Full Matrix Capture Ultrasonic Inspection of Girth Welds in CS Pipe and CRA Clad Pipe

JOINT INDUSTRY PROJECT OUTLINE

PR25561

Summary

The accurate sizing, positioning and characterisation of flaws in corrosion resistant alloy (CRA) clad and J-bevel carbon steel (CS) pipeline girth welds is a key aspect of laying and maintaining pipelines of high structural integrity in the oil and gas (O&G) industry.

Ultrasonic techniques, including conventional and phased array, are commonly used to determine the structural integrity of such welds in both J-bevel CS pipe and CRA clad pipe. Coherent noise contributions, caused by differences in acoustic impedance at the interface between parent, clad and weld materials, as well as coarse grained materials typically used, create challenges for effective UT inspection. Furthermore, accurate flaw sizing and characterisation of near vertical flaws in J-bevel CS girth welds (i.e. lack of side wall fusion (LoSF)) relies heavily on accurate calibration using flat bottomed holes orientated along the weld bevel. This calibration relies on a complex, time consuming and operator dependent set up process and the resulting technique is still dependent on the orientation of the defect during inspection. Even slight mis-orientation can significantly affect probability of detection and sizing accuracy. The project promotes a novel approach, combining full matrix capture (FMC) data acquisition with the total focusing method (TFM) image reconstruction algorithm, to: overcome the challenges of material noise contributions and improve inspection capability through image processing techniques; minimise the effects of defect misorientation through improved focussing and imaging; relieve the operator of complex, time consuming calibration through a semi-automated calibration routines.

It is proposed that the project includes a number of work phases including (i) development of optimised ultrasonic inspection setup (ii) FMC+TFM ultrasonic inspection of girth weld pipe samples (iii) validation of inspection performance, for example, through sectioning and microscopy (iv) development of a best practice guide for FMC+TFM inspection of girth welds. At the end of the project, sponsors will receive a licence for TWI's FMC+TFM software package, a report detailing all major outcomes and results, as well as a best practice guide for FMC+TFM inspection of girth welds, which will be issued at the end of the project.

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Project Concept

Industry problem

Quick and reliable detection, characterisation and sizing of flaws in pipelines are key requirements in the O&G industry during installation and maintenance of safety critical pipeline structures. Ultrasonic testing (UT) and phased array (PA) are common ultrasonic inspection techniques used to assist with pipeline structural integrity assessments. Such techniques have gained popularity over radiography due to their lower cost and reduced health and safety implications. However, there are numerous inspection scenarios where these techniques currently fail to satisfy the needs of pipeline operators.

Since the 1990's ultrasonic testing using zonal inspection with focussed ultrasonic transducers has been the preferred inspection technique on pipeline girth welds. The principle of zonal inspection is that the weld cross-section is divided into zones, with separate focal laws used per zone to maximise the response off the weld fusion face. One of the most common bevels in pipeline girth welds is the J-bevel, used for gas metal arc welding (GMAW), however this weld profile contains very steep angles (typically 3° to 10° off vertical), which render pulse-echo UT and PA approaches ineffective as the oblique incident angle reflects sound away from the transducer. As such, self-tandem techniques were developed which rely on backwall echoes to reflect the sound back to the transducer(s) using a round-trip beam path. Since self-tandem PA and UT techniques are unable to image using the usual B-scan view the use of strip charts is now common practice. For a typical inspection a single strip chart is used per weld zone, allowing fast identification and sizing of flaws. However, accurate detection and flaw sizing of flaws such as LoSF, relies heavily on accurate calibration using flat bottomed holes orientated at the angle of the weld bevel. Slight mis-orientation can significantly affect the amplitude response and sizing accuracy of the technique, leading to false calls and missed defects.

Similarly to CS girth welds, ultrasonic inspection of CRA clad pipeline girth welds has now become common place. However poor detection rates, false calls and inaccurate sizing can be an issue with ultrasonic inspection of such welds due to coherent noise contributions caused by differences in acoustic impedance at the interface between parent, clad and weld materials, as well as the often coarse grained and anisotropic material properties of the clad and weld material.

Proposed solution

In recent years the combination of FMC data acquisition technique and the associated TFM image reconstruction algorithm have been shown to outperform existing UT and PA techniques due to the ability to focus fully with high resolution throughout the inspection volume.

The FMC data acquisition technique is based on the concept of firing on a single element in an ultrasonic array transducer while receiving on all elements. The process of 'fire on one and receive on all' then repeats until all elements in the array have fired once. Data is then processed using the advanced TFM image reconstruction algorithm, to provide an image where all points within the insonified area are fully focused. Real-time scanning speeds are achieved through a combination of rapid data processing using the parallel processing capabilities of the graphical processing unit (GPU), as well as very fast data transfer from the array pulser-receiver unit to the control PC.

To date the technology has shown several advantages over phased array, including high inspection sensitivity to small flaws and generation of high resolution, fully focused images, offering the potential for improved flaw detectability and sizing. The inherent ability of FMC+TFM to generate fully focused images reduces the complexity of the focal law parameters input by the operator during setup, and offers the potential to relax requirements in standards and procedures relating to positional accuracy of inspection equipment and knowledge of the weld profile. The technology also takes away many of the setup and inspection complexities associated with existing techniques, and as such has the potential to greatly de-skill the task of the operator.

Additionally, for inspection of CS girth welds FMC+TFM facilitates B-scan view imaging using the self-tandem technique, allowing flaws to be sized and characterised in the same manner to that of standard PA pulse-echo. This negates the need to seperate the weld into zones, which greatly simplifies the inspection setup and calibration as well as offering a more intuitive and reliable defect detection and sizing approach.

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Objectives

The main aim of the project is to implement advanced ultrasonic inspection techniques such as FMC+TFM to overcome some of the limitations which exist with industry standard ultrasonic inspection of pipelines in the O&G industry.

- Develop ultrasonic inspection procedures for CS and CRA clad pipe components
- Perform FMC+TFM inspection of girth welds in CS and CRA clad pipe
- Determine sizing accuracy of FMC+TFM inspection technique
- Validate results from inspections through sectioning and microscopy
- Develop a best practice guide as a prerequisite to standardisation of the FMC+TFM technique for inspection girth welds

Benefits

Potential benefits of the FMC+TFM inspection technique include:

- Reduced setup time through simplified calibration process and reduced input parameters
- Opportunity to relax requirements relating to positional accuracy of inspection equipment and knowledge of weld profile, as the full focussing ability of FMC+TFM has potential to reduce the need for high precision knowledge of focal spot position
- Ease of interpretation through use of fully focussed and high resolution (B-scan) images to replace strip charts used with the zonal discrimination technique.
- Greater reliability of flaw detection and sizing
- Increased levels of safety through improved accuracy of fitness for purpose assessments

Approach

The total number of weld configurations, flaw types and flaw locations which can be included in the project scope will ultimately depend on the number of sponsors. Sponsors may propose CS pipe and/or CRA pipe samples, but the total number of samples provided, per sponsor, in the project will remain fixed and will be agreed before the project start. Prior to the start of each work phase, discussions between TWI and sponsors will be held to agree details of the work activity. TWI’s FMC+TFM software system currently facilitates automated and encoded weld inspection using half-skip, full-skip and self-tandem (alternative to ZDT) inspection modes. If additional software functionality is sought during project, TWI will agree requirements with the consortium and develop further its software capability as a separate activity in parallel with this project.

Phase 1 – Develop optimised ultrasonic inspection setup (Months 1 - 8)

To optimise the ultrasonic inspection setup, modelling and simulation of the beam profile and defect interaction will be conducted using CIVA – a NDT specific modelling and simulation package. The results from modelling and simulation will be used to (1) assist with the design of a suitable ultrasonic transducer/wedge configuration (2) determine the optimum scan offset of the transducer/wedge configuration. Results from modelling and simulation will then be used to assist with optimisation of the inspection setup in conjunction with empirical studies, to be carried using reference samples containing well defined artificial reflectors such as flat bottomed holes, side drilled holes and EDM notches located throughout the weld volume.

Phase 2 - Inspection of samples (Months 8 - 20)

This phase will focus on ultrasonic inspection of girth welds in CS pipe and CRA clad pipe using TWI's FMC+TFM technology. Assessment of results will be carried out against performance criteria defined by the project sponsors. TWI may provide a small number of pipe samples for use in the project, although sponsors are encouraged to provide samples specific to their requirements. Specifically this phase of work will include:

- Supply of samples and reference/calibration blocks by sponsors and possible manufacture of additional samples if required.
- Inspection of samples using FMC+TFM technique
- Analysis of results against performance criteria outlined by sponsors

Phase 3 – Validation (Month 18 - 24)

On completion of sample testing, TWI will seek permission of sponsors to perform sectioning and microscopy on selected samples in order to assist with validation of the FMC+TFM technique. If sectioning is not acceptable then radiographic inspection may be considered as an alternative.

Phase 4 – Best practice guide (Months 18 - 24)

A barrier to early adoption of new technologies can be a lack of codes and standards against which to ensure compliance and demonstrate due diligence. Experience has shown that a premature rush to publish standards before the technology is mature, and supporting training infrastructure is in place, can lead to exclusion of new innovative implementations and put users out of compliance due to difficulties in certifying operators.

This phase will seek to develop a best practice guide for FMC+TFM inspection of girth welds in CS pipe and CRA clad pipe. The intention is to make the guide available to developers and users (including organisations outside the project participants), so that it can be used as a reference document. This will give early information to training providers, equipment manufacturers and end users and encourage feedback to enable updating of the guide.

The intention is that this guide, once mature, will form the basis of a harmonised international standard.

Deliverables

- A licence for TWI's FMC+TFM software package (Beta) including two years maintenance and support.
- A report detailing all major outcomes and results will also be issued at the end of the project.
- A best practice guide

Price and Duration

The overall estimated price for the work is £400,000 (excluding VAT), which requires £50,000 per annum for two years (£100,000 total) from each of the four Sponsors. It is anticipated that the project will commence with an agreed scope of work with a minimum of two Sponsors.

Further Information

For further information on how a Joint Industry Project (JIP) runs please visit:

http://www.twi-global.com/services/research-and-consultancy/joint-industry-projects/

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