

In-Line Inspection using Ultrasonic Technology

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ABSTRACT

Ultrasonic (UT) is currently the most accurate and reliable In-Line Inspection (ILI) technology available in the market. These UT ILI Tools will record data while travelling through the pipeline from Launcher to Receiver. In most cases, the Pipeline Operator does not need to make major adjustments to their pipeline's normal operating conditions when conducting the inspection survey.

Piezo-electric transducers are arranged to cover 100% of the pipe wall and it will directly measure the defects (metal loss and cracks). The data recorded by the tools are analyzed by in-house specialists before a final report is produced in both digital and hardcopy. A special viewing software is also provided to allow visualization of the inspection data.

Using UT as the inspection method greatly increases the confident level of the inspection survey results. This in turn will give Pipeline Operators a greater peace of mind that their true pipeline condition is known thereby reducing unnecessary and costly digs and repairs.

Key words: Accurate, Reliable, Peace of Mind, Ultrasound

INTRODUCTION

Inline inspection tools are used since the 1960s and are crucial to maintain and secure safety, efficiency and environmental integrity for oil and gas pipelines. They utilize NDT (Non Destructive Testing) to collect data on flaws and defects during operation of pipeline. Especially ultrasonic (UT) inspection tools provide accurate and reliable quantitative data. Latest developments show big steps forward in specifications with regard to resolution of wall thickness, as well as axial and circumferential direction, subsequently leading to increased detection and sizing capabilities, especially for small scale corrosion, e.g. pitting or pinholes. Due to pipeline operator requirements efforts have been spent during the last few years to allow running UT tools under more challenging conditions with regard to high pressure, high temperature, and high velocities. Special configurations for dual and multi diameter pipelines, bi-directional operation and combined wall thickness and crack measurements are available.

Solutions to inspect wax-rich crude oil pipelines, which are nearly impossible to inspect with MFL tools, exist and provide reliable data for the entire pipeline due to an advanced sensor carrier design with a flushing system.

Ultrasonic tools allow to inspect CRA (Corrosion resistant alloy) - clad pipes without harming their surface, which is more and more applied offshore. Evidence shows that ultrasonic tools can even provide realistic data in flexible pipe systems.

UT WALL THICKNESS INSPECTION

Technology principles

Piezo-electric transducers mounted on a pigging tool - in most cases within a special sensor carrier - are used for measuring the wall thickness and corrosion of pipelines. This technique requires a suitable one-phase liquid coupling medium. For wall thickness measurement application, the sensors have to be arranged perpendicular to the wall. Figure 1 explains the principles of the UT wall thickness measurement.

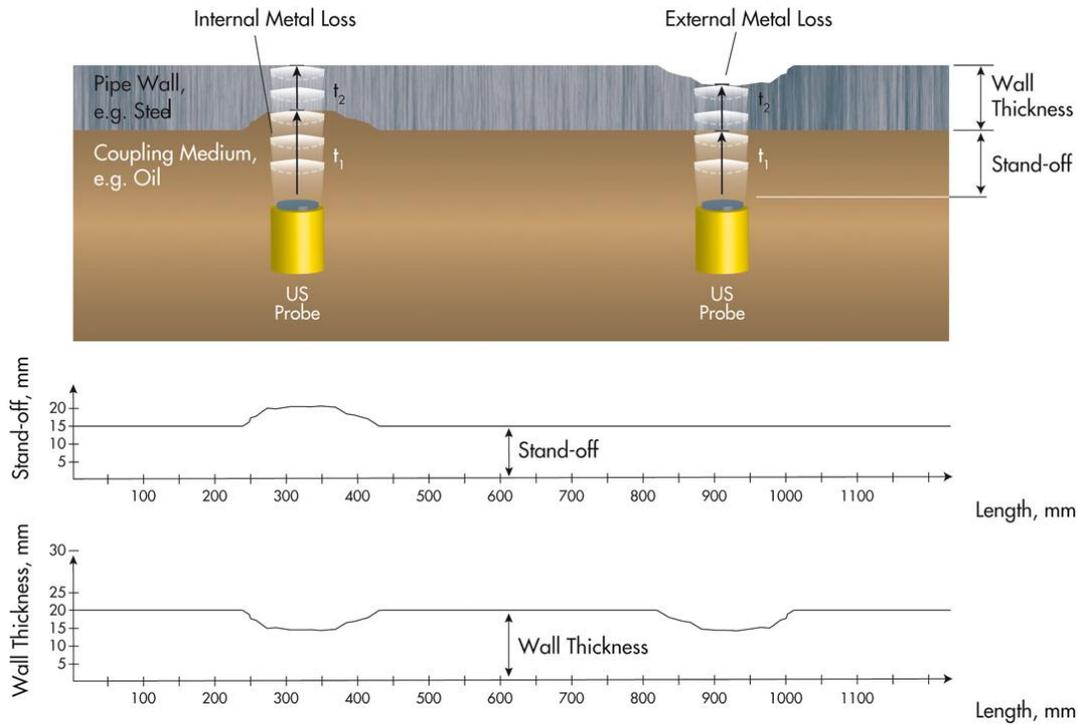


Figure 1: Schematic representation of UT wall thickness principle

The transducer is operated in an impulse-echo mode, which means that one transducer emits and receives the signal. A sufficient number of sensors cover the full 360° circumference of the pipe. The transducer emits a short pulse of ultrasonic energy which is initially reflected by the internal pipe wall. Portion of the signal transmits inside the pipe wall and is reflected at the rear wall. The ultrasonic tool's electronics measures the time of flight. As the speed of sound in the product, e.g. water, jet fuel, oil, etc. and in the steel is known, the distance from sensor to the inner wall (Stand-off=SO) and the wall thickness (WT) can be calculated. Differentiation between internal and external flaws can be done via the stand-off (SO) signal. If the wall thickness varies and the stand-off remains constant the flaw is external. If the stand of varies with the wall thickness the flaw is internal. In addition, laminations and inclusions can be detected.

High resolution pitting configuration

State-of-the-art UT tools provide an axial sampling of 1.5mm; for special investigation a resolution down to 0.75mm is possible. In circumferential direction the spacing is 4mm. Combined with a high-end electronic system with high dynamic ranges the technology offers a direct wall thickness measurement approach which can be used in a wide range of media with different attenuation properties.

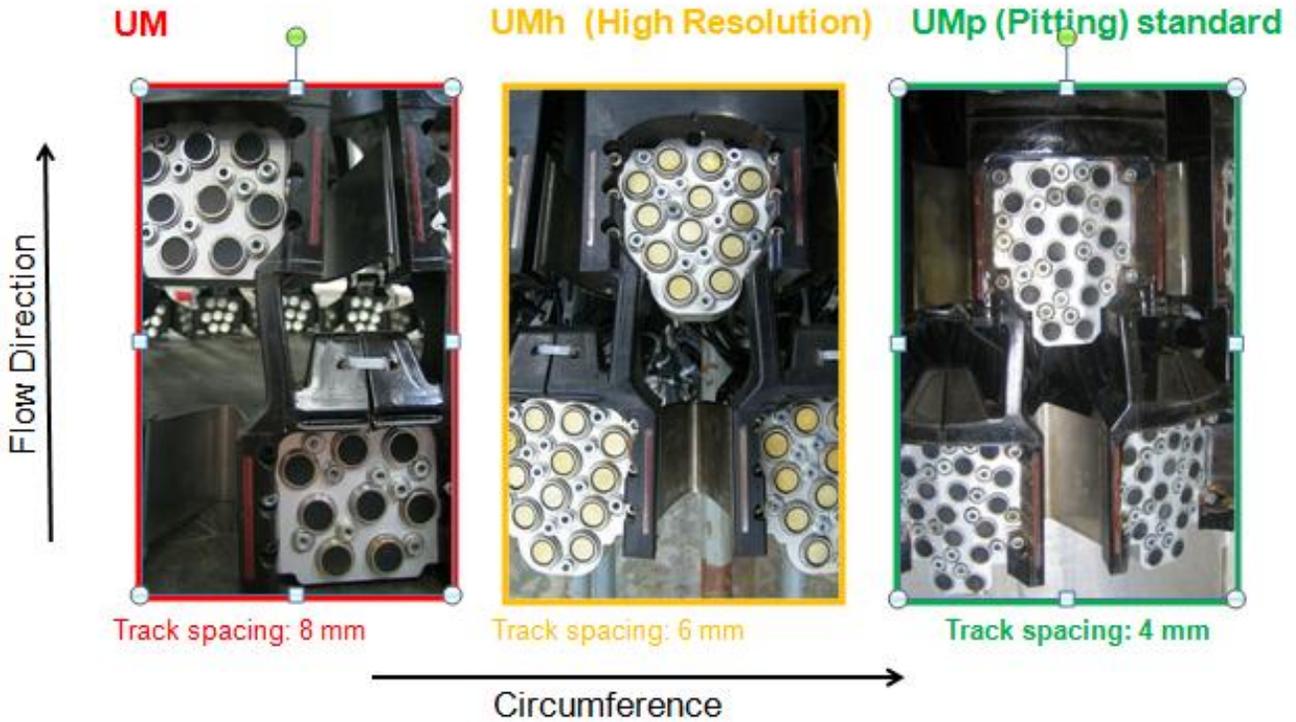


Figure 2: Design of UM, UMh and UM pitting sensor configuration. UM pitting configuration represents state-of-the-art design applied for inline inspections nowadays. The resolution in axial and circumferential direction is 1.5 x 4mm.

Figure 2 shows three different sensor carrier designs. Left hand side UM (8x3mm), center UMh, high resolution (6x3mm) and right hand side Ump, pitting configuration (1.5x4mm). Last design is usually used for inline inspections today. Figure 3 depicts the different numbers of measurements per square meter for initial UT (UM), UMh and the actual UM pitting (UMp) tool design. The high number of measurements offers excellent input for defect assessment calculation methods. Pipeline operator will have the relevant information available to manage their pipeline and asset integrity according to international standards and rules and without being too conservative.

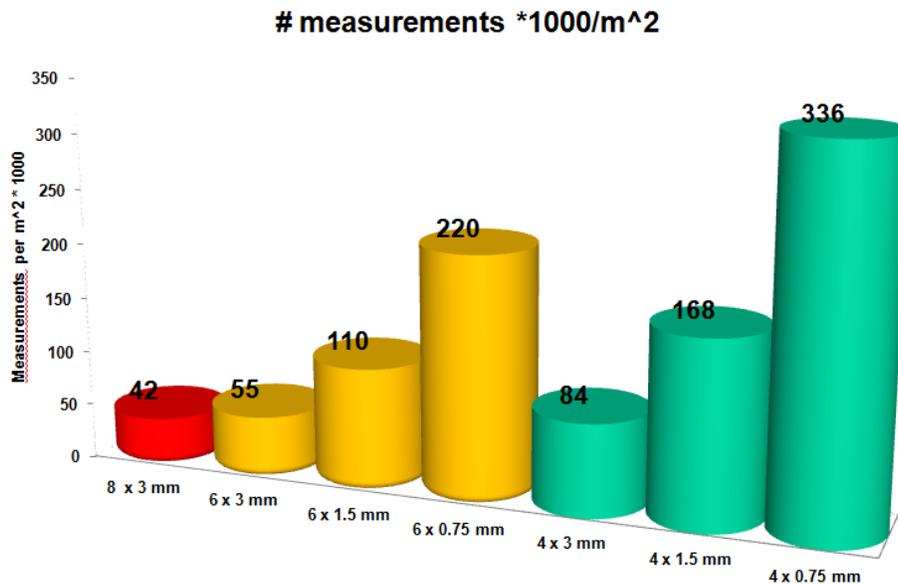


Figure 3: Graph indicating different number of measurements per square meter for different tool and sensor designs.

Wax-rich crude pipelines:

It has been always asserted in the past that UT tools were not suitable in very waxy crude oil lines. The ILI tool could scratch and push wax and debris from the internal wall as a "candle" through the pipeline at the risk of getting completely stuck. The chance to collect 'bad' data or no data at all caused by the wax on the sensors remains high. Latest developments of one company showed that specially designed UT tools can even beat MFL tools in that area. A specific sensor carrier design, special coatings (lotus effect) and a bypass flushing system, enabled to perform several pipeline inspections with excellent data quality from launcher to receiver. Figure 4 depicts the result of a conventional tool and an optimized wax tool with bypass and flushing design for identical pipeline. All below shown pictures are taken directly after receiving of the tool. The achieved improvement of the wax tool design is clearly visible.



Figure 4: Left and center: conventional UT tool after inspection of wax rich pipeline; right: sensor carrier with flushing system after inspection of identical pipeline.

CRACK DETECTION

Technology principles

While wall thickness measurement UT tools use transducers that are placed perpendicularly to the inner pipe wall, UT tools for crack detection contain transducers oriented at a different angle to the pipe wall. This ensures that ultrasonic shear waves propagate under a 45° path through the wall. The signal is reflected by internal and external cracks (Figure 5). Calculation of crack location is done with the time of flight; the crack depth is determined depending on the signal amplitude in relation to saturation amplitude of a perfect reflector.

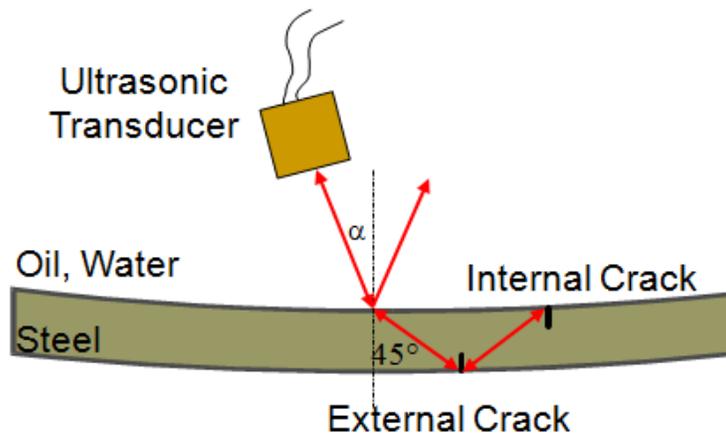


Figure 5: Sketch for UT crack detection measurement principle.

Most of the cracks found so far are situated along the long seam weld and are axial oriented due to the hoop stress. However, in girth weld areas circumferential oriented cracks can appear. Another occasion for these types of cracks may be high bending stresses which might be caused by landslides and pipeline movement. A few companies offer crack detection in axial direction, two have solutions available for circumferential crack detection.

Figure 6 depicts a sketch illustrating the two types of cracks and used sensor configuration. In both cases a redundancy is achieved due to the fact that each position of the wall is scanned from both sides. For axial cracks a clock wise and counter clock wise setup is used. For circumferential cracks transducers oriented downstream and upstream are used. Nowadays, results are provided to pipeline operators with absolute crack depth values. Position at the inner or outer pipe wall is clearly identified in the reports for each indication in addition to the length of a flaw. Crack depth profiles are also available, if required.

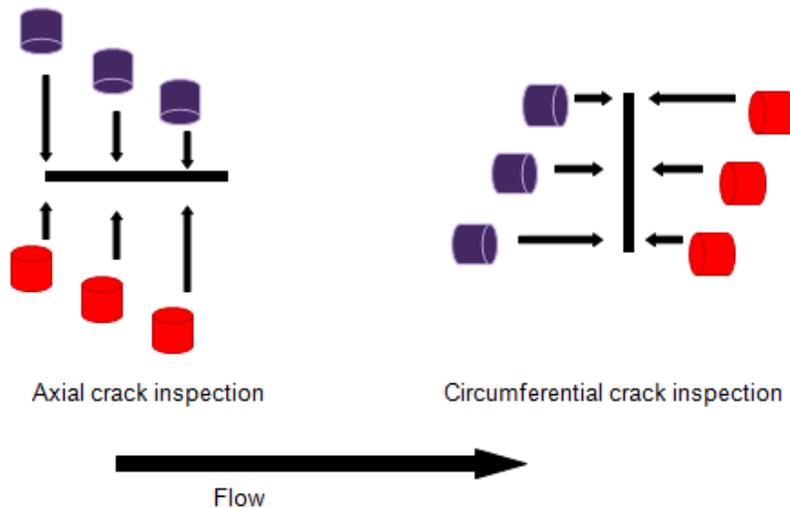


Figure 6: Schematic drawing illustrating axial (left) and circumferential (right) transducer arrangement

Crack tools are available from 6 inch onwards to 48 inch; both orientations of cracks can be addressed. Some inspection vendor offer combined inspection tools for wall thickness and crack inspection in one tool. Typical specifications for UT crack tools are: detection of cracks with a minimum length of 30mm and depth of 1mm in base material and at welds, 2mm depth in welds. Most of these tools are so sensitive to detect flaws with only 0.5 mm in depth. In general the specification in length and depth is the same for cracks in different direction. Figure 7 shows the capabilities for MFL and conventional UT tools for cracks with different openings. Cracks at and in welds are typically below 0.01mm in width; the majority of SCC cracks is grouped around 0.01mm. MFL tools can detect cracks with an opening of approximately >0.5mm with acceptable probability. Conventional UT crack tools are able to detect cracks below 0.001mm opening with high probability.

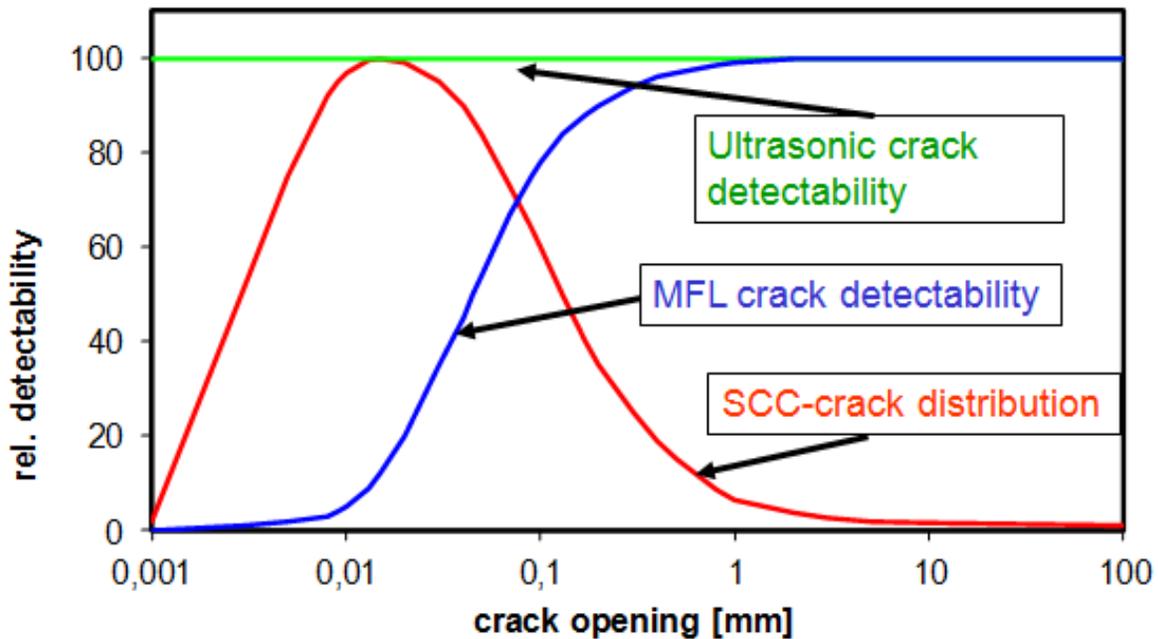


Figure 7: Ability of detection for cracks with different crack openings for MFL and conventional crack tools.

LATEST TECHNOLOGICAL DEVELOPMENTS

Pipeline operators are pushing inline inspection companies strongly to develop tools that withstand rough and challenging operational conditions. E.g., some few years ago UT crack or wall thickness tools were able to pass 3D bends. Today standard crack tools can easily pass 1.5D bends, some UT tools even 1.0D bends. Some other areas of technological improvement are listed below:

Temperature:

Most tools can withstand 55-60°C for a considerable time. Latest developed tools have improved these capabilities to 65°C respectively 70°C for a long time.

High pressure:

Usually, most UT tools withstand 120-150 bar (pressure tested at 1.5 x higher pressure), one company offers tools for 275 bar for deepwater application and is working on 500 bar tools.

Speed range:

UT tools are usually running in liquid lines with lower speed than gas lines. However, in some cases liquid lines are operated up to 3-4m/s. Latest generation of UT tools can inspect pipelines @4m/s and full specification.

Wall thickness range:

UT tools are able to cover up to 60mm wall thickness. These tools can even offer the same good resolution (0.06mm) for the wall thickness measurement over the full range from thin to thick wall. New UT tools can measure down to 2 mm remaining wall thickness, for internal defects they have no problem down to 0mm remaining wall (via Stand-off measurement).

Multi diameter / Combo tools:

All UT vendor offer dual and multi diameter capabilities, e.g. a 38"/48" combined wall thickness and crack inspection tool (Figure 8). Tools can also be designed to only inspect smaller diameters and pass through wider diameters. INS (inertial navigation systems for xyz coordinates) can often be combined as well.



Figure 8: 36/48" UT crack and wall thickness combo tool

BIDI tools: For loading lines, offshore risers and other pipelines which are only accessible from one side (launching trap = receiving trap), some UT vendors offer bi-directional tools, free swimming or tethered/cable operated. An example is shown in Figure 9.

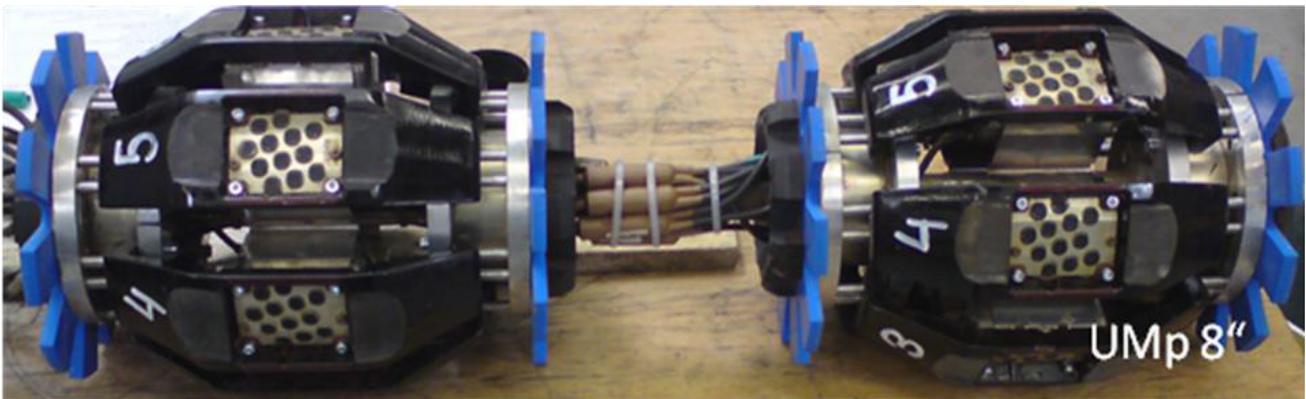


Figure 9: Bi-directional UT wall thickness tool offering highest resolution (pitting tool)

NEW FIELDS OF APPLICATION FOR UT ILI

Clad pipelines:

Claded pipe for highly corrosive pipeline media are increasingly used, especially for offshore pipelines. It consists of a thin (for example 3mm) internal austenitic steel pipe and a standard (for example 15mm) external ferrite steel pipe. Depending on the manufacturing process used

for of this clad pipe (mechanical or chemical bonding), UT tools can inspect only the internal metal loss in the inner layer or also external metal loss through the full pipe. Disbonding between both layers can be detected and sized with high accuracy. Crack inspection is also possible. During the last few years several inspections were performed and proved the capabilities of state-of-the-art UT tools for this type of pipelines.

Flexible riser:

Flexible pipes, e.g. flexible risers are used offshore. For many years there have only been camera inspections for this type of pipes. Therefore operators used to exchange the flexible pipes after some years without knowing whether a safe operation was still possible or not. Just recently, one UT ILI company has started some more detailed research and has been able to prove that inspections with UT tools were suitable to find damages in the inner layer of the carcass. Figure 10 depicts a photography of a flexible riser, showing the internal side (left) and the corresponding UT wall thickness data (right). The deformation in the riser is clearly visible in the UT data. Length and width provided after ILI matched the NDE/visually determined results.

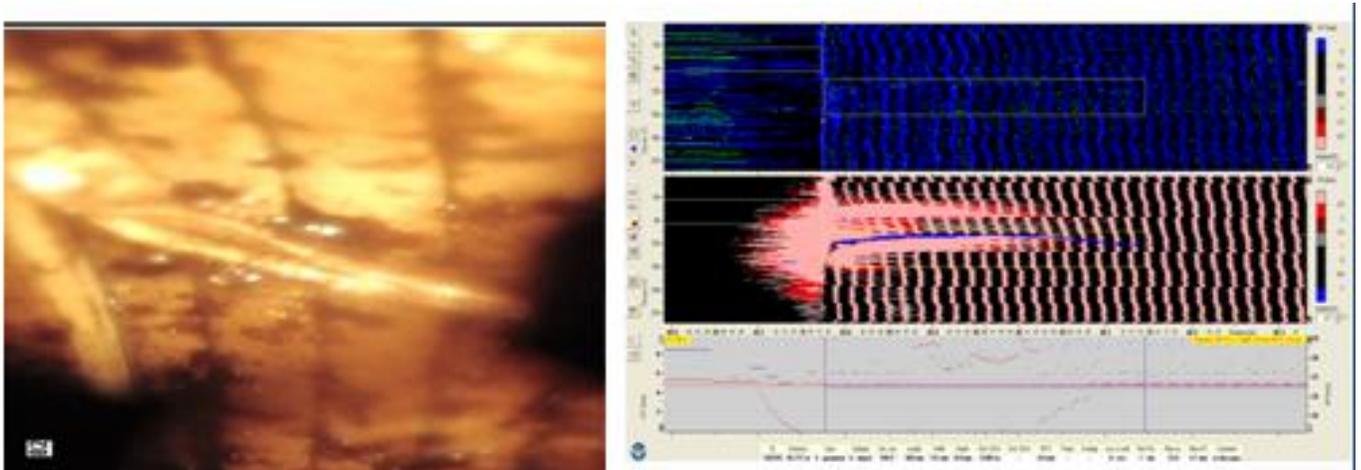


Figure 10: Visual inspection result and UT data of flexible riser.

RESULTS

Today Inline Inspection Companies using UT tools for wall thickness and crack inspections are able to offer tools for a wide variety of operational conditions. They provide a direct measurement technology with high accuracy and reliability. The data can and should be used for further pipeline integrity assessments and calculations that provide precise corrosion growth and life time evaluation, risk assessment, maintenance and inspection schedules. Inline inspection and integrity assessment methods in combination provide an excellent picture for the inspected asset.