Testing with waves

Hermann Schubert, MISTRAS Group, Germany, and Thomas Vogt, GUL Ltd., United Kingdom, discuss the various applications and benefits of guided wave pipeline testing.

Pipeline corrosion is a massive problem in the petrochemical and other related industries. Conventional methods for measuring wall thickness, such as ultrasonic testing, supply measured values that are local and specific to the inspected area. These quantitative results cannot comment directly on adjacent areas. Measurements are often carried out at selected locations on the pipe, which increases the probability of wall thickness reduction. As a result of their under-sampling rate of the pipe, local methods are not always the best practice of finding the defect. Whilst this can be improved by increasing the number of measurements, this will also increase the amount of time and costs. This is significant when

pipelines are isolated or difficult to access. Especially with insulated pipes, where the preferable corrosion points cannot be predicted, the insulation of the pipeline has to be removed for full inspection. This is also needed in cases where access to the pipeline is not possible, such as in road crossings, buried pipes, casings or offshore risers. In addition, a sensible risk assessment must include the locations of a pipe, which cannot be detected with conventional methods.

Ultrasonic guided waves

Guided wave (GW), a testing capability using ultrasonic guided waves, has become a qualified test method classified into series of established test procedures. Originally developed for the inspection of insulated piping, the examination is usually aimed at the effective implementation of testing tasks as described above, where a quantitative inspection cannot be handled satisfactorily.

GW generally refers to waves that are guided through the external wall of the inspected object. In the default GW testing of pipelines, relatively low-frequency ultrasonic waves of about 20 - 120 kHz are used to propagate in the pipe. When GW is introduced in the pipe, a ring with an array of ultrasound transducers used. This GW is reflected by discontinuities/features like welds, tees, flange, defects or corrosion, and this is detected by the ring in the pulse-echo method (Figure 1). Different to the conventional ultrasonic testing, the area below the ultrasonic transducer is not tested, but a wide range of the pipe can be evaluated. In some applications, from a single point location, more then 25 m in each direction of the ring can be evaluated.

In addition, GW examination is useful in conjunction with additional inspection methods provided by MISTRAS GMA. For high reliability, an inspection must have two properties:

- A high probability of detection in a reasonable time and budget.
- The option for the accurate classification of defects in severity categories.

No available method of inspection of pipelines over long distances can fulfil both requirements. Combining two or more inspection methods, however, can achieve this. This develops a new test philosophy, where a search or screening method, such as GW, is used in the first instance. If a discontinuity is found, which points to corrosion at a certain point, a second inspection method should be used from MISTRAS' suite of traditional and advanced non-destructive testing capabilities to test for the accurate measurement – i.e., complements the defect – for classification. For the classification there are several methods depending on the application in question. For example, by means of the local thickness, testing higher frequency ultrasound or visual inspection.

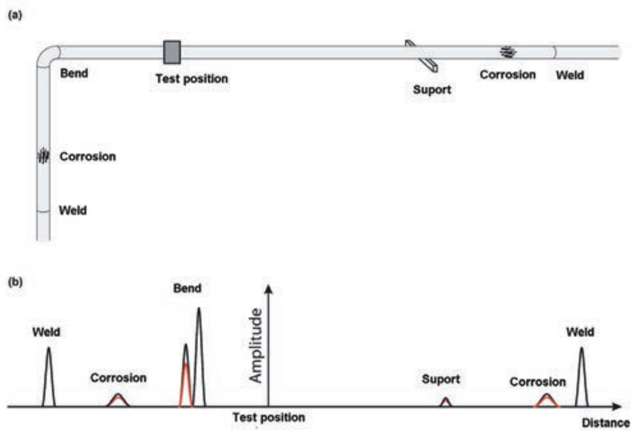

Figure 1. The ultrasonic pulse will be reflected when there is a change in the wall thickness and the stiffness of the pipe, from both sides of the test ring (a). These reflections will be absorbed by the test ring. All data will be evaluated by special software and will be shown as an A-Scan (b).

Figure 2. Typical test configuration with test ring and GW equipment from Guided Ultrasonics Ltd. There are several different types and models of test rings, from diameters DN 25 - 1500.

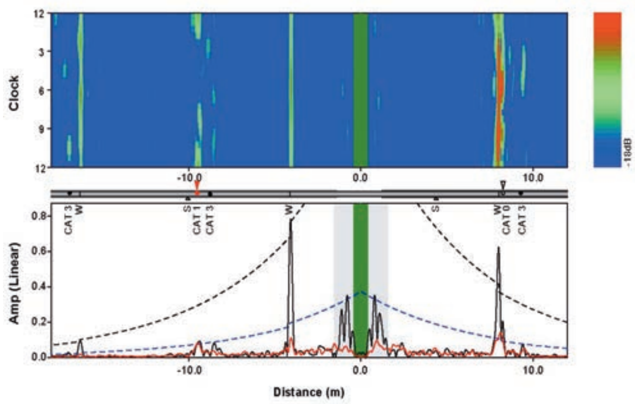

Figure 3. A picture with a schematic representation of the pipe features (bottom) and C-scan (top) of a GW test. It shows the typical appearance of corrosion at about -10 m. Note also the irregular shape of the welded seam at about +8 m, which indicates a defect in the weld seam, or directly behind it. On both sides of the test ring is the dead zone (green) and the near field (grey).

Although it is a relatively new technology, GW is used worldwide as a screening tool. The industry's acceptance of this inspection method becomes apparent when one looks at the number of papers published and the preparation of international standards.[1]

The practical application examples presented are intended to give a brief overview of the possibilities and limits of the GW test. They illustrate how NDT leaders like MISTRAS GMA and GUL Ltd. use GW as a qualitative screening tool to reduce the amount of testing and to increase the detection probability for defects.

Background for guided wave inspection

The GW inspection of pipelines is carried out almost exclusively with torsion waves.[2] Guided waves are sent from the ring with transducers in both directions along the tube. Because the torsion mode over the pipe wall's cross section is uniformly distributed, 100% of the pipe wall can be checked within the scope of the GW. Both internal and external defects are therefore recognised equally. The amplitude of the reflection is dependent on the torsional shape and dimensions of the reflective characteristic, and is therefore used for the classification of defects. Traditionally, a cross-sectional loss is calculated from the amplitude.

Figure 4. Pipe racks in Espirito Santo, Brazil, which were otherwise investigated only locally at some points.

In contrast to traditional ultrasonic inspection, in which there are only two propagation modes (transverse and compression mode), there are many different modes of propagation in pipes because of the interfaces. If the torsional mode is reflected by a cross-sectional change, it is because of a non-axisymmetric modification, not only the reflection, but also to the mode conversion in so called flexural modes. This fact is used and explored, and due to this behavior it is possible to have a C-scan showing the circumferential position of a tube characteristic indication, there is no mode conversion to flexural modes.

It is important to note that the GW inspection is a volumetric method and therefore provides qualitative information only. Consequently, it is not possible to make an exact indication of the remaining wall thickness after at a certain location, but it is possible for MISTRAS GMA or GUL Ltd. personnel to localise the indication with a good accuracy. Although we use the reflection amplitude of the torsional mode and the C-scan to determine the severity of the corrosion, a local test method must be used.

Figure 2 shows a typical test result. The black trace in A-scan correspond to the torsional mode, while the red trace corresponds to a flexural mode. For example at about -4 m, there is a weld. Since this is large axially symmetric for the quantitative determination, such as ultrasonic thickness measurement or visual inspection.

The conventional ultrasonic testing distance amplitude correction (DAC) curves are used to estimate the true reflection amplitude, regardless of the distance (dashed lines in Figure 2). Within the scope of the GW,

Figure 5. Testing of inaccessible pipes in a river crossing in Rio Grande, Brazil.

Figure 6. Pier in the northeast of Brazil. Within a few weeks, 20 km of pipeline was inspected.

discontinuities with a cross sectional loss of 3% may be detected.

Examples of application

The following examples give a brief insight into the scope of GW application. The three main application areas, listed below, expose the basic ideas behind GW testing.

Jump over and pipe bridges

Pipe bridges are an ideal application for GW in two ways. First, it has long distances and due to their installation in other levels and often only allow partial access, the visual examination becomes very difficult (see Figures 3 - 5). In addition, conventional ultrasound examinations can only be used locally. Using GW, this test can be performed quickly and without much effort. Normally on the pipe bridges we have simple geometry and simply supported uncoated tubes. In these conditions, a single test, from a single location can cover up to 50 m. Under ideal conditions up to 1.5 km/d can be inspected using one GW team.[4]

Figure 7a. Overview from the test location.

Figure 7b. Discontinuity found with GW in about 8 m of the ring position in a positive direction.

Secondly, using MISTRAS GMA and GUL Ltd.'s GW method, the contact points or supports can also be checked. Simple contact supports can be quickly divided into different classes of damage. Consequently, complementary inspection of the individual supports can be prioritised. An example of such supports is given in Figure 6.

A more difficult application occurs when welded supports are used, as they may affect the range of the GW test. The testing of pipelines is not affected by liquid or gaseous content in the tube, but solid deposits in the tube can attenuate the signal. In addition, coatings will also attenuate the signal and may reduce the range of the inspection.

Insulated lines

When the pipe's insulation must be removed, there is considerable cost. Instead of removing the complete insulation, only individual checkpoints are expected to have their insulation removed for the GW test. If discontinuities are found, which indicate corrosion, the insulation at these locations are removed and complementary inspections are made with other test methods. The insulation itself, if it is made of mineral acoustic wool or a similar material, has no influence in the range of the GW, therefore, in this application, long distances are also expected to be reached by one location.

Generally, it is recommened that a stripping team is assigned to the GW inspection team, as the inspector will choose the best location for the next inspection point based on the results from the prior inspection. In addition, it enables the GW team to be able to immediately identify and check the indications. It is important to note that in certain cases the brackets for tracing must be relaxed near the test position to set the test ring.

A particular application is the testing of district heating pipes, which are not only isolated but are often located in inaccessible bays.

Road crossing

For road crossings the situation is similar to insulated pipes. An inspection cannot be done without high costs and considerable additional expense with conventional test methods. With GW, however, it can be estimated

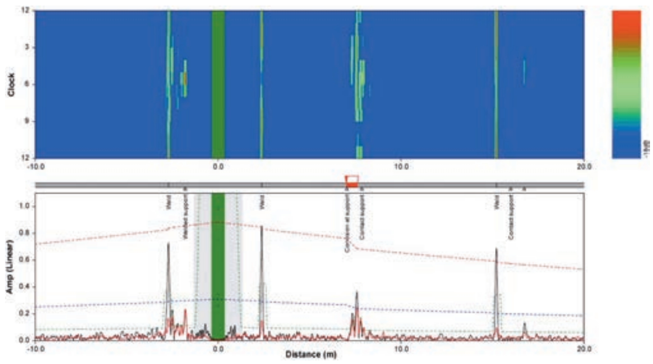

Figure 7c. The resulting image shows, among other features, the exact position of the discontinuity.

whether the effort and costs are necessary, and if a more conventional investigation must be carried out at the selected test location. Frequently, a refinery has several hundred pipes, which are laid in ducts or street casing pipes (Figure 9). Of course, only a fraction of the pipes are affected by damage. Yet, the benefits that a screening tool can have are often overlooked. They can sort out which lines have no damage and do not need to be excavated, reducing the costs of inspection.

Figure 9 is an example where access is difficult, where special work permit is needed, as for confined spaces, which at the first moment does not apply to GW. The GW test is performed by default at both inputs of the road crossing to reduce false calls and to increase the coverage for pipes with welded supports.[5]

Summary

GW has proven to be a fast and accurate test method for finding local corrosion worldwide. It has various applications, ranging from the examples listed above to monitoring the splash zone from risers in the offshore industry, pipe trespassing walls and testing the so-called sphere legs with fire protection coating.

The range, productivity and applicability, of the GW test can, however, be limited by several factors including sound-absorbing coatings such as bitumen and a high density of features such as pipe bends, welded flanges or clamps.

In all cases, it should be noted that it is a qualitative test procedure which should be followed by a quantitative method. The combination of both methods is important because rarely a reliable inspection will achieve with a single method. Unfortunately, this is not always immediately possible, for example, in the road crossings with the casing. In this case, the GW test must by itself make a relatively accurate assessment of the severity of a suspected defect. Although nowadays there are tools that make the interpretation of the results easier, but it requires high level of expertise and experience in dealing with GW. Newly qualified auditors should first tackle only those applications where a direct appeal with a complementary method is the principle method.

Figure 8. Only 0.5 m of insulation must be stripped to the test position.

References

1. BS 9690-1:2011, 'Non-destructive Testing. Guided Wave Testing.' *General Guidance and Principles.* ASTM E2775 - 11, 'Standard Practice for Guided Wave Testing of Above Ground Steel Pipework Using Piezoelectric Effect Transduction.'
2. ALLEYNE D, VOGT T, CAWLEY P, 'The choice of torsional or longitudinal excitation in guided wave pipe inspection', *INSIGHT*, Vol. 51. 2009. p 373 - 377.
3. LOWE M, CAWLEY P, 'Long Range Guided Wave Inspection Usage – Current Commercial Capabilities and Research Directions', 2009. Download available at: http://www3.imperial.ac.uk/pls/portallive/docs/1/55745699.PDF
4. H Schubert et al, 'A realidade pratica do ensaio por ondas guiadas no Brasil, 11a. COTEQ – Congresso sobre Tecnologia de Equipamentos'. Brasil, 2011.
5. VOGT T, ALLEYNE D, 'Prüfung von Rohrleitung in Straßendurchführungen mit Guided Waves.' *DGZfP Fachtagung*, 2009.

Figure 9a. Pipelines in a road crossing with no access, which were otherwise not tested but with GW they were 100% scanned.

Figure 9b. Pipelines in casing.