December 2011
  - Product ID: 1022876

Calculate F_{en}

- NUREG/CR-6909
- Regulatory Guide 1.207
- Both documents currently under revision

Calculate CUF_{en}

- *Evaluation of Controlling Transient Ramp Times Using Piping Methodologies When Considering Environmental Fatigue*
  - Issued September 2007
  - Product ID: 1015014
- *Guidelines for Addressing Environmental Effects in Fatigue Usage Calculations*
  - Issued December 2012
  - Product ID: 1025823

Analytical Committee Activities
Current Activities

- Efforts directed by EPRI EAF Focus Group comprised by industry fatigue practitioners
- Two projects to propose changes to conventional fatigue CUF calculations are underway
  - Alternative Approaches for ASME Code Simplified Elastic Plastic Analysis
  - Fatigue Usage Gradient and Life Factors
  - Projects will be discussed in detail in subsequent presentations
- Proposed changes to CUF calculations would partially offset F_{en} penalty under EAF conditions
- Proposals being made to and vetted by appropriate ASME Code committees
  - WG Design Methodology has jurisdiction for applicable Code sections
  - WG Environmental Fatigue Evaluation Methods also being engaged for additional stakeholder input

Experimental Committee Activities

- Begin with high-priority gaps from EPRI EAF Roadmap
- Understand relationship of gaps to hypotheses
  - Understand and characterize critical environmental effect variables
  - Reconcile lab data and operating experience
- Use of RFP process to identify industry capabilities and solicit input
- Establish a 5 year collaborative & coordinated testing plan
- Activities will be discussed in detail in the next presentation

Summary and Conclusions

- EAF has mostly been addressed for plant operation up to 60 years, although this has often required detailed analyses or transient monitoring
- Additional challenges may be encountered for plants to operate to 80 years or perform flexible operation
- Development of modified analysis methods would help to reduce CUF_{en} and address these challenges
- Additional testing is needed to understand the disconnect between fatigue specimen testing and plant component operating experience
- Testing that is more representative of actual plant operation is expected to provide data for future revision of the F_{en} factor

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