Conquering coatings to quantify corrosion

Alison Craigon, Sonomatic, UK, discusses corrosion mapping through challenging coatings.

Inspection plays a major role in assuring the in-service integrity of pipelines and similar business or safety critical assets. Corrosion, internal or external, is often the primary degradation mechanism of concern, hence wall thickness measurement is the main focus of the inspection. In the case of pipelines, inspection may be possible using inline tools. However, there are many circumstances where inline inspection is not physically possible, not economically feasible or does not meet the inspection performance requirements.

In these situations inspection using externally applied techniques is necessary. In addition to pipelines, there is a wide range of asset types for which external inspection techniques are beneficial or the only practical option, e.g. pipework, pressure vessels and structures.

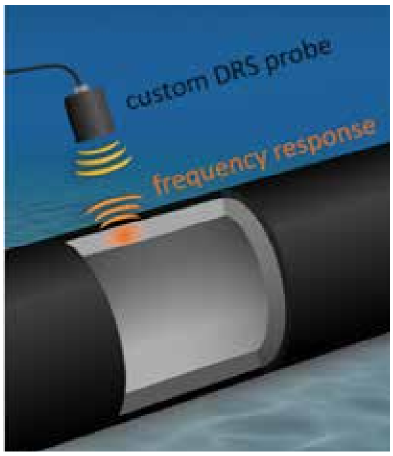

Figure 1. Dynamic Response Spectroscopy excites the coated pipe with ultrasonic energy and utilises the natural frequency response of the steel to determine its thickness.

Inspection technique selection

A variety of techniques are available for external application based on ultrasonic, electromagnetic or radiographic technology. The objectives of a particular inspection define the requirements that the technique must meet. The objectives vary according to the situation, and consequently have different requirements with respect to measurement.

For example, where the objective of the inspection is to validate the absence of active internal corrosion, a targeted low coverage inspection with very accurate wall thickness measurement performance and a high probability of detection (POD) would meet the requirements. Alternatively, where potentially severe degradation is expected, the objective is to identify the regions of worst degradation so that follow up action can be taken. In this situation, a screening approach would be appropriate, where the focus is on detection of degradation with potential to threaten integrity in the short/medium term. A greater focus on measurement accuracy would then be necessary when sizing the degradation identified by the screening. In many cases, sizing would require a different technique to that used in the screening.

Wall thickness inspection

Where quantitative wall thickness measurements are required, ultrasonic inspection techniques are usually the preferred option. The main techniques for wall thickness measurement are based on 0° pulse echo and Time of Flight Diffraction (TOFD).

The pulse echo technique measures the wall thickness at a specific location using the travel time of an ultrasonic pulse applied by a probe at the outer surface of the pipe, which reflects from the inner surface and returns to the probe. It can be used to make spot thickness checks or, in more sophisticated automated scanning systems, to generate a corrosion map at a fine spatial resolution over the region of interest.

TOFD utilises a pair of probes on the outer surface of the pipe in a pitch-catch arrangement with a fixed separation. An ultrasonic pulse, transmitted at an angle from the first probe into the steel, reflects from the inner surface and is received by the second probe. TOFD typically allows more rapid coverage of thicker material while providing a high POD for small corrosion features, hence it is growing in application for corrosion related inspections.

These ultrasonic techniques are widely used and can deliver very accurate measurement and reliable detection of in-service wall loss. They are proven to work well with many typical paint and corrosion protection coatings, e.g. fusion bonded epoxy. However, they are limited to application on thinner coatings and/or coatings for which the ultrasonic attenuation is low. This limitation is related to the high ultrasonic frequencies necessary for these techniques, i.e. typically in the range of 4 - 15 MHz.

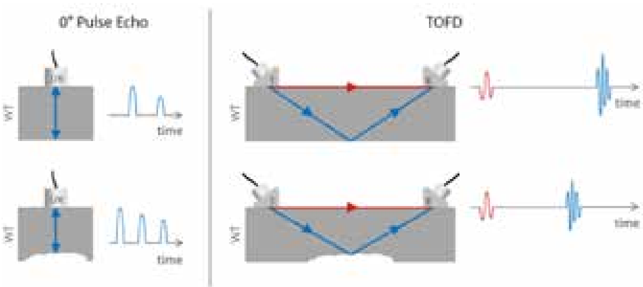

Figure 2. Existing corrosion mapping techniques: 0° pulse echo and Time of Flight Diffraction (TOFD).

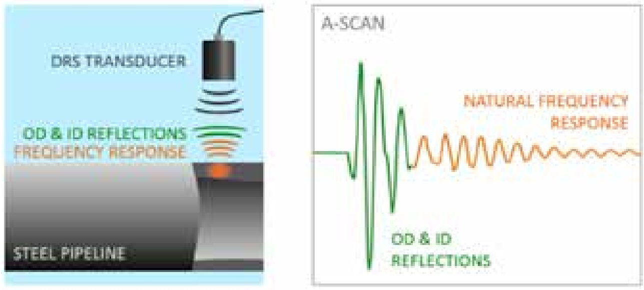

Figure 3. DRS transducers cause the steel to vibrate at frequencies related to its thickness. The A-scan shows signals reflected from the pipe's outer and inner diameters, followed by the dynamic response of the steel. Frequencies extracted from the A-scans are used to calculate the steel wall thickness.

Attenuation of ultrasound in materials is directly related to frequency, with a rapid increase in attenuation with increasing frequency. Signal transmission significantly improves at lower frequencies but the time resolution necessary for accurate thickness measurements cannot then be achieved. This limits the thickness and types of coatings through which it is possible to successfully apply 0° pulse echo or the TOFD technique for thickness measurement.

There is a wide range of situations where the coatings present are thick and/or attenuative, to the extent that inspection using 0° pulse echo or TOFD is not practical. Examples include:

- Polymer insulation on subsea pipelines.
- Corrosion protection tapes.
- Polypropylene wraps at pipeline field joints.
- Composite repairs.
- Fire protection materials.

The ability to obtain quantitative wall thickness measurements in these situations would be a major benefit in supporting cost effective integrity management and there is a strong interest from asset owners in techniques that have this capability. Sonomatic has reacted to this situation by investing in the development of Dynamic Response Spectroscopy (DRS).

Dynamic Response Spectroscopy

DRS corrosion mapping utilises low frequency ultrasound (<1 MHz) to penetrate coatings and excite the natural frequencies of vibration of the underlying steel.

A custom DRS probe, held above the pipe surface, emits a broad range of low ultrasonic frequencies. The lower attenuation at these frequencies allows the ultrasound to pass more easily through challenging coatings. The steel responds to the input signal, vibrating at frequencies related to its thickness. These vibrations pass out through the coating and are received by the DRS probe as it scans across the pipe surface. The frequency content of the received signals is then extracted, using advanced signal processing algorithms developed by Sonomatic, and used to determine the thickness profile of the steel.

Over the past two years Sonomatic has developed DRS from a theoretical concept, through a process of computer modelling and laboratory testing, to a field-ready inspection system capable of both subsea and topside corrosion mapping. A comparison between 0° ultrasonic wall thickness measurements and DRS corrosion mapping on a corroded steel plate has shown the technique to have a thickness accuracy of 0.5 mm. The DRS spatial resolution is currently 10 mm, although further development work is ongoing to refine this.

DRS applications

DRS has already been successful in measuring steel wall thicknesses through a wide range of challenging coatings. One of the most commonly requested DRS inspections is for pipelines with composite wrap repairs, such as Technowrap™. These GRP-type materials are currently classified as temporary repairs due to the lack of a suitable inspection method for monitoring corrosion growth post installation. DRS has successfully mapped corrosion through 10 mm of Technowrap and work is underway to inspect through even thicker composite repairs.

Corrosion protection tapes are another challenging coating. They prevent external corrosion on pipelines, but also act as a barrier to the existing ultrasonic inspection techniques used to map internal corrosion. DRS has proved to be successful in penetrating these tapes to produce a wall thickness map of flat-bottomed holes in the underside of a taped plate.

Thick polypropylene and polyethylene field-joint shrink-wraps, and intumescent passive fire protection have been evaluated and found to be excellent candidates for DRS corrosion mapping. Promising results have also recently been obtained through 75 mm of injection moulded polypropylene (IMPP). Other coatings are currently under investigation and any specific material can be evaluated upon request.

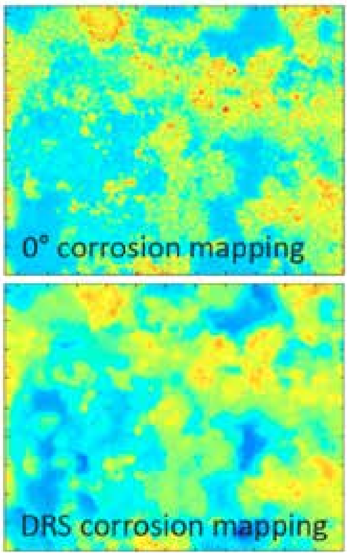

Figure 4. Comparison of 0° and DRS corrosion mapping of a corroded steel plate. The DRS spatial resolution is 10 mm and the wall thickness accuracy is 0.5 mm.

DRS field deployment

The DRS corrosion mapping technique is deployed on Sonomatic's range of proven topside and subsea scanning technology. All scanners are designed in-house and are easily modified to accommodate challenging access requirements. Sonomatic's R&D capability, advanced technology and extensive field experience make them well placed to deliver DRS as a practical solution to corrosion mapping through challenging coatings.

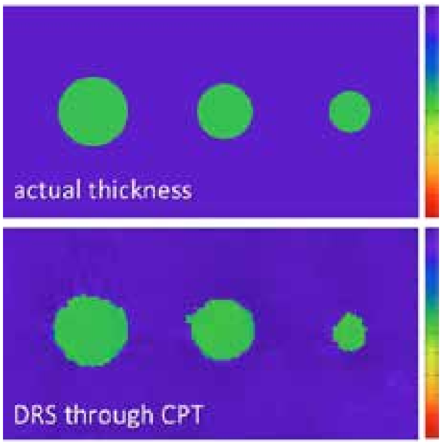

Figure 5. A DRS wall thickness map through corrosion protection tape. Measured thicknesses are within 0.5 mm of the actual thickness.

DRS benefits

DRS penetrates challenging coatings to produce corrosion maps of the underlying steel. It provides quantitative wall thickness measurements with 0.5 mm accuracy and 10 mm spatial resolution.

This means:

- The absence of corrosion on subsea lines with thick insulation such as IMPP can be validated.
- Repeat inspections can be used to measure corrosion growth rates for pipelines.
- The lifetime of temporary composite repairs can be extended.
- Statistical analysis can be conducted on the data e.g. limited coverage inspection provides useful results.

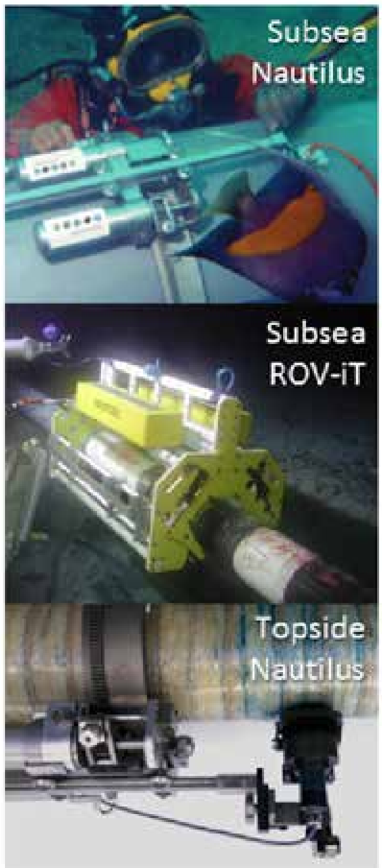

Figure 6. Sonomatic topside and subsea tools used for deployment of the DRS corrosion mapping technique.