Flaw Evaluation Issues with a Recent Inspection

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Background

- Recently an indication was found in the DM weld of the RV Outlet nozzle of Seabrook
- Mitigation was not planned for this outage, so a flaw evaluation was called for
- The evaluation was completed and submitted to NRC
- NRC review turned up a large number of questions about the proper residual stresses to be used in the analysis

Actions Taken in Response

- A lunch meeting was held with NRC staff on the Monday of ASME Code week
- It was decided that a meeting of experts would be held on Nov. 19-20 at NRC Research offices in Rockville
- The meeting brought together NRC staff and consultants with industry experts on operating plant flaw evaluation
- The agenda was developed in a brain storming session the next day in the WG Flaw Evaluation

The Meeting

- The meeting was held the afternoon of Nov. 19, and the morning of Nov. 20, and was hosted by Al Csontos
- It was a public meeting
- Invitees were reps of those organizations who perform flaw evaluations, and those who have developed stress information for such evaluations. Included are:
  - Westinghouse
  - Areva
  - Structural Integrity
  - Dominion Engineering
- The meeting was useful, in that the results helped to clarify the NRC issues

Findings and Actions

- Here are the key findings of that meeting:
  - The stainless steel closure weld creates a beneficial stress distribution in the DM weld, for both axial and hoop stresses
  - Safe end length is critical, longer safe ends could negate the beneficial effect of the stainless steel closure weld
  - NRC expects plant specific or at least manufacturer specific analyses to be performed for each case to support residual stresses used in flaw evaluations
- Follow-up actions
  - Discussions will continue at the next ASME Code meeting, the first week in February
  - MRP preparing a topical report that provides guidance on PWSCC flaw evaluations
- The goal of this discussion is to reach agreement on two key issues:
  - What are the key (required) attributes of an effective residual stress finite element modeling process?
  - What depth of repair must be assumed

Attributes of an Acceptable Residual Stress Calculation

- Geometry
- Weld Fabrication Sequence
- ID Surface Repairs, if any
- Stainless Steel Closure Weld Effect
- Benchmarking of Analysis Methodology
- Proper Curve-fitting of Stress Profile
- Correct Operating Temperature and Pressure
- Consistency with inspection results

Geometry

- The plant-specific diameter, thickness and other geometrical features need to be considered
- All materials need to be appropriately modeled
- Using a generic design or published solution is acceptable as long as all relevant differences between the analyzed configuration and the plant specific configuration have been properly reconciled

Weld Fabrication Sequence

- The model must account for the fabrication process followed at the fabrication facility
- For example, if the ID of the nozzle to safe end weld region is machined after the initial welding process, this can affect the residual stresses
- The buttering, if present, should be modeled directly, but its impact is small if it is heat treated
- Any post weld heat treatment is not important to model, as the effect is not significant for DM welds

Example: Safe End to RV Nozzle Weld Fabrication for Combustion Engineering

- A summary of the nozzle fabrication process:
  - Alloy 82/182 buttering applied to low alloy steel (multi-layer)
  - Nozzle bore clad with stainless steel
  - Nozzle buttering machining to prep for U-groove weld
  - RV, including the nozzle and buttering receives PWHT
- Safe End is fit up to the nozzle, with the lands of the machined weld preps butted together
- At this point the ID of the nozzle is smaller than the design requires
- Layered Alloy 82/182 weld passes are applied from ID to OD to complete the weld
- The nozzle buttering and safe end weld lands are now removed by machining the ID, and Dye penetrant (ID and OD), UT and radiography exams are completed
- Weld repairs to the ID would not be in-process, since they would involve a break in the fabrication traveler sequence, requiring documentation

ID Surface Repairs, if any

- It is well known that ID surface repairs result in tensile residual stresses at the pipe ID
- A search of available repair records should be made, and documented
- It is also important to have knowledge of the fabrication practices and procedures of the shop where the DM weld was produced
- This information, along with the repair information, will enable a defendable estimate to be made of the maximum repair depth to be modeled
- If this information is not available, a repair depth of 25% should be assumed, 100% around the circumference, for large bore welds (>16 inch NPS)
- For smaller bore nozzles, a repair depth of 50% should be assumed
- must be assumed, 100% around the circumference

Stainless Steel Closure Weld Effects

- The stainless steel closure weld may create a beneficial stress distribution in the DM weld, for both axial and hoop stresses
- The magnitude of this effect is dependent on the proximity of the closure weld to the DM weld
- Safe end length is therefore critical; a longer safe end could negate the beneficial effect of the stainless steel closure weld This distance needs to be determined in a defendable manner for the application of interest
- Safe ends are often cut to fit in the field, so as-built dimensions are best. Since closure weld effects are smaller for longer safe-ends, use of design lengths is conservative

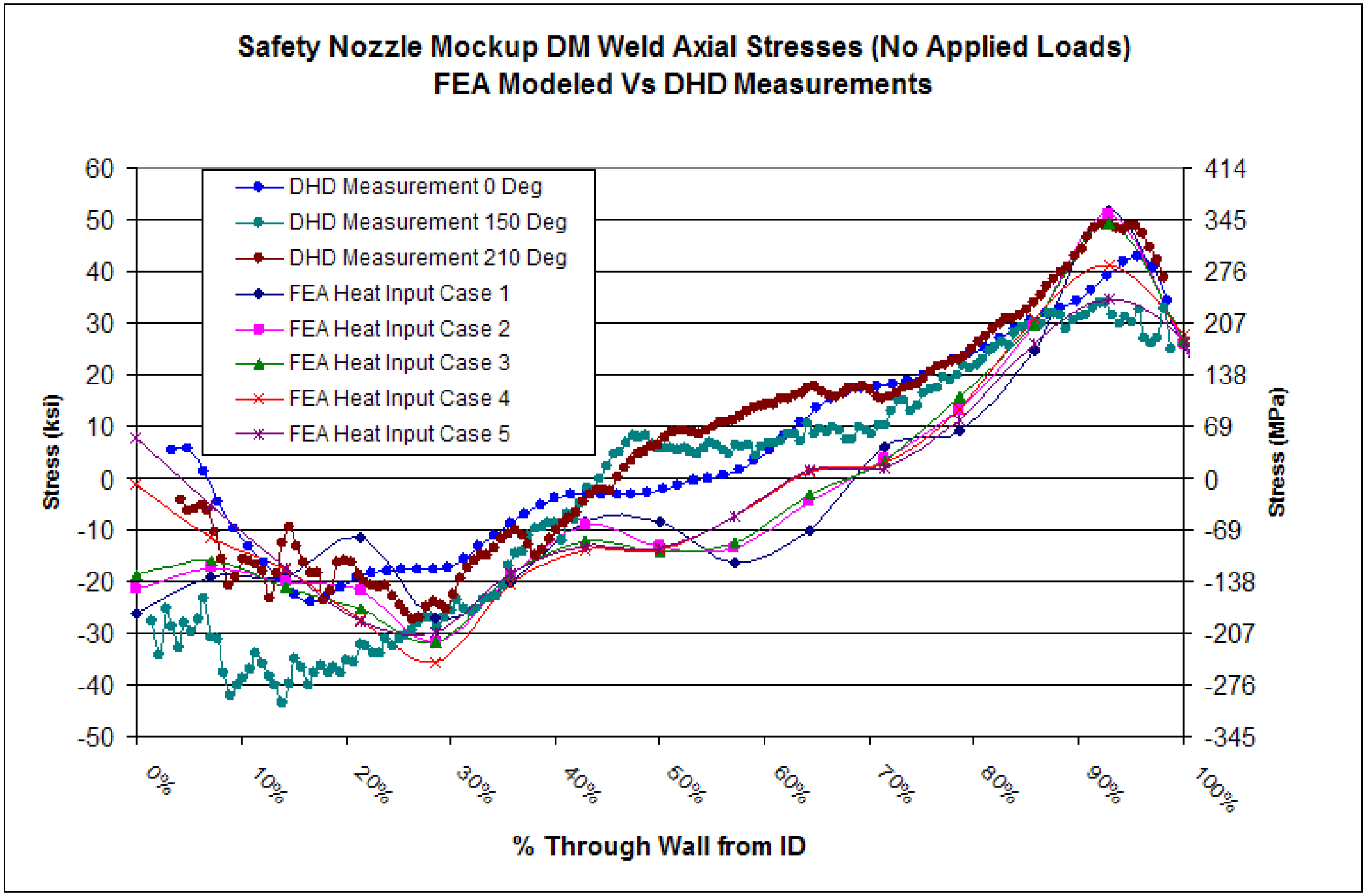
Benchmarking of Analysis Methodology

- The modeling methodology used must be verified and validated through comparison with actual measurements of residual stresses, on a mock-up
- A mock-up is not required for every analysis
- The mock-up should have sufficient complexity that it provides a realistic test of the residual stress predictions
- An example of bench-marking is shown in the next two slides, which are for a safety/relief nozzle in a Westinghouse-designed pressurizer mock-up No pressure, no repairs, no closure weld

Example of Bench-marking

SIMULATION AND MEASUREMENT OF THROUGH-WALL RESIDUAL STRESSES IN A STRUCTURAL WELD OVERLAID PRESSURIZER NOZZLE

By Steve Marlette et al, to be published at PVP 2010



Example of Bench-marking

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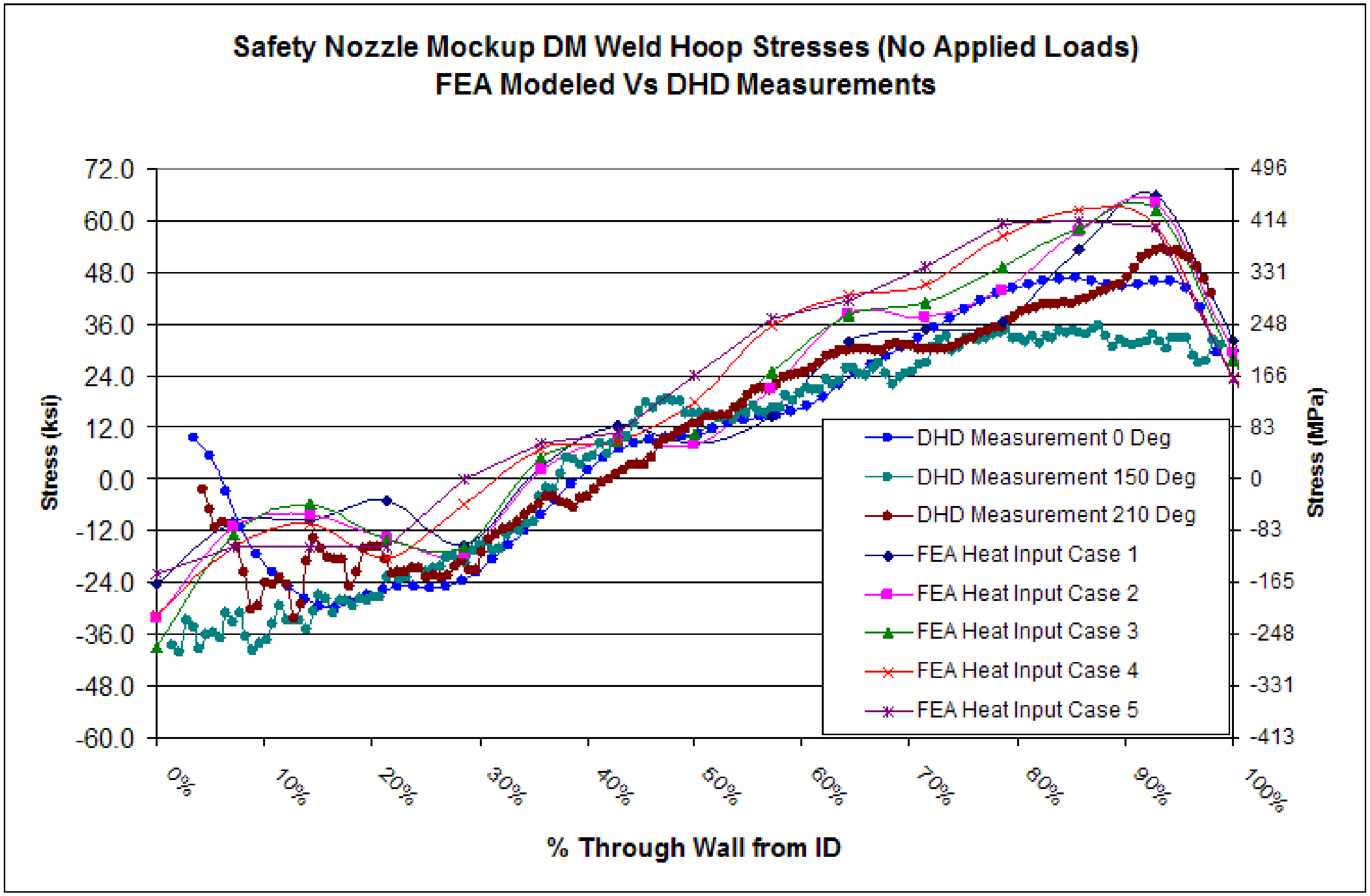

Proper Curve-fitting of Stress Profile

- Often residual stress profiles are complicated curves, and may not be amenable to third order curve fits
- Care needs to be taken to ensure that the fitting approach taken does not misrepresent the residual stress profile
- Fourth order fits are available to generate stress intensity factors, or the distribution can be modified slightly so that the third order fit is improved

Correct Operating Temperature and Pressure

- The operating temperature and pressure both have important impacts on the level of residual stress, so both must be modeled correctly
- Steady state conditions should be used, as these are the conditions which will grow a crack under PWSCC
- Superposition may be used to combine residual stresses with operating temperature and pressure, since the residual stresses are strain controlled and highly localized

Consistency with Inspection Results

- It is recognized that repairs or other forms of ID welding often contribute to the initiation and growth of PWSCC cracks
- For example, Ringhals 3 and 4 (double-Vee welds) both experienced PWSCC in the RV nozzle DM weld region
- One had extensive repairs, and the other did not
- The residual stresses used in the evaluation should be consistent with the NDE findings being evaluated