EVO SERIES 1.0 - LATEST GENERATION OF UT CRACK AND CORROSION TOOLS FOR OFFSHORE PIPELINE INSPECTION

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Abstract

Intelligent inline inspections (ILI) are widely used to guarantee a safe operation of pipelines. The inline inspection provides reliable data in an economic way. Ultrasonic (UT) is currently the most accurate and reliable In-Line Inspection technology available in the market for liquid lines. These UT ILI Tools record data while travelling through the entire pipeline from Launcher to Receiver. In most cases, the Pipeline Operator does not need to make major adjustments to their pipeline. Nevertheless, pipeline operators may have to adjust medium flow rates to accommodate optimum inline inspection conditions, e.g. down to 1m/s.

NDT Global recently introduced the latest generation of UT tools - EVO SERIES 1.0. This generation offers highest inspection velocities of up to 4m/s. These high-speed tools overcome reduction of flow rates for intelligent inspection runs. In addition, highest axial resolution available at the market (0.75mm) and circumferential resolution of 4mm provide excellent input for accurate pressure calculations, e.g. based on Riverbottom and crack depth profiles or even 3D Finite element modeling.

The authors will present basic background information about ultrasound inspection technologies. Theoretical aspects of EVO Series 1.0 tools are discussed for crack and wall thickness inspections. Furthermore, EVO generation offers capabilities of combining different technologies in one tool. One single inspection tool with corrosion and crack transducers enables pipeline operators to operate their system safe with a minimized impact while inspection.

Introduction

Pipeline operators have to ensure a safe operation of pipelines during the entire lifespan of their asset. Depending on geographic area, country, and operator, different legal boundary conditions might apply for safe operation. These conditions directly define approaches and methods, e.g. intelligent pigging. This method is widely used and accepted to gather accurate and reliable information about the pipeline system. Using highly specialized tools, intelligent inline inspection can detect and size threats like corrosion, cracking or deformation - even combinations of them are possible. The development of EVO Seris 1.0 tools especially focusses on the challenging requirements in offshore pipelines as high pressure, temperature and passage capabilities. Inline inspection companies overcome operational challenges like thick wall pipe, tight bends or bend combinations, multi diameter pipelines or high pressure & high temperature applications as often faced in offshore deepwater assets. Reliability and accuracy of inline inspection results and minimized impact on operational conditions are main aspects considered by pipeline operators. First run success rate (FRS) is another major aspect during the planning phase on an inline inspection project. This paper shows major advantages of ultrasonic inline inspection technologies for metal loss/corrosion and crack detection with EVO Series 1.0 tools.

Technology principles

Metal loss/corrosion

Piezo-electric transducers mounted on a pigging tool - in most cases within a special sensor carrier - are used for measuring the wall thickness of pipelines. Wall thickness variations, mainly caused by corrosion can therefore be detected and measured. The ultrasonic technique (UT) requires a suitable single-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.

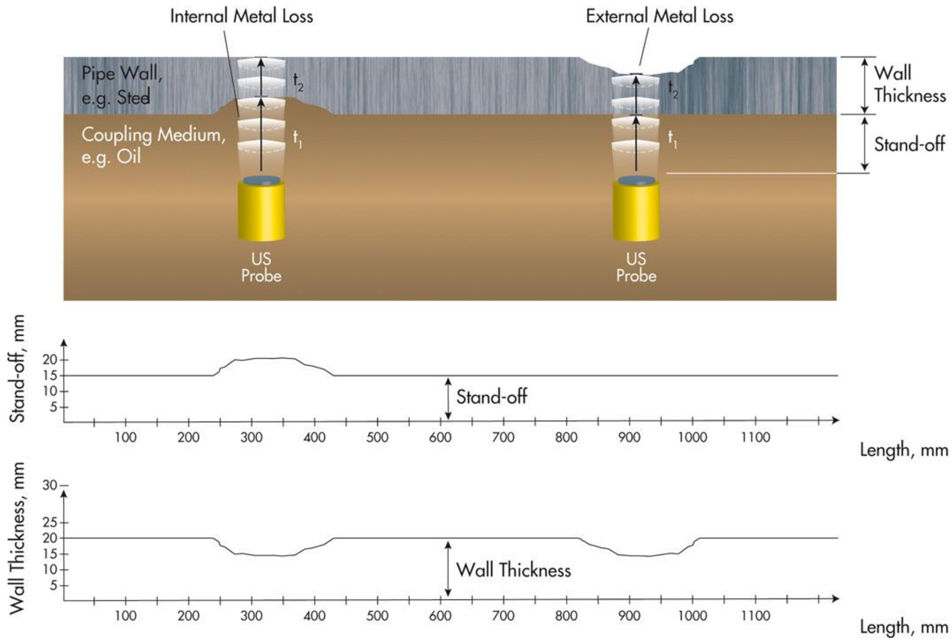

Figure 1: Schematic representation of UT wall thickness principle

The transducer operates in a pulse-echo mode: 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. The internal pipe wall reflects the signal back. A portion of the signal enters the pipe wall. The rear wall reflects a portion of the signal. The ultrasonic tool's electronics measure the time of flight. As the speed of sound in the product, e.g. water, jet fuel, oil, or similar, 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 SO 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. This method is a direct measurement, which does not require a calibration. It is independent from the wall thickness and works with identical accuracy of ±0.4 mm in thin (4 mm) and thick wall pipelines (60 mm).

Crack detection

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 along a 45° path through the wall. Internal and external cracks reflect the energy (Figure 2). 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 reference reflector.

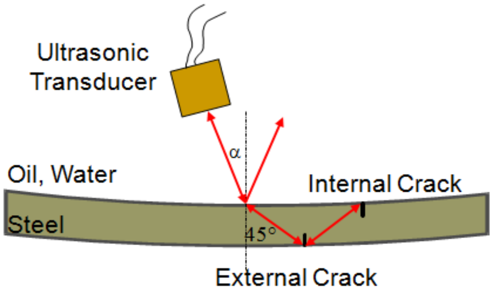

Figure 2: Sketch for UT crack detection measurement principle

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 geohazzards and pipeline movement. A few companies offer crack detection in axial direction, two have solutions available for circumferential crack detection.

Figure 3 depicts a sketch illustrating the two types of cracks and sensor configurations. In both cases, a redundancy is achieved because each position of the wall is scanned from both sides. For axial cracks, a clock wise and counter clockwise 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.

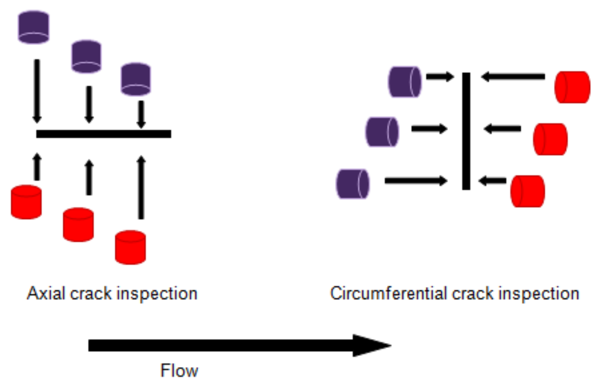

Figure 3: Schematic drawing illustrating axial (left) and circumferential (right) transducer arrangement

Crack tools are available from 6 inch to 48 inch; both orientations of cracks can be addressed. Combined inspection tools for wall thickness and crack inspection in one tool are also available, including multi diameter tools, e.g. 36"/48" Corrosion/Crack Combo. Typical specifications for UT crack tools are detection of cracks with a minimum length of 20 mm and depth of 1 mm in base material and at welds, 2 mm depth in welds. Most of these tools are sensitive enough to detect flaws with only 0.5 mm in depth. In general, the specification in length and depth is the same for cracks with different orientations. **Figure 4** depicts the capabilities for MFL and conventional UT tools for cracks with different crack width openings. Cracks at and in welds are typically below 0.01 mm in width; the majority of SCC cracks is grouped around 0.01mm. MFL tools can detect cracks with an opening of approximately >0.5 mm with acceptable probability. Conventional UT crack tools are able to detect cracks below 0.001 mm opening with high probability.

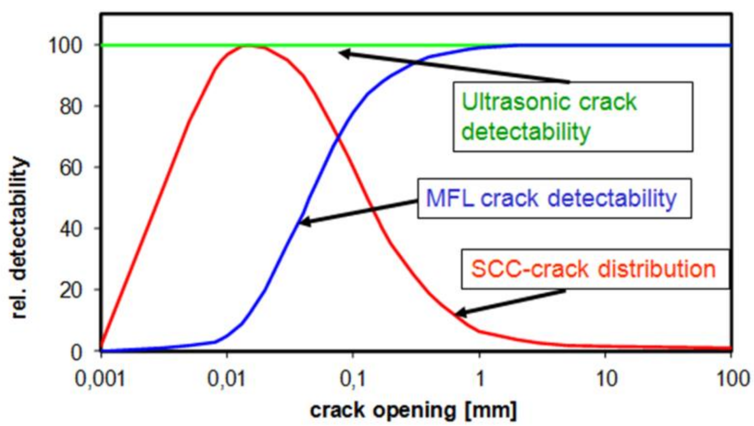

Figure 4: Ability of detection for cracks with different crack openings. Conventional UT crack tools show a significant higher detection ability for thin cracks than MFL technology.

EVO Series 1.0

Capabilities

Based on market research and an increasing number of direct requests from pipeline operators, NDT Global decided to invest in the development of a new tool fleet for corrosion and crack detection. One major requirement for the development is to increase the maximum tool velocity by a factor of four, compared to the current industry standard. The EVO Series 1.0 tools enable inline inspections with increased data density (0.75 mm axial sampling) and tool speed up to 4 m/s. These high-density datasets for corrosion or crack inspections enable accurate and reliable data analysis. In addition, detection and sizing of smaller defects becomes possible.

Other operational driven improvements are also included, e.g.:

- Up to eight times more onboard storage,
- High attenuation media measurements, e.g. measurement in heavy crude oil without need to use specialized sensitive sensors
- Online adaption of tool settings when properties change over distance, e.g. caused by temperature or pressure variations
- Speed up of data download and data quality checks
- The increased resolution and accuracy directly translates into an improved performance specifications

Corrosion:

Detection of corrosion features with a diameter of 6 mm reaches a probability of detection level (POD) of more than 90%. Classification and depth sizing is provided for all metal loss defects from 5 mm onwards. High-resolution Riverbottom profiles enable accurate defect assessments. Figure 5 depicts the feature classification diagram in accordance with Pipeline Operators Forum (2009). The blue colored area indicates the application range for EVO Series 1.0 tools with regard to detection, classification, and sizing of metal loss anomalies.

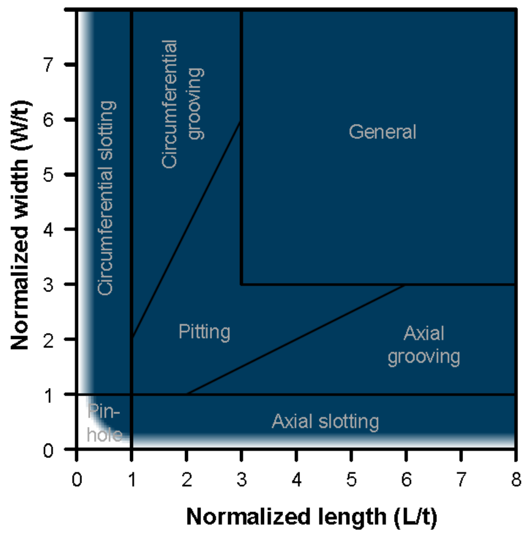

Figure 5: POF feature classification diagram. Colored area indicates application range of EVO Series 1.0 UM tools for detection, classification, and sizing with t = minimum {Wall thickness, 10mm}.

Crack inspection:
EVO Series 1.0 UC fleet improves speed capabilities and resolution for crack inspections. A maximum inspection speed of 4 m/s and an axial resolution of 0.75 mm become standard. Figure 6 shows the area of application for crack and crack-like anomalies. The new EVO Series 1.0 tools can detect and size features with minimum dimension of 20 mm by 1 mm in base material at a POD greater than 90%.

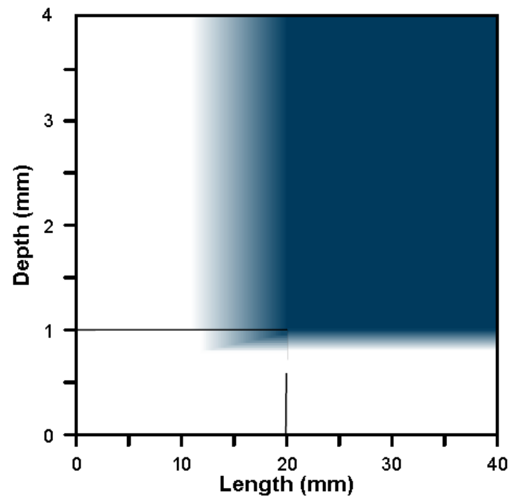

Figure 6: Definition for crack and crack-like anomaly classification based on length and depth. Colored area shows application range of EVO Series 1.0 UC technology for detection and sizing of crack and crack-like anomalies.

EVO Series 1.0 system validation

One major key aspect in NDT Global's philosophy is a 100% first run success rate (FRS). As a direct consequence, testing is the important factor for a successful product development and roll out. The entire EVO Series 1.0 development and testing approach follows new standards in project management and tool validation.

NDT Global decided to perform extensive testing of all components, modules, hardware, software/firmware, and finally the entire tool in full scale testing. A positive result for each of these tests is mandatory to reach the next step in the development process. Consequently, testing becomes a time consuming component in the development project.

E.g., a test rack is used to perform variation and testing of different parameters, e.g. tool speed or measurement technology in an early stage of development. The findings of these tests provided important information for optimization of the hardware and firmware. After successfully passing all tests, an entire inline inspection tool is assembled and tested in the workshop first, afterwards in a test loop.

For the full scale testing of EVO Series 1.0, NDT Global designed and built a new looped pipeline (Figure 7, left). It is equipped with automated valves and control stations and enables automated and monitored operation. The test spools contain 453 flaws with known dimensions below and above minimum feature dimensions. In total, EVO Series 1.0 tools ran more than 20 times collecting data over a total distance of 1500 km in the loop - before the first commercial inspection. The test program started with inspections of less than 10km in length. After successful data quality checks and analysis of the entire dataset, inspections with increased distance were performed. The longest test run collected 270km of data - almost 2000 laps in the test loop. Several essential variables and tool settings are tested and optimized during the test program.

Figure 7: 12" test loop, total length of 150m with 453 (left); control panel for test loop (right)

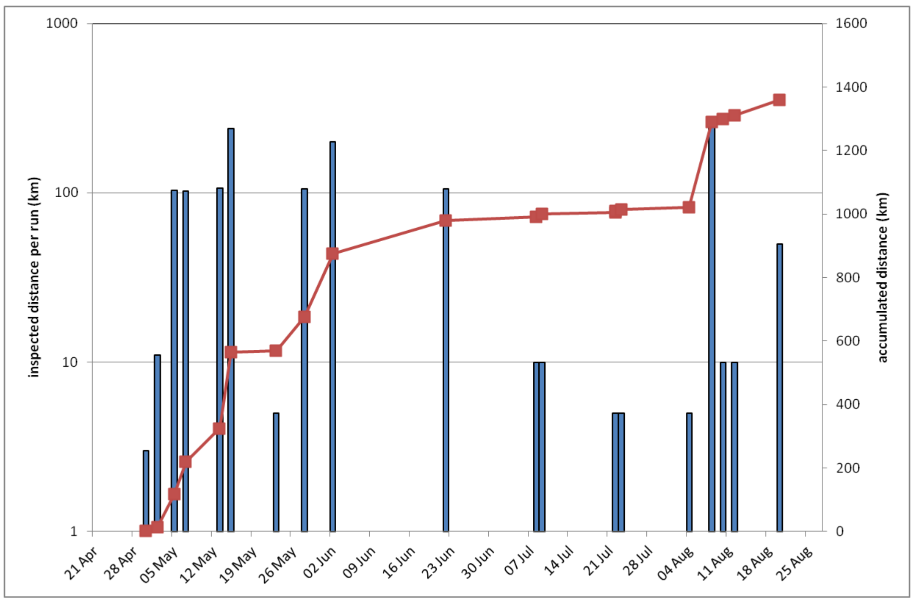

Figure 8: Utilization of 12" test loop over time. Individual run distance (blue) and accumulated distance in km is shown.

The collected data provides an excellent basis for determination and proving of performance specifications. Analysis of probability of detection, sizing accuracy, and repeatability, showed that EVO Series 1.0 technology enables an improved performance specification - especially with regard to smaller defects and higher tool velocity. As an example, Figure 9 depicts the depth sizing histogram for one of the test runs. In total, 99.5% of the flaws are within specified tolerance for depth sizing of circumferential cracks.

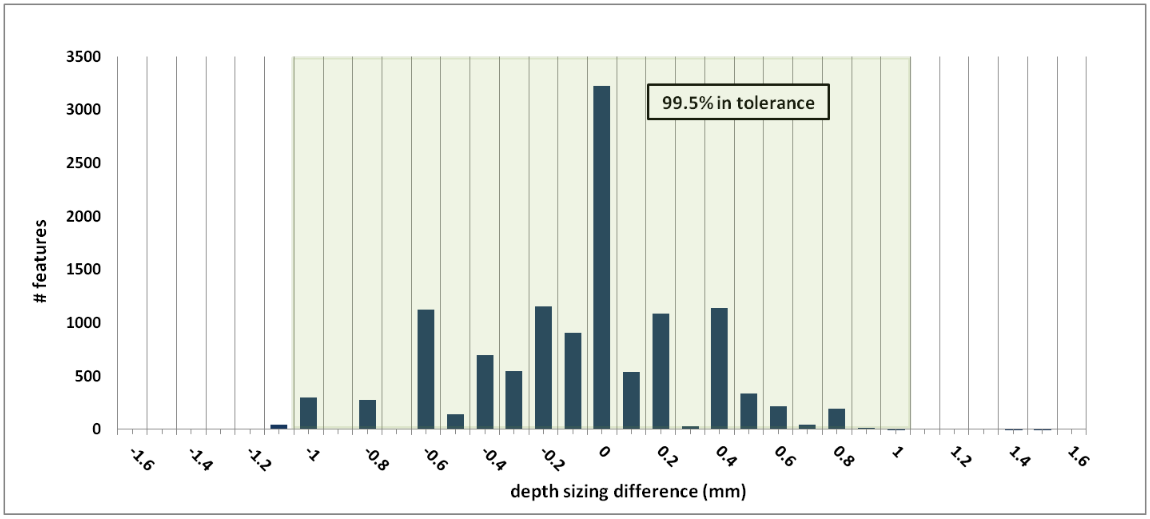

Figure 9: Histogram of depth sizing deviation for one of the test runs. In total 99.5% of flaws are within specified depth sizing accuracy.

EVO Series 1.0 corrosion and crack tools and technologies are qualified according to the latest version of American Petroleum Institute Standard 1163, In-line system qualification (API 1163, 2013).

Table 1 and Table 2 show the overall derived performance specification for EVO Series 1.0 metal loss and crack inspection service.

Key performance specification - EVO Series 1.0 Metal loss/Corrosion

EVO Series 1.0 - UM - Metal loss/Corrosion Performance Specification		
Axial Sampling Distance (mm)		0.75
Circumferential Sensor spacing (mm)		4
Minimum dimension for detection of metal loss anomalies at POD >90%	Diameter (mm)	5
	Depth (mm)	0.8
Depth sizing accuracy at 90% certainty (mm)		±0.4
Length sizing accuracy at 90% certainty (mm)		±1.5
Width sizing accuracy at 90% certainty (mm)		±4.0
Minimum Dimension for Detection of planar & mid wall anomalies at POD >90%	Diameter (mm)	10.0
	Depth (mm)	2.0
Maximum tool velocity (m/s)		4.0

Table 1: Key performance specification for Metal loss corrosion inspection with EVO Series 1.0 tools

Key performance specification - EVO Series 1.0 Crack detection

EVO Series 1.0 - UC - Crack Performance Specification		
Axial Sampling Distance (mm)		1.5
Circumferential Sensor spacing (mm)		5.0
Minimum dimension for detection of crack and crack-like anomalies at POD >90%	Length (mm)	20.0
	Depth (mm)	1.0
Depth sizing accuracy at 90% certainty (mm)		±1.0
Length sizing accuracy at 90% certainty (mm)		±10.0
Maximum tool velocity (m/s)		4.0

Table 2: Key performance specification for crack inspection with EVO Series 1.0 tools

Offshore application

NDT Global's portfolio consits of several single, dual and multi diameter tools. Especially for the offshore application, high-pressure tools are developed. Figure 10 depicts an overview of some tools/projects for offshore applications. Especially dual diameter range in combination with high wall thicknesses required to new or modified tool designs.

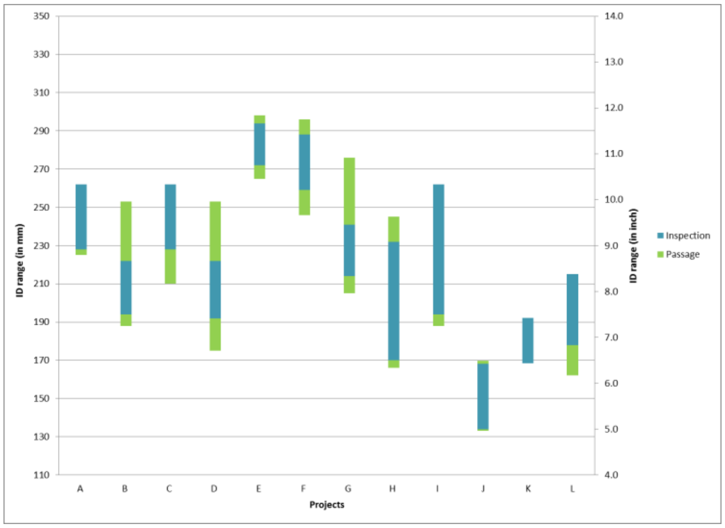

Figure 10: Pasage and inspection range for some offshore tools/projects recently developed by NDT Global.

As an example, a Dual Diameter tool for high-resolution corrosion measurement is shown in Figure 11. The tool can withstand pressures of 275bar and temperatures of up to 65 degrees Celsius.

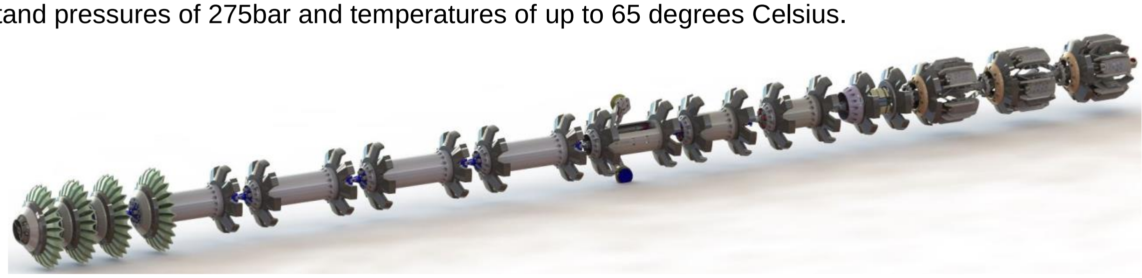

Figure 11: Dual Diameter tool for high-resolution wall thickness measurement, 275 bar capable

Conclusion

NDT Global developed a new fleet of UT tools for inline inspections.
The major improvements are:

- inspection speed up to 4 m/s
- axial resolution up to 0.75 mm
- performance specifications - increased detection capabilities for small and shallow defects
- increased robustness and reliability of tool
- First run success rate (actually 100%).

First inspections show excellent quality of crack and wall thickness data. Pipeline operators directly benefit from high-speed inspection capabilities of EVO Series 1.0. Integrity management and assessment of defects becomes more accurate due to high-resolution data.