TSC SUBSEA

Subsea Advanced Ultrasonic Testing (AUT)

www.tscsubsea.com

Contents

Introduction

Advanced Ultrasonic Testing (AUT) includes a portfolio of technologies and is widely accepted as a specialist Non-destructive Testing (NDT) method. AUT methods include:

- Phased Array (PA)
- Automated Phased Array Corrosion Mapping (PACM)
- Time of Flight Diffraction (ToFD)
- Total Focusing Method (TFM)
- M-Skip
- Bespoke Solutions

As with all NDT methods, each has its unique benefits and limitations.

The following list of applications is a reference to show the most suitable inspection method depending on the component and expected damage mechanism. The Subsea Phased Array (SPA) system from TSC Subsea can deliver all recognised AUT methods and perform them simultaneously if required and at water depths down to -3000m (10,000ft).

SPA is fully compatible with all TSC Subsea's robotic ROV deployed scanning solutions, delivering high-quality data safely and efficiently whilst removing the dependency on divers.

Subsea Assets – Pipelines and Large Structures

Corrosion mapping, pitting and wall thickness measurements

Phased array technology is now a recognised and trusted volumetric inspection method for typical weld inspection and crack detection applications. The unique ability to produce a fully active volumetric ultrasonic beam allows for increased sensitivity along with rapid data collection.

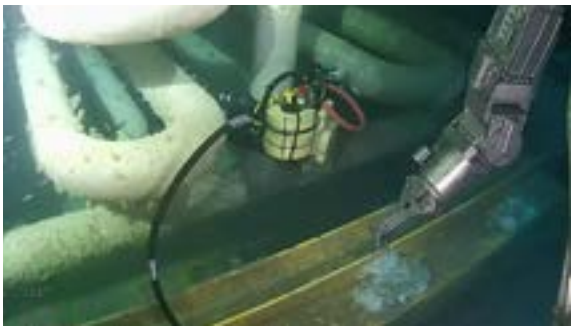
In recent years, phased array has been introduced for Corrosion Mapping (PACM) and has shown to be essential for determining the internal surface morphology of piping systems. PACM can be carried out through numerous coatings and when the asset is online and offline. These specific features can therefore offer significant cost savings over other inspection methods.

Detecting corrosion and identifying corrosion rates while equipment is online can enable engineers and operational personnel to strategically schedule shutdowns and repairs or replacements by accurately forecasting equipment life expectancy.

Automated subsea phased array ROV deployed robotic scanning solutions.

Tight access 3-axis scanning

Pipeline 360-degree scanning

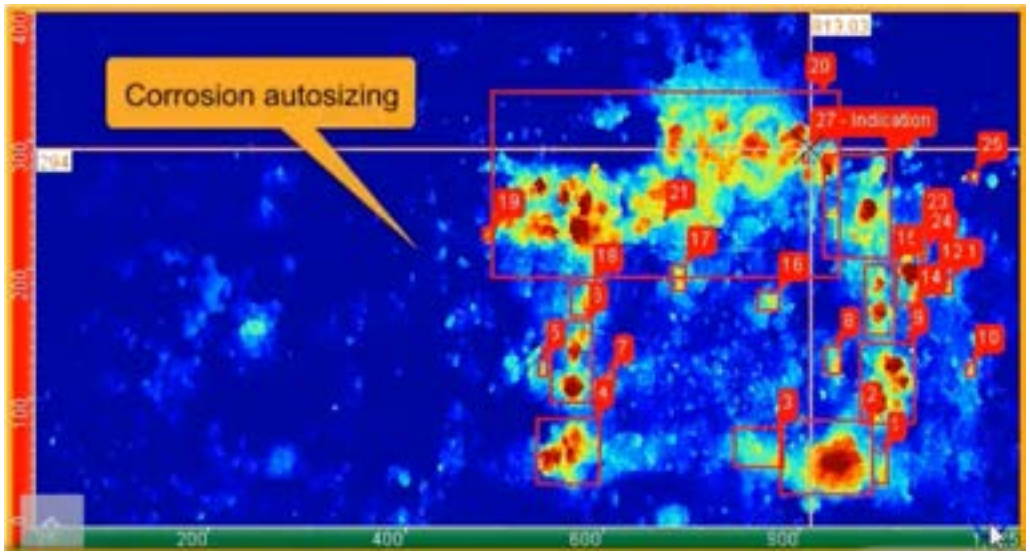


Limited access motorised scanner

Wall thickness measurements

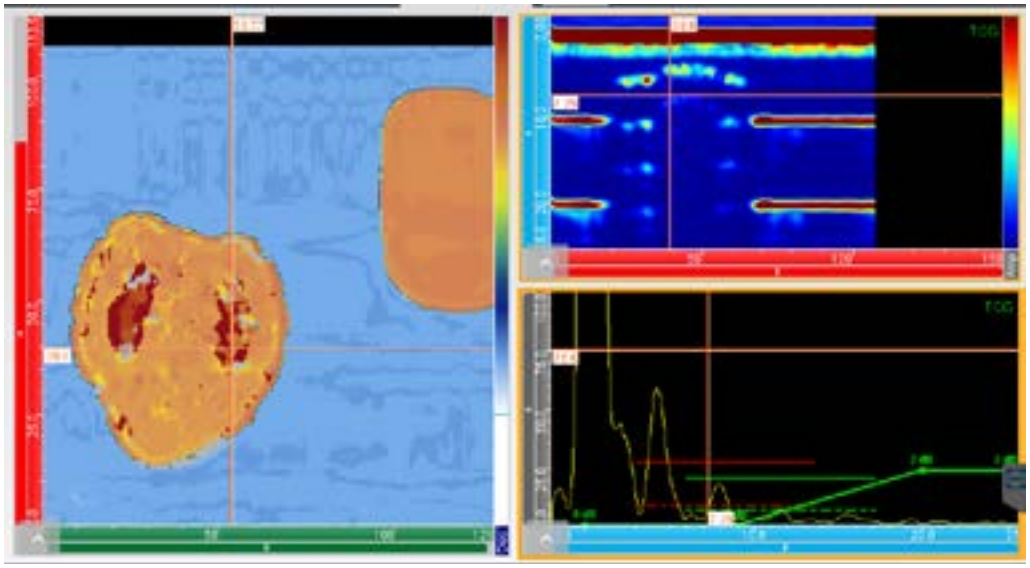
Corrosion mapping phased array probes can be mounted on various TSC Subsea field-proven scanners, including the vCompact for corrosion mapping, LineScanner and Extrados for wall thickness line scans. The scanners are fully encoded and have the ability to inspect pipes from 76mm (3in) OD through to flat plate primarily on ferromagnetic material. Without sacrificing resolution and guaranteeing a collection step of 1 x 1 mm, phased array can detect pits from 2mm diameter and 0.5mm wall loss.

The Subsea Phased Array (SPA) system is designed to offer the very best inspection solution for detecting wall thickness reductions due to corrosion, abrasion and erosion. The system's high resolution is achieved by utilising 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.



C-Scan image showing corrosion with autosizing

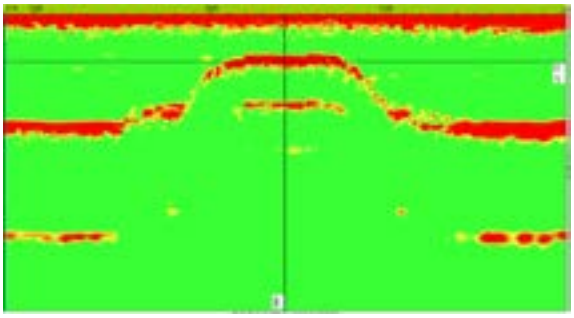
The high sensitivity of the phased array beam allows for the detection of deflected and/or diffracted signals, ultimately allowing for in-depth defect characterisation by imaging the true morphology of the damage mechanisms.



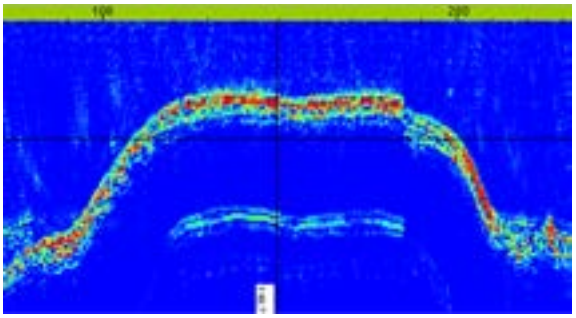
C-Scan image showing defect morphology - scanned from the external surface

In addition to phased array, the SPA system from TSC Subsea also has automated Total Focusing Method (TFM) capabilities. TFM is an emerging technology that uses post processing algorithms to allow a fully focused scan within the inspection zone. This increased focusing eliminates the near-surface dead zone, provides high-resolution imaging and can improve sizing for certain defects.

Phased array B-Scan and TFM view of the same corrosion area, showing the removal of the near-surface dead zone and improved defect imaging of the edges of the corrosion.



Phased array B-Scan view



Phased array TFM view

Elbows Extrados

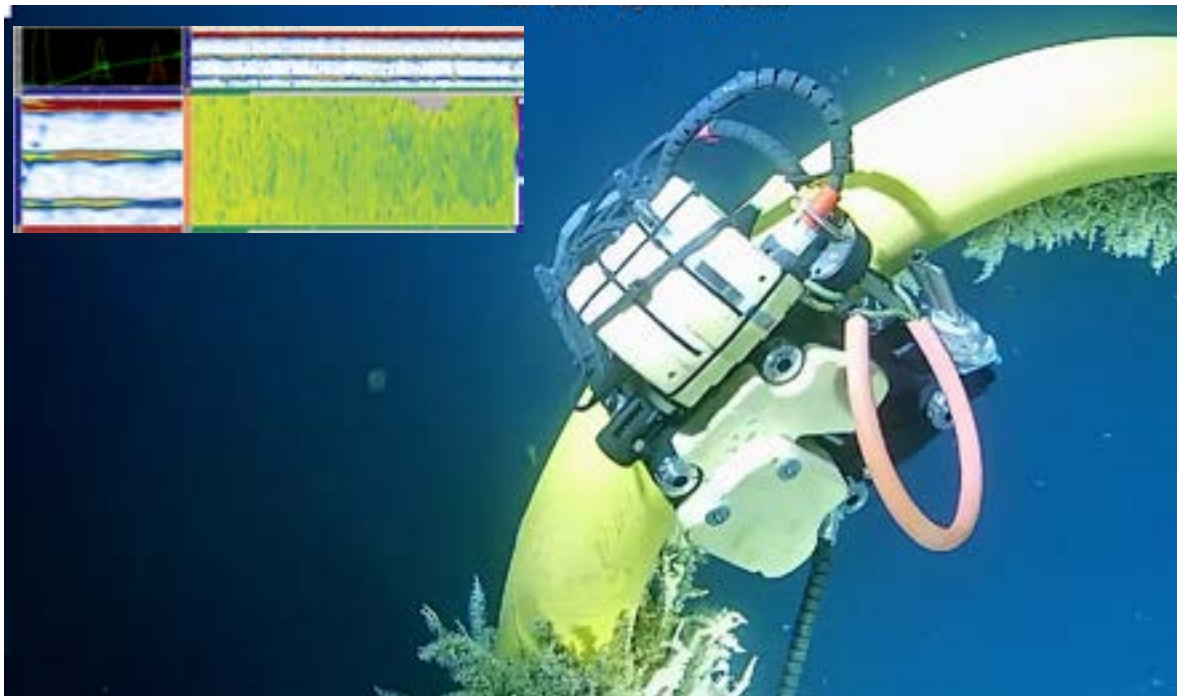
Wall thickness measurements

Pipeline End Manifolds (PLEMs), Pipeline End Terminations (PLETs) and Jumpers are subsea structures that act as a connection point between the main or branch pipelines. Cooling skids are generally a piping system that utilises the temperature of the seawater to cool the liquid within.

These systems have a few things in common, they are generally contained within another subsea structure, and the pipe work is in close proximity and includes multiple bends, which are more prone to erosion. This brings unique challenges as they are difficult to reach, and the pipe clearance allowance is minimal.

Subsea Phased Array (SPA) combined with motorised scanners such as the LineScanner is the perfect solution. The compact scanners can be deployed with the use of an ROV, then once in place, can manoeuvre around the test pipe. With an internal encoder to measure the distance travelled, accurate positional data is recorded with the pipe wall thickness measurements.

This same technology can be used for a plethora of subsea assets and has been successfully deployed on riser bends and pipe elbows. The automated LineScanner has a diameter range from 3" outside diameter and upwards can be deployed by ROV and, with self-aligning technology, will automatically position itself on the pipe elbow extremity.



SPA motorised LineScanner inspecting subsea jumper & riser extrados

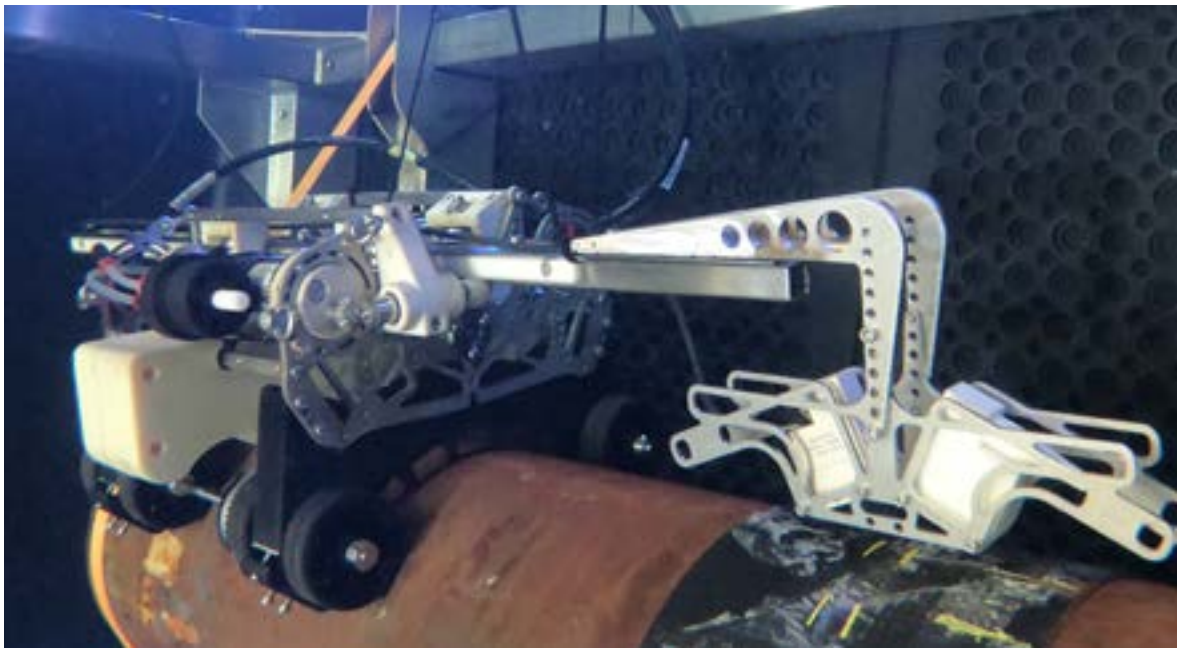
LineScanner

Extrados scanner

Volumetric Weld Inspection

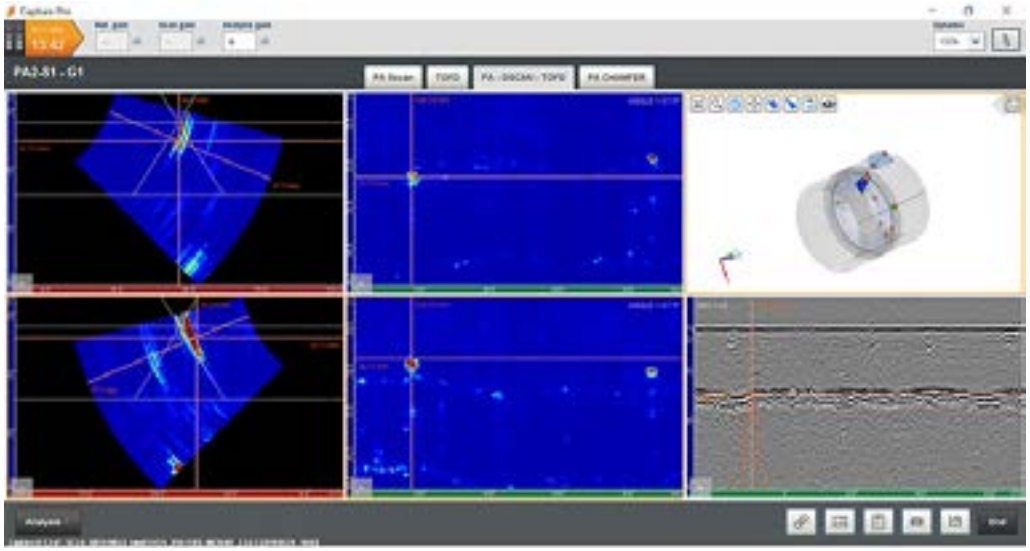
Phased Array Ultrasonics (PAUT) and Time of Flight Diffraction (ToFD)

Phased array combined with Time of Flight Diffraction (ToFD) has been successfully implemented to replace radiography for fabrication and in-service weld inspection. Welding defects can manifest at either surface of the pipe or can also be embedded within the weld volume. To successfully guarantee the integrity of a weld joint, the inspection method must therefore have the ability to detect embedded flaws and accurately characterise and size these potential discontinuities.



Phased array pipe weld inspection FAT

Phased array technology has the ability to create a volumetric beam that can interrogate the whole weld volume without the need to raster scan. The beam can be generated to include a number of inspection angles, and operators can set the technique to specifically inspect any given weld. The advanced software within the SPA system provides 3 dimensional images and part specific overlays that will improve the probability of detection and help produce a report that can easily describe the condition of the weld.



Combined phased array and ToFD weld inspection data

Phased array can be used from both sides of the weld or deployed with single sided access if required. Using a highly focused beam, defects such as cracking, porosity and lack of fusion can be sized and accurately positioned within the weld. The minimum detectability of in-service cracking is highly dependent on the configuration and material of the component, but case history has shown that cracks of 0.5mm in depth and 5mm in length are readily detectable.

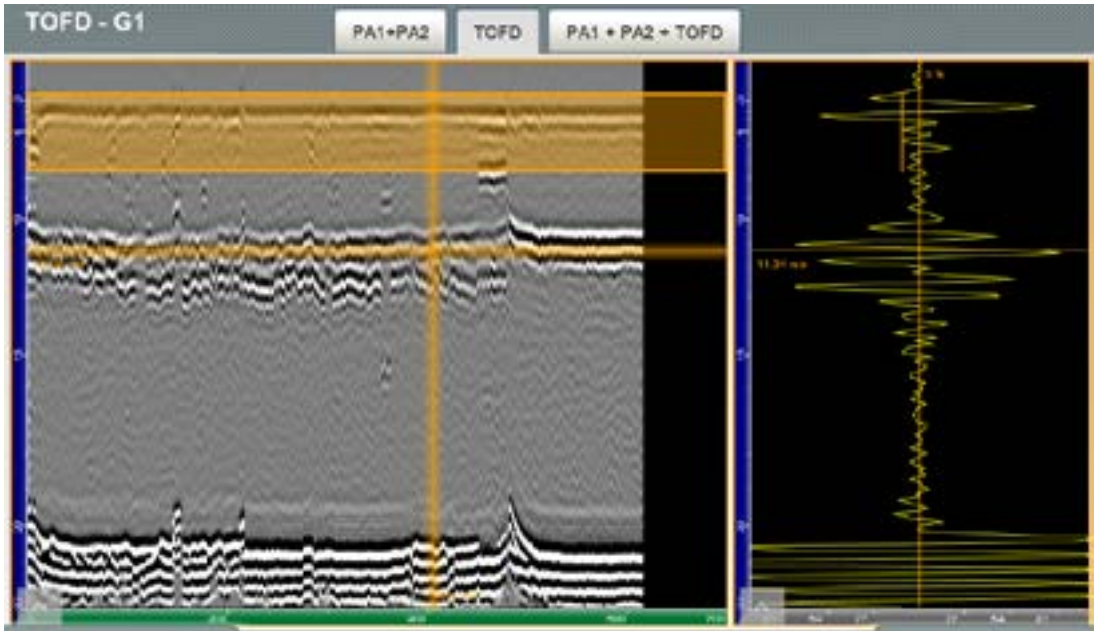
Weld Root Erosion and Corrosion

Time of Flight Diffraction (ToFD)

ToFD is an advanced ultrasonic inspection method used primarily for weld inspection. It is a key method in Non-Intrusive Inspection surveys (DNV-RP-G103). TSC Subsea's phased array 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.

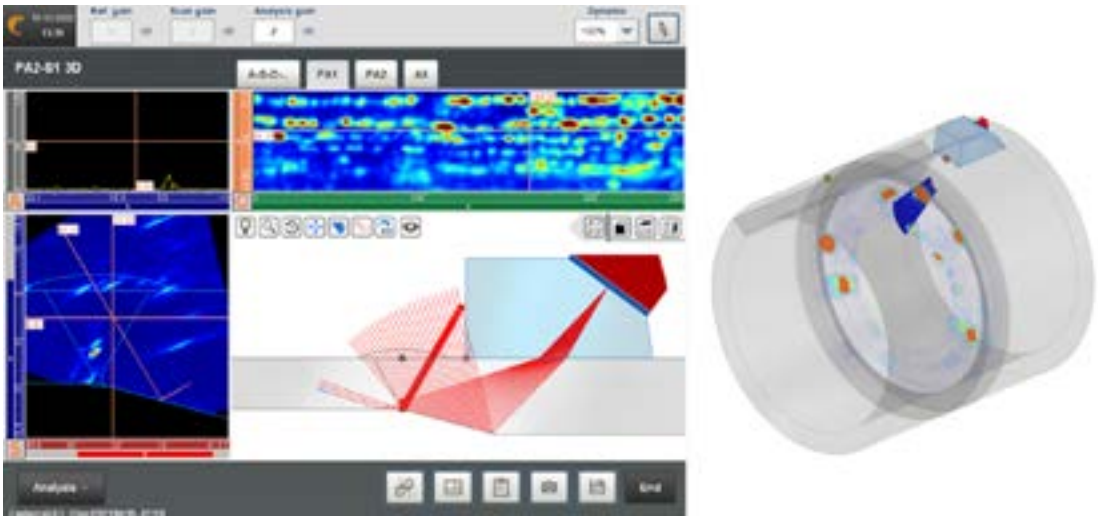
Weld Root Erosion/ Corrosion usually occurs below the area of the weld cap, therefore direct inspection using conventional ultrasonic 0° techniques is impossible without weld cap removal. ToFD uses a probe on either side of the weld cap and is recognised as the most reliable method for detecting and sizing Weld Root Erosion/Corrosion (HOIS(09)RP2 Issue 2).

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.



ToFD signal for weld root erosion/corrosion

If single sided access is required, phased array weld inspection can be used with similar benefits and provide accurate sizing results of material losses.



Single sided phased array setup

Flange Face Inspection

Complex Geometry Phased Array

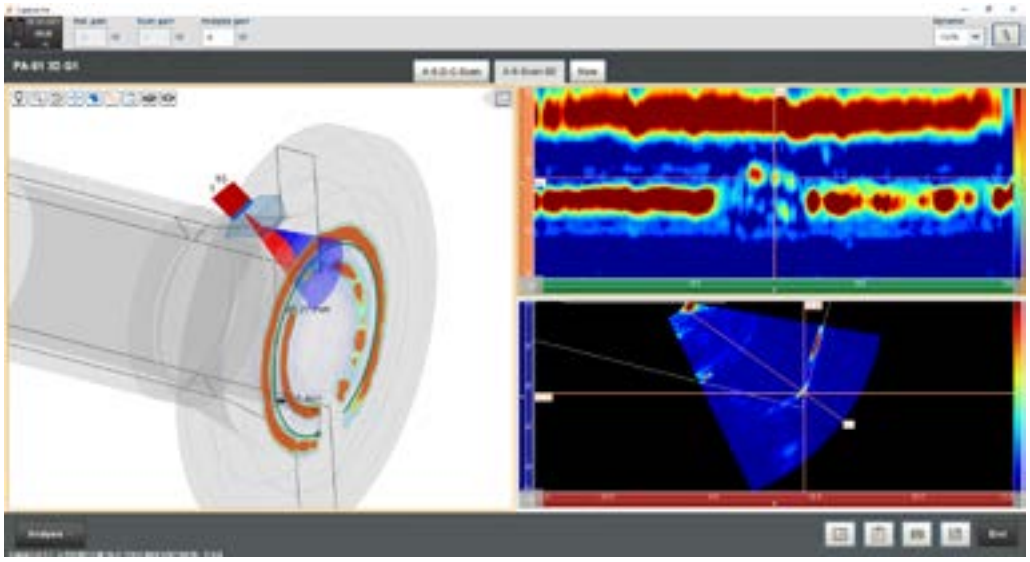
Crevice corrosion is caused by a concentration of corrosive substances within a confined space, making the crevice between two adjoining flanges the ideal environment for corrosion to initiate. The concentration of these corrosive substances in a localised area causes the rate of corrosion to accelerate.

Due to the complexity of the flange face geometry, it has become a requirement to improve upon the inspection methods that have traditionally utilised A-Scan ultrasonics. Phased array (PA) has the ability to collect A-Scan data at a number of given angles simultaneously. 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 offshore assets, with the subsequent visual examination during plant downtime proving 100% reliable phased array results. The proven phased array 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.

The technique approach for flange face corrosion can also be adapted for many complex geometry components. The phased array beam can be created with the specific angles required to interrogate areas of concern and therefore does not require perfectly aligned surfaces to create the desired refracted angle.



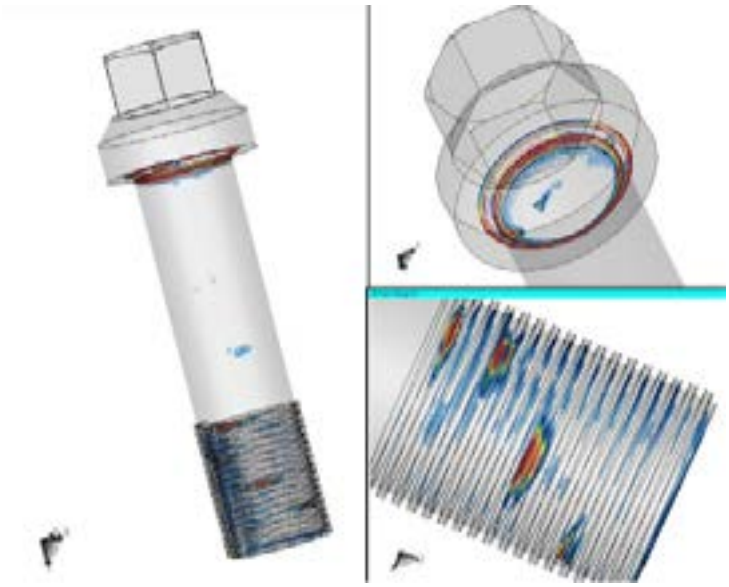
Flange face corrosion with CAD overlay

Bolt Inspection

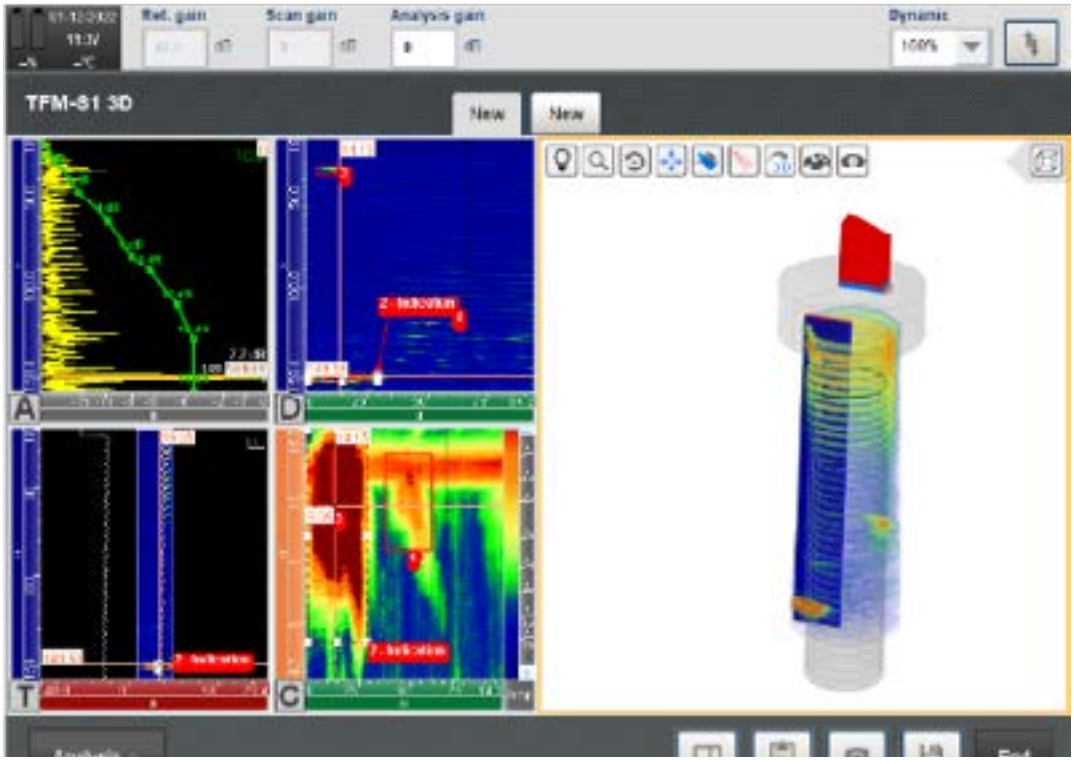
Total Focusing Method (TFM)

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 combining several ASCAN data sets with a continuous fine grade of sweeping angles. The crack facets are therefore detected by a multitude of angles simultaneously. Combining 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 Ultrasonic (UT) technique for any oblique scanning requirements in which defect propagation is not favourably 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.



3D imaging of PA data overlaid onto riser bolt CAD model



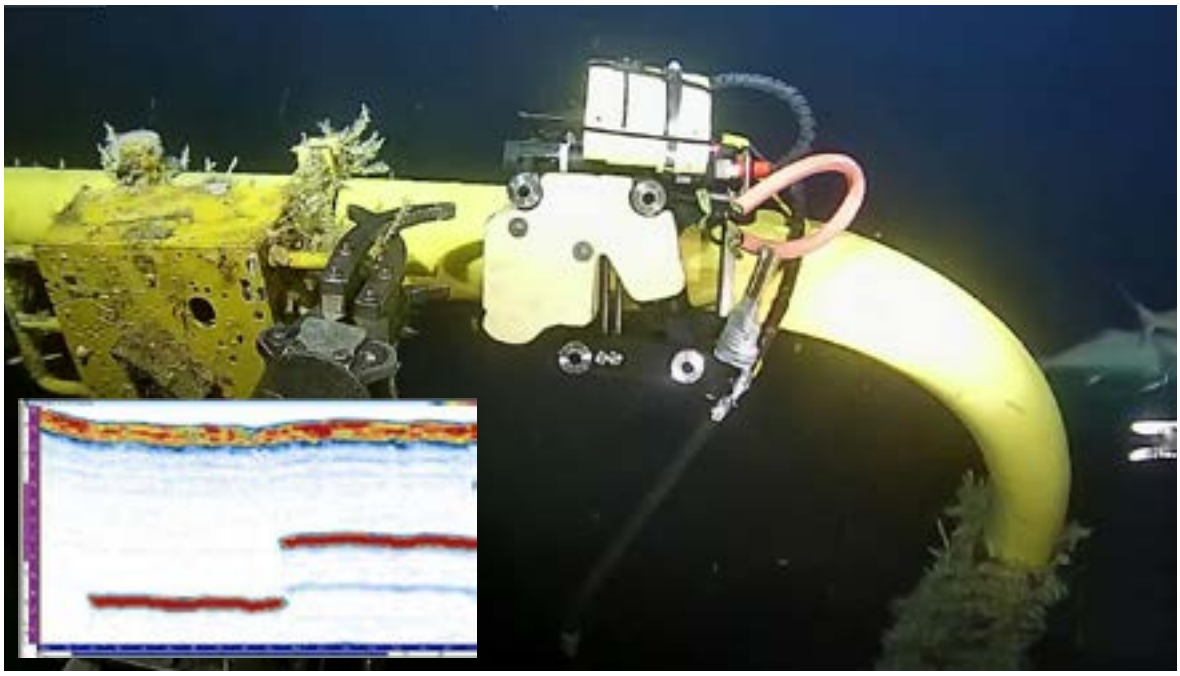
Non-Ferrous Pipework

Phased Array Corrosion Mapping (PACM) and wall thickness measurements

Advanced ultrasonic systems provide a suite of techniques for the examination of stainless steel, duplex and similar corrosion-resistant alloys. 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.

Using the vCompact or hydraulic clamping system, phased array can be deployed on non-ferrous pipework for both corrosion mapping and weld inspection. The hydraulic clamp is an iteration of the vCompact in which the magnetic feet are replaced with automated clamps, allowing it to create a stable platform for accurate NDT data collection.

A motorised LineScanner, which includes an internal encoder to measure the distance travelled, can be placed on the asset to be inspected and then released to allow the ROV to observe from a distance while providing camera views.



B-Scan wall thickness measurements with LineScanner

Corrosion Pipeline Screening

M-SKIP

TSC Subsea SPA system is capable of rapid pipeline screening, looking for corrosion and other forms of material wall loss.

vPush Scanner

Using the vPush scanner design fitted with 4 x UT M-SKIP probes and 8 x 0 degree paintbrush UT probes will give 100% coverage of diameter ranges from 4in OD and upwards. The vPush scanner can be remotely deployed using either work class ROV or inspection class ROV and collect data at 200mm/sec.

It is designed to be pushed by ROV on top of the pipeline on a wheeled system, and encoded positional data is recorded with the UT scanning readout. The UT MSKIP method employs ultrasonic transducers in a pitch-catch geometry positioned on opposite sides of the pipe.

Shear waves are transmitted in the axial direction within the pipe wall, reflecting multiple times between the inner and outer surfaces before reaching the receivers. Along this path, the signals accumulate information on the integral wall thickness (e.g., via variations in travel time).

The additional 0 degree paintbrush probes provide detailed wall thickness data focusing on the top-of-the-line corrosion.

M-SKIP and 0 degree UT probe setup

M-SKIP is a well-established method for top-side applications and has third-party qualification for corrosion under pipe supports and remaining ligament assessment of corrosion scabs. The technique has been successfully demonstrated through the HOIS (Harwell Offshore Inspection Service) program, and many NDT service providers have successfully deployed the method for quantitative assessment of restricted access inspection.

The technology is included with DNV RP G101 as a recognised advanced NDT method and can provide sub-millimetre accuracy given the optimum conditions.

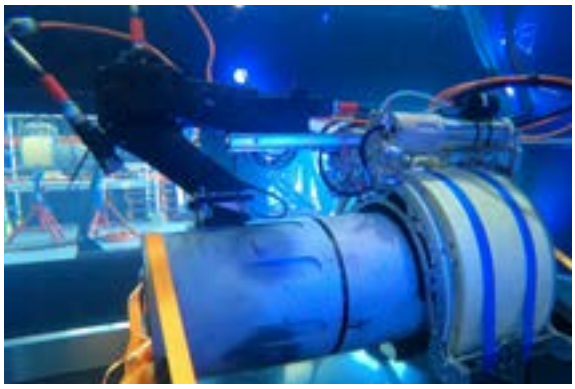
M-SKIP is a semi-quantitative inspection method which will provide wall thickness measurements beyond screening.

Bespoke Solutions

For over three decades, TSC Subsea has been a trusted provider of expert engineering services dedicated to inspecting critical subsea assets. We remain fully committed to collaborating closely with our clients to identify optimal and highly efficient solutions that perfectly align with our client's unique inspection requirements.

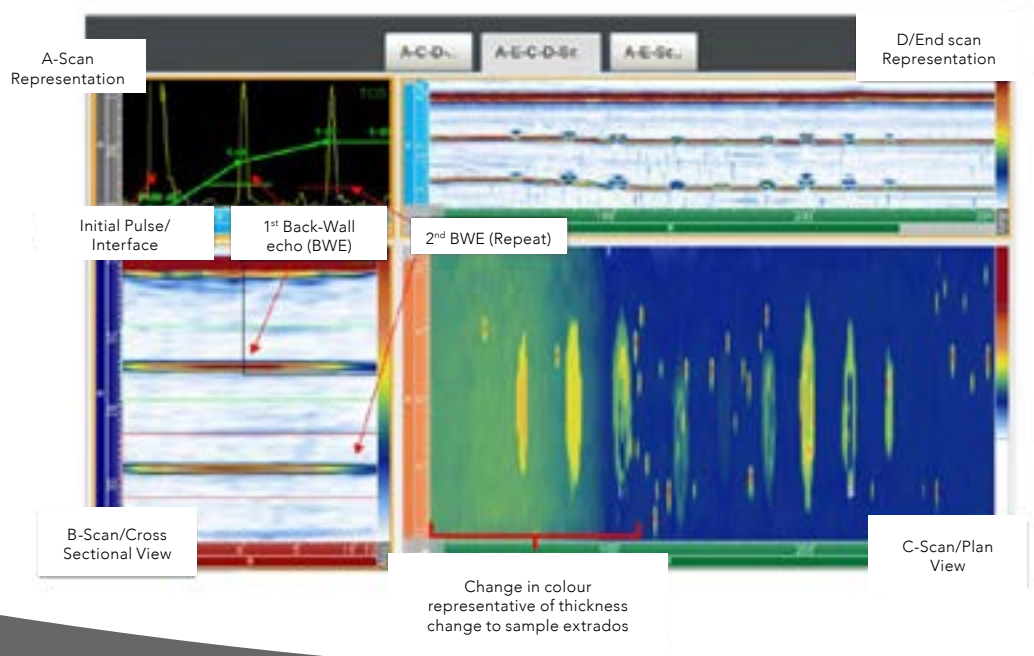
Leveraging our application specialist's extensive knowledge in advanced ultrasonic testing, we design bespoke robotic solutions for conducting remote inspections with maximum safety and efficiency.

One of our custom solutions is a robotic scanner for detecting and sizing surface and subsurface cracks in intricate anode welds. The robotic arm exhibits the same level of dexterity as a human hand, enabling meticulous scanning motions across the semi-elliptic weld surface. With this advanced technology, we ensure accurate and precise crack detection and sizing, even in complex welding configurations.



Phased array scanner FAT

Phased array complex weld inspection



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