Ultrasonic Guided Waves
Evaluation of Trials for Pipeline Inspection

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Abstract

The Guided Wave UT method has been subject of several papers presented and discussed on NDT seminars and conferences worldwide due the method's potential to solve some technological challenges regarding inspection of pipes such as buried pipes, insulated pipes, offshore risers and road crossings. These sections of pipelines are very difficult to inspect using other conventional NDT methods because of limited or no access.
A first trial was carried out in Brazil in 2003 and planned to use the two main guided waves systems available on the market at that time to test coated, buried pipelines and insulated pipes. The results obtained in this occasion were not satisfactory for Petrobras targets. In the meantime the guided waves technology has been improved with new developments both on software and hardware and several companies worldwide have increased the use of this technology. Based on the information published claiming good performance of the technology in several applications Petrobras decided to proceed with a second trial divided in two stages: the first one carried out in November of 2005 consisting in an inspection of three rigid risers located on an offshore platform in Brazilian Northeast cost and the second one carried out in August of 2007 on an 8"gas pipeline onshore.
The results achieved in the above mentioned second trial were extremely positive. Based on these results this paper will discuss the future of guided waves in the oil and gas industry.

Keywords – Guided Waves, Ultrasonic, Pipeline Inspection

1 – Introducing Guided Waves – GW

1.1 – The Technology

Conventional ultrasonic techniques for NDT inspection of pipes provide a point measurement using a transducer at a location where direct access is permitted. GW method needs an access area along a short length of the pipe length (25cm) in order to attach a collar of transducers. A sonic beam generated at the transducers location travels through the transversal section of the pipe allowing a long length of pipe to be screened from a remote location. The pipe walls act as a guide for ultrasonic waves, which directs them down the length of the pipe**. (Figure 1)**

Guided waves are a low frequency and long wavelength mechanical wave which allows a long range of coverage.

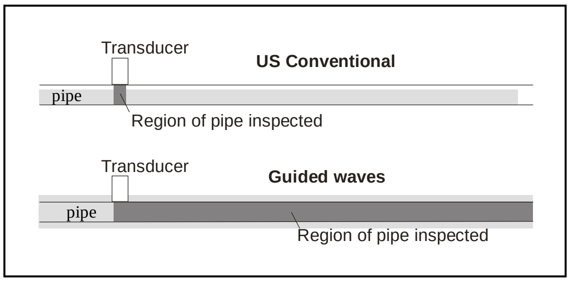

Figure 1. Conventional UT vs.GW

The presence of changes in the pipe cross section due loss of thickness, circumferential welds, pipe features and others of the same magnitude (essentially any changes in the acoustic impedance of the pipe) causes a reflection of the GW. This reflection is detected and recorded at the ring of transducers in pulse echo configuration. **(Figure 2)**

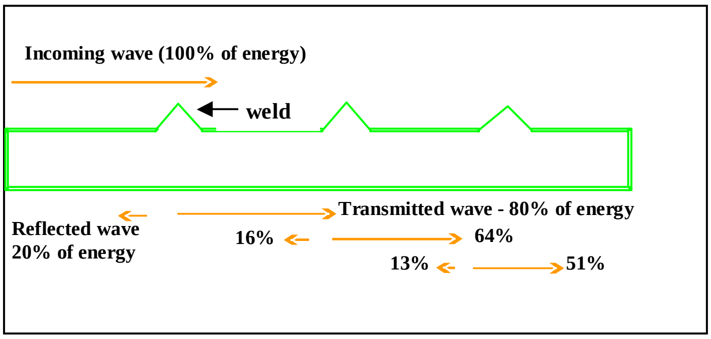

Figure 2. Schematic of wave behavior in the presence of welds

The behavior of the ultrasonic wave, presented schematically in Figure 2, appears in the GW instrument screen as a multi echo signal. Each reflector (welds, in this case) cause a signal in the screen with an amplitude directly proportional to reflector size and decays with the distance from the ring of transducers. **(Figure 3)**

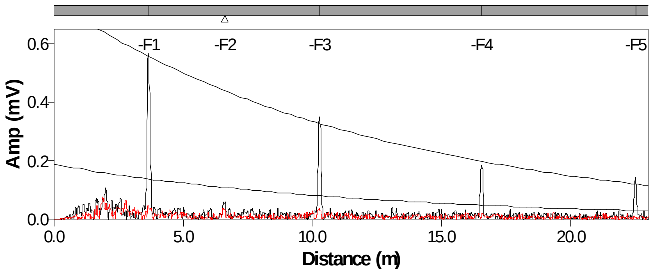

Figure 3. – Reflections of GW on the instrument screen

In presence of a reflector with symmetric configuration such as circumferential weld the ultrasonic beam is reflected symmetrically (provided that a pure symmetric wave is excited at the transducers) and appears on the instrument screen diagram as a black trace.

The trace appears black and red in presence of localized defects such as corrosion pitting. (**Figure 4**)

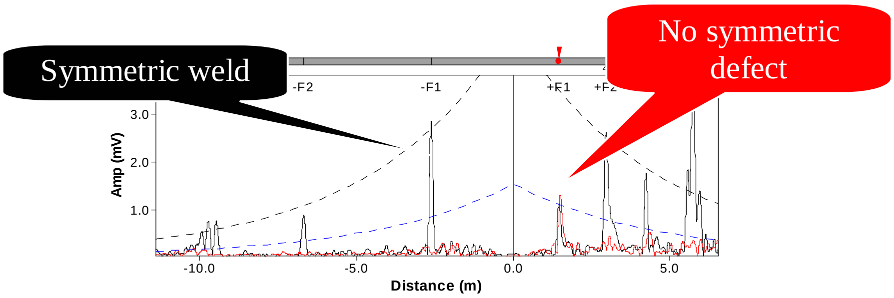

Figure 4.

The remaining wall thickness cannot be measured directly by using this technique, which should always be considered a screening tool. It is necessary to prove up any defective areas using a complementary method such as UT thickness measurement or visual inspection.

1.2 – Typical Application

- **Pipe racks –** generally easy to test; over 100m can be tested with one single test.
- **Insulated pipes** – small section of insulation removed at each test point; over 100m can be tested with one single test.
- **Overhead pipes –** only limited access needed; over 100m can be tested with one single test.
- **Sleeved road crossings** – only external access is required; up to 35m can be screened from one single location depending on coatings (**Figure 5**).
- **Wall penetrations** - only external access is required; concrete wall up to 1m thick and earth wall up to 20m thick can be screened.
- **Buried pipes** – holes dug at predefined intervals; up to 20m of pipe can be tested depending on pipe, coating and soil conditions (**Figure 6**).
- **Offshore pipe** – riser splash zone inspection (top side) and sub-sea pipe inspection using special transducers and instrumentation (**Figure 7**).

Figure 5

Figure 6

Figure 7

1.3 – Typical Performance

- **Detection threshold** - Typically minimum detectable defect is 5% cross sectional loss. If pipe is in good general condition defects down to 1% have been detected. 1% defect in a 3” pipe equates to a half wall defect of 5mm (0.2”) diameter.

- **Diagnostic Range** - In ideal conditions 200m of pipe can be screened in each direction from a single test location. Typically range on above ground pipe is 50m in each direction. For buried pipes 10m in each direction is more typical unless the pipe is sleeved.

- **Frequency sweeping -** Wide frequency range transducers and animation software developed. Higher POD – Possibility Of Detection using frequency animation software.

- **Unrolled Pipe “C Scan” -** Circumferential orientation can be determined accurately. Works best with developed 16 channel rings. Gives equivalent information as in-line inspection tools. (**Figure 8**)

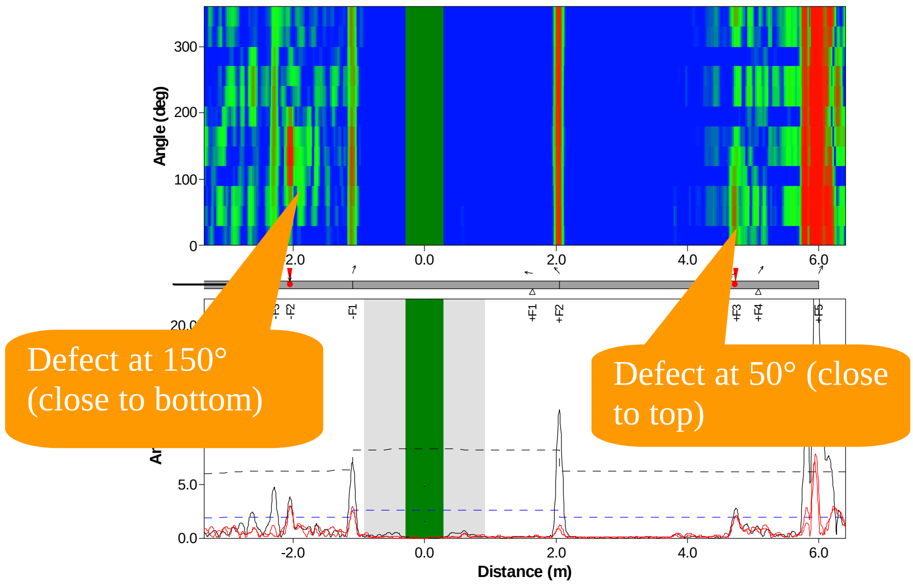

Figure 8. Typical screen for unrolled pipe C Scan

1.4 – Main advantages

- 100% volumetric coverage.
- Rapid screening.
- In service inspection.
- Significantly reduced access costs.
- Access to inaccessible components or areas for other NDT technique.
- Potential reduction of costs in industrial plants turnaround.

1.5 - Limitations

- General condition of pipe determines detection threshold and range.
- Some coatings and embedding materials (for example earth) reduce range.
- High external noise, such as compressors, affects the GW result
- Pipe features and contents can affect the range and/or sensitivity of the inspection.

1.6 – Typical arrangement for a guided waves system

The typical arrangement for a guided wave system consists of rings of transducers, fixed rings (**Figure 9**) or inflatable rings (**Figure 10**), a portable computer (laptop) responsible for running the control software and an instrument responsible for the excitation and reception of the GW signal. (**Figure 11**)

Figure 9

Figure 10

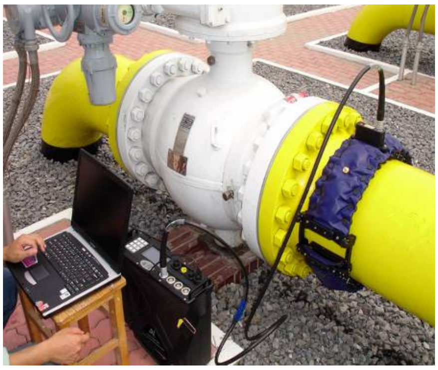

Figure11

2 – Brazilian Trials

2.1 – First trial

A first trial was carried out in Brazil in 2003 which was planned to test 2 GW systems of the two main global providers at that time. Limit conditions for the GW technique consisting of buried pipelines coated with bitumen and gas sphere legs coated with concrete were chosen to test the method limits.

In both cases results were not satisfactory at all. In some situations ultrasonic beam attenuation was almost totally reducing the method range for a few centimetres.

An explanation about that disappointing trial results could be found considering a mix of three factors: - stage of method development – customer expectation over-excited due a lack of knowledge regarding method limitations – providers failed to provide the necessary information on real limitations of the method before starting the trials.

2.2 – Second trial

After taking in account several technical papers published in NDT magazines and conference articles all over the world presenting satisfactory results for GW applied for several demands on oil and gas industry, Petrobras contacted one of the providers

mentioned before in order to get explanations about discrepancy between these results and those obtained in Brazil two years before. The provider mentioned that of the field results was caused by new software and hardware developments.
Considering the exposed above reported information, Petrobras decided to implement a second program of trials. This programme consisted in inspecting offshore risers and pipelines in 3 different sites and dates.

The first part of this programme was carried out in November 2005 [1] in the offshore platform PCM-9 (**Figure 12**) operated by Petrobras in Sergipe coast, Brazilian Northeast. Three different risers (**Figure 13**) were inspected at that time covering sections above and below the splash zone (**Figure 14**). These pipes were characterized by a variety of conditions which have an effect on the GW result such as presence of sections of pipe with bitumen-epoxy coating (5mm thickness), riser clamps, marine growth, heavy crude oil inside and overall corroded pipes. Two pipes were 8”OD and third one 6”OD.

Figure 12- PCM-9 platform

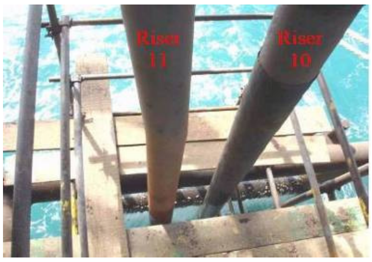

Figure 13 – Risers top view

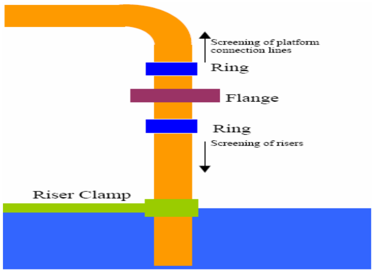

Figure 14 – General scheme

The torsional wave mode was used to perform all inspections because it is the most adequate for liquid filled pipes bitumen coated.
These pipes were chosen to show the effect of several limitation factors and the potential effectiveness of the newly improved technology to cope with different testing conditions.

Compared to the first trial, the results obtained in 2005 were much better and very promising. Although the limitations for range and sensibility of the method caused by the presence of bitumen coating, crude oil, supports and bends on the risers have been confirmed along the trial, several positive points could be noted:

- Range of the ultrasonic beam, in other words of the method, have overcome best expectancy because it allowed to access a length of 12 meters, 7 meters of them below sea level, in presence of bitumen and other strong attenuators;

- All pipe fittings and features such like flanges, bends, welds, supports and transition of sectors with and without coating could be identified in the trace of instrument screen; (**Figure 15**)

- Some corroded areas were pointed;

- Simplicity and rapidity to perform the inspection;

- Notable evolution of the system in 2 years;

- Clearness of results presentation.

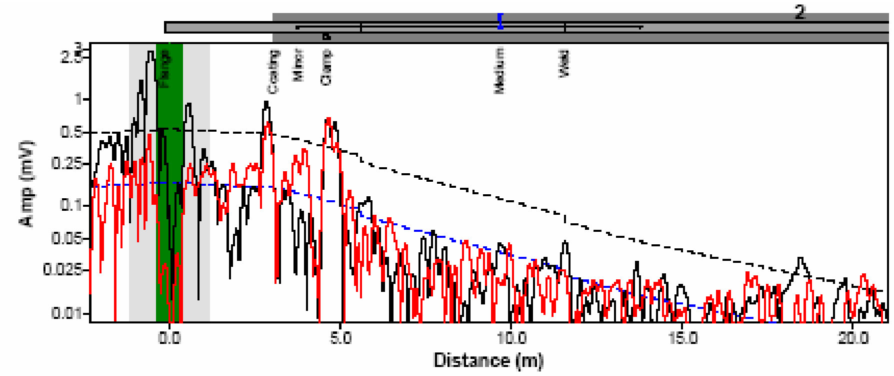

Figure 15 – Result trace for 6" riser inspection

The main limitation for method application remains the highly skilled operators needed to interpret the traces appearing on the screen in presence of limiting factors (coating, complex geometries, other).

Based on the results obtained in that trial Petrobras decided to buy a system and establish a training program which was carried out in August 2007 for 6 Petrobras employees whom were successfully certified GUL – Guided Ultrasonics Limited as level 1 operators. The second and third parts of the second trial were performed with Petrobras own instrument and operators.

The second part of the trial consisted in a test on an 8"OD pipeline (GN8ECA/PCM-01) previously inspected using magnetic (MFL) smart PIG which had identified two critic corroded areas to be checked. This trial was carried out in August of 2007 in Aracajú, Brazilian Northeast [2].

Guided Waves identified and located the critical areas mentioned above and several other critical areas (**Figure 16**). All of the defect locations identified using GW were verified using conventional UT measurement. The defects classified as severe by the GW operator were very large wall loss and therefore considered critical by Petrobras for the integrity of the pipeline. After the GW results Petrobras decided to stop the pipeline operation and ordered its substitution.

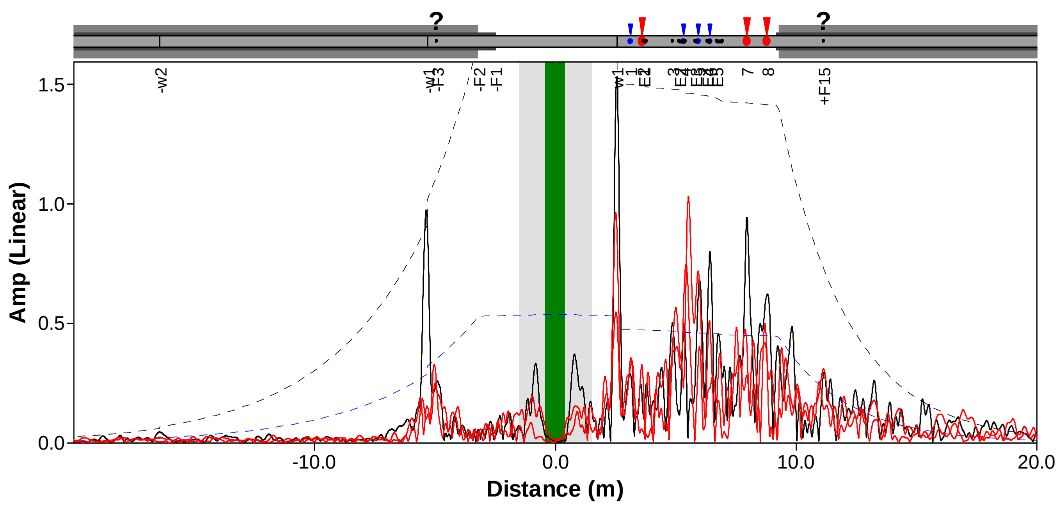

Figure 16 – Result trace for the GN8ECA/PCM-01 pipeline

The third part of the trial was carried out in February 2008 and consisted in testing an 18"OD (18"-PE-6112001-Ba) pipeline used for offloading crude oil tankers inside of Mucuripe Harbour, in the city of Fortaleza, Brazilian Northeast. (**Figure 17**). The pipeline presented many severe external corrosion areas and the harbour operators were concerned about a possible internal corrosion which combined with external corrosion could cause leakage, with significant impact for safe and environment.

The GW results obtained were precise in pointing out every external corrosion area, including weld corrosion and pitting (**Figures 18a and 18b**), no significant internal corrosion areas were identified. (**Figure 19**) [3]

Figure 17 – Mucuripe harbour

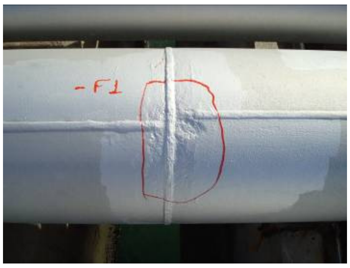

Figure 18a

Figure 18b

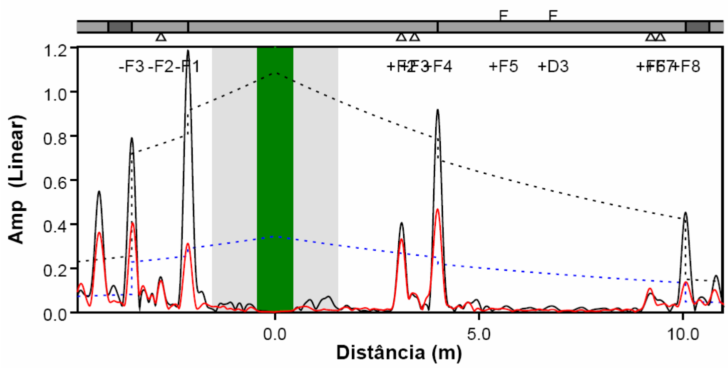

Figure 19 – Trace of 18"-PE-6112001-Ba

3 – Perspectives for Future

3.1 – Oil and Gas Industry

In general, the GW method offers solutions to old inspection problems never tackled using other NDT methods (buried, sleeved, insulated and underwater pipeline). GW permanently installed monitoring system - PIMS is another interesting option for use in large oil and gas plants, isolated or long pipelines and underwater pipeline.

A potential reduction of costs in industrial plants turnaround is a factor to be considered.

New developments for using GW in inspection of planar components such as crude oil carriers shell plates or even FPSO – Floating Production Storage and Offloading tanks are ongoing.
A GW system for heating exchange tubes inspection – T-SCAN - is now available on the market

3.2 – In Petrobras

As mentioned before Petrobras has acquired a GW system and certified a few operators.

Nowadays a long term plan for improvement of operators' skill is ongoing with the target to reach GUL level 2 certification and to get knowledge to develop a Brazilian national procedures, standards and certification scheme for GW application.

Additionally, Petrobras is preparing a trial with GUL PIMS for monitoring of offshore risers.

4 – References

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