ELECTRIC POWER RESEARCH INSTITUTE

Current Industry Depth Sizing Capability for Dissimilar Metal Welds

Carl Latiolais
Senior Program Manager Performance Demonstration

PDI/NRC Meeting
June, 2010

Overview

- Current Depth Sizing Qualification Status
- Description of Issue
- Actions Taken to Increase Accuracy
- Current Industry Evaluation Criteria
- Future Work
- Summary

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Depth Sizing Qualification Status

- Outside Surface
  - Several automated procedures fully qualified
    - Conventional and phased array techniques
  - Several manual phased array procedures qualified
  - No conventional manual procedures qualified
- Inside Surface
  - No procedure has been capable of meeting acceptance criteria
    - Several procedures have shown sizing capability, but were not able to meet current acceptance standards
  - Every US and several international vendors have attempted qualification and non were successful

© 2010 Electric Power Research Institute, Inc. All rights reserved.

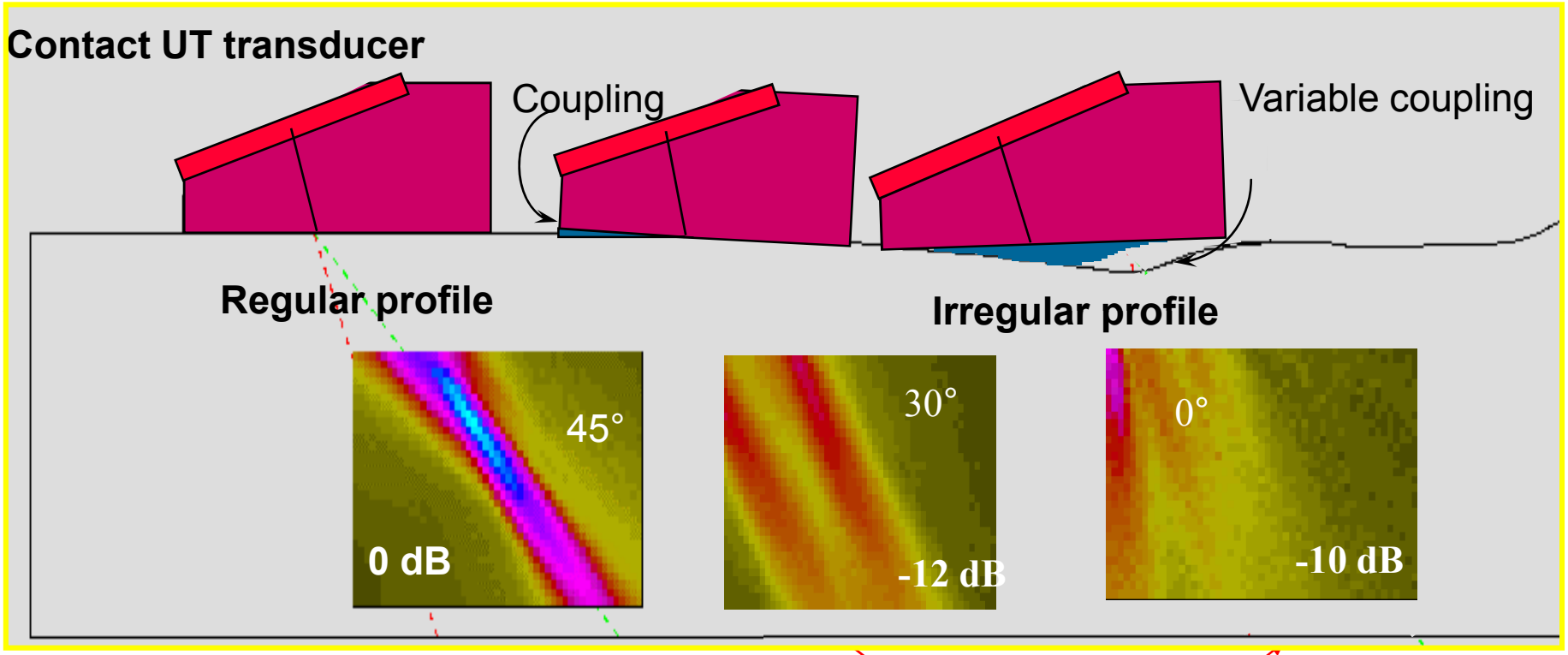
Description of Issues

- Outside Surface Depth Sizing Requirements
  - Requires smooth surface
    - 250 RMS
    - No more than 1/32” gap under search unit
  - Requires focused search units
    - Size increases with thickness
    - Larger footprint
  - Qualification encompasses a range of thicknesses from very thin to very thick
    - No consideration for different wall thicknesses made in calculation

- Inside Surface Depth Sizing
  - Surface in most cases is not smooth
    - Greater than 250 RMS
      - Must scan on clad to gain access to weld
    - Gap under search unit in many cases greater than 1/32”
      - Effect of second weld geometry
  - Search unit size is limited by surface condition
    - Larger search units affected more by surface condition
  - Qualification is focused on very thick components
    - More room for error
    - Requires increased accuracy
      - Allowable RMS error is very small compared to the wall thickness, typically 3%
      - Much smaller than what was considered in the establishment of the criteria

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Description of Issues



Nominal beam characteristics

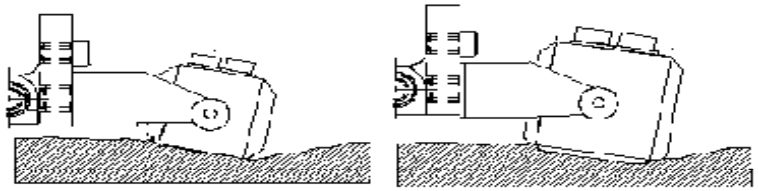
Degraded and distorted beam

© 2010 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Description of Issues

- Search units must be smaller to assure detection, but are not optimum for depth sizing in thick components
  - Aperture size is limited thus reducing focusing capability



- Gaps under search unit adds to sizing inaccuracy and reduces penetrating capabilities
- Irregular surfaces compound the already difficult sizing process
  - Several compensation factors must be applied for every measurement with each one inducing error into measurement
  - Accurate profile measurements are necessary
  - Geometry changes at every circumferential position
- Software must be able to compensate for changes in geometry, but error is added in every measurement

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Description of Issues

- The depth sizing process for dissimilar metal welds has inherent error due to various factors
  - Measurement of flaw tip
    - Material effects due to multiple materials with varying velocities
      - Inaccuracy increases with thickness
    - Dendtric structure of weld causes beam skewing
      - Inaccuracy increases with thickness
  - **Measurement of surface profile**
  - **Measurement of search unit tilt on irregular surface**
  - **Measurement of flaw position on surface**
  - **Compensation for velocity changes between water and material due to gaps between search unit and component surface**
    - **Inaccuracy increases with thickness**

Factors contributing to measurement inaccuracy for OD examinations

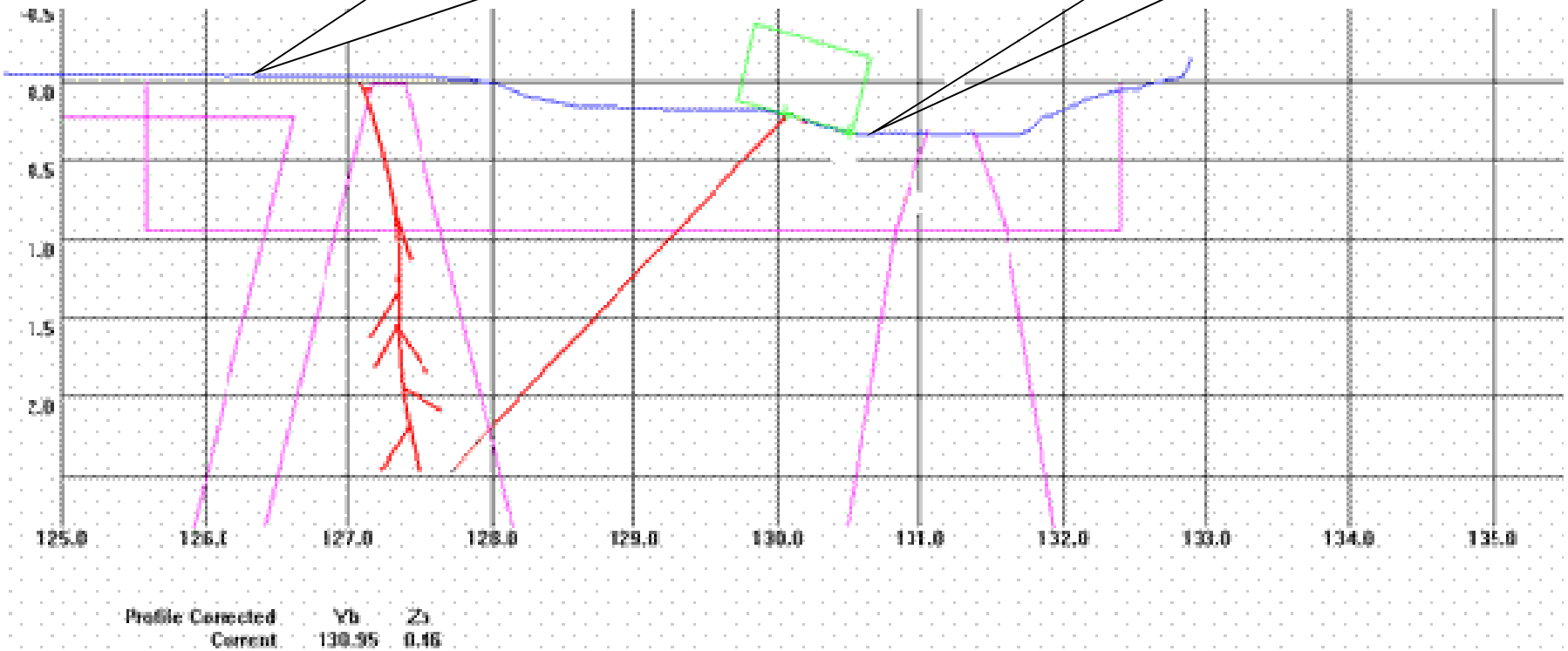
Additional factors that must be considered for inside surface examinations and each factor contributes to the total error of the measurement

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Description of Issues

Surface near dissimilar metal weld is relatively smooth with the exception of the nozzle cladding, but the effect of adjacent weld is apparent

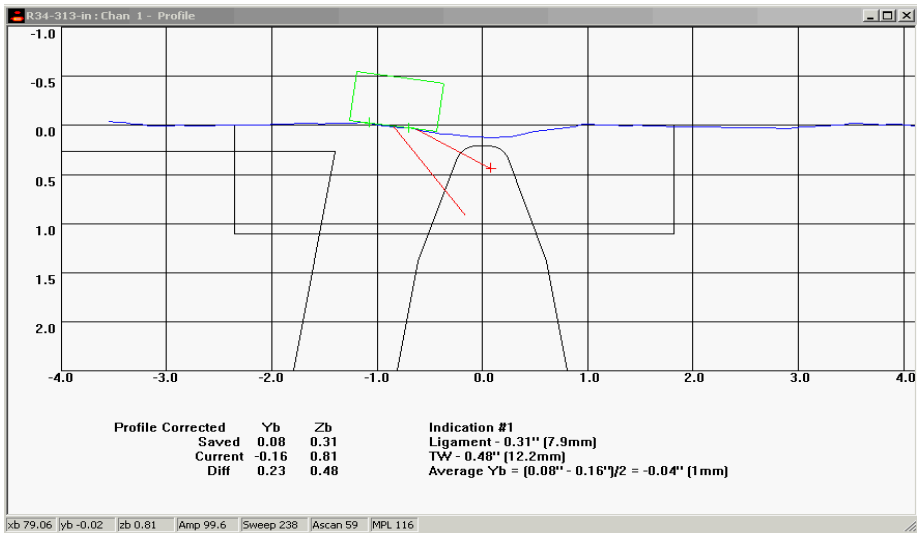
Irregular surface causes gaps under search unit and changes angle, which must be accounted for during measurement

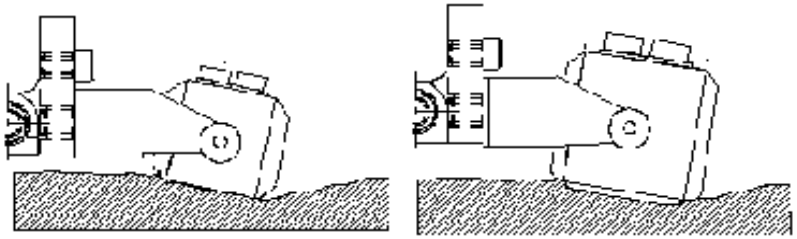


© 2010 Electric Power Research Institute, Inc. All rights reserved.

ELECTRIC POWER RESEARCH INSTITUTE

Actions Taken to Increase Accuracy





- Vendors have put tremendous effort in to qualifying
  - Designed new delivery systems to optimized coupling
  - Designed new search units
  - Developed profiling technology
  - Made changes to analysis software to correct for surface geometry
  - Supplemented ultrasonic examinations with eddy current to improve characterization capabilities

© 2010 Electric Power Research Institute, Inc. All rights reserved.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Current Industry Evaluation Criteria

- After numerous unsuccessful attempts at qualification PDI has developed a screening criteria for evaluating depth sizing procedures (PDI Policy 03-01)
  - Not currently an acceptance criteria
  - Used to gage performance of procedures that were unsuccessful
  - Takes in consideration the increased thickness of the components

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Industry Evaluation Criteria

- Description of Current Acceptance Criteria
  - RMS error is used as the criterion for acceptable depth sizing performance in Appendix VIII and is calculated according to the following equation:
    - Equation 1:

$$RMS = \left[\frac{\sum_{i=1}^{n} (m_i - t_i)^2}{n} \right]^{1/2}$$

  - *where*
  - *mi=measured flaw size*
  - *ti = true size of a flaw*
  - *n=number of flaws measured*

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Industry Evaluation Criteria

- The PDI Policy follows the following steps
  - Calculate RMS according to Equation 1.
    - Step A. If RMS < 0.125”, this is acceptable to Appendix VIII criteria, and the PDQS can be issued
    - Step B. If RMS > 0.125” and < 0.187”, this does not meet appendix VIII criteria, but the sizing error can be documented in a separate letter to PDI members upon request
    - Step C. If RMS > 0.187”, then calculate Root Mean Square Percentage (RMSP) according to equation 2

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Industry Evaluation Criteria

$$RMSP = \left[\frac{\sum_{i=1}^{n} \left(\frac{m_i - t_i}{t_{wall\ i}} \right)^2}{n} \right]^{1/2} * 100$$

- Equation 2
- where
  - *mi=measured flaw size*
  - *ti = true size of a flaw*
  - *n=number of flaws measured*
  - *twall= wall thickness of the sample containing each flaw*

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Industry Evaluation Criteria

- This calculation expresses the RMS error in terms related to a percentage of wall thickness (RMSP) similar to the IWB-3500 tables
- If RMSP <10% the sizing error can be documented in a separate letter to licensees upon request
- Documenting sizing errors in this way is for the sole purpose of
  - Providing information to licensees on the sizing performance of procedures and personnel for their use in evaluating indications
  - Ensuring that documented sizing errors are meaningful and reliable
- Personnel will not be considered successful unless their RMSP results are within the 10% RMSP

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Current Industry Evaluation Criteria

- If the procedure's documented sizing error exceeds all three of the previously stated steps the documented error may be provided to the licensee if requested, but the licensee will be responsible for developing the technical basis on how they will be applied
- Documentation of sizing errors that exceed Appendix VIII criteria does not imply that the procedures or personnel are qualified to Appendix VIII or PDI criteria

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Depth Sizing Evaluation Criteria

- How does the licensee currently use these values?
  - The licensee must submit a request for alternative detailing how flaws will be sized
  - To date all licensees that had made this request follow the process detailed below
    - Flaw is sized using procedurally defined techniques
    - The delta between the current requirement (<=0.125” RMS) and the procedure’s achieved accuracy is added to each depth measurement
      - Example:
        - Procedure documented = 0.200”
        - Requirement = 0.125”
        - (0.200” – 0.125” = 0.075”)
        - Reported flaw depth = Measured flaw depth + 0.075”
    - If the flaw is considered embedded this correction factor is added to both the upper and lower tip measurements
      - Could have an effect in determining if the flaw is surface connected and when performing proximity determinations

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Depth Sizing Evaluation Criteria

- To date ~20 Safety Evaluation Reports (SER's) have been issued to licensees using this process
  - A testimony that the process described is adequate to assure safety
- The process is conservative and adequately takes into account the procedure's documented sizing capability
  - In most cases if a flaw is detected and the correction factor is added the flaw automatically exceeds the IWB-3500 tables

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Future Work

- Industry will work with ASME in Codifying current process documented in SER's
  - Acceptance criteria will remain 0.125"
  - If procedures cannot meet this criteria, but demonstrate performance better than 10% RMSP then performance will be documented
  - Correction factor must be added to every depth measurement made with procedure that does not meet 0.125" acceptance criteria
  - Alternative approach will be limited to thick components examined from inside surface only
  - Will continue to drive vendors to achieve best achievable accuracy

© 2010 Electric Power Research Institute, Inc. All rights reserved.

Summary

- The industry has expended tremendous effort in obtaining depth sizing capability for dissimilar metal welds
- Automated and manual procedures are qualified for depth sizing from the outside surface
- While procedures from the inside surface have not successfully satisfied the current acceptance criteria, they have demonstrated adequate depth sizing capability, which is supported by the conclusions documented in the approved SER'S obtained to date
- The industry has developed a conservative approach to dealing with this limitation
- The industry continues to work on improving its capabilities, however, due to inherent limitations the ASME Code must be changed to adopt alternative approach to evaluating procedure performance

© 2010 Electric Power Research Institute, Inc. All rights reserved.