

## U.S. NUCLEAR REGULATORY COMMISSION PUBLIC MEETING SUMMARY

**Title:** Public Meeting on Draft NUREG-2228 on Weld Residual Stress Validation and Extended Finite Element Research Project

**Meeting Identifier:** 20180999

**Date of Meeting:** September 24, 2018

**Location:** U.S. Nuclear Regulatory Commission  
One White Flint North, O9-B4  
11555 Rockville Pike  
Rockville, MD 20852

**Type of Meeting:** Category 2

**Purpose of the Meeting:** (1) Provide overview of draft NUREG-2228, 'Weld Residual Stress Finite Element Analysis Validation: Part II – Proposed Validation Procedure' (ADAMS ML18242A007). (2) Discuss initial stakeholder feedback on the draft NUREG issued for public comment. (3) Provide overview on the NRC research program on applications of Extended Finite Element Analysis for assessment of reactor component integrity.

### **Summary:**

The U.S. Nuclear Regulatory Commission (NRC) held a Category 2 public meeting on September 24, 2018 from 1:00 p.m. to 5:00 p.m. eastern daylight saving time. NRC and Electric Power Research Institute (EPRI) representatives participated in the meeting. Specific attendees of the meeting are listed in the Appendix.

Michael Benson, Office of Nuclear Regulatory Research (RES), began the meeting by presenting an overview of draft NUREG-2228. Patrick Raynaud, RES, followed by presenting more details on the metrics and acceptance measures found in NUREG-2228. The slides for these presentations are publicly available in NRC's ADAMS system at ML18270A091 and ML18270A089, respectively.

Gary Stevens, EPRI, led a discussion of the U.S. nuclear industry's initial feedback on draft NUREG-2228. A summary of all comments received during the meeting is included in the Appendix. While the staff responded to the comments in the Appendix, the staff is not committing to specific actions on the draft NUREG at this time. The staff will decide on appropriate actions after the formal public comment period is ended.

Giovanni Facco, RES, provided an overview of NRC's research project on the extended finite element method (xFEM). This project aims to continue developing in-house technical capabilities in RES. The talk included a brief description of an international research project on xFEM performed under the Committee on the Safety of Nuclear Installations (CSNI). The slides for this presentation are publicly available in NRC's ADAMS system at ML18270A092. The U.S. nuclear industry's feedback on the xFEM project are included in the Appendix.

No members of the general public attended this meeting or addressed the NRC staff during the public comment portion of the agenda.

**Action Items/Next Steps:**

- The U.S. nuclear industry should finalize their comments for the formal public comment period.
- The NRC staff should respond the comments received during the formal public comment period, make any necessary changes to the NUREG, and publish the final NUREG.

## APPENDIX

### Attendee List:

<b>Name</b>	<b>Organization</b>
Patrick Raynaud	NRC
Giovanni Facco	NRC
Bob Davis	NRC
Raj Iyengar	NRC
Steve Ruffin	NRC
David Dijamco	NRC
Jay Collins	NRC
Keith Hoffman	NRC
Andrew Johnson	NRC
Rob Tregoning	NRC
Ali Rezai	NRC
John Tsao	NRC
Daniel Leary	Rolls-Royce
Seiji Asada	Mitsubishi Heavy Industries
John Broussard	Dominion Engineering, Inc.
Glenn White	Dominion Engineering, Inc.
Gary Stevens	EPRI
Dave Rudland	NRC
Daniel Sommerville	EPRI
Ronald Janowiak	Exelon
Do Jun Shim	Structural Integrity Associates, Inc.
Christopher Lohse	Structural Integrity Associates, Inc.
Jana Bergman	Curtiss-Wright Corporation
Ashok Nana	Framatome

## Summary of U.S. Nuclear Industry Comments on Draft NUREG-2228:

- What is the industry expected to do with the procedure in the draft NUREG?
  - The staff suggests that the relevant ASME Code committee consider the draft NUREG content for potential implementation. Any actions beyond the Code is up to further discussion.
- Would the NRC expect this procedure to be implemented for industry-submitted relief requests?
  - NRR has no immediate plans to require a validation procedure for licensee relief requests. However, this process can increase confidence in residual stress calculations, leading to greater regulatory stability and enhanced technical justification for the granting of relief.
- What is the fabrication history of the mockup?
  - Fabrication details are summarized in Chapter 2 of draft NUREG-2228. The document also references other publicly-available reports that provide more details on fabrication history.
- Can NRC clarify how bootstrapping was used?
  - Bootstrapping allows for determination of relevant confidence bounds and tolerance bounds for the dataset. The most important application of bootstrapping in the draft NUREG is found in Section 5.2, where a method to compare measurements and modelling results was introduced.
- Does the NRC envision that additional validation datasets will be needed?
  - The Phase 2b dataset covers a certain class of problems: dissimilar metal butt weld with multiple welds (i.e., repair weld, nozzle-to-safe end weld, safe end-to-pipe weld). While many applications are well represented by the Phase 2b mockup, there are welding configurations that may benefit from additional data to demonstrate modeling proficiency.
- If an analyst is validated against the Phase 2b mockup, must that analyst re-validate for all welding processes and geometries?
  - The NRC expects that the Phase 2b dataset will represent a wide class of problems encountered by the nuclear industry, making re-validation unnecessary in many cases. The meeting participants discussed what circumstances might require re-validation (e.g., high heat input, high deposition rate processes; materials exhibiting phase changes; and 3D moving arc analyses).
- Section 5.4.7 seems to say that one needs to come up with metrics for each and every case being analyzed.
  - The metrics and acceptance measures presented in the draft NUREG are specific to the Phase 2b mockup. This mockup is intended to be representative of a wide class of problems. If validating a process not well represented by the Phase 2b mockup, then metrics and acceptance measures may need to be re-developed.
- Weld residual stress distributions have been published in the past. With the publication of this draft NUREG, will those existing distributions be questioned by the staff?
  - The staff is not questioning the basis of currently-published distributions.
- Why did the NRC choose a benchmark based upon the predictions rather than the measurements?
  - The staff presented an argument in Section 5.4.2 of the draft NUREG on this point. However, the staff recognizes that an argument may be made in favor of the measurements. In the federal register notice announcing the public comment period for draft NUREG-2228, the staff requested public feedback on this topic.

Alternative methods for addressing this issue should be proposed to the NRC staff, along with an appropriate technical justification.

- Regarding Section 5.4.3, the industry cautioned against using through-wall growth as a means to justify acceptance measures. There are cases where allowable flaw sizes are small compared to the wall thickness, which would imply that through-wall growth may not be the optimal means of justification.
  - Developing and justifying metrics and acceptance measures is a challenging technical problem. In the federal register notice announcing the public comment period for draft NUREG-2228, the staff requested public feedback on this topic. Alternative methods for addressing this issue should be proposed to the NRC staff, along with an appropriate technical justification.
- Section 5.4 should be updated to include the material covered in Patrick Raynaud's presentation.
  - The staff will consider this comment before final publication.
- The language introducing the hardening law recommendation should be softened to allow greater flexibility in applying the ideas in draft NUREG-2228.
  - The staff will consider this comment before final publication.
- The bounds on the validation process should be clarified.
  - The staff will consider this comment before final publication.
- The process presented in draft NUREG-2228 is more important than the specific values for acceptance measures in the document.
  - The staff will consider this comment before final publication.
- The staff should consider isotropic hardening as the recommended hardening law.
  - In the federal register notice announcing the public comment period for draft NUREG-2228, the staff requested public feedback on this topic. Alternative methods for addressing this issue should be proposed to the NRC staff, along with an appropriate technical justification.
- The statistical model does not account for stress balancing of the axial stresses that are extracted from an axisymmetric finite element model.
  - While this is true, it is not immediately clear that redoing the analysis to account for this effect would substantially impact the findings of the draft NUREG. However, the NRC is open to improvements upon the methods presented in draft NUREG-2228.
- Axisymmetric models do not account for start/stop locations around the circumference in a true weld.
  - Measurements in the mockup were carefully made to avoid start/stop locations. The draft NUREG showed that axisymmetric models can reasonably predict the behavior away from start/stop locations. Whether 3D moving arc analyses are required to account for start/stop effects should be evaluated from a cost/benefit perspective.
- Why did the staff choose centerline weld residual stress profiles for crack growth studies?
  - Regulatory relief requests in the U.S. are based upon a 1D stress profile for crack growth calculations. The centerline location is convenient because the measurement data was obtained in that location.
- How does one take into account the fact that having the right answer in one location does not mean the solution is correct everywhere?
  - One could envision a validation scheme based upon all the stress contours across the entire cross-section of the component. However, that is a much more complicated process to develop and apply. Since current industry practice in the

U.S. is to extract one (or, at most 2-3) 1D stress profile from finite element stress contours, draft NUREG-2228 focuses on validating that problem.

- What about wavelength uncertainty, in addition to the identified phase and amplitude uncertainty?
  - The uncertainty quantification scheme was based upon established mathematical procedures developed for functional data (see references in the NUREG). Further comments on this topic should include references to published works so that the staff can account for the new information, as draft NUREG-2228 moves forward.
- Please consider an alternative option whereby the modeling organization runs the Phase 2b modeling case with their preferred hardening model as long as they have a documented basis that ensures that they meet the acceptance measures.
  - The acceptance measures currently proposed in draft NUREG-2228 are based upon the assumption of a certain hardening approach (i.e., the averaging approach). This is a consequence of choosing the mean of the models as the benchmark. Therefore, the acceptance measures are not applicable to alternate hardening approaches. Flexibility in hardening approach may be possible if a measurement-based benchmark is employed.
- When can the industry continue engaging NRC on this topic?
  - A second public meeting on this topic may be scheduled, depending on the outcome of the public comment period. The February ASME Code meeting may also be an opportunity to discuss this topic in a public forum.

## Summary of U.S. Nuclear Industry Comments on xFEM Research Project:

- Is this work in-house, or is the NRC relying on contractors?
  - At this time, this work is solely performed in-house in RES. This work was informally endorsed by the Advisory Committee on Reactor Safeguards.
- Are there any industry representatives participating in the CSNI international research project?
  - Structural Integrity Associates, Inc. is participating in the project.
- The NRC should perform a thorough literature survey to learn the range of potential capabilities of xFEM. One proceedings paper discusses xFEM application to studying pressurized thermal shock events. The NRC should be aware that limitations do exist and that different software may behave differently. Round robin studies can help in this regard.
  - The NRC staff will take note of this comment, as the xFEM project progresses.
- Who is funding the international research project?
  - The project is performed under CSNI and lead primarily by BelV (i.e., Belgian regulator technical support) and IRSN (i.e., French regulator technical support). All contributions to the project are in-kind, so required funding is minimal.
- EPRI may consider funding more organizations to participate in the CSNI project.