STRUCTURING A PROBABILISTIC MODEL FOR RELIABILITY EVALUATION OF PIPING SUBJECT TO CORROSION-FATIGUE DEGRADATION

Professor Mohammad Modarres

Center for Risk and Reliability
Department of Mechanical Engineering
University of Maryland
College Park, US

Presented to ADNIC/PI Visitors
Riggs Alumni Center
University of Maryland
June 11, 2012

Copyright 2012 by M. Modarres
Research work

• Probabilistic model for reliability evaluation of piping subject to corrosion-fatigue degradation: Dr. Mohamed Chookah

• Pitting corrosion modeling: Abdallah Al Tamimi and Taher Abu Seer

• Advanced probabilistic modeling for reliability evaluation of piping subject to multi-site fatigue and other environmental stresses: Abdallah Al Tamimi (PhD Candidate)

• Probabilistic-mechanistic approach to modeling stress corrosion cracking: Gary Wu

• Classification and probabilistic model development for creep failures of structures: a study of X-70 carbon steel: M. Nuhi
Reliability Engineering Graduate Program

- World’s largest and most comprehensive concentration of education and research activities in risk, reliability, and safety of engineered systems and processes
- Offering MS, PhD, and Graduate Certificate in Reliability Engineering and Risk Analysis
- 21 Graduate Courses in diverse areas of risk, reliability and safety.
• Formed in 2003, umbrella organization for many of the risk and reliability research and development activities in the Clark School of Engineering
• 23 Full Time, Adjunct, and Affiliate Faculty
CRR Research Laboratories

- Hybrid Systems Reliability Laboratory
- Information Assurance Laboratory
- Human Reliability Laboratory
- Microelectronics Reliability Laboratory
- Mechanistic and PPoF Laboratory
High Level View of the New DPRA Platform (SimPRA) (A. Mosleh –NASA)

Risk Based Design
Dynamic PRA of X-ware Systems
Objective

Pitting and Fatigue leading to Pipe Failure - Ductile Iron

Degradation of pipeline due to corrosion and fatigue

Leaks & ruptures

Unwanted plant shutdowns

Consequences

Cost due to inspection & repair

Cost due to loss of production

Cost due to impact on environment

Predict the extent of degradation to prevent or reduce consequences

→ here comes the need for probabilistic Models
Objective

• Why Physics based probabilistic model?
  
  • PoF (Physics of Failure) models capture material degradation and failure mechanism and forms the basis for prognosis and health management of structures

  • Probabilistic models can adequately represent all of the factors that contribute to variability
    
    • Materials properties
    • Environmental stresses
    • Human and sensor-based inspections
    • Human and other detection errors
Example: Corrosion-Fatigue Modeling

- Basic degrading elements

- Cyclic Load
- Material Microstructure
- Environment

Corrosion Fatigue
Example: Corrosion-Fatigue Modeling (Cont.)
Pitting Corrosion

- Pitting Corrosion is an electrochemical oxidation reduction process, that occurs within localized holes on the surface of metals coated with a passive film.
  - A pitting corrosion model was constructed
  - one conference paper was published
Corrosion Fatigue Testing

- Corrosion fatigue experimental work was done using in UMD labs

\[ a = A \cdot \sigma^{0.182} \cdot \nu^{-0.288} \cdot I_p^{0.248} \cdot N^{1/3} + \]

\[ B \cdot \sigma^{3.24} \cdot \nu^{-0.377} \cdot I_p^{0.421} \cdot N^2 \cdot e^{(4 \times 10^{-10} \cdot \sigma^{2.062} \cdot \nu^{0.024} \cdot N)} \]
Multi-Site Corrosion Fatigue

• simultaneous development of fatigue cracks at multiple sites in the same structural element, such that fatigue cracks may coalesce to form one large crack

• This will lead to having a realistic model that could be used in the industry

• The experimental work will be done in collaboration with Honeywell corrosion lab facility in Houston, Texas
Vision for Next Phase Research

- Multi-Site Pitting and Corrosion Fatigue
- Incorporation of Inspection and Sensor Data and Updating of the Models Developed: Pitting, Corrosion-Fatigue, Stress-Corrosion-Cracking, and Creep
- Accounting for Uncertainties in Visual and Sensor-Based Inspection Data
- Bayesian Updating of the Models using ADNOC data and Experiences in Past Pipeline Failures
- Risk Management and Decision Making for Operational, Replacement and Maintenance Policies
THANK YOU