



EPRI / NRC Joint Program on Welding Residual Stress Model Development and Validation

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Industry – NRC Materials Tech Update

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Program Time Frame

- 2008 to 2011 – Initial joint validation program effort
 - Measurement and modeling of small and full scale mockups as well as canceled plant components
 - Baseline study of variability between modelers and measurements
- 2012 to 2015 – Model improvement and standards-based development
 - Improve understanding of variability between modelers and measurement
 - Develop validation criteria
 - Incorporate WRS information into consensus standards

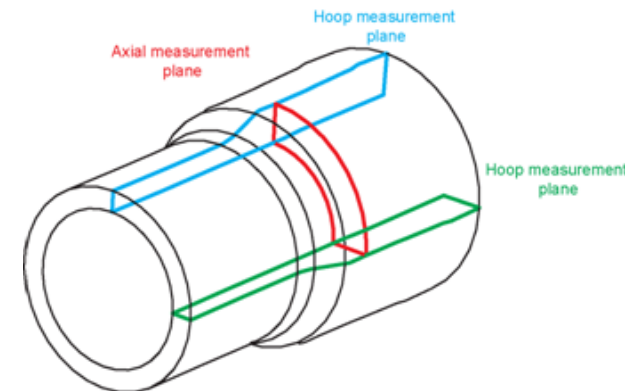
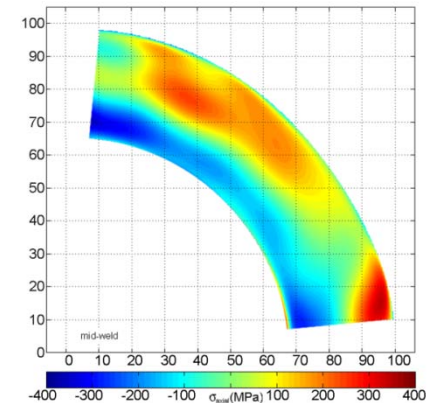
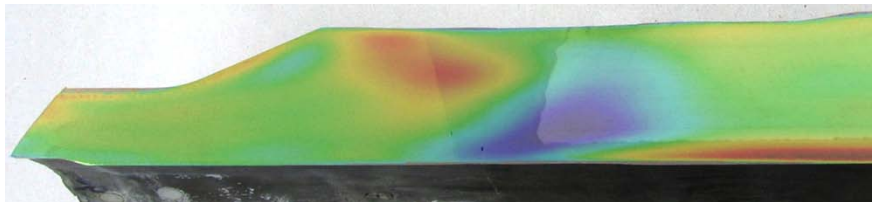
Key Deliverables and Products

Published

- **Finite-Element Model Validation for Dissimilar Metal Butt-Welds, MRP-316, Product ID: 1022861**
- **Welding Residual Stress Dissimilar Metal Butt-Weld Finite Element Modeling Handbook, MRP-317, Product ID: 1022862**
- **Weld Residual Stress Finite Element Analysis Validation: Part 1 – Data Development Effort, NUREG-2162, ML14087A118.**

Future

- MRP-316 and -317 - Revisions in 2015
- NRC NUREG – Part 2
- Complete incorporating results into xLPR and ASME Code



Residual Stress Inputs to xLPR

- NRC and EPRI modelers providing the welding residual stress distribution inputs for the xLPR database
- Three different nozzle weld types analyzed covering multiple plant designs
 - Steam generator nozzle (narrow gap weld)
 - Reactor pressure vessel outlet nozzle
 - Reactor coolant pump nozzle to pipe weld
- Modeler uncertainty has been low (good agreement) for many cases
- Uncertainties associated with heat input and material properties are being quantified

International Round Robin

- 2nd Modeling Round Robin (Phase 2b mockup) in progress
- NRC and EPRI developed problem statement
 - Oriented towards improving consistency of analysis submissions versus 1st Round Robin
 - Provides geometric details, weld process, recommended modeling approach, material property input files
 - All modelers requested to perform verification of their models
- Modeling results submitted to NRC Summer 2014
 - EPRI and NRC have participating modelers
- EPRI and NRC will take part in reviewing modeler results
 - Use modeler and measurement results to investigate validation approaches

ASME Code Section XI Development

- Draft Section XI Non Mandatory Appendix on WRS
 - Development of through-wall stress distributions for use in subsequent calculations
- Three level approach for through-wall stress distributions:
 1. Assume at yield strength
 2. Use bounding through-wall distributions developed for standard weld types
 - Proposed approach and rough values
 - Draft language and technical basis in development
 3. Use standard practice and conduct own analysis
 - Acceptance criteria under consideration and will be included in next NUREG
 - Additional discussion of best modeling practices

Other SOW to be Completed in 2014

- Development of 3D modeling techniques. Examples where 3D models could be useful are:
 - Partial arc repairs
 - Mitigation techniques, e.g., excavation weld repair
- Investigation of dynamic strain hardening
 - Improve material hardening model by investigating material behavior under cyclic thermal and strain
- Improvements to Contour Method RS measurement to provide biaxial stress mapping at a single cut plane

Conclusions

- Successful, multi-year cooperative WRS research program between Industry and the NRC completing in 2014
 - WRS FEA Butt-weld models validation studies completed
 - Two, double blind International Round Robin WRS FEA Modeling Studies conducted
 - Residual stress measurements for DM butt-welds completed
 - Applicable methods identified and new methods developed
 - Developed guidance on key parameters for WRS modeling assumptions, inputs, and methodology
 - Providing WRS inputs to xLPR code
 - Providing standardized inputs for ASME Section XI Non-Mandatory Appendix on WRS
 - Through-wall distributions and modeling guidance
 - Proactive publication and transfer of research results for existing and new plant applications