Eddyfi Technologies

NII

Non-Intrusive Inspection

Vessels, pressure systems and associated pipework

Contents

Overview

As part of any inspection and maintenance program, pressure vessels and associated pipework are required to undergo periodic inspection. These inspection regimes are typically governed by regulatory requirements, however the fundamental output is to ensure continued safe and reliable operation.

Historically this periodic inspection has involved vessel entry and visual assessment. The very nature of Internal Visual Inspection (IVI) requires plant shutdown, extensive cleaning programs and confined space working environments. This combination is time consuming, costly and introduces safety concerns for operators.

Recent developments in Non-Destructive Testing (NDT) technology has introduced a range of inspection tools and scanning equipment, which can reliably test pressure system components without the requirement for plant shutdown. Carefully combining the use of specifically designed inspection methodologies, it is now possible to provide close to 100% coverage on commonly designed pressure systems.

This combined inspection philosophy is regarded as Non-Intrusive Inspection (NII) and when used in conjunction with a robust risk-based assessment can offer a complete replacement to internal visual inspection, provide quantitative data sets for fitness for service calculations and overlay periodic information to assess degradation rates.

Major oil and gas companies are quickly adopting this inspection strategy and annual savings are reported to be greater than $100 million in some circumstances.

Introduction

Historically, NDT was used in construction and fabrication of new plant and equipment involving 5 fundamental methods; Ultrasonic Testing (UT), Radiographic Testing, (RT), Electromagnetic Testing (ET), Liquid Penetrant Testing (PT) and Magnetic Particle Testing (MT).

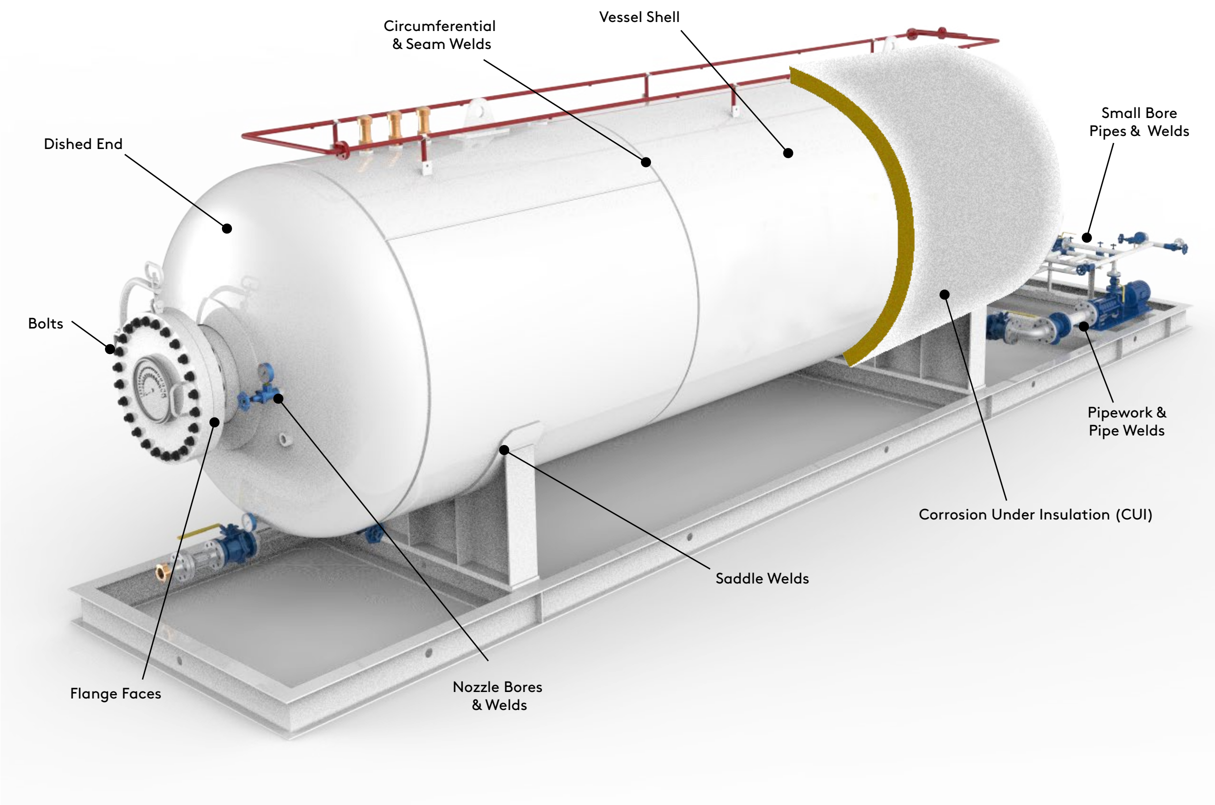
In the last 20 years the focus of NDT has changed to in-service inspection, to find process induced flaws in pipes and vessels which are temperature varying, painted, lagged, difficult to access and now even underwater. Increasingly stringent legislation designed to improve safety and protect our environment is driving the demand for more sophisticated NDT techniques.

Studies have shown that Non-Intrusive inspections can be more effective than Internal Visual Inspections. In addition, Non-Intrusive Inspections can detect metallurgical anomalies which would not be detectable during an Internal Visual Inspection.

Eddyfi Technologies have developed and perfected an array of advanced techniques to offer close to 100% coverage of pressure systems and associated pipework. All of the techniques outlined within this document are fully recordable and auditable, making them ideal to monitor the condition of the asset under evaluation.

Listed below are some of the most common challenges and technical solutions:

- Internal Corrosion of Vessel Shell – Automated Phased Array Corrosion Mapping
- Root Erosion/Corrosion of Circumferential and Seam Welds – ToFD
- HTHA – Total Focusing method – Total Focusing Method (TFM)
- Flange Face Corrosion – Phased Array
- Erosion of Nozzle welds – Phased Array
- Corrosion Under Insulation – Pulsed Eddy Current
- Pitting/Corrosion of Pipe Work – Various Automated & Semi-Automated techniques
- Bolt Inspection



Vessel Shell and Dome End

Automated & Semi Automated Phased Array Corrosion Mapping (PACM)

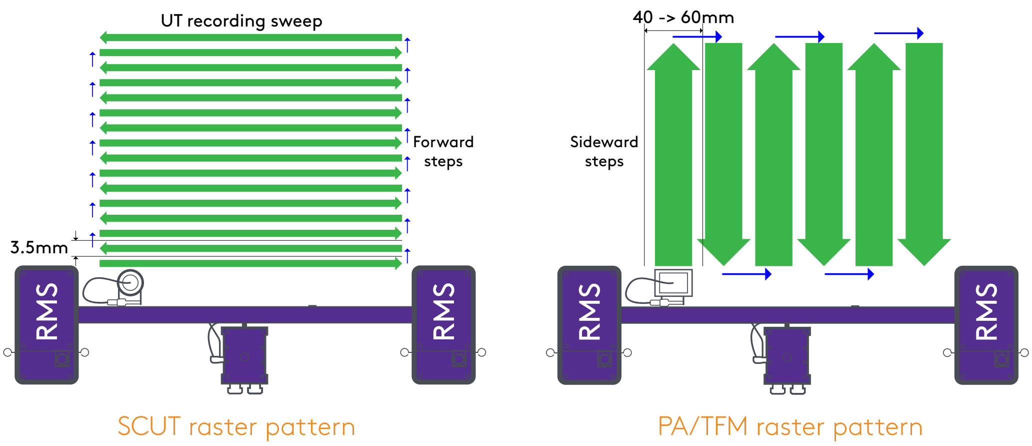
Phased Array Corrosion Mapping (PACM) is a useful tool for determining the internal surface morphology of pressure systems. PACM can be carried out when the part is both online and offline and can therefore potentially offer a significant cost saving over an Internal Visual Inspection (IVI), which can only be carried out when the part is offline, usually requiring a costly shutdown. Detecting corrosion and identifying corrosion rates while equipment is on-line can enable engineers and operational personnel to strategically schedule shutdowns and repairs or replacements by accurately forecasting equipment life.

Phased Array technology is fast becoming a recognized and trusted method of volumetric inspection, with typical applications being weld inspection and crack detection. The unique ability to produce a fully active volumetric ultrasonic beam allows for increased sensitivity along with rapid data collection. The system incorporates the phased array water box probe that allows for both circumferential and axial zero-degree data collection of ferrous test items up to 100°C.

Figure 1 Automated Phased Array with Silverwing RMS2 and M2M Gekko

The Phased Array probe has the capability of being mounted into automated RMS scanner and connected to either the Mantis or Gekko acquisition system. The scanner is fully encoded on both axis and has the ability to inspect pipes from 6" OD through to flat plate primarily on ferromagnetic material. Without sacrificing resolution and to guarantee a collection step of 1 x 1mm, Combing RMS with PA acquisition can increase productivity as much as x10.

Figure 2 Conventional SCUT vs PACM scanning pattern



The system is designed to offer the best inspection solution for detecting wall thickness reductions due to corrosion, abrasion and erosion. The systems high resolution is achieved from utilizing an effective ultrasonic beam that is 60mm wide and can collect A-scan information every 0.5mm. This ensures 100% coverage of the inspection area.

The high sensitivity of the phased array beam allows for detection of deflected and/or diffracted signals which ultimately allows for in-depth defect characterization by imaging the true morphology of the damage mechanisms.

In addition to typical corrosion mapping uses, Phased Array technology offers a range of advanced applications and with the automated Total Focusing Method (TFM) capabilities of the Gekko and Mantis, defect imaging can be further advanced. Below are Corrosion mapping data sets collected using Phased Array (top) and TFM (below). The scanning times were equal and a 1800 x 300 mm area was scanned and recorded within 9 mins.

Figure 3 Phased Array Scan with C-SCAN, B-SCAN and D-SCAN

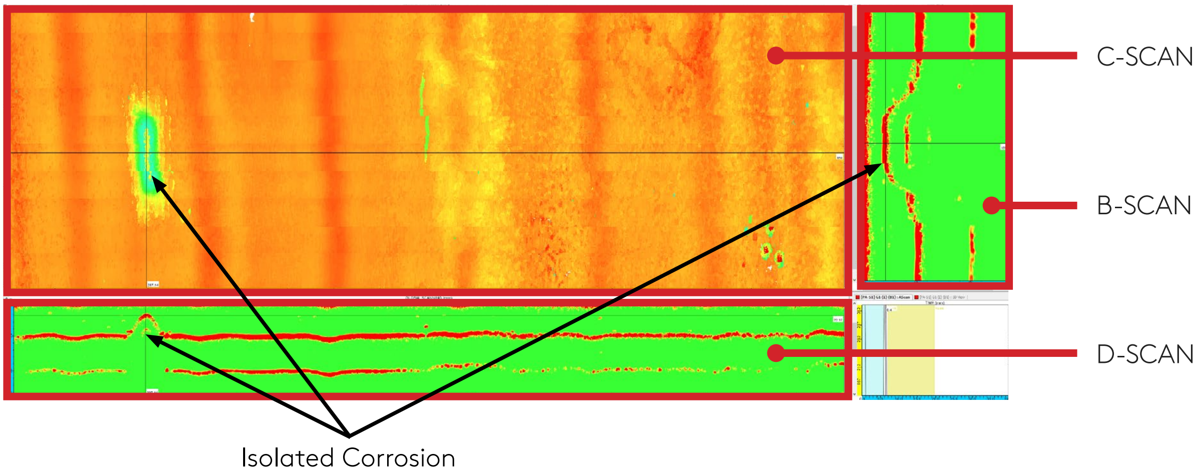
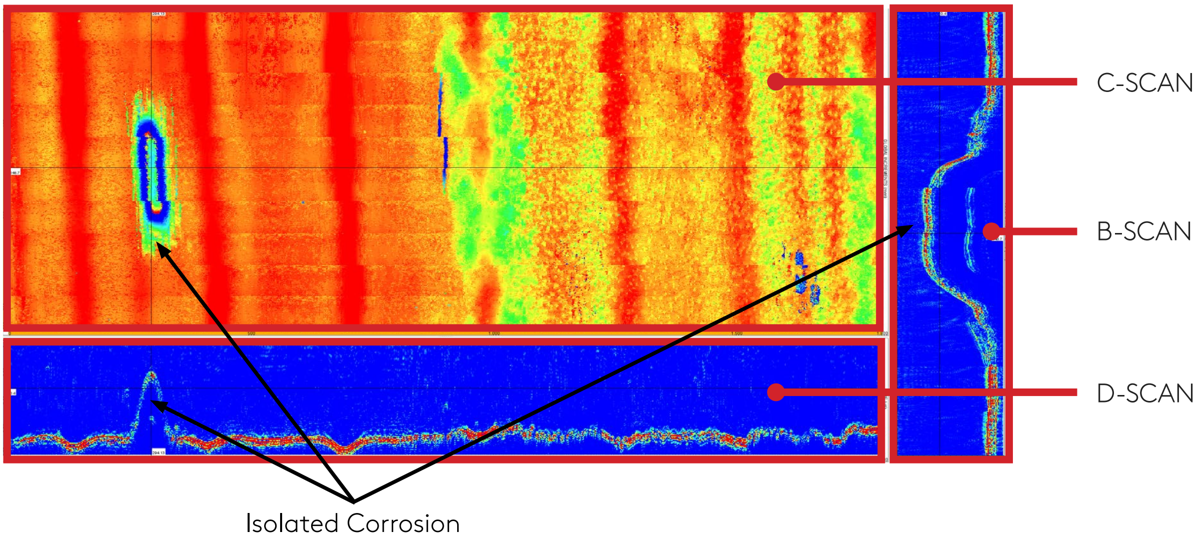
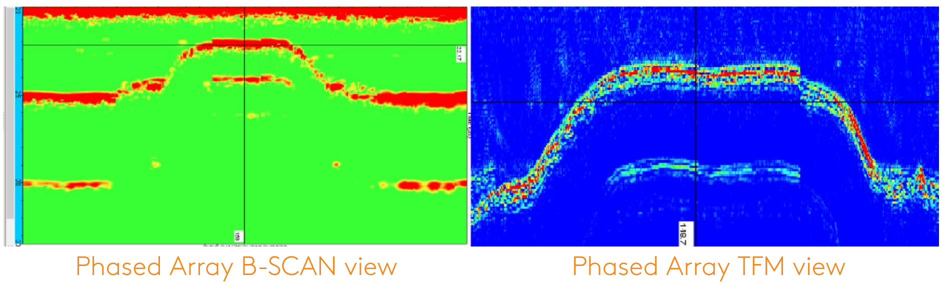


Figure 4 Full Matrix Capture and TFM scan with C-SCAN, B-SCAN and D-SCAN



Although the C-SCAN image shows similar data quality, the area of superficial corrosion (less than 1mm wall loss) shows enhanced clarity using TFM. In addition, TFM helps improve characterisation and defect morphology as signal strength is less reliant on defect orientation and therefore defects faces that do not lie orthogonal to beam orientation are still images.

Figure 5 Phased Array B-SCAN and TFM view of the same corrosion area



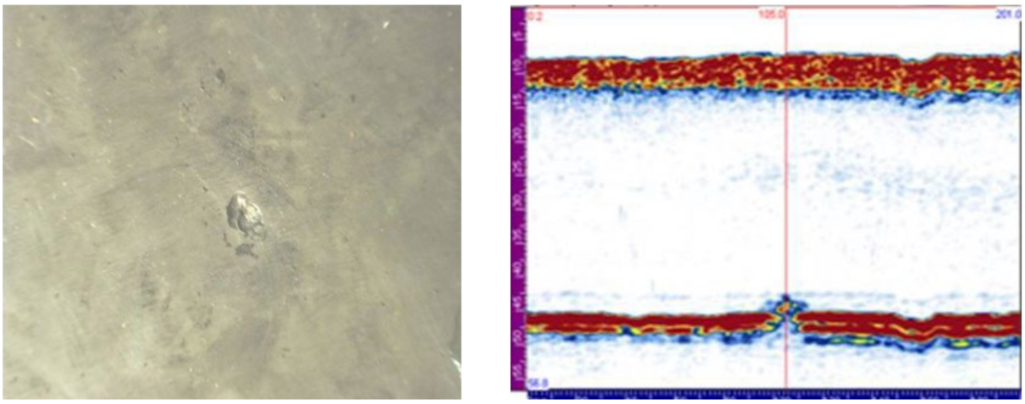
Finally, comparing the images in figure 5 it is clear that TFM has reduce/eliminated the near surface dead zone and therefore the ability to detect and characterise defects at or around the top surface is now possible.

Clad Lined Vessels

Automated & Semi Automated Phased Array Corrosion Mapping (PACM)

Using the method described in the previous section, there are added benefits using Phased Array to test carbon steel vessels with a stainless-steel clad lining. Due to the slight variance in acoustic properties the high sensitivity of the Phased Array system can identify the substrate-to-lining interface and therefore determine if corrosion is contained within the protective clad layer, or if it has propagated into the carbon steel substrate.

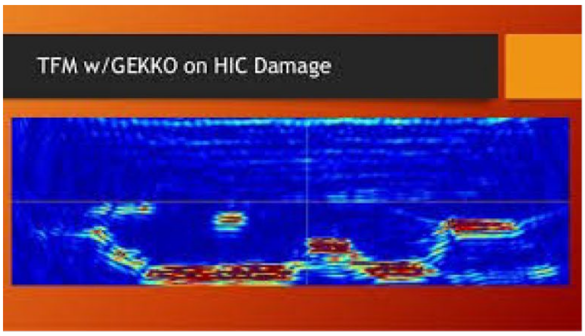
Figure 6 PACM Data depicting Cladding Damage



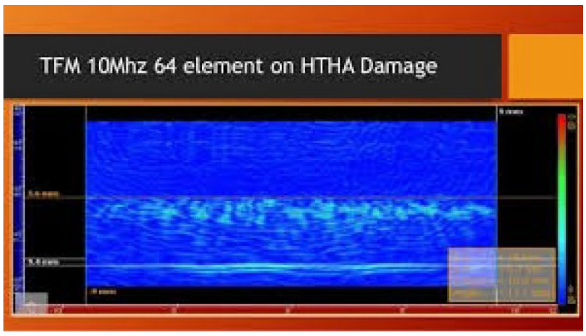
High Temperature Hydrogen Attack (HTHA)

There are many different forms of hydrogen damage that originate from fabrication anomalies such as inclusions and laminations which can migrate into hydrogen accumulation, blistering and then blister with stepwise cracking. TFM is the only proven technology that can both reliably detect early stages of HTHA, but also provide quantitative information on the severity.

Figure 7 D-SCAN display of Hydrogen induced damage using TFM



TFM view of step wise cracking



TFM cross-sectional view of HTHA

It is important to determine these stages and with TFM techniques Eddyfi can provide a reliable method. The 0° beam will detect laminar indications with accurate sizing, and based on analysis, the technician can determine the stage or classification of damage. The image above shows TFM data and cross-sectional view of HTHA (right) and step wise cracking (left).

Non-Ferrous Vessels and Pipework

PACM Techniques

The majority of in-service inspection solutions are aimed at homogeneous steels. However advanced ultrasonic techniques offer a range of solutions for the examination of austenitic materials. Eddyfi Advanced ultrasonic systems offer a suite of techniques for the non-intrusive examination of stainless steel, duplex and similar corrosion resistant alloys.

Phased Array Ultrasonic Testing (PAUT) using Phased Array Wheel probe or contact dual array technologies can provide a NII package comparable to that available for carbon steel vessels. These solutions are also applicable to corrosion resistant cladding and linings.

Figure 8 Phased Array with Gekko System

Weld Root Erosion and Corrosion

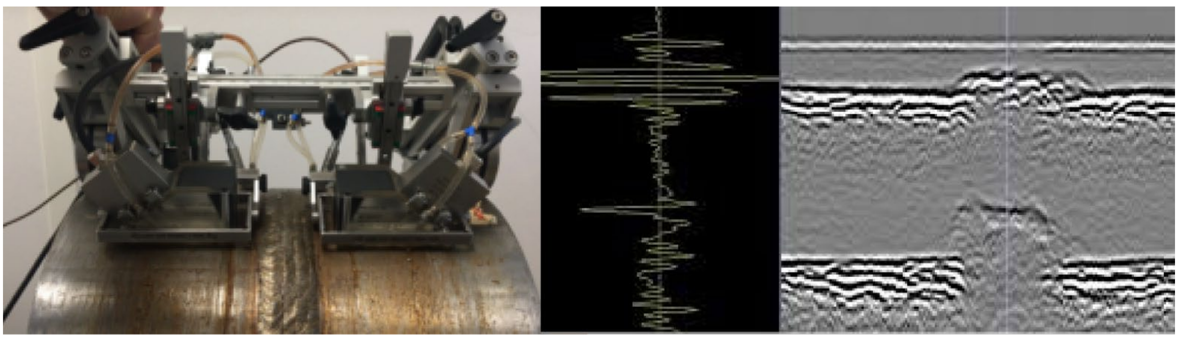
ToFD (Time of Flight Diffraction)

Time of Flight Diffraction (ToFD) is an advanced ultrasonic inspection method that is used primarily for weld inspection. It is a key method in Non-Intrusive Inspection surveys (DNV-RP-G103). The system provides fully encoded data collection, ensuring 100% weld coverage, significantly increasing the probability of detection (POD) of weld flaws and in-service cracking, enabling engineers to determine the optimum repair strategy and improve Risk Life assessment (RLA) and Risk Based Inspection (RBI) maintenance programs.

Weld Root Erosion/ Corrosion usually occurs below the area of the weld cap, therefore direct inspection using ultrasonic 0° techniques is not possible without weld cap removal. ToFD uses a probe either side of the weld cap and is recognized as the most reliable method for detection and sizing of Weld Root Erosion/ Corrosion (HOIS(09)RP2 Issue 1).

ToFD provides recordable weld data, like Radiography, but without the associated safety issues of radiation. ToFD is also the most accurate tool for through wall height/ remaining ligature sizing and is less sensitive to defect orientation, such as lack of fusion/crack type flaws.

Figure 9 Gekko performing TOFD inspection



Typical magnetic TOFD scanner

Weld root erosion data

Flange Face Inspection

Manual Phased Array

With timely advances in Phased Array (PA) technology it is now possible to replace expensive visual inspection with an in-service noninvasive approach. The HOIS Recommended Practice for in-service inspection of RF flange faces using phased array ultrasonic techniques (HOIS(11)R7 Issue 2) is based on the techniques developed by service providers and equipment manufacturers.

Crevice corrosion is caused by a concentration of corrosive substances within a confined space, making the crevice between two adjoining flanges the ideal environment for corrosion to initiate. The concentration of these corrosive substances in a localized area causes the rate of corrosion to accelerate.

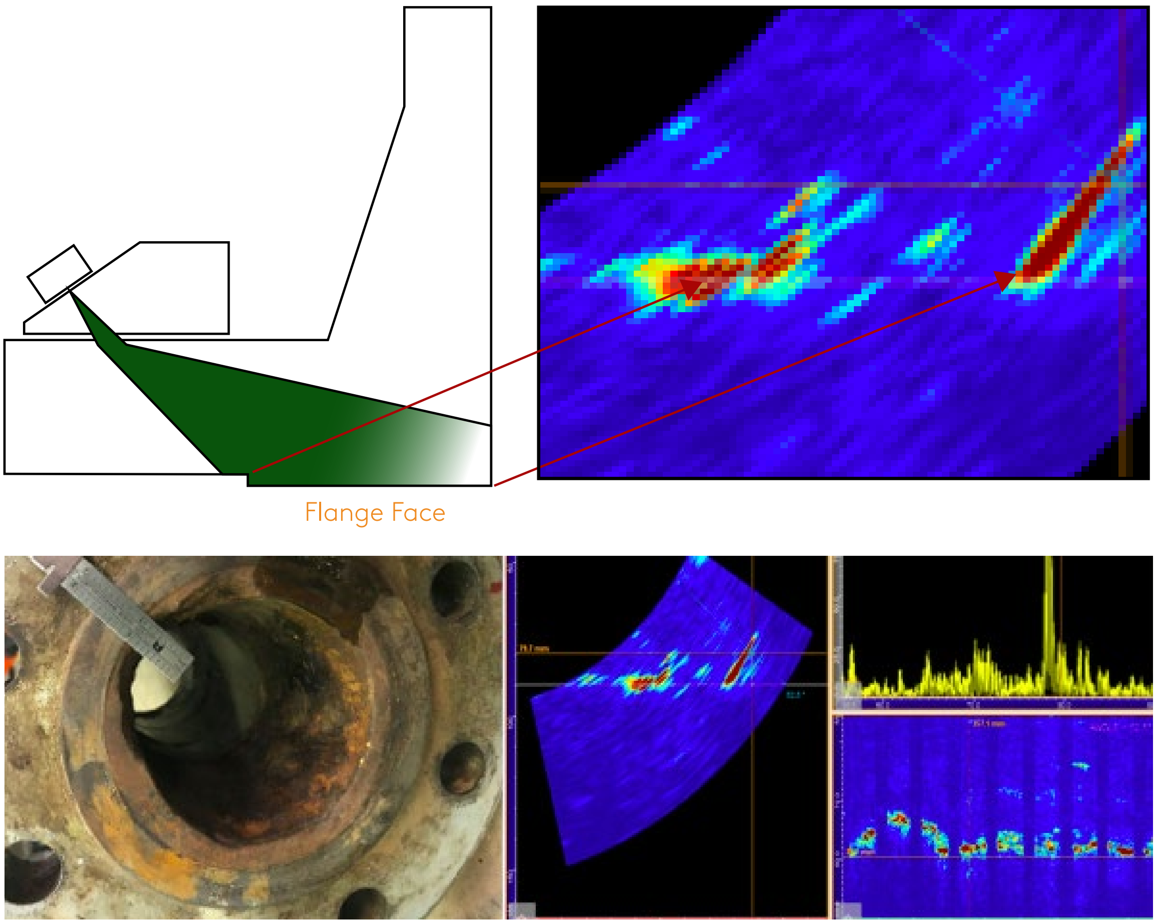
The Recommended practice has been independently validated as part of an industry initiative to determine a reliable inspection method for this widespread problem. Trials on ex-service flanges recorded a positive Probability of Detection (PoD) and therefore the RP is now recognized as a direct replacement to splitting flanges.

Due to the complexity of the flange face geometry, it has become a requirement to improve upon the inspection methods that have traditionally utilized A-scan ultrasonics. Phased Array has the ability to simultaneously collect A-scan data at a number of given angles. This unique feature produces a volumetric beam allowing operators to distinguish between geometric reflectors and defect signals, increasing the likelihood of detection.

Pre-shutdown inspection campaigns have been implemented on a number of onshore and offshore assets with the subsequent visual examination during plant downtime proving PA results 100% reliable. The proven PA technique provides a significant advantage by combining this latest development with our already established corrosion mapping and weld root erosion systems.

Features of Flange face Phased array are; suitable for pre-shutdown inspection campaigns and in-service inspection, small footprint probe suitable for all flanges down to 3/4 inch, third party qualified techniques and procedures and can be used in conjunction with advanced software that can incorporate CAD drawings as visual overlays.

Figure 10 Phased Array Flange Face Inspection PAFF



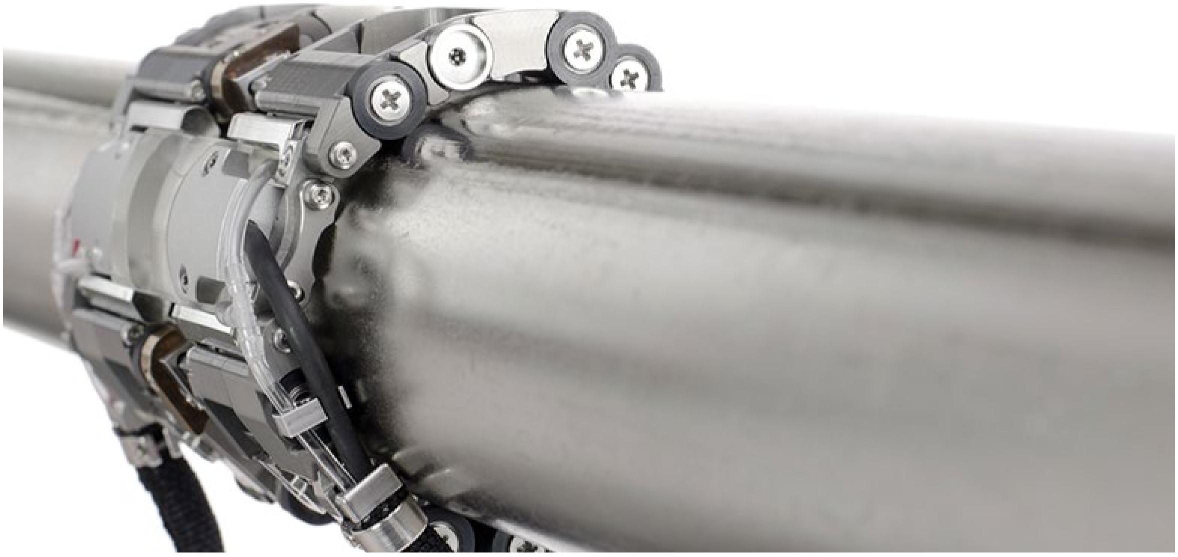
Inservice Pipe Inspection

Small Bore Phased Array

With advances in Phased Array (PA) scanner technology it is now possible to replace on-site radiography with a fully auditable ultrasonic inspection technique.

The innovative systems allow for circumferential inspection on thin walled piping, providing semi-automated data collection on pipe diameters starting from 19mm. Low profiled scanners are specifically designed for use on small bore piping where minimal clearance is a requirement. The design of the scanners allow for adjacent restrictions to be as close as 15mm, making the system ideally suited for boiler tube inspection.

Figure 11 Small diameter PA scanner



The state-of-the-art scanner is fitted with a specifically designed 7.5 MHz 16 element Phased Array (PA) transducer which has been designed to give extended focal ability while achieving high ultrasonic sensitivity. The probe has interchangeable wedges that can be selected depending on pipe diameter. The scanner is used with a PA acquisition unit capable of simultaneously controlling 16 UT channels that, with a micro wheel encoder, allows for fully encoded data collection, ensuring the system is fully code compliant. By combining corrected C-Scan imaging and S-Scan displays, indications can be accurately measured for circumferential length and through wall extent.

Figure 12 Small Bore PAUT Weld Inspection

Bolt Inspection

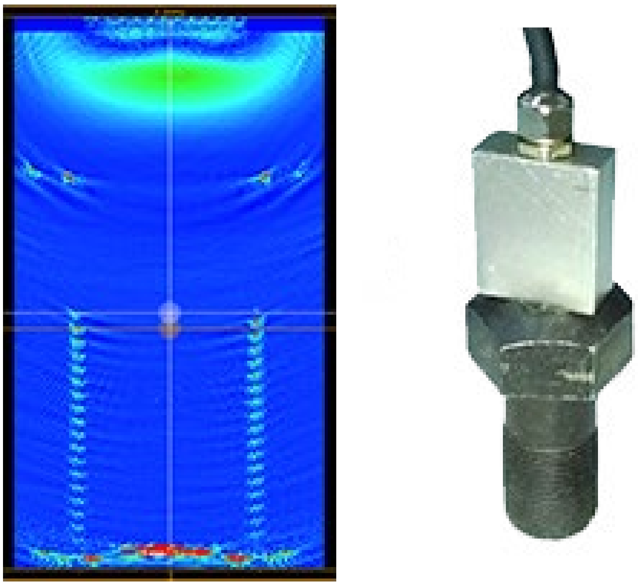
TFM

The development of portable TFM phased array ultrasonic instruments has contributed to a new phase in crack detection and sizing in a range of plant components. The crack is visualised and sized using a total focused image which combines several ASCAN data sets with a continuous fine-grade of sweeping angles. The crack facets are therefore detected by a multitude of angles simultaneously. Combing this unique ability with a narrowly focused beam allows for an increased signal-to-noise ratio of the backscattering signals and also the recognition of both reflected and diffracted ultrasonic

responses. TFM is the preferred UT technique for any oblique scanning requirements in which defect propagation is not favorably orientated for a standard UT beam.

The image below shows the data acquired using TFM technology during bolt inspection. It is clear that the facets in which the cracks are most likely to propagate can be visually identified and individually assessed.

Figure 13 TFM bolt inspection



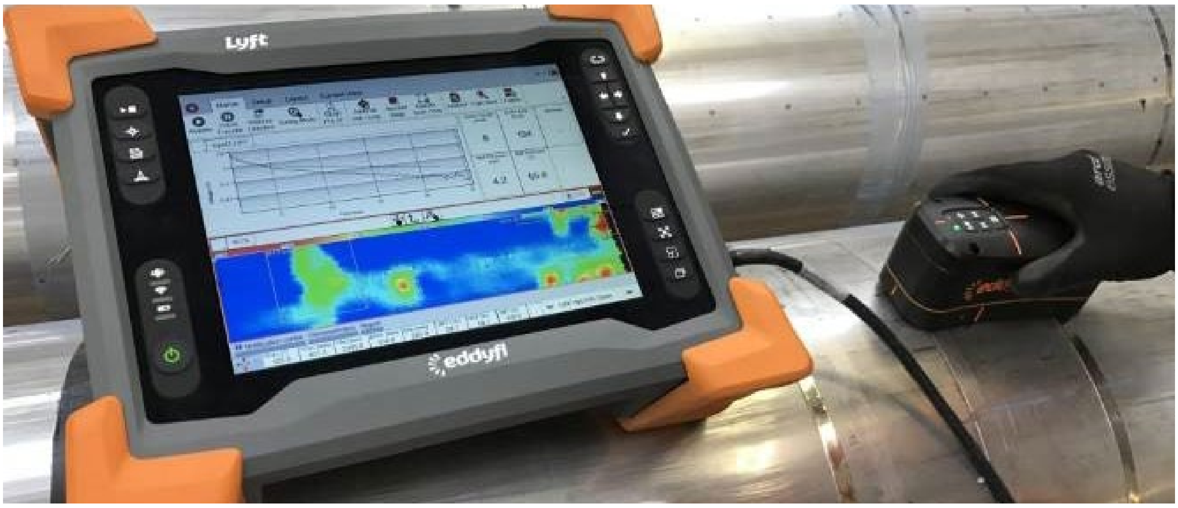
Corrosion Under Insulation

Pulsed Eddy Current (PEC)

Although currently regarded as a semi-quantitative tool for Non-Intrusive Inspection, LYFT technology can allow early stage assessment of vessels and pipework and this information could be used to guide the focus during turnarounds and outages.

PEC is a non-contacting screening tool, which means it is suited for applications where there is no access to the steel surface due to the presence of non-conductive materials such as; insulation, fire proofing, coatings, composite wraps, marine products and corrosion products such as scabs. This can potentially have a positive economic impact by negating the need for the costly and time-consuming process of insulation removal, which in some cases can only be done during a shutdown.

Figure 14 Lyft Pulsed Eddy current System



PEC is an electromagnetic technique used for measuring the thickness of steel objects, such as pipes and vessels, without the need for contact with the steel surface. Readings are generated when a transmitter coil produces a magnetic pulse which induces eddy currents within the component wall. The eddy currents in turn induce a secondary magnetic field which is detected by a receiving coil. The system monitors the rate of decay of the eddy current field within the steel wall which can be related to the average thickness value.

The system monitors the rate of decay of the eddy current field within the steel wall and data can be used to generate an average thickness value. Readings are generated when a transmitter coil within a protective housing produces a magnetic pulse which induces eddy currents within the component wall. The eddy currents, in turn, induce a secondary magnetic field which is detected by a receiving coil.

The Eddyfi Lyft system meets end user demands for expedited results. Individual readings are completed in under a second and dynamic scanning is possible at speeds of up to 75 mm/ sec with 10 mm scan resolution. Encoded probes allow corrosion mapping of components which supports better characterization of anomalies and scanning of larger areas in a shortened timescale.

Nozzle and Saddle Welds - Surface Cracking

Alternating Current Field Measurement (ACFM)

Many Non -Intrusive inspection campaigns require the nozzle and saddle welds to be inspected for surface cracking at the weld toes. This inspection has been traditionally completed with MPI or DPI, but requires costly paint removal and as with many conventional NDT methods, these rely heavily on operator interpretation and do not provide a permanent record.

In addition, there is a restriction on surface temperature with traditional methods and as NII campaigns are often on line, advanced methods are used to allow weld testing to be completed at elevated temperature.

Figure 15 Saddle weld inspection with Amigo2 ACFM

ACFM has the ability to inspect at elevated temperatures and can provide significant cost savings by avoiding plant shut down, additionally avoiding any problems of cracks closing up when structures are cooled down.

By using special temperature resistant components, ACFM® probes can be designed to inspect at temperatures of 500°C (930°F) or more for long periods. Even standard ACFM® probes can be used at high temperatures for short periods because of the ceramic noses used to house the sense coils

Conclusion

When a Non-Intrusive Inspection campaign is performed using Advanced NDT equipment, there are significant advantages to performing an NII inspection over an IVI, such as;

- Avoidance of Confined Space access which is hazardous and can also require upgraded protective equipment and systems such as lighting and breathing apparatus.
- Reducing shutdown/turnaround times, NII can be carried out prior to a shutdown event allowing the turnaround to be restricted to repair/maintenance work. This also allows for advanced planning.
- Removal of a requirement to break containment/isolate/drain and purge the vessels under evaluation.
- Minimize disturbance to the vessel, which may create new anomalies.
- Allowance for the inspection to be performed as soon as an issue is identified.
- Metallurgical defects which would not be identified during an IVI can be identified.
- Periodic NII inspections allow engineers to calculate remaining plant life of operational equipment.

References

1. DNVGL-RP-G103 (May 2017), Recommended Practice – Non-Intrusive Inspection
2. HOIS (09) RP2 Issue 1, Recommended Practice – Weld Corrosion Inspection
3. HOIS (11) R7 Issue 2, Recommended Practice for in-service inspection of RF flange faces using phased array ultrasonic techniques

Useful links

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