High-Resolution Corrosion Monitoring for Reliable Assessment of Infrastructure

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Abstract. Manual point thicknesses measurement is a technique that is used extensively for monitoring the corrosion of infrastructures such as pipelines, energy plants, pressure vessels, and more. Because inspectors are limited in the data they are able to acquire (productivity, data management), only the minimum thickness within a certain grid can be reported, typically a one square inch area. The search for a component’s minimum thickness can vary from one inspector to the other, making the data nearly unusable for long-term corrosion growth rate monitoring. In addition, localized corrosion, such as pitting, may go unnoticed by the inspector. Owing to the evolution of phased array technology and data processing speed, off-the-shelf phased array equipment, when combined with a motorized scanner, can be used to perform high-resolution surface inspection. With this technique, large surfaces can be inspected with high productivity without compromising precision. Interpreting acquisition data is facilitated by easy-to-read imaging, and ASME B31G calculations or other recognized methods can be used to perform corrosion assessment of components. This paper presents the advantages of using motorized ultrasonic phased array equipment to achieve high-resolution corrosion inspection in accordance with today’s demanding industry standards.

Introduction

Manual point thickness measurements using conventional ultrasound (UT) is a widely used technique for monitoring corrosion in many infrastructure applications. An inspector typically records the minimum thickness reading within a grid (usually 1 in.²); the search for a minimum thickness can vary from one inspector to the other, making the data nearly unusable for long-term corrosion growth rate monitoring. In addition, localized corrosion, such as pitting, may go unnoticed by the inspector.

Owing to the evolution of phased array technology and data processing speed, off-the-shelf phased array equipment, when combined with a motorized scanner, can be used to quickly perform high-resolution corrosion monitoring. Typically, a thickness reading is performed every 1 mm², which represents 500 more acquisition points than conventional ultrasound. This high resolution makes it possible to detect small, localized indications, such as corrosion pits, and it enables the operator to profile the shape of the corroded area. This helps users to accurately evaluate the severity of corrosion defects.

Olympus has developed a fully motorized solution for corrosion mapping. Using intuitive and affordable phased array instruments, the OmniScan MX2 and SX, the system is easy to
setup so users can perform the inspection, record, and archive data for further analysis. Easy-to-read images make interpreting acquisition data straightforward. The data can be used to perform corrosion assessments according to ASME B31G or other applicable standards.

**Principle of operation of phased array for corrosion inspection**

Phased array technology is based on the capacity to electronically modify ultrasonic beams generated by a phased array probe that contains multiple small elements. When these elements are excited using different time delays (focal laws), the beams can be steered at different angles, focused at different depths, or multiplexed over the length of a long array, creating the electronic movement of the beam.

Multiplexing, sometimes called an electronic or linear scan, is used to perform corrosion monitoring. The sensor consists of a long phased array probe (25–100 mm; 1–4 in.) with between 32 and 128 elements. A small group of elements, defined as the active aperture, is activated to generate an ultrasonic beam propagating normal to the interface. This group of elements is then indexed using electronic multiplexing, creating a true physical movement of the ultrasonic beam under the array with an index as small as 1 mm. The electronic indexing is performed so fast that a 4 in line length is covered by the ultrasonic beams in milliseconds. The travel time of these beams is used to determine the component’s thickness at each acquisition point.

![Figure 1: Principle of operation of a phased-array probe for corrosion inspection](image)

**Phased array sensors**

Olympus has developed different types of phased array sensors that can be used to perform corrosion monitoring. When near-surface resolution is critical, such as for very thin pipes, the operator might choose the dual linear array (DLA) probe. In pitch-catch configuration, the emitting array and the receiving array are acoustically isolated, eliminating the ultrasonic echo coming from the interface. This results in a reduced dead zone and excellent near-surface resolution. To work correctly, the surface of the components must be relatively smooth to achieve proper coupling.
Coupling can be improved on rough surfaces with a phased array probe mounted on a water delay line system like the HydroFORM. Local immersion is maintained using sufficient pressure on the part, and a gasket is used to prevent excessive water consumption. Such instruments require the use of a water pump to maintain the local immersion while scanning the component.

When water management is an issue, a phased array probe mounted in a wheel filled with water, like the RollerFORM, is a useful alternative if the component’s surface is smooth enough. The wheel is usually made of a material that has acoustic characteristics similar to water in order to reduce interface echo and increase ultrasonic penetration. With such a probe, the operator just needs to wet the inspection surface to ensure coupling.
Phased array instruments

Olympus has two off-the-shelf phased array instruments optimized for corrosion monitoring: the OmniScan MX2 and the OmniScan SX. Differentiated by their specifications, like multi-group capabilities and modularity, both instruments offer 2-axis encoders for raster scan, full high-resolution A-scan, storage, and both are easy to setup via wizards.

![Figure 5: Left: Olympus OmniScan MX2 (left) and the OmniScan SX (right)](image1)

The imaging used to analyze corrosion data is composed of a C-scan of remaining thickness, S-scan and B-scan that are 2 cross-sections of the component, and the A-scan as demonstrated below. The C-scan is a color-coded map that enables users to identify regions of corrosion at a glance and facilitates deeper analysis.

![Figure 6: Corrosion monitoring imaging](image2)
Automated ultrasonic phased array systems are the method of choice to inspect pipelines and other infrastructure since they can inspect large areas very quickly. A motorized scanner is equipped with an arm that holds the phased array probe assembly. When the scanner performs a rotation around the pipe, the phased array probe scans an area a few inches wide with 1 mm resolution, creating a C-scan segment. At the end of the rotation, the arm indexes the probe to cover a second segment. The scanner reproduces this sequence until the probe reaches the end of the scanner arm. The result is a single acquisition data file consisting of one C-scan of the zone inspected. Typically, a 1 m long segment of a 12-inch diameter pipe can be inspected in one minute, which is about 50 times faster than using a conventional UT sensor.

Once the data is acquired, it can be analyzed onboard the device or exported to a PC and analyzed with PC-based software. Using C-scan images to assess remaining wall thickness is common since the C-scan provides a quick overview. B-scan images are also useful as they show the progression of wall thickness change. A quick change in thickness may represent localized damage, such as a corrosion pit, while a smooth change may represent a FAC (flow accelerated corrosion) defect.
The software has analytical tools that help users quickly find the location of minimum thicknesses and the size of the corroded areas for robust reporting. The data can be archived and reviewed any time after the inspection.

**Assessing the remaining strength of corroded pipelines**

One of the most common uses of remaining wall thickness data for pipelines is to evaluate the pipeline’s remaining strength. Different standards exist including ASME B31G, B31G modified, and DNV-RP-101. These standards predict the maximum burst pressure of a corroded pipeline based on a pipe’s corrosion profile in a given area.

One of the advantages of phased array is that a large quantity of measurement points can be easily transferred to a PC and used for calculations that assess corrosion strength. The C-scan data from phased array instruments can be saved and exported as a .csv file, compatible with common spreadsheet software as well as third-party software designed to calculate the remaining strength of a pipeline.

![Figure 9: Export of C-scan data (top); that same data in a spreadsheet (bottom left); an example of processed data (bottom right)](image)

**Conclusion**

Ultrasonic phased array instruments optimized for corrosion monitoring are used by the industry in many inspection applications. Olympus has successfully developed a fully motorized solution for corrosion mapping that is able to quickly inspect large surfaces with high resolution. Using Olympus’ intuitive and affordable phased array instruments, the
OmniScan MX2 and SX, the system is easy to setup and the easy-to-read images make interpreting acquisition data straightforward. The data can be used to perform corrosion assessments according to ASME B31G or other applicable standards.