Assessing NDE Methods for Dissimilar Metal Welds: A Research Plan

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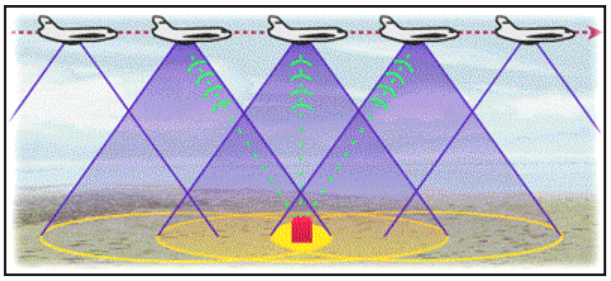
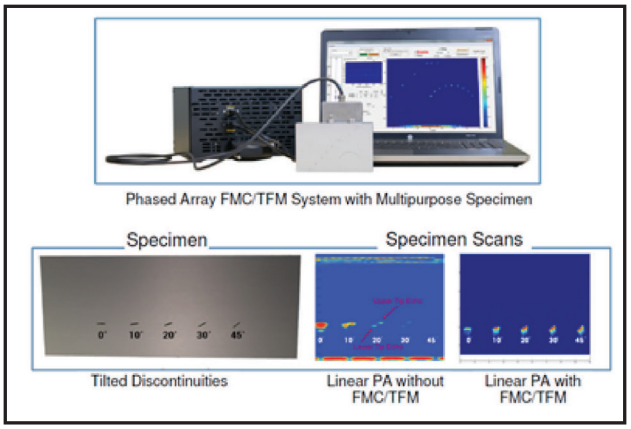
Background

Phased-array ultrasonic test (PAUT) methods have been widely used for nondestructive examination (NDE) in many industries for several years. PAUT methods are routinely used to inspect high-consequence structures such as critical components in aircraft, high-pressure natural gas and hazardous liquid pipelines, and load bearing beams supporting bridges in our roadways to name only a few examples. Recent advancements in PAUT technology have increased resolution and sensitivity for finding certain defects or anomalies that previously were difficult to consistently detect. Using concepts similar to those in synthetic aperture radar scans used for 3D topographic mapping of the earth's surface, full matrix capture/total focusing methods (FMC/TFM) have been commercialized for PAUT to significantly improve resolution for inspection of metal structures. EWI has recently obtained a state-of-the-art PAUT FMC/TFM system and will be evaluating potential improvements for inspection of welded structures consisting of multiple metals, such as Inconel clad to steel pipelines. These dissimilar metal welds have inherent challenges for NDE inspection due to metallurgical features that often can deflect or scatter the ultrasonic wave as it moves through the material. The FMC/TFM capabilities offer promise for minimizing these difficulties and improving the resolution of PAUT inspection for dissimilar metal welds.



Synthetic Aperture RADAR



Phased-Array UT with FMC/TFM

The oil and gas industry has been increasingly using dissimilar metal corrosion resistant alloys (CRAs) in subsea infrastructure in an effort to achieve enhanced corrosion protection and fatigue corrosion resistance. A typical scenario involves a carbon steel or high-strength, low-alloy (HSLA) material clad with an Inconel or stainless steel overlay and often utilizing CRA butt and/or girth welds to fabricate pipelines, flowlines, jumpers, manifolds, and similar subsea hardware.

Inspection of dissimilar metal welds following fabrication is an important part of an integrity assurance program. The most common inspection method for such joints is radiographic testing (RT), either single or multiple shot, which can provide very good detection of volumetric flaws such as lack of fusion or trapped slag. However, RT may not provide high detection probabilities for sharp flaws such as hot cracks or tight lack of fusion, depending on flaw orientation. Therefore, automated PAUT systems have been employed in some circumstances to give increased flaw detection and sizing sensitivity. However, use of PAUT is not universal in the oil and gas industry and in many cases RT remains the standard inspection methodology.

Ultrasonic techniques for carbon steel weld examination are well known and have been widely used for many years. When applied on dissimilar metal welds, however, complications can arise from grain coarsening and anisotropic microstructure, which may produce scattering of the ultrasonic wave, signal attenuation, and beam skewing. Current practice for performing PAUT inspections are typically more expensive compared with RT and require higher skilled personnel to setup and calibrate instrumentation, perform scans and interpret results. In addition, since the number of qualified PAUT inspectors is more limited, project delays can occur due to more limited availability of these inspectors. Consequently, EWI is developing a research program to assess potential improvements for inspection dissimilar metal welds. This will provide side-by-side comparisons of RT and conventional PAUT, and then quantify any improved resolution and sensitivity by using PAUT with FMC/TFM on the same set of test coupons.

Research Objective

This project seeks to evaluate three NDE methods in their accuracy and reliability for inspection of dissimilar metal welds and provide a feasibility assessment of FMC/TFM methods. The outcome may identify approaches to improve the accuracy while reducing cost and complexity associated with inspection of dissimilar metal welds.

Research Plan

This proposed project will have two tasks. Task 1 will provide a side-by-side comparison of single and multi-shot RT and conventional AUT on three seeded girth weld samples. Task 2 will utilize the FMC/TFM method on the same seeded defect coupons to provide corresponding data for comparison with RT and conventional PAUT results.

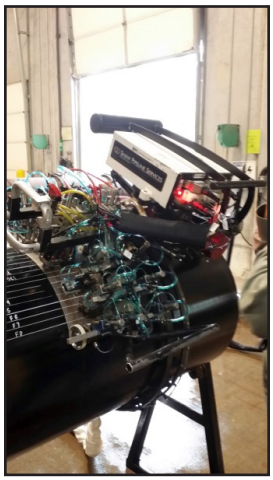
Previously prepared seeded defect Inconel girth weld coupons will be made available for this study. Each coupon contains approximately 18-20 defects of various types and locations. Under previous work, conventional PAUT inspections have been already been made on these coupons and results will be provided to this project, including the number, type, size and location of each defect.

Task 1: Side-by-Side Comparison of RT and Conventional PAUT

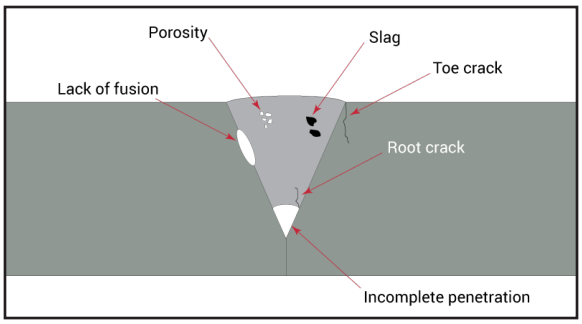
Since extensive PAUT data already exists for these coupons, only RT inspections will be performed in Task 1. Two RT inspection vendors will be contracted to perform single and three-shot radiographs of each weld coupon. This will be a blind study as the inspection vendors will have no prior knowledge of the defects imbedded in each coupon. RT results will be compared with the previously provided PAUT data to assess sensitivity to detecting various flaw types and flaw locations. The outcome of this task will allow a direct comparison of detection sensitivity between RT and conventional PAUT for various flaw types and locations. However, the project will not produce probability of detection (POD) or sizing accuracy data. Based on the results, informed guidance can be offered on inspection methodologies that should be considered for dissimilar metal welds. Further work could be performed to produce actual POD and sizing accuracy data and to establish improved inspection protocols and standards.

Task 2: FMC/TFM Feasibility Trial

Following RT inspections, the same weld coupons will be inspected by EWI using a recently purchased FMC/TFM system consisting of 256 element arrays. EWI staff performing the inspections will have no knowledge of the defects in each coupon. The results will be compared with RT and conventional PAUT data to assess the feasibility of FMC/TFM inspections on dissimilar metal welds.



Conventional PAUT Pipe Inspection



Types of Weld Discontinuities NDE Methods Seek to Identify

It is anticipated that the FMC/TFM capability may reduce complexities associated with instrument calibration and signal interpretation often found with dissimilar metal welds using conventional PAUT methods. FMC/TFM techniques produce a greater volume of inspection data and beam angles at which the ultrasonic wave is directed into the weld and potentially reduces attenuation and scattering effects. This is expected to simplify calibration efforts, eliminating the need to have detailed information about the weld bevel that is commonly required with conventional PAUT. Recent advancements in computer processing power enables FMC/TFM inspections to be performed in about the same period of time as required for conventional PAUT improving feasibility for using PAUT FMC/TFM in field inspection scenarios. Implementation of FMC/TFM techniques could potentially reduce the cost and complexities of current PAUT inspection technology, and open the possibility of a greater number of inspection vendors being capable of performing FMC/TFM inspections since skill requirements are reduced and interpretation simplified.

Deliverables

A detailed project report will be provided detailing all inspection procedures and results. This will include an assessment of the sensitivity and reliability of RT, PAUT and FMC/TFM methods. A guidance document will be provided to discuss the advantages and disadvantages of the various NDE methods used. This work could support the development of improved industry standards for inspecting dissimilar metal welds and establishing inspection standards for field vendors.

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Tom McGaughy, Senior Technical Advisor for Structural Integrity and Materials Evaluation, has special expertise in fracture mechanics and materials technologies. He is involved in developing client relationships and technology development strategies with the oil, gas, and petrochemical industries, and is Director of the EWI Strategic Technology Committee (STC) for Oil & Gas.