Uncertainties in Dissimilar Metal Weld Residual Stress Modeling

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*the views expressed herein are those of the author and do not represent an official position of the USNRC

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Issues

- ***With advancement in computer technology, welding residual stress analyses is becoming routine.***

- ***US regulatory approach for power plant safety may rely on stochastic procedures for predicting likelihood of large break loss of coolant accident (LOCA).***

- ***With welding residual stress driven cracking mechanisms such as stress corrosion cracking, reliable methods for making accurate predictions is necessary.***

- ***In addition, understanding and accounting for uncertainties in such analyses is critical for accurate and reliable predictions of LOCA probabilities.***

Issues that Add Uncertainty

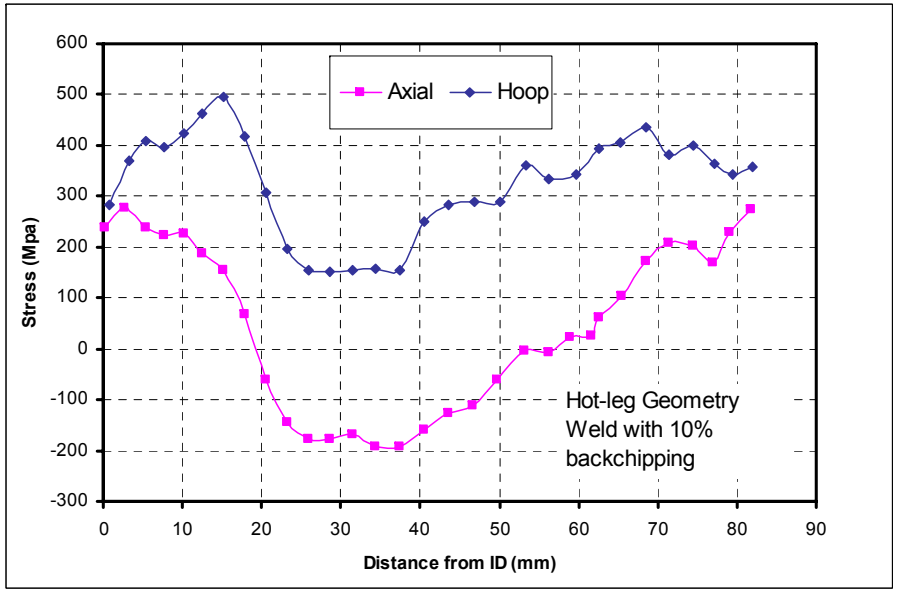
- *Welding process*
  - *Fill-in welds*
  - *Weld sequencing*
  - *Safe-end to pipe weld influence on DMW residual stresses*

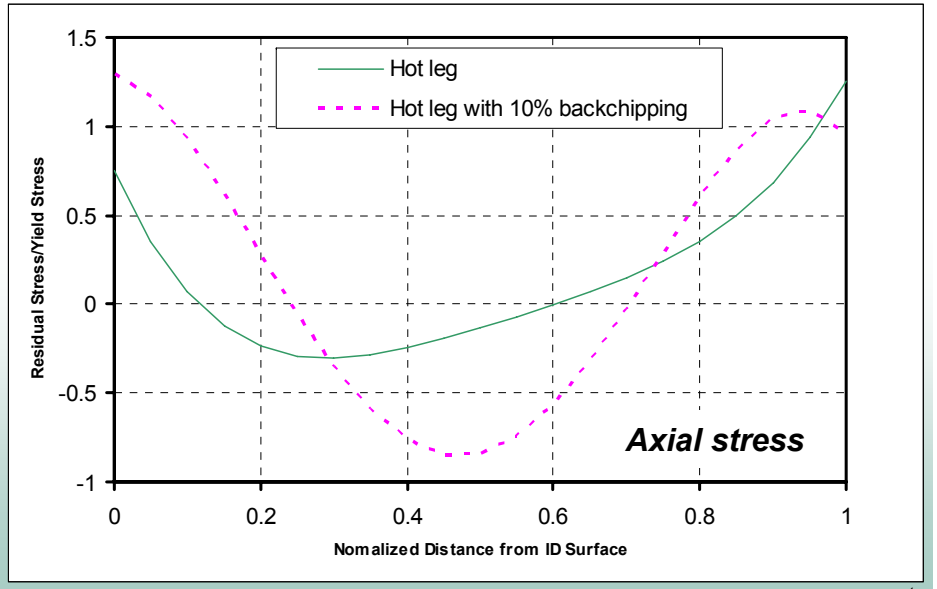
- *Modeling Issues*
  - *Weld pass assumptions*
    - *CRDM*
    - *Overlays*
  - *Constitutive modeling*
  - *Phase Transformation*
  - *WRS Measurement and Validation*

Back-chipping and Back-weld

- *Processed used to remove weld land on DM welds – similar to shallow 360 deg ID weld repair*
- *Grinding 360 deg on ID*
- *Excavation back-welded using A182*
- *Creates higher tensile residual stresses on ID*
- *Fit-up, grinding, etc also affects uncertainty*

Ignoring weld process adds uncertainty





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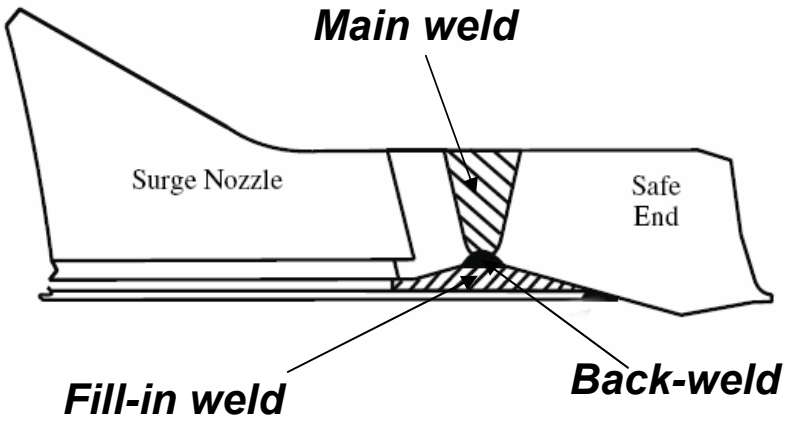
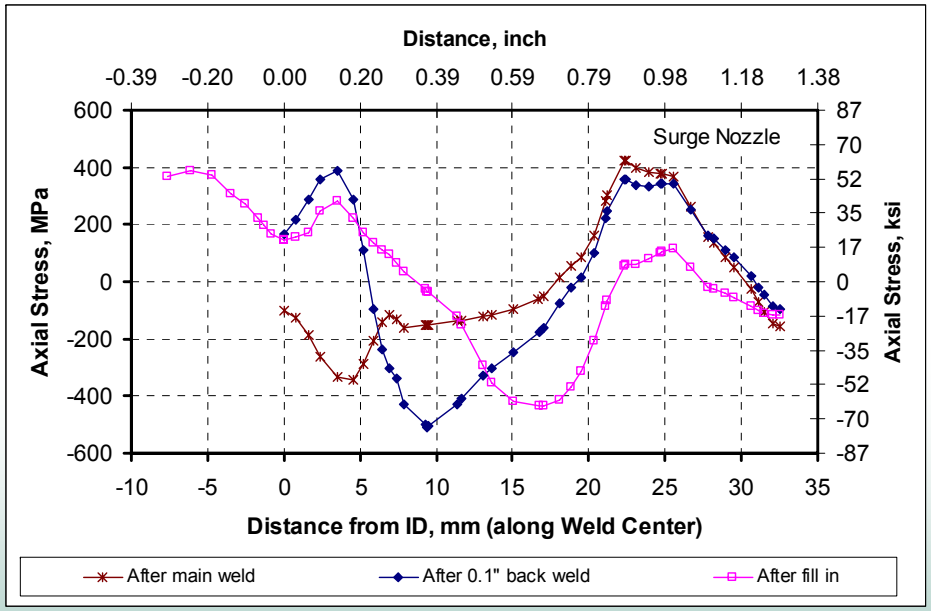
Fill-in Welds

- *Fill-in weld necessary when welded thermal sleeve is used*
- *Deposited on ID after backweld with A82/182 for 360 degrees*
- *Can increase ID stress and distance where tensile stress become compressive*





Ignoring weld process adds uncertainty

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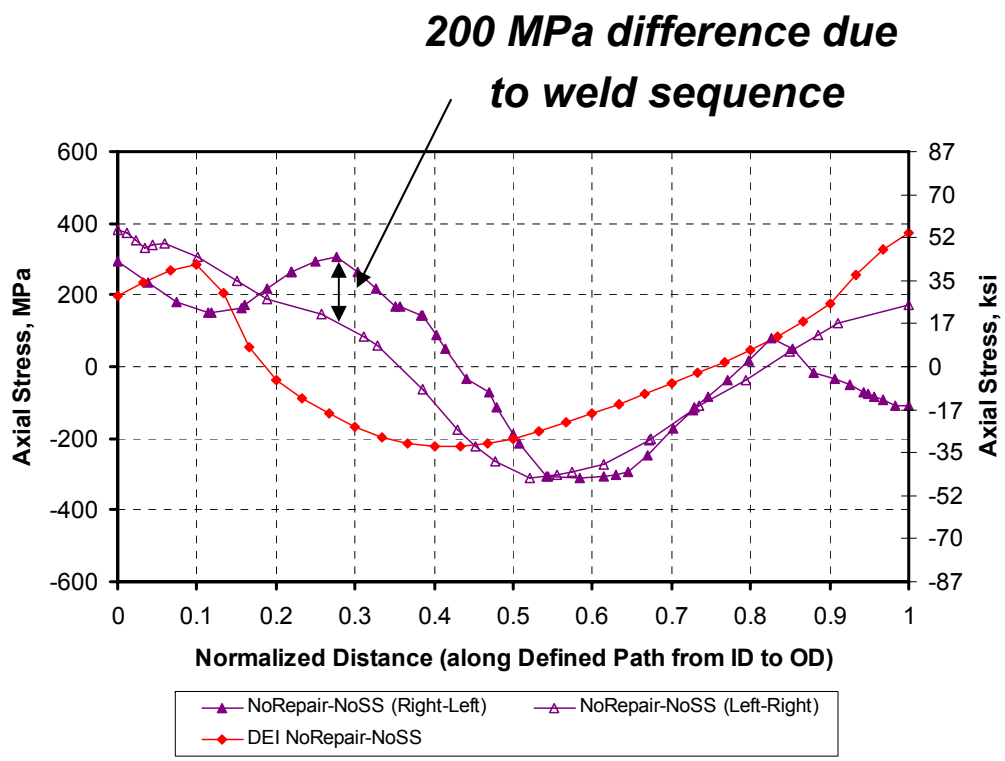
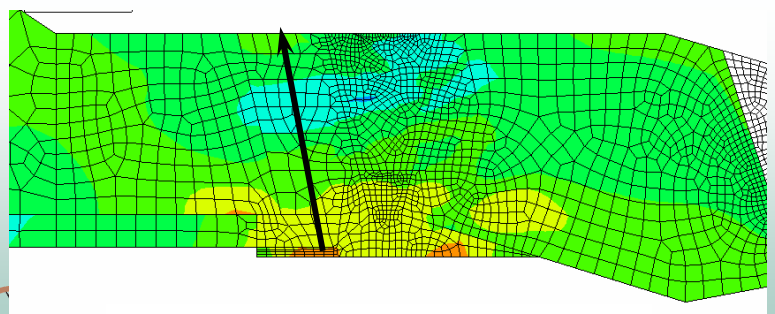
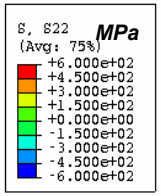
Weld Sequence

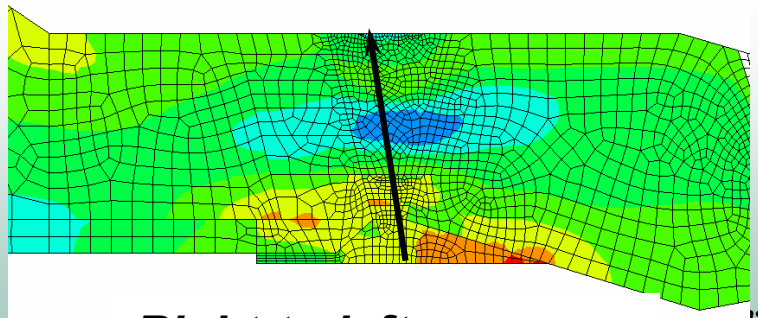
- ***Weld bead size and sequence can influence the calculated WRS.***
- ***Sequence cannot only change magnitude of highest stress, but also position. Poorly documented welding history add to uncertainties in predictions***
- ***Knowledge of proper sequence is important to accurate stress predictions. Should be designed in future fabrications.***





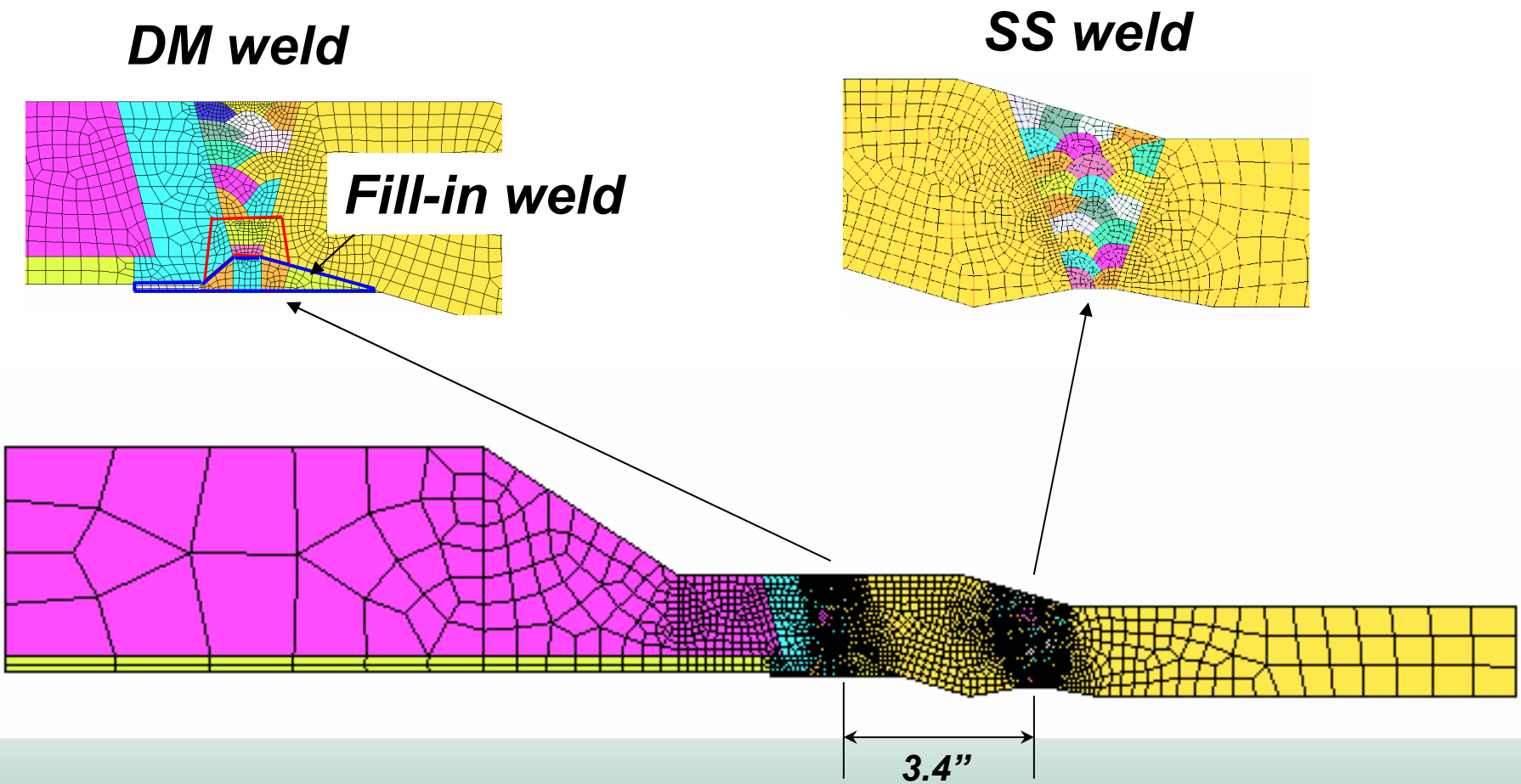
Left-to-right sequence





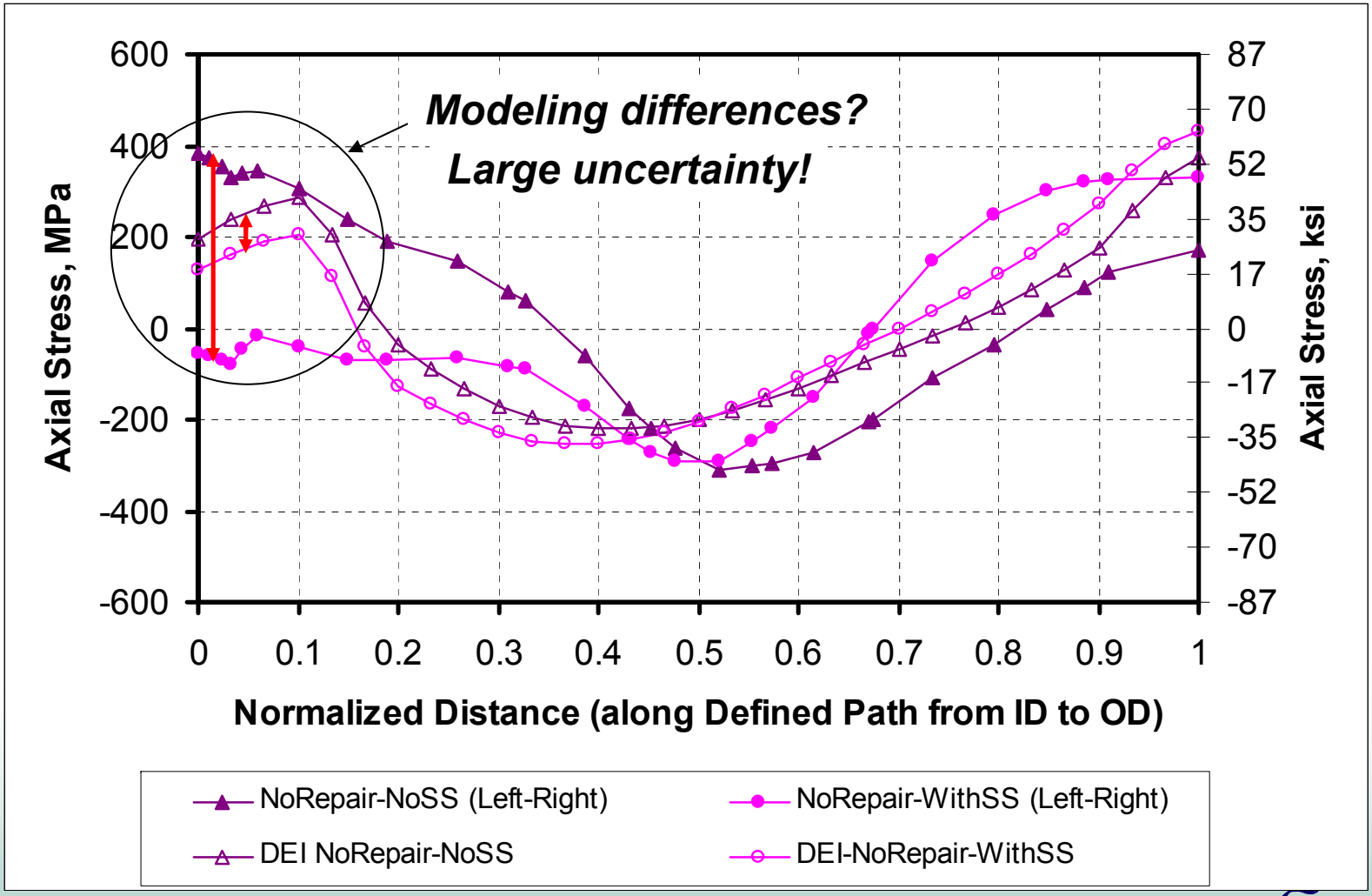
Right-to-left sequence

Effect of Safe End Weld

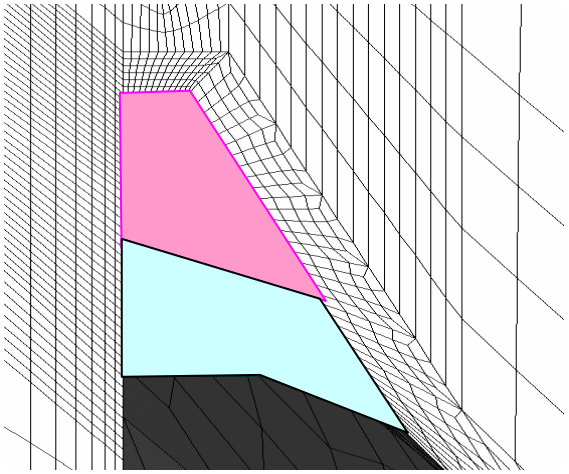


Surge Nozzle Geometry

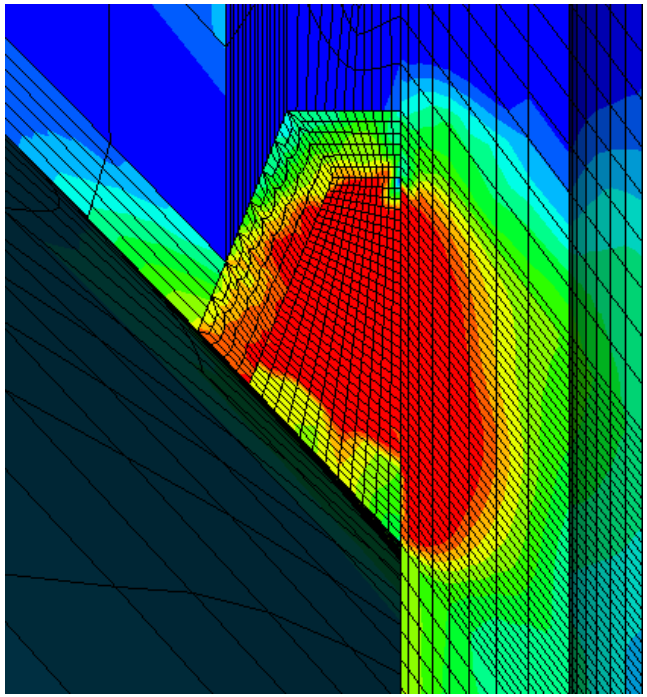
Effects of SS Safe End Weld



Lumping Pass Assumption

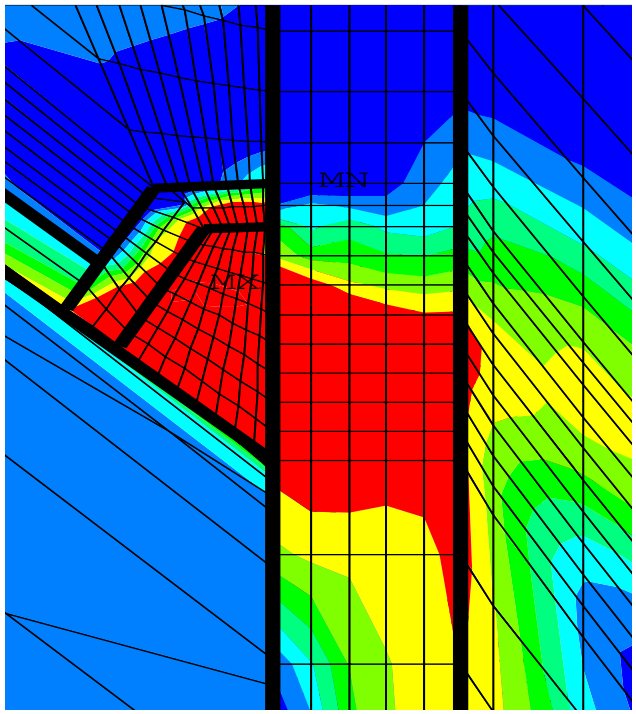


CRDM – J-weld



14 passes

Higher stresses



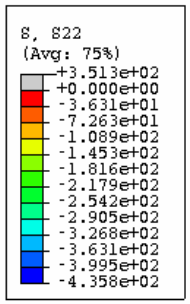
Lumped pass – 2 passes

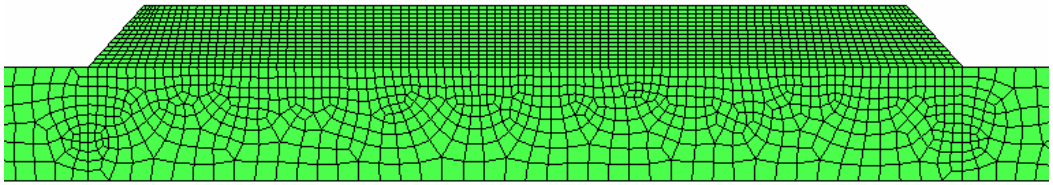
Hoop Stress

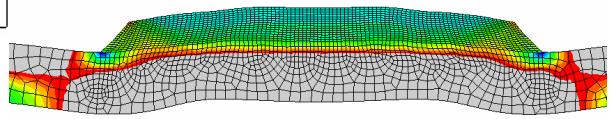
Analysis assumptions add uncertainty

Weld Overlay – Weld Sequence

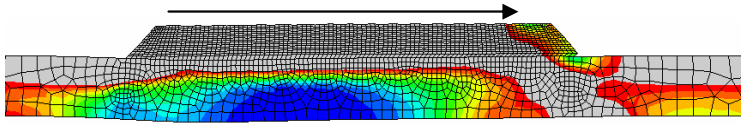
- *Examples of 6-inch FE Analyses (no ID water cooling)*



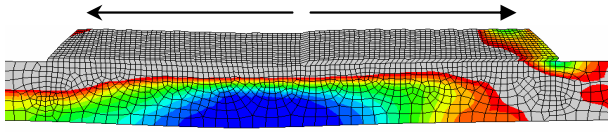




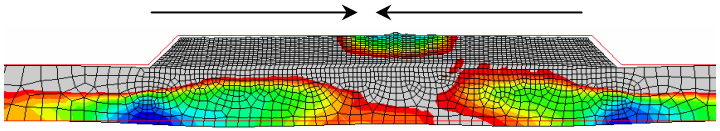
The entire weld



20 beads – 1 layer



20 beads – 1 layer



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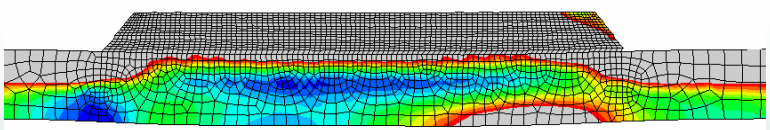
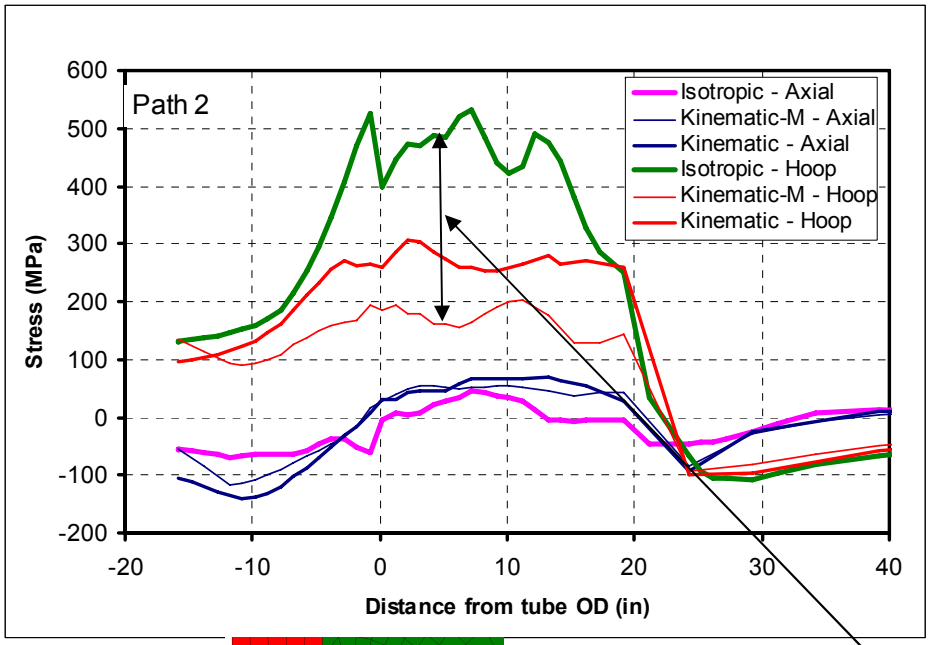


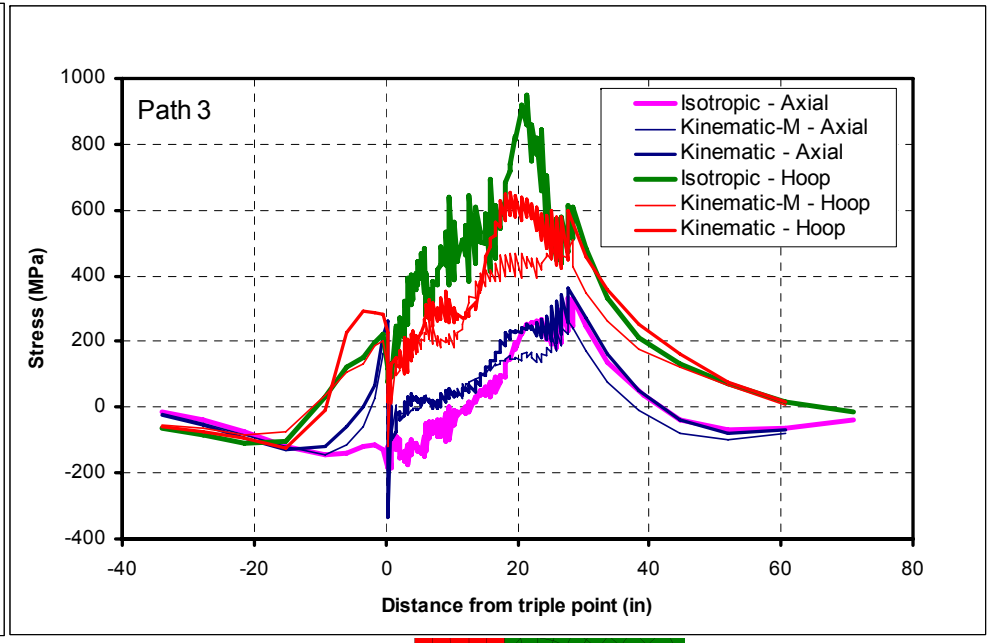
60 beads – 3 layers

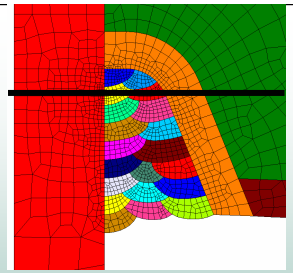
Uncertainty in weld sequence leads to uncertainty in stress prediction

Effects of Hardening Law

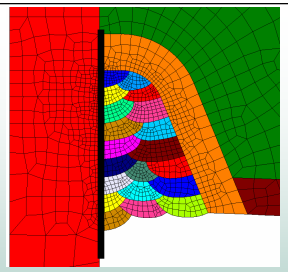
Effects of hardening law on CRDM J-Weld WRS – Will be investigating in Butt Welds!!





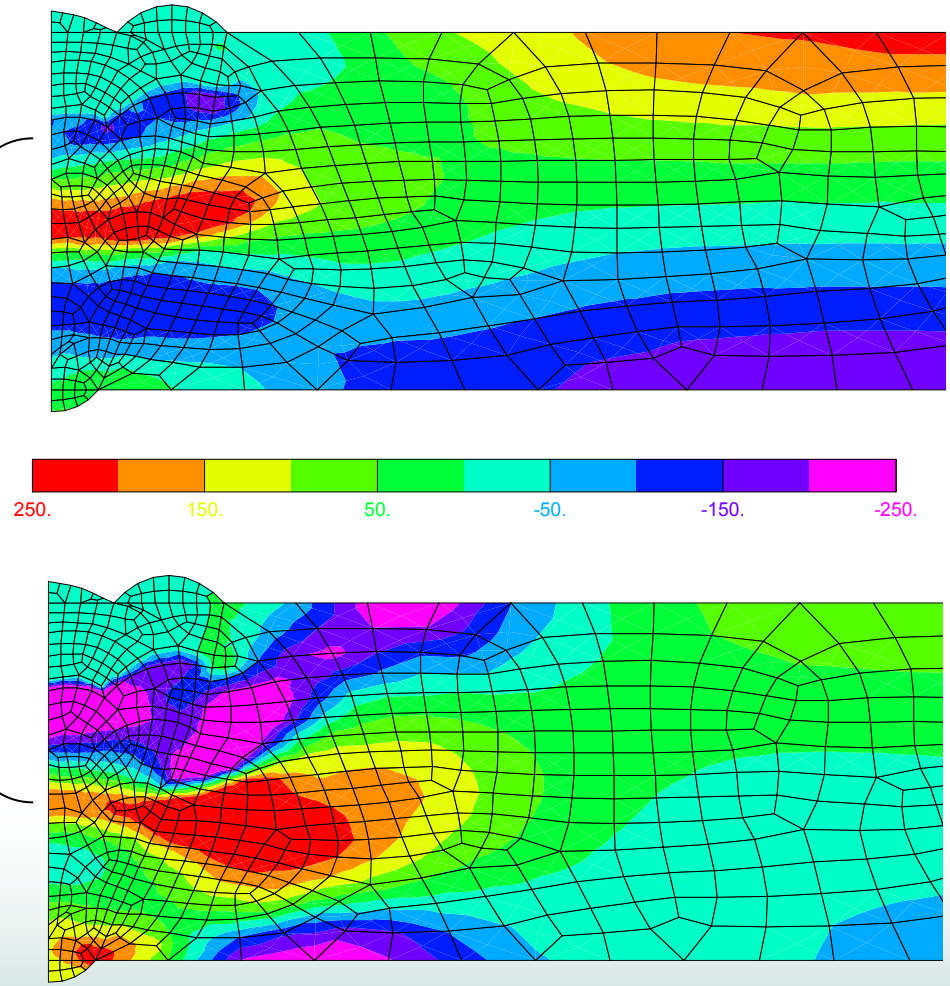


Uncertainty can mask actual values of stress



Effects of Phase Transformation

Ignoring phase transformation increases uncertainty

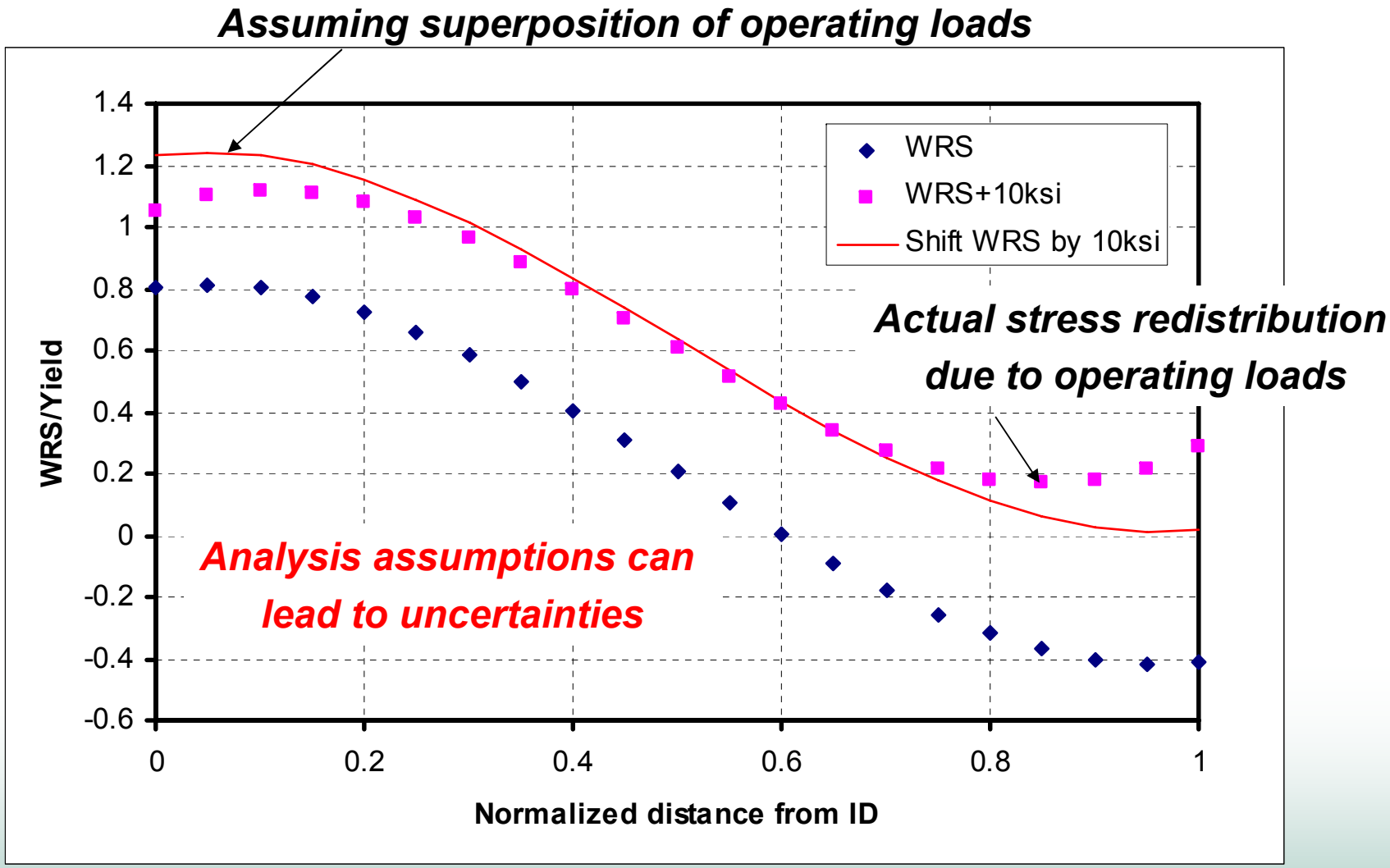


Isotropic Hardening
No Phase
Transformation Effect

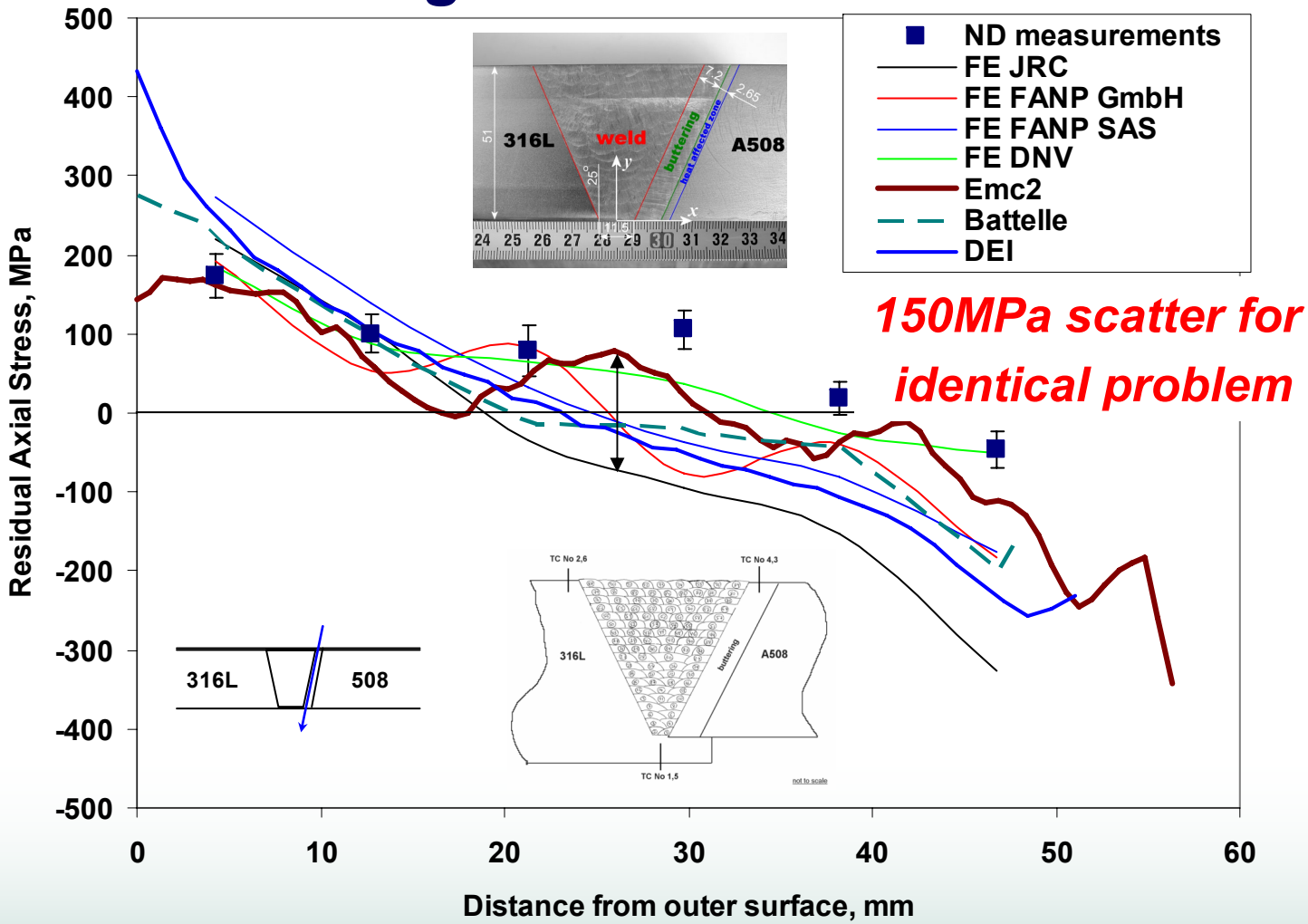
Isotropic Hardening
Leblond Model Phase
Transformation Effect

Carbon Steel (A508) Butt Weld

Effects of Operating Stress



NESC III Welding Residual Stress Validation



150MPa scatter for identical problem

Modeling differences are an inherent source of uncertainty

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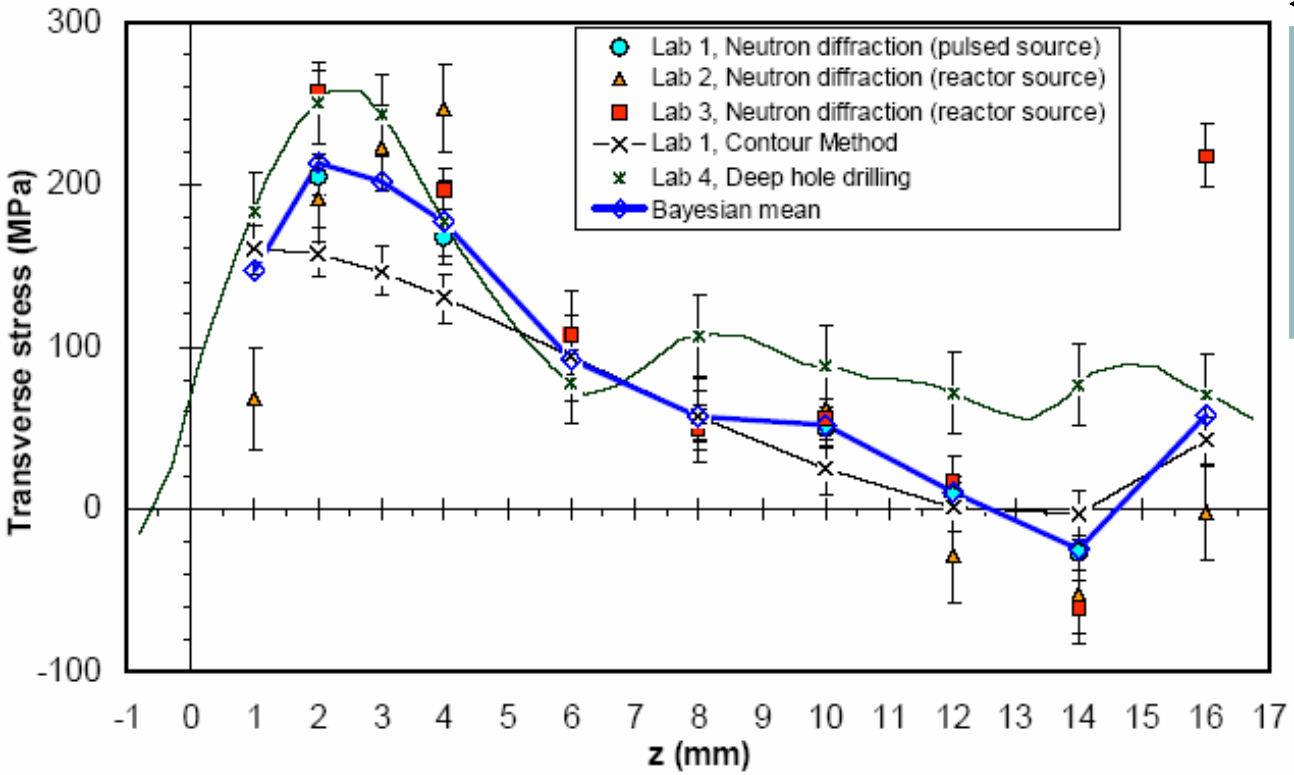
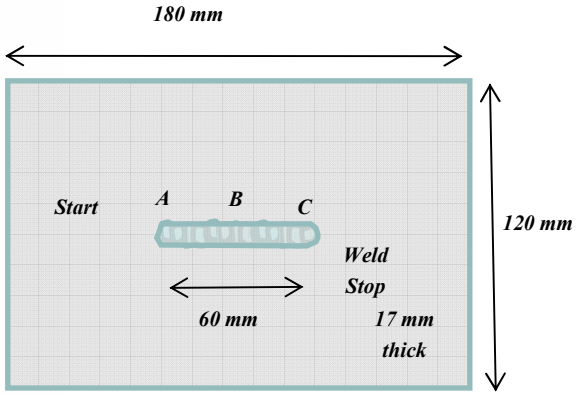
Residual Stress Measurements

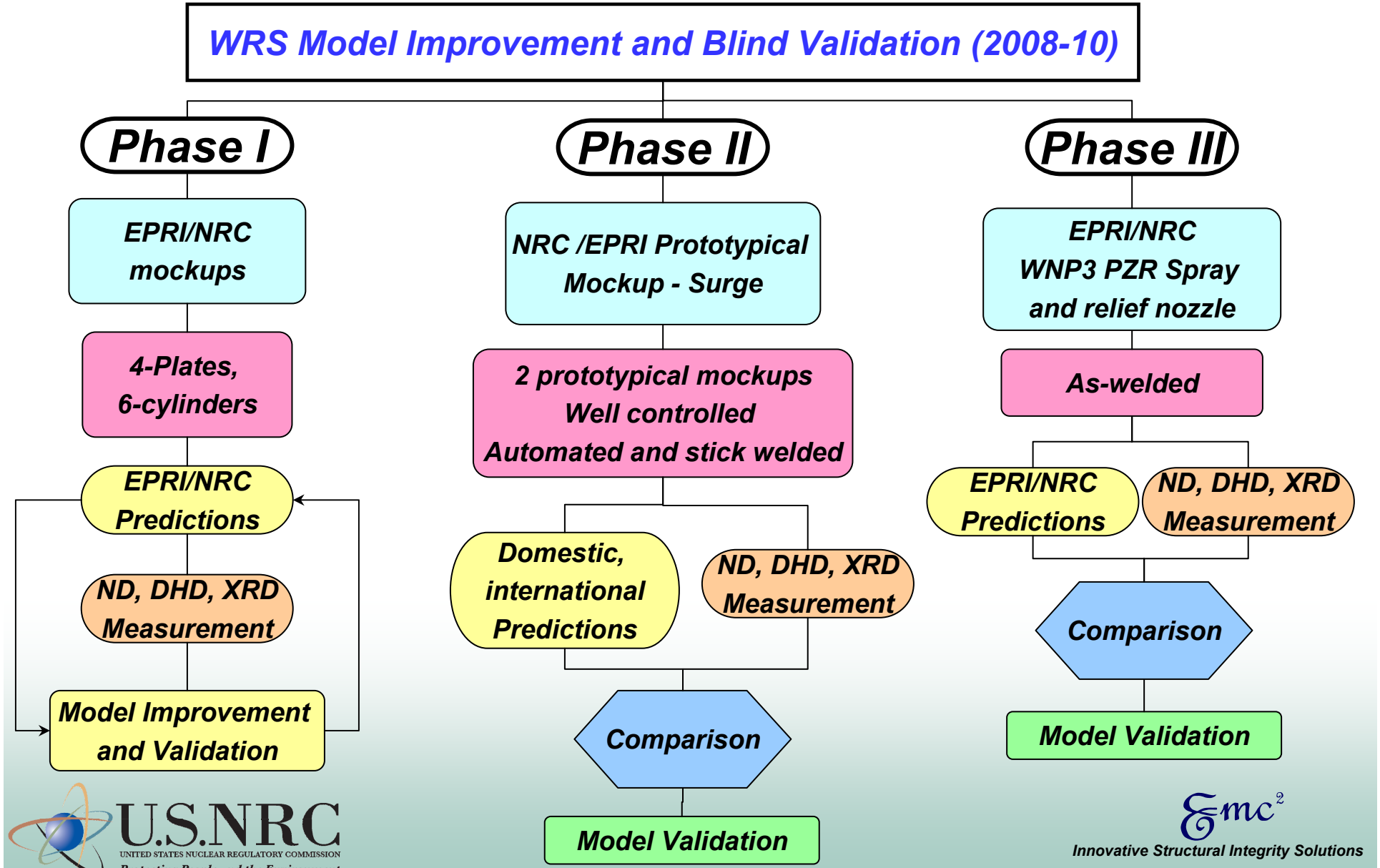




From Reference [12]: Turski, M., Edwards, L., James, J., Bouchard, P. J., Smith, M., and Withers, P. J., "Residual Stress Measurement Within A Single Pass Grove Weld Specimen Utilizing Neutron Diffraction and the Contour Method" , 2006 ASME Pressure Vessel and Piping Conference, Vancouver, BC, Canada, PVP2006-ICPVT-11-93991, July, 2006.

Measurement differences are an inherent source of uncertainty

NRC WRS FEA Model Validation Program



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Summary

- ***SCC is a stochastic process and uncertainties in both predictions and experiments must be characterized for reasonable predictions.***

- ***Capturing the correct welding procedure, boundary conditions, and material properties important to increase accuracy of stress predictions and decrease uncertainty.***

- ***Numerical analyses can be used to develop WRS distributions for inclusion in probabilistic pipe fracture codes.***

- ***Validation of numerical procedures is necessary not only for determining accuracy, but also in understanding uncertainties in analyses. Important to understand and keep in mind experimental measurement uncertainty.***