

EPRI/NRC Joint Program on Welding Residual Stress Guidance

Paul Crooker - EPRI
Michael Benson – NRC

Industry/NRC Materials Technical Update
June 2015

Background on MOU



- Concludes work performed under previous MOU
- Status of deliverables
 - Mockup measurements and round robin: complete
 - 3-D analyses and EWR: underway
 - WRS inputs for xLPR: complete
 - ASME Code practices for WRS: underway
- Expires December 2015
- No follow-on MOU currently planned

Program History



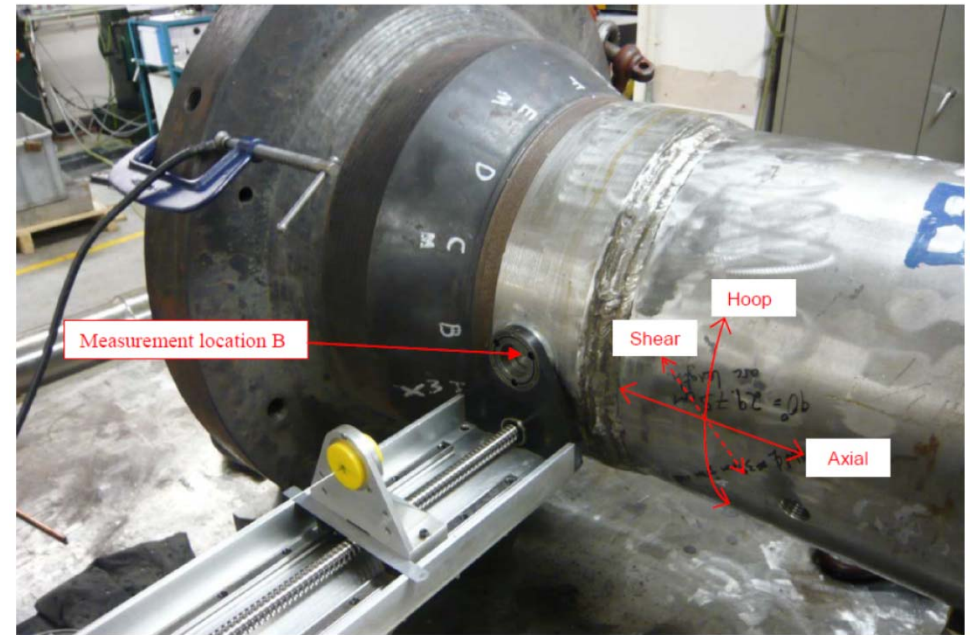
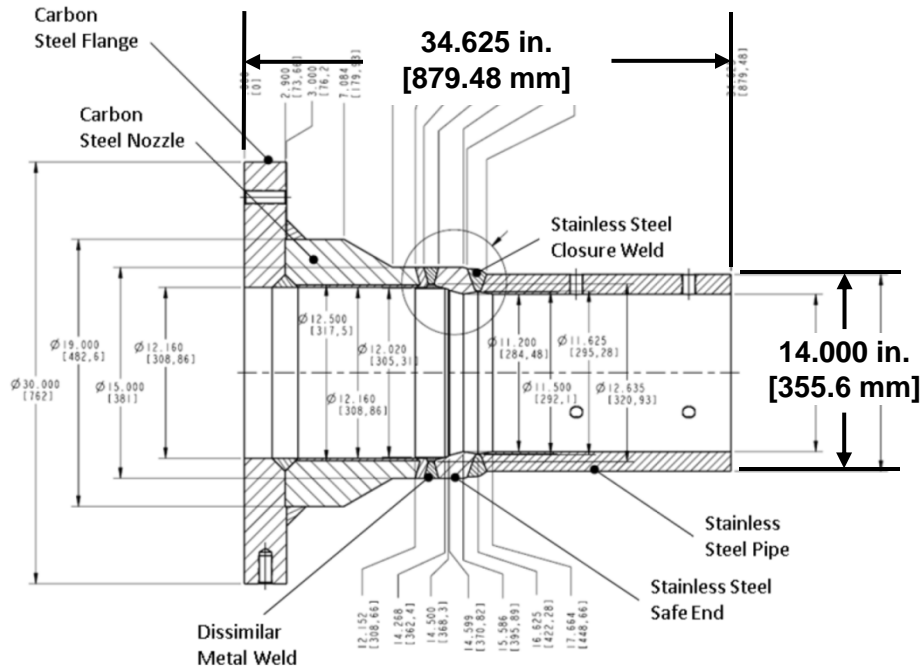
- 2008 to 2011 – Initial joint validation program effort
 - Measurement and modeling of small and full scale mockups as well as canceled plant components
 - Baseline study of variability between modelers and measurements
 - Documented in both NRC and EPRI documents
- 2012 to 2015 – New mockup and round robin study
 - Improve understanding of variability between modelers and measurement
 - Develop validation criteria
 - Incorporate WRS information into consensus standards

Progress Since June 2014



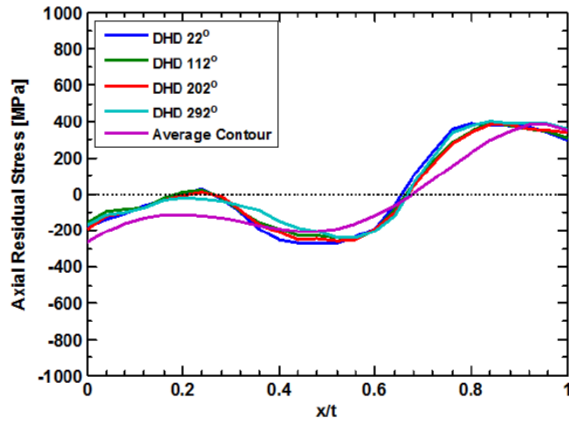
- Closed round robin in August 2014
- Round robin results made public
 - December 2014 NRC public meeting: ML14352A195
 - EPRI/NRC PVP paper: PVP2015-45636
- ASME Code Case development in Task Group Crack Growth Reference Curves
- EPRI-sponsored [UC Davis] research on uncertainty and validation criteria
- NRC-sponsored research [Sandia National Lab] on uncertainty and validation criteria

WRS Round Robin Mockup

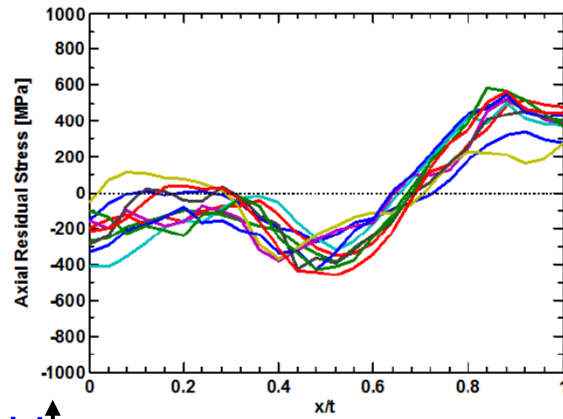


WRS Round Robin Mockup

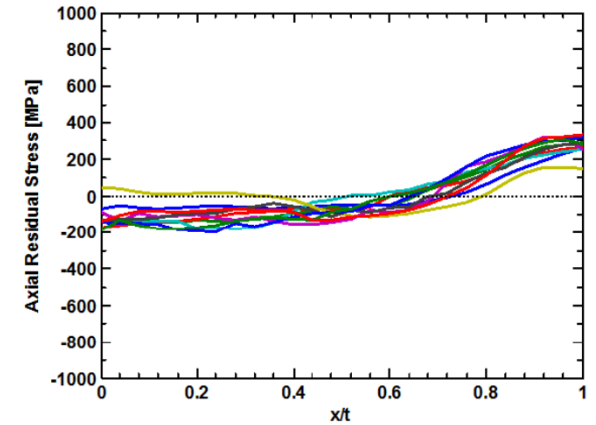
Measurement Data



Modeling Data—Isotropic Hardening

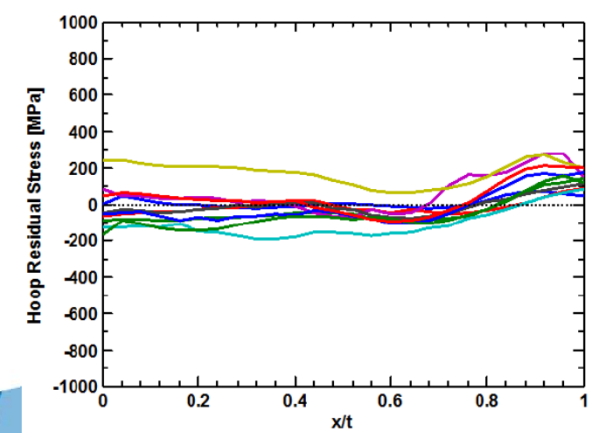
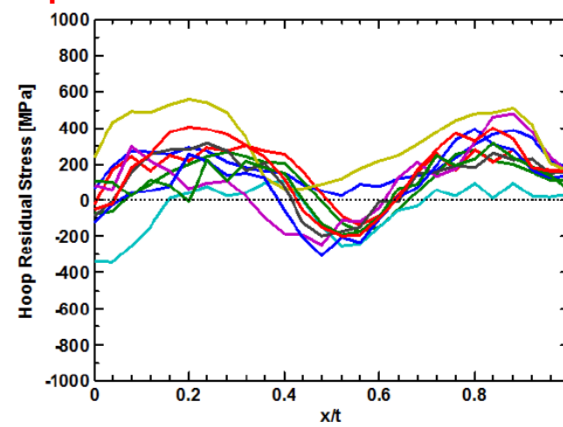
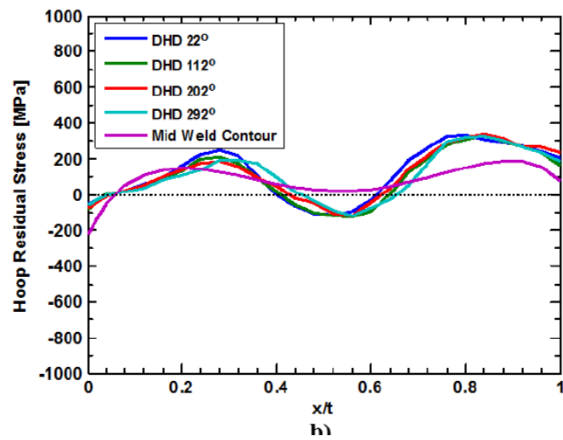


Modeling Data—Kinematic Hardening



↑ Axial

↓ Hoop



ASME Section XI Code Case Development



- Section XI Code Case governing WRS for DM welds
- Draft language in development
- Analyses options include three level of analysis:
 - Assume at yield strength through-wall
 - Use bounding through-wall distributions developed for standard weld types
 - Proposed approach described in PVP2015 paper
 - Use standard practice and conduct own analysis
 - Acceptance criteria discussion informed by modeler variability from 2014 Round Robin submissions
 - Jan and April 2015 ASME Code Week Meetings on 2014 Round Robin results used to develop Code Case approach regarding model acceptance

Excavate and Weld Repair



- EPRI shared EWR mockup information with NRC through the WRS MOU
- NRC developing finite element model
- Can be compared with measurements and other modeling efforts
- ASME Code Case currently under consideration

Challenges Moving Forward



- Identification and disposition of outliers
- Quantifying measurement uncertainty
- Quantifying modeling uncertainty
- Use engineering judgement to determine acceptance criteria
 - Criteria types (K, root-mean-square prediction error, etc.)
 - Acceptable numbers
- Use engineering judgement to formulate hardening law guidance