

Probabilistic Fracture Mechanics

Patrick Raynaud, RES/DE/CIB

Stephen Cumblidge, NRR/DE/EPNB

Mark Kirk, RES/DE/CIB

Annual Materials Meeting

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Probabilistic Fracture Mechanics (PFM) Background

- New way of looking at engineering problems
 - PFM and DFM both address uncertainty, but differently
 - No longer 1 deterministic conservative analysis
 - Many deterministic analyses with randomly sampled inputs
 - Statistics performed on collection of outputs to determine probability of an event

Probabilistic Fracture Mechanics (PFM) Regulatory Issues

- Difficult for NRC staff to reproduce or verify PFM calculations
 - Complex regulatory review
 - ‘Black Box’ codes with insufficient vetting of inputs and code: low confidence in outputs
- Challenges where PFM was proposed as regulatory basis for long term inspection programs under NRC rulemaking
 - MRP-105, “Materials Reliability Program Probabilistic Fracture Mechanics Analysis of Pressure-Water Reactor [PWR] Reactor Pressure Vessel Top Head Nozzle Cracking,” dated April 2004
 - MRP-113, “Materials Reliability Program Probabilistic Fracture Mechanics Analysis of PWR Reactor Pressure Vessel Top Head Nozzle Cracking,” dated July 2004

Need for PFM Guidance

- With advent of xLPR, increased number of industry PFM submittals expected
 - Proposed alternatives to ASME BPVC and ASME Code Cases
 - PFM calculations with new or modified PFM codes
 - Relief requests and topical reports
- Need to develop a regulatory guide to better inform applicants using PFM as a technical basis to support relief requests, license amendment requests, and topical reports
- Project main steps / deliverables
 - Technical Letter Report (short term, high level)
 - NUREG (longer term, in-depth technical basis)
 - Regulatory Guide (in parallel with NUREG)
 - Staff review guidance
 - Pilot study to test draft guidance

PFM Confidence Technical Letter Report (1/2)

- GOAL: highlight important concepts that are relevant for PFM quality and confidence
- Topics covered:
 - Definition of PFM, including similarities and differences with deterministic analyses
 - Analysis models
 - Selection, definition
 - Verification & validation
 - Uncertainty
 - How to gain confidence in models used in PFM analysis?
 - Analysis inputs
 - Construction of input distributions
 - Input bounds
 - Quantification of assumptions and conservatisms

PFM Confidence Technical Letter Report (2/2)

- Topics covered (cont'd)
 - Uncertainty framework
 - Identification and classification of uncertainty (epistemic/aleatory)
 - Probabilistic framework development, verification, and validation
 - Uncertainty propagation, sampling techniques
 - Analysis outputs
 - Convergence and stability
 - Output uncertainty analysis
 - Sensitivity analyses and studies
 - Problem drivers and confidence demonstration
 - Assessment of PFM quality
 - Displayed vs. required quality
 - Performance metrics

PFM Draft Regulatory Guide (DG) and Technical Basis NUREG (1/2)

- Draft guidance will outline a path for generating an acceptable PFM analysis
 - Process chart
 - PFM analysis tools
 - PFM analysis methodology
 - Reporting guidelines
- NUREG will follow DG outline and provide technical bases and other necessary details
- PFM analysis tool
 - Quality requirements and standards
 - Different paths to show acceptable quality based on ‘pedigree’ of tool

PFM Draft Regulatory Guide (DG) and Technical Basis NUREG (2/2)

- PFM analysis methodology
 - Inputs
 - Analysis parameters, initial analysis, advanced analyses
 - Output uncertainty analysis
 - Convergence and stability
 - Sensitivity analyses and studies
 - Results assessment
 - Decision-making
- Reporting requirements
 - Software Quality Assurance (SQA)
 - Detailed documentation of analyses

Pilot Study: Testing the Draft PFM Guidance

- Define pilot study to test draft guidance
 - Use xLPR but do not treat as NRC code
 - Reference xLPR V&V to satisfy SQA requirements
 - Fictitious piping failure analysis problem that can test various aspects of guidance
- Follow draft guidance as best as possible
- Identify deficiencies in guidance
- Correct deficiencies in guidance
- Update draft guidance

Project Schedule and Milestones

- Final TLR available ~June 2017
- Draft Guidance and supporting NUREG technical basis:
 - Round #1
 - Initial Draft Guide (internal to NRC): September 2017
 - Initial supporting NUREG (internal to NRC): November 2017
 - Subsequent drafts through FY18
 - To be informed by pilot study lessons-learned, NRR review, and feedback from public meetings
- Pilot study:
 - Round #1:
 - Initial definition of pilot study in FY17
 - Initial study completed by March 2018
 - Subsequent rounds: April to September 2018
 - As needed based on changes to draft guidance

- Public meetings:
 - Today
 - ACRS and public meeting after 1st round pilot study: May 2018 target
 - ACRS after final draft guidance is completed: September-December 2018 target

PFM Education and Training

- Work on PFM consistent with NRC's risk-informed goals, however it is not as familiar as it might be to all practitioners & reviewers.
- Familiarization with PFM, and it's many commonalities with deterministic approaches, enable more efficient review of PFM applications in the future