

**Progress of Japanese activities
in development and standardization
of PFM methodology for PTS evaluation**

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W14 Deterministic vs. Probabilistic Assessment of Component Integrity
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Q & A

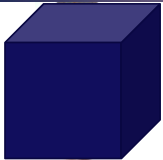
- Question posed
 - What are the most important considerations when using probabilistic fracture mechanics?

- Possible answer
 - Understanding or removing of complication in PFM process to establish the general acceptance.

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How the PFM looks like?

Deterministic




→

Acceptable or Unacceptable

Simplicity brought by (excessive) conservatism

Probabilistic



→

10⁻⁶

Additional step required for the decision make (Ex. 10CFR50.61a)

How reliable the criteria is?

The decision makers are not necessarily the PFM experts


Quantitative and realistic! ...but cannot be directly used for decision making.

Need to understand the complicated physics behind the "probability."

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How PFM can archive the general understanding



- Improvement of PFM code
 - Reliability assurance
 - Improvement of input data and RPV model
 - Employment of sophisticated calculation method
- Consensus to PFM procedure
 - Benchmarking
 - Establishment of guide, which will help the selection of detailed PFM process to obtain unique "probability."
- Education
 - Continuous discussion in PFM techniques
 - Text book for PFM
 - Lecture
 - Exercise using PFM as a structural integrity assessment tool

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Improvement of PFM code

- PASCAL3 code (JAEA; Japan Atomic Energy agency)^[1]

"Failure Probability Evaluation Based on Domestic Regulatory Framework and the Latest Information using PFM for RPVs"

 - Codified based on codes and standards in Japan
 - JSME Rules on Fitness-for-Service
 - JEA Codes on Fracture Toughness^[2, 3]
 - Implementation of the latest fracture mechanics research results
 - Stress Intensity Factor Calculation
 - Master Curve Method
 - Probabilistic Models based on Domestic Data
 - Fracture Toughness K_{Ic} and K_{IIc} curves for Japanese materials
 - Employment of new embrittlement trend curve (JEAC4201-2007(2013addenda))^[3]
- Development of a FAVOR based code for Japan
 - Employment of Japanese embrittlement trend curve (JEAC4201-2007(2013addenda))
 - Employment of JEAC4206-2016^[3] based K_{Ic} curve
 - Master Curve based K_{Ic} curve
 - T_c by Master Curve is replaced with $T_{30} + \Delta T_1$ ^[4]

[1] IWES, International Symposium on Improvement of Nuclear Safety Using Probabilistic Fracture Mechanics (2014).
 [2] Japan Electric Association Code, JEAC4201-2007 (2013 addenda)
 [3] Japan Electric Association Code, JEAC4206-2017
 [4] Yoshitake et al., Proc., ASME PVP conference, PVP2015-45275 (2015)

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Consensus to PFM procedure

- Development of Japan Electric Association Guide (JEAG) for PFM
 - Purpose of the guide
 - Assuring the uniqueness of resulted probability
 - Contents
 - PFM analysis procedure that can be recommended for RPV PTS evaluation
 - Background methodology and line up of variables to be considered.
 - Consistency to related standards and activities.
 - Employment of the latest research results from inside and outside Japan
 - Embrittlement trend curve by JEAC4201-2007(2013 addenda)
 - K_{Ic} curve by JEAC4206-2016
 - Working group
 - Broad discussion among academia, plant maker and utility
 - First draft is under discussion among the working group
- Industrial side activities for PFM research and information exchange
 - PFM experts (Univ. of Tokyo, Ibaraki univ., Nagaoka univ. of Tech., JAEA, MHI, IHI, TEPSYS, CRIEPI...)
 - International and domestic benchmarking activities
 - Development of new codes and tools for PFM analyses


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Education

- Prof. Shinobu Yoshimura (Univ. of Tokyo) is leading the educational scenes through PFM subcommittee in JWES.
 - Lecture, conference
 - JWES international symposium on Improvement of Nuclear Safety Using Probabilistic Fracture Mechanics (2014), Invited lecturer: Dr. Mark Kirk
 - JSME Material and Mechanics conference 2015, PFM panel session (2015)
 - Text book
 - Probabilistic Fracture Mechanics for Risk-Informed Activities – Fundamentals and Applications -
 - International benchmark study



http://www.it.jwes.or.jp/inf/index.jsp
English version will be available soon



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Open issues

- (Personal opinion) How to simplify and clarify the PFM process
 - ✓ Calculation of total probability controlled multi-variables is one of the greatest advantage of PFM.
 - ✓ "Many variables" may be a cause of complication.
 - ✓ PFM can be used for determine "what are the effective variables."
 - ✓ Is it possible to make a simplified and understandable PFM code?
- Effect of "deterministic assumption" on probability
 - ✓ Are there any of deterministic assumptions that drastically affect the probability. ex) Assumption of crack shape change from embedded elliptical crack to infinite crack, conservative proximity rule...
 - ✓ Such the deterministic boundaries are to be set so as to give little effect on probability.
- How to effectively carry out the education?
 - ✓ How do we minimize the discrepancy between the feeling between technical side and publics on probability? (The discrepancy between "hardly be happening" and "someday may be happening.")
- How PFM can contribute to PRA?
 - ✓ Are there any possibility of to have quantitative relationship? Is 10^{-8} really 10^{-2} ? For example, how 5×10^{-7} will affect the CDF probability?

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