Guided Wave Testing for touch point corrosion
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Abstract
Guided wave testing (GWT) is established in the petrochemical and related industries, primarily for the detection of corrosion flaws. Touch point corrosion at support positions in pipe-work has become a significant problem within many operating gas, chemical and petro-chemical plants world-wide, particularly as a high proportion of these plants have been operational for many decades. This article demonstrates how GWT using guided waves sent axially along the pipe can be performed for the detection and accurate classification of touch point corrosion.

The major advantage of GWT methods for the detection of touch point corrosion is its ability to examine several support positions from a single easy to access transducer position. The strategy is then to prioritize or rank the condition of the pipe at the supports by removing those with negligible wall loss from scheduling for further inspection. Guided waves are accurate at detecting and classifying corrosion patches at support positions, but deep pits within such patches are more difficult to accurately identify. Examples using data from routine inspection testing are used to support the development of the methods and testing approaches presented. Recent developments of the interpretation methods, testing procedures and calibration methods have significantly enhanced the capabilities of GWT for this important application.

1 Introduction
The petro-chemical majors have increased their support for the application of guided wave testing (GWT) for the inspection of both on-site and off-site piping over the last decade. This method of inspection is continuously developing as more knowledge and on-site experience are gained and better inspection procedures are developed to interpret the powerful data sets generated by the latest technology. Guided wave screening was first developed for the inspection of inaccessible insulated pipe-work and the method has gained acceptance over a wide range of applications where it is commercially or practically advantageous. As guided wave testing applications have grown the need to improve and develop the technology to meet ever greater demands has also grown. At the same time the technology has evolved from primarily being a screening method, where all potential corrosion is verified and quantified using a complimentary technique, to more of a stand-alone method capable of classifying corrosion into severity groupings. This allows for the prioritizing of resources so that corrosion sites above a predefined level is analyzed according to the relevance they have on the fitness for service of the pipe. This form of inspection also facilitates on-going monitoring of piping over extended regions.

Although guided wave methods are now widely accepted [1-4] there are limitations and restrictions to the use of the technology for many applications. As the technology and understanding of its use has improved many of the initial limitations and restrictions have been reduced and in some cases removed. The quoted sensitivity of the guided wave method is a function of the change in pipe wall cross section caused by the corrosion and in the late 1990’s a conservative limit of about 5-10% was quoted. This meant the technology was ideally suited for the detection of corrosion areas and not for pitting. However, with the advent of new generations of the technology, an order of magnitude smaller change to the pipe wall cross section can be found particularly if repeat tests are carried out from the same position on the pipeline and data is compared so as to monitor for changes caused by the pipe condition. Moreover, experience over the last ten years has shown that simplistic methods of quoting the detection capability and reliability of GWT [5] are flawed and not helpful in communicating the capability and limitations of the technology.
This article will present and discuss advances in the GWT method for the inspection of touch point corrosion at supports and the advantages that using this approach presents to the inspection engineer. It is also worth reiterating that guided wave interpretation methods require a high level of understanding. This is the major reason for the stipulated training and certification requirements for the accurate and reliable detection of touch point corrosion using the GWT method.

2 GWT data collection and post processing techniques

The conventional GWT method employs the pulse-echo configuration in which guided waves are propagated in the axial direction of the pipe by a transducer ring which is also used to receive the returning reflections. The major advantage of this configuration is that it minimizes the requirements for equipment and testing time. All of the results presented in this article were collected using the pulse-echo technique.

Reflections are generated at locations where there is a change of stiffness (for example, at contact supports) or a change of the pipe cross sectional area (for example, at girth welds or corrosion patches) along the pipe length. These two types of reflections can occur simultaneously at contact support locations. In the case of a change in the stiffness, the reflection amplitude tends to be larger at lower frequencies. This is demonstrated in Figure 1, where the reflection coefficient (RC) percentage from a 0.2m long contact support with a 1000kg load on an 8” Schedule 40 pipe as a function of frequency, is calculated analytically [6]. Although the (RC) varies with different pipe size, contact area and loading force, the overall trend of the curve remains the same with the (RC) much higher at a lower frequency. In most cases this (RC)-frequency relationship is the major consideration when using guided waves to test for touch point corrosion in pipe-work.

![Figure 1 Analytical solution of the variation of the reflection coefficient from a 0.2m long contact support with 1000kg loading on an 8” Schedule 40 pipe.](image)

Therefore, GWT is normally performed over a range of frequencies. In particular, at higher frequencies the (RC) due to the contact loading becomes negligible or very small and only reflections caused by touch point corrosion would be present. Furthermore gathering data over the correct range of frequencies improves the test sensitivity to corrosion by a significant margin, because, crucially, at some frequencies the reflections from corrosion will be very small (well below the call level) and would almost certainly be missed during a routine
inspection. In such cases it could be assumed that the sensitivity of guided waves to touch point corrosion was very poor. However, the dynamic frequency sweeping capability built into Wavemaker® systems enables the frequency to be adjusted continuously over a wide range to maximize the signals from the corrosion (maximum sensitivity), while ideally minimizing the amplitude of any signals from supports.

Focusing using data processing methods was first introduced in 2007. This synthetic data processing method utilizes the information from data at different circumferential locations around the pipe circumference. The data can then be post-processed so that the circumferential distribution of guided wave energy can be determined at any axial support location within the test range. The results of this method of processing the data allows the interpretation to locate both the axial and circumferential (clock) location of touch point corrosion. This also allows for a more accurate prediction of the corrosion characteristics and provides a more intuitive method of displaying the GWT results.

3 Results

The interpretation rules developed by Guided Ultrasonics Ltd. (GUL) and given to inspectors during GWT training form the basis of the methods used for the evaluation of touch point corrosion. Identifiable reflections from welds are used to calibrate the DAC levels and the results are classified into severity groupings based on the estimated wall loss range. The possibility of an echo generated by the contact of the support is the major cause of the complication when testing for touch point corrosion as any corrosion present will also generate an echo but this may be masked or obscured by the echo from the support contact. In fact different types of corrosion with different geometries (corrosion areas or pitting) reflect guided waves in a different way and respond to changes in the frequency of the guided wave test (and the pipe diameter) differently. The Frequency-regime (Fr), first introduced with the launch of the Wavemaker® G3 is a measure of the frequency pipe diameter product instead of the frequency alone. The frequency pipe diameter scaling property underpins the concept of Fr which is used in practical GWT today. Frequency-regime is defined to be a dimensionless logarithmic function of frequency and diameter according to scaling based on the dispersion curves for the pipe. Most GWT for touch point corrosion is performed in the range 5<Fr<12, where the amplitude of the reflection coefficient from most contact supports will be less than a few percent.

Therefore, the GWT inspector must not confuse echoes from supports with echoes from wall loss and vice versa. The example cases discussed below will highlight the benefits and limitation of the GWT method to detect and accurately classify touch point corrosion.

3.1 Case 1: Tank farm line, 16” diameter schedule 10

The purpose of this test was to determine the condition of the pipe, where internal and external corrosion was identified as the major threat. Data were collected over about 25 meters in each direction from the transducer ring position (typically this process takes a few minutes) and the result is shown in Figure 2. All of the supports locations were classified as having no significant touch point corrosion (less than 20% wall loss). The increased amplitude of the echoes from the three supports in the positive direction was caused by the nature of the contact loading between the pipe and the support. This test was performed over a range of frequencies where the predicted (RC) shown in Figure 1 was about 2%. During the data interpretation the frequency was adjusted using the dynamic frequency slider within the
Wavemaker® system software to establish that the amplitude of the echoes from the supports reduced continuously as the frequency was increased.

Figure 2  GWT result from the 16” tank farm piping which rests on metal contact supports at Fr=10.

Figure 2 is displayed in two forms, the bottom plot is an A-Scan, where the vertical axis is amplitude and the horizontal axis is distance from the transducer ring. The colour plot above this is the C-Scan map of the result, where the vertical axis is the angular position around the pipe circumference. A scale showing the dynamic range of the colour contours is included for clarity and is a measure of the amplitude or intensity of the reflection. The large reflections in the A-Scan are from four girth welds, which are slightly non-uniform in the C-Scan because of misalignment between the sections of piping. This test covers five contact support positions and as can be seen from the A-Scan the echoes from these positions are very small (relative to the weld echo amplitudes). There is no evidence of a signal above the call level at these positions in the C-Scan (at the 6 o clock position in the un-rolled view). With reference to the A-Scan plot, the blue dashed line is the “call level”, this was set to a level of 3% and none of the support echoes exceed this level so they were not called. It is worthwhile noting that the amplitudes of the echoes from the contact supports at 1.8m, 9.7m and 17.4m are increased because at these positions the load, which is caused by the weight of the pipe, is relatively high.

3.2  Case 2: Dock line, 8” diameter schedule 80

Figure 3a is a picture of the dock line, where the white lines on the pipe mark the position of the transducer ring during the data collection. The touch point corrosion shown in Figure 3b was identified on this line at a distance of about 7.4m from the transducer position.
The GWT result is shown in Figure 4. The amplitude of the indications from the corrosion is well above the call level, indicating that this corrosion has changed the pipe wall cross section by less than 10% and is concentrated within 25% of the pipe circumference (see Figure 3b). This touch point corrosion was therefore given the most severe classification (estimated wall loss greater than 60%). A pit gauge measurement of the maximum wall loss confirmed it to be approximately 80%. Touch point corrosion of this form is relatively straightforward to detect with GWT and the accuracy of the call in terms of severity or wall loss estimation can be good if the data is accurately calibrated, for example, by measuring the dimensions of at least one weld cap profile from any of the girth welds within the test range. However, the call level must be adjusted correctly and the axial and circumferential dimensions of the corrosion should be around an order of magnitude greater than the pipe wall thickness. It is also worthwhile noting that this dock line had generalized internal corrosion along its entire length. The internal corrosion caused indications with an amplitude
of about 1.5%, so the call level was set at 4% (>6dB above the background level). It is evident from the C-Scan plot that the distribution of the touch point corrosion is over a limited axial and circumferential region of the pipe around the contact support position.

3.3 Case 3: Vapor line, 12” diameter schedule 40

The GWT test result shown in Figure 5 is from a 12” vapor line within a terminal. A visual inspection suggested the pipe had negligible external corrosion threat and random UT thickness measurements confirmed that the threat from internal corrosion could be neglected too. The GWT results confirm that the general condition of the pipe was good.

Within the test range displayed there are three welds, two welded supports and three contact support positions. The data SNR was such that a cross sectional change of a few percent would be detected reliably and the call level was set to 3% for small isolated pitting. The isolated echo at about 2.9m in the positive direction, which also shows up clearly in the C-Scan un-rolled view is from a contact support position. This indication is from touch point corrosion that it more like a pit and therefore is only a small change in the pipe wall cross section. This indication was given the most severe classification (greater than 60% wall loss) even though the amplitude of the echo was only 3%. (The small amplitude is because this localized pitting reduced the pipe wall cross section by a few percent). A picture of the touch point corrosion at this support is shown in Figure 6.
4 Conclusions

Guided wave testing is a powerful method for the inspection and screening of operating pipelines. The method is advantageous for the inspection of touch point areas at supports that are not directly accessible for visual inspection. Examples from routine tests have been presented to confirm theoretical investigations that predict the behavior of guided waves when they are reflected from contact supports. This information was used to establish that a frequency-regime greater than about five is best for the detection of both isolated pitting and corrosion patches at contact support positions.

Recent equipment changes and additions to the data processing and software tools have significantly improved the capability of GWT for the detection and classification of touch point corrosion. Focusing and the C-Scan display can also be used to improve the SNR for pits that are axially and circumferentially localized at supports.

However, there are still challenges when applying guided waves to detect and correctly classify touch point corrosion. Crucially, the accuracy of the results is strongly dependent on the training and expertise of the inspector and the testing procedures used. Thick uneven coatings and/or internal deposits can cause scattering echoes and high attenuation, which may greatly reduce the frequency-regime range of data used for the interpretation.

References

2. TUV qualification certificate KC/771/01/181/01/10, (2010).