WELD INSPECTION PAPARAZZI

Guillaume Neau and the Eddyfi Technologies team, Canada, discuss the use of ultrasound imaging techniques for inspecting pipe welds of varying configurations.

It is no secret that millions of miles of pipeline infrastructure are operating beyond their intended design life, with limited condition information. Prone to damage by corrosion, cracking, and potential design flaws, pipelines require regular non-destructive testing (NDT) to help ensure structural integrity and regulation compliance, as well as verify the remaining useful life of infrastructure. Screening inspection of in-service pipes is often conducted using devices that contain test and data recording tools that travel through the pipeline and continuously test the pipe wall along its journey. These devices are referred to as 'smart pigs', and they use various NDT techniques including magnetic flux leakage (MFL) and ultrasound. The inspection results from inline inspection (ILI) tools, or smart pigs, are limited to the detection of anomalies, and in order to evaluate, quantify, size, and characterise any findings, further inspection is required.

This article discusses the use of ultrasound imaging techniques for the inspection of pipe welds. Pipe welds come in many configurations. Commonly manufactured using electric resistance welding (ERW), steel pipes present different inspection challenges compared to CRA-clad girth welds, for example. This article addresses both scenarios, with phased-array ultrasonic testing (PAUT) techniques and total focusing methods (TFM) embedded in the latest generation of commercially available, advanced, portable PAUT instruments.

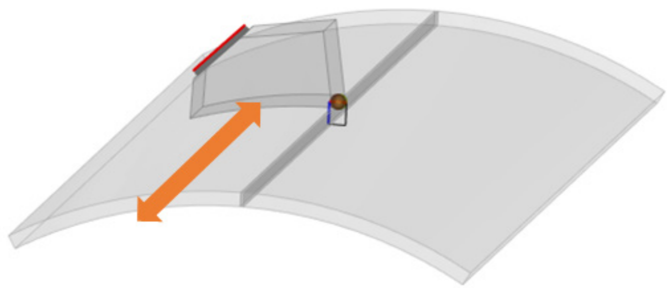

Figure 1. COD wedge configuration for axial scanning of ERW pipe welds.

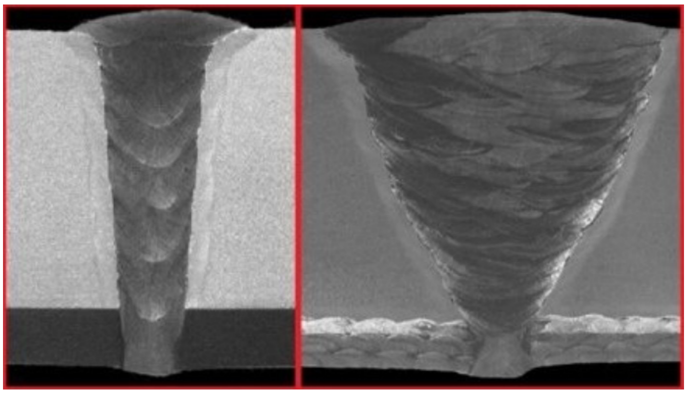

Figure 2. CRA-clad dissimilar-material welds. Photo courtesy of Absolute NDE.

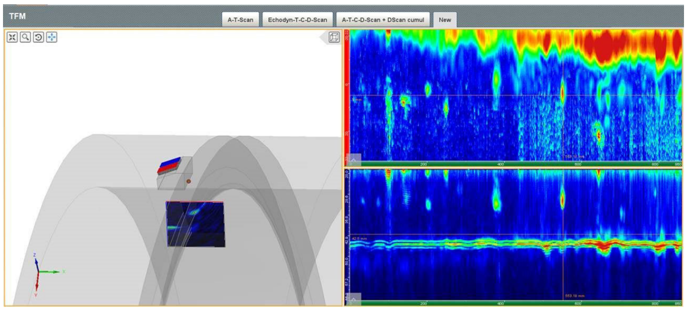

Figure 3. DMA probe L-wave, Inconel 625 – single V, 50 mm thick with a 12.5 mm stainless cladding.

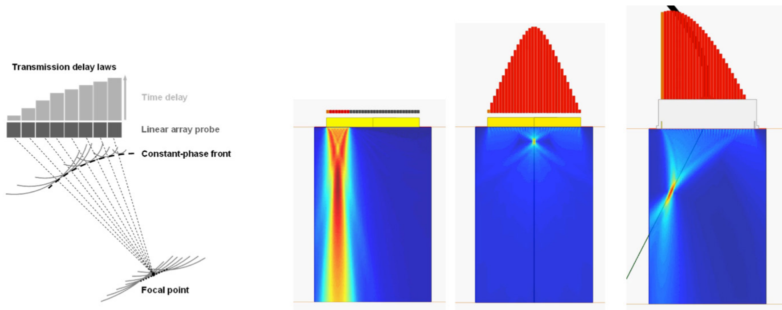

Figure 4. PAUT principles: electronic scanning, point focusing, and beam steering.

PAUT and TFM imaging techniques

While conventional ultrasonic testing (UT) consists of a single active element that generates and receives sound waves, phased-array probes contain an assembly of small, individual elements that can be pulsed separately. The core of phased-array technology resides in computing and applying time delays to each element of a probe, in order to focus the energy of a desired location for maximum resolution imaging of defects that affect the structural integrity of a specimen.

TFM is a high-resolution imaging technique based on the buffering or storage of full matrix capture (FMC) data. FMC data is gathered by firing each crystal sequentially, while listening with all the other elements. Signals are recorded in order to create a matrix of signals, with lines displayed as transmitted signals and columns as received signals – hence the name, full matrix capture. Many variations exist for both the data acquisition and the imaging process. However, for simplicity purposes, the generic name, TFM, is used in this article.

While PAUT steers and focuses the ultrasonic beam both in transmission and reception, TFM uses multiple transmissions with a single channel, without focusing or steering, and uses substantially large reception focal laws to achieve high-resolution imaging. PAUT and TFM have their advantages and disadvantages. Hybrid methods attempt to combine advantages of each method. In commercially available integrated software, the TFM-D (directional) combines beam steering with a large aperture in transmission and TFM reception focal laws. Depending on the application, this variation enhances the signal-to-noise (SNR) ratio of the TFM significantly, while increasing the resolution and data acquisition speed of PAUT.

Overcoming ERW inspection challenges

Cracking in ERW pipes occurs predominantly in the weld seam region. Steel pipelines that have evidence of cracking in the ERW seams are excavated and further inspected. This task potentially involves miles of ERW indication validation. The challenge for the NDT of long-seam welds is handling the pipe curvature for precise defect sizing and location, while maintaining a high-speed scanning rate.

To overcome this, commercially available operating software for the latest generation of advanced PAUT units accounts for the pipe radius and circumferential outside diameter (COD); axial scan configuration of probes is used for this specific inspection. The onboard software offers high-resolution imaging techniques such as PAUT and TFM, resulting in easy-to-interpret scans for not only defect detection, but also characterisation. Newly implemented TFM algorithms offer PAUT scanning speeds up to 20× faster, without compromising on resolution. The TFM imaging has been tested on ERW piping with both shear waves and longitudinal waves. Inspection procedures requiring only one pass to cover the full volumetric inspection (ID to OD) have been implemented and tested successfully on reference samples.

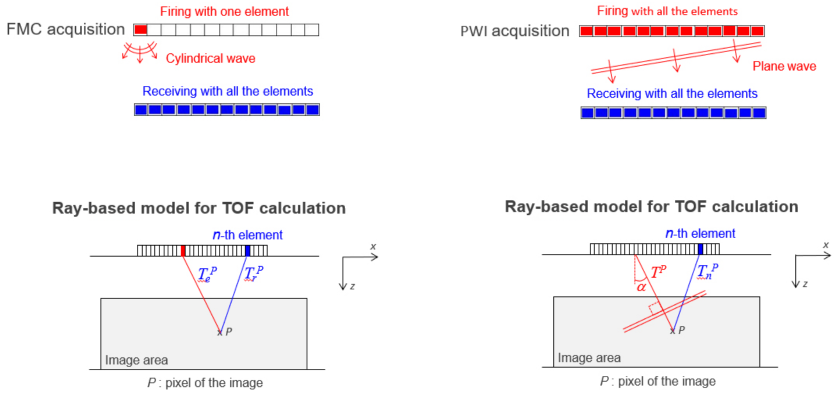

Figure 5. **The principles of total focusing methods: two variations of TFM imaging. Left: TFM-FMC, right: TFM-PWI.**

Overcoming CRA-clad inspection challenges

To improve the service life of components prone to corrosion, pipelines are sometimes manufactured in solid CRA material like Inconel, 13-chrome, duplex stainless steel or super duplex stainless steel. For onshore and offshore pipelines that need to achieve a balance with cost, mechanical properties, and corrosion-resistance, clad or lined pipes may be used. CRA-clad pipelines are increasingly used for the transportation of hot and corrosive materials because of their higher resistance to corrosion. The protection layer, however, affects the ultrasonic inspection of girth welds. CRA welds are not favourable to shear wave transmission; their inspection is performed by refracted longitudinal being limited to half-skip mode (half-vee), which often requires removal of the cap for 100% coverage. Moreover, failure of the CRA portion of the weld root exposes the sour fluids to carbon steel, which can have disastrous effects. For this reason, special attention is given to the root integrity of these pipes.

To overcome the challenges coming with dissimilar materials, the use of linear and dual probes in transmit-receive elongational waves (TRL) is recommended by the industry. These probes are referred to as dual linear and dual matrix arrays (DLA and DMA). Standard pulse-echo linear arrays can also be applied if they are used with a large transmit-receive aperture. In the TRL technique, also known as a pitch-catch technique, the transmitter and receiver transducers are different, so that the collected signals originate only from the area where the two beams cross each other. Using a separate pulser and receiver, the wedge size is reduced, and the probe can be used closer to the weld – providing higher sensitivity. Combining this approach with a large aperture, as well as the ability for precise steering, is recommended for better SNR ratios and probability of detection (PoD) in thick specimens. In terms of solution equipment, it translates into 64+ parallel architecture systems driving probes with 64+ elements.

Commercially available advanced PAUT systems exist in 64:64 and 64:128 architectures with a native support of DMA/DLA interface. Users can configure the full inspection procedure directly from the unit, using the embedded operating software for these systems. The dual probes can be used with a set of optimised techniques for each inspection case. Phased-array sector scanning can be set and optimised by the user, as well as total focusing methods (TFM and variations) live on the PAUT system.

Conclusion

ILI tools are efficient to detect cracking in pipes, leading to direct examination with various NDT methods. Compared to conventional UT, PAUT combined with TFM for pipe weld inspection can not only enable higher PoD of defects but also provides characterisation. Commercially available advanced PAUT units offer operational efficiencies with comprehensive inspection results.

Advanced ultrasonic techniques available in real-time

With a native support of PAUT, TFM, and hybrid methods on M2M Mantis, Gekko and Panther, the operator can optimise the ultrasound settings to get the best inspection possible, without compromising speed or resolution.

Handling high-channel counts phased-array probes

Handling up to 128-element dual probes on Gekko 64:128 and Panther 128. Probes with more than 128-elements are handled by Panther 128:256 and above.

Automatic time corrected gain

One of the most appreciated tools of the software interface, the automatic time corrected gain is also available for dual probes. Less of a struggle with procedure configuration enables more efficient inspections.

Compatible with manufacturers

With the most popular probe connectors (IPEX) on PAUT units, the user can choose their favourite dual probe manufacturer. Also, the intuitive probe numbering software tool can help the user to easily configure their probes with the correct orientation.

Compatible with all axial and circumferential scanners

All Eddyfi Technologies ultrasound imaging units are compatible with most commercially available scanners. For both axial and circumferential scanning configurations, Mantis, Gekko, and Panther offer 3D rendering of inspection data.

Set-up of curved wedges and dual probes

Benefitting from intuitive interfaces like Capture, the user can set-up and configure linear, DLA, and DMA probes in a couple of clicks. These probes can be paired with flat or curved wedges. There is no need to use a third-party software; all parameters can be specified directly in the unit.