ONDES GUIDÉES : ASPECTS FAVORABLES ET LIMITATIONS
GUIDES WAVES: OPPORTUNITIES AND LIMITATIONS

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Résumé

L'opération en sûreté d'une installation pétrochimique exige l'inspection des tuyauteries pour s'assurer qu'il n'y a aucun niveau inacceptable de corrosion. Chaque installation a beaucoup de milliers de mètres de tuyaux, beaucoup dont est isolé ou inaccessible. Les méthodes conventionnelles de CND comme l'inspection visuelle et les ultrasons exigent l'accès à chaque point du tuyau, cette procédure est longue et très chère. Les ondes guidées fournissent une solution à ce problème parce qu'elles peuvent être générées à une position sur le tuyau et propageront beaucoup de mètres, les échos indiquant la présence de corrosion ou d'autres components soudées au tuyau.

Abstract

The safe operation of petrochemical plant requires screening of the pipework to ensure that there are no unacceptable levels of corrosion. Unfortunately, each plant has many thousands of metres of pipe, much of which is insulated or inaccessible. Conventional NDT methods such as visual inspection and ultrasonic thickness gauging require access to each point of the pipe which is time consuming and very expensive to achieve. Guided waves provide an attractive solution to this problem because they can be excited at one location on the pipe and will propagate many metres along the pipe, returning echoes indicating the presence of corrosion or other pipe features.

Introduction

Guided Wave Testing is a relatively new NDT method complementary to existing NDT methods and widely used for screening of pipes. Originally developed for screening of insulated lines because of its capability to reduce the need for insulation removal, this approach is now used in a variety of applications : from screening of pipes in pipe racks to inspection of buried and underwater lines. Most European refineries and plants are rather old and need to be maintained. The presence on single sites of several kilometers of piping to be checked, monitored and maintained is a major task. Standard NDT approach offers solution targeted to areas that are most likely to be affected by deterioration of the original conditions. However in many cases, because of lack of information or because of the limitation of a specific technique or approach, piping may leak or even cause catastrophique failures. Moreover in several cases it is difficult to gain access to the part to be inspected. In all of the cases listed above, Guided waves offer an opportunity to obtain relevant and critical information that may avoid incidents and loss of production.

Guided Waves

A Guided Wave system is composed of three primary components: the transducer ring, the instrument, and a laptop computer running the controlling software. The transducer rings are specific to the pipe sizes to be tested. They use either springs or air pressure to force piezoelectric transducer elements onto the pipe. Figure 1 shows the instrumentation, for an example case using an inflatable ring.

Figure 1: The guided wave inspection equipment, set up for testing using an inflatable ring.

In general very little surface preparation is required because the operating frequency is low: typically below 100 kHz. The transducers are able to couple directly through paint, thin layers of epoxy, or a small amount of general corrosion, but any flaking paint, thick coating or loose corrosion has to be removed. It is not necessary to use any kind of coupling fluid. The transducer ring must be able to contact the pipe wall around the entire circumference of the pipe.

Once the inspection planning and the preparation of the inspection locations have been completed, the measurement process at each location is very quick. The ring is attached, software settings selected, and measurements captured in just a few minutes. In doing this the system performs a considerable amount of processing, including a range of self-checking procedures, calibration, and the recording of all measurements and settings.

The results are first of all presented graphically on distance-amplitude axes (A-scan, see Figure 2). The system is able to gather data separately for each direction along the pipe, so the results are plotted for both positive and negative distances from the transducer ring position. Indications of features or defects are given by reflected signals whose amplitude exceeds a threshold. Additionally, two different kinds of waves are used concurrently by the instrument, allowing it to differentiate defect indications from those coming from axially symmetric reflectors such as butt welds [Lowe et al, 1998; Alleyne et al, 2001].

A secondary presentation of results shows the variation of the strengths of the reflections according to their location around the circumference of the pipe. This information is plotted as a "C-scan" image (see Figure 2), the two axes being the longitudinal and circumferential dimensions. The Cscan images are calculated using separate signals from the transducer elements around the ring, and processed by imaging algorithms; they indicate the circumferential extent of defects and allow for focusing, thus helping to distinguish localised deep pits from spread-out general corrosion. Testing is always done over a range of frequencies. This is important because the sensitivity to defects varies with frequency according to their dimensions [Demma et al, 2004], so a frequency sweep brings out the best sensitivity for each of any defects along the length being tested, thus increasing the POD; this also helps in the interpretation of defect reflections separately from the reflections coming from regular geometric features.

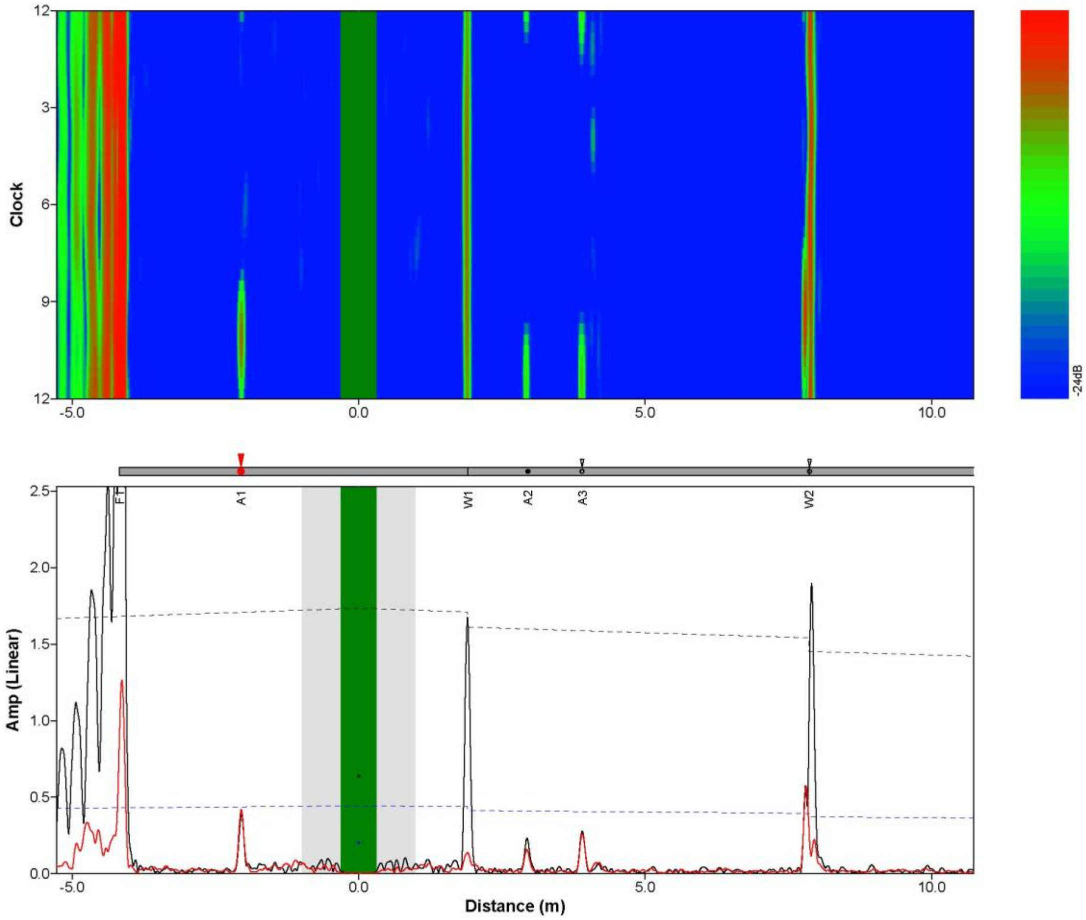

Figure 2. Example result, showing both the A-Scan type result trace (below), and the C-Scan type unrolled pipe display (above). The weld *W1* is a symmetric feature, extending around the entire circumference, whereas the defect *A1* is non-symmetric and localized at the 9 - 12 o'clock position. The dashed curves are DAC curves (black - weld DAC, blue - call DAC).

Advantages

Coverage

A Guided Wave system offers the advantage of nearly 100% coverage. This may be regarded as unnecessary due to the capabilities of other types of inspection combined with statistical approach. However it has been verified in a number of cases that small coverage may lead to disappointing outcomes. One example of this is in Figure 3. As per internal company procedure this 10 inch schedule 40 carbon steel pipe was tested every 12m at 4 points (3,6,9 and 12 o'clock position). Figure 3.a shows a UT test carried out at the 3 o'clock position, the thickness at this position was 10mm. Figure 3.b shows a UT test carried out at the 5 o'clock position where an anomaly was identified at this location using a Wavemaker G3 test result; the thickness at this position was 4.5mm. This defect was isolated and other internal defects on this pipe appeared at different clock positions. This example demonstrates that even in the unlikely event that following company procedures based on existing international codes and standards it would have been impossible to identify this defect (even in the unlikely event that the position for the UT inspection was the same as the axial location of the defect). Inspection coverage is a very important parameter that affects the efficiency of an NDT method (including equipment and procedure) to identify a threat to the normal operation of a pipe. Typically UT, RT and other classic NDT methods have relatively high probability of detection (POD), however it is difficult/expensive to achieve large coverage. GWT has relatively low POD (will not find small defects such as single pits) and high coverage (nearly 100%). As a result of the combined effect of POD and coverage GWT is in several cases the most efficient method to identify a threat before failure (this will depend on the critical defect size and inspection interval as identified in a study reported by Trimborn et al.). After a potential threat is identified using GWT, standard NDT methods must be used to size the defect and further evaluate the integrity of the pipe.

Figure 3. UT follow-up inspection on a 10" pipe schedule 40. On the left, thickness at the 3 o'clock position is 10.1mm. On the right, thickness at the 5 o'clock position is 4.5mm.

Reduced access costs

When planning an inspection one of the items to consider is the access to the part to be inspected. In some cases several solutions may be available to carry out the inspection but due to limited access the choice is drastically reduced. In most cases access can be achieved, however one must evaluate the cost for gaining access that may be well above the cost of the inspection. As the cost for gaining access may be dependent on specific country

and location (for example onshore against offshore) it is difficult to assign a specific value, however it is possible to explain the process of estimating the cost for gaining access.
Let us assume that an insulated line need to be inspected and the cost per unit length of insulation removal and reinstatement is 100. If NDT technique A requires full removal of insulation the total cost of this operation will be:
Cost of inspection A + (100xlength)
If NDT technique B does not need full insulation removal but only 5%, the total cost of this operation will be:
Cost of inspection B + (5xlength).
If you demonstrate with an engineering evaluation that inspection approach A and B are equivalent in terms of their efficacy to identify a critical threat, the most efficient approach will correspond to the cheaper of the two (including the insulation removal cost as indicated above).

The cost for inspection of insulated lines can also be higher than just the cost of insulation removal and reinstatement if the pipe is elevated (scaffolding costs) or within a earth barrier (cost for removing the earth barrier) or simply because carrying out the test would cause reduced productivity/efficiency of the pipe (for example because the pipe shall be taken out of service to use inspection method A in the previous example).

In service inspection
Using Guided Waves it is possible to inspect pipes while they are in service. Liquid or gas phases may be free flowing and the measured pipe temperature must be between -40^{o}C and 200^{o}C. Special rings may need to be used at high temperatures (see Figure 4).

Figure 4: Special ring and modules used for inspection at high temperatures (up to 200C).

Limitations

Pipe Geometry
The geometry of the pipework to be inspected using Guided Waves affects the test range. GWT is more productive and effective the further the pipe features are apart from each other. The flange represents the end of test. Other features such as Ts, valves, changes in direction and welded supports strongly reduce the test range.

Coatings
Viscoelastic coatings (such as bitumen or polyethylene) reduce the test range. The effect is more severe when the coating is soft and well adhered to the pipe wall. Wide frequency range must be used to optimize test range.

Contents
Gas and non-viscoelastic fluids do not affect the test range when using torsional waves. Viscoelastic fluids or heavy deposits reduce the test range.

Ambient noise
Ambient noise may be caused by pumps or compressor at a location close to the inspection area, the fluid flow inside the pipe and repair or construction work on the pipe under inspection. In some isolated cases the GWT may not be carried out while the source of noise is active. Most commonly the noise is at a lower frequency than the range used for the pipe inspection and the GWT can be completed using standard procedures.

Pipe condition
General corrosion reduces the test range and when the general corrosion on the pipe is extended over a long length and severe GWT may not be suitable to carry out the inspection.

Latest developments

Current GW technology comprising transducers, instrument, software and interpretation methods has been developed over the past 10 years for rapid 100% screening of pipelines.

Recently more efforts have been made to target other types of short range GWT where greater sensitivity and resolution is required. Therefore new higher frequency capabilities are to be developed to harness the potential of existing systems for new applications such as inspection under support and interface inspection.

Conclusions

This article briefly explained the basis of Guided Wave inspection looking both at the opportunities offered by the existing technologies and the limitations that should be considered when planning to use Guided Waves for rapid screening of pipes.

References

1. Alleyne, D.N., M.J.S. Lowe and P Cawley, “The reflection of guided waves from circumferential notches in pipes”, J. Appl. Mech., Vol. 65, 1998, pp. 635-641.
2. Lowe, M.J.S., D.N. Alleyne and P. Cawley, “The mode conversion of a guided wave by a part circumferential notch in a pipe”, J. Appl. Mech., Vol. 65, 1998, pp.649-656.
3. Demma, A., P. Cawley, M.J.S. Lowe, A.G. Roosenbrand and B. Pavlakovic, "The reflection of guided waves from notches in pipes: a guide for interpreting corrosion measurements", NDT & E International, Vol. 37, 2004, pp.167-180.
4. Trimborn, N., Heerings,J. and Herder, den Adriaan, "Inspection effectiveness and its effect on the integrity of pipework ", 4th ME NDT conference, 2007