ART – A UNIQUE TECHNOLOGY FOR UNIQUE PIPELINES

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Introduction

Offshore pipelines represent a host of unique challenges from multi-diameter configurations, high pressures, poor accessibility, and - as assets age - lower and lower throughputs.

How to inspect challenging pipelines is an evergreen topic of the PPSA event in Aberdeen and over the years we have seen numerous approaches and technologies. This paper will explore two offshore examples that utilised NDT Global's unique, Acoustic Resonance Technology, ART.

Technology Principles

ART is an ultra-wideband acoustic measurement technology that delivers highly accurate pipeline wall thickness data. ART was first introduced in 2013 and has since gained a reputation for being highly adaptable. Like other ultrasonic technologies, ART provide direct measurement of internal and external metal loss features which can provide significant improvement over other traditional technologies, when compared in terms of defect detection, classification, and sizing. This applies to internal, external and mid-wall defects and equally for metal loss as well as deformation, which is collected in the same run.

The core principle of ART of the use of the ultra-wideband signal which operates at frequency ranges of 400khz to 1.1MHz. Not only does this allow inspection in both gaseous and liquid mediums but also permits corrosion inspection of pipelines with a wall thickness of up to 100mm at the same depth sizing accuracy of high-resolution ultrasonics (±0.4mm).

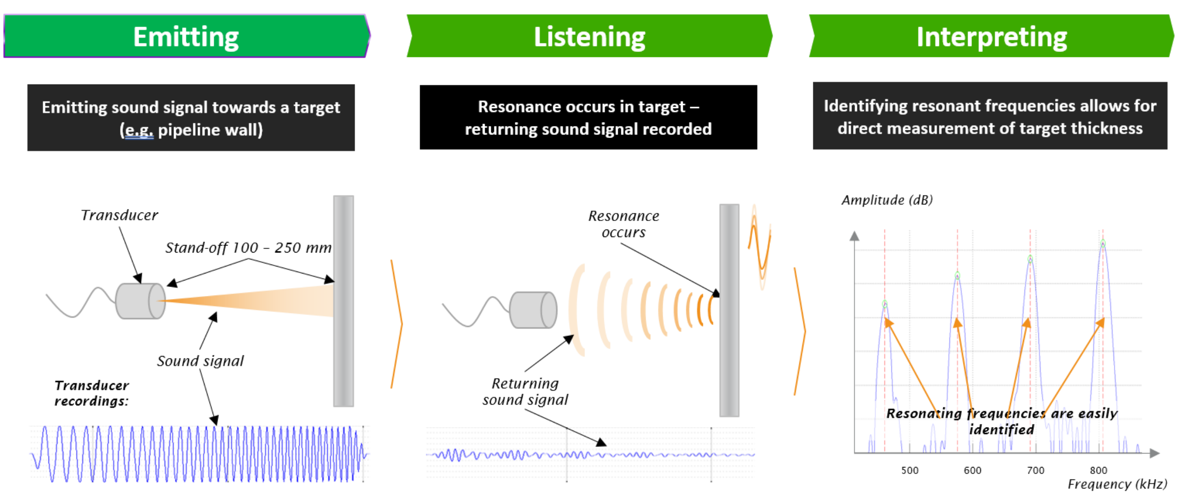


Figure 1: Principles of ART

Two primary measurements are taken from the sensors – the first is the traditional time of flight (TOF) measurement and the second a tail signal which represents the thickness measurement of the inspected object. By conducting a frequency analysis, the structural thickness can be directly measured. Wall thickness is derived from resonance frequency bands, as shown in Figure 1, which has the beneficial result of not degrading with increased wall thickness or as tool speed increase.

Beyond wall thickness, the non-contact sensors also provide a full ultrasonic geometry survey of dents, buckles, out-of-straightness and ovality as standard, without the need for additional modules. This data is captured through the TOF element of the data and is a standard feature of all ART inspections.

Example #1: Low flow wye passage

Introduction

One challenge attributed to the in-line inspection of ageing offshore pipelines is the low flow rates available to propel the tool through the pipeline.

This example explores this issue further, coupled with further challenges to executing one particular inspection campaign effectively.

The Challenge

NDT Global (at the time Halfwave) were awarded the inspection contract for an 18” x 27km pipeline. The pipeline transports oil and condensate from platform to platform.

The main pipeline details and points of interest were:

- Offshore location for both launch and receive.
- Heavy wall sections of 29.2mm.
- SSIV crossovers to be traversed.
- A wye with 2 x 18” ball valves to be navigated and passed without slowing or stopping the tool.
- The receiver trap was positioned vertically.

In addition to the pipeline construction and fixtures, the pipeline also had challenging environmental conditions to overcome, including:

- Very low flow rates, with an anticipated average pigging speed of 0.03m/s.
- No fluid was to be pumped through the unused wye leg, removing any potential flow assistance to push through the wye.

The Solution

<u>Concept design</u>

Prior to testing and operations, the ART Scan tool was re-configured to ensure its compatibility with the pipeline challenges.

Conceptual designs were created and reviewed to ensure the layout, both mechanically and electrically, were correct. The standard 16-26” ART Scan tool accommodates up to 5 lithium battery packs. Due to the anticipated run duration of >200 hours, additional batteries (with associated wiring and electronics) were required, without the addition of an extra battery vessel, to ensure the tool fitted within the standard sized launcher and receivers. To accommodate the additional batteries the tool length increased, resulting in a more suitable sealing length between drive cups to cross the wye without losing drive.

<u>Detailed design</u>

The detailed design phase then commenced. This included the manufacture and pressure testing of the new extended body battery vessel, PU cups/spacer considerations and the piggability requirements of the tool.

In this detailed design phase, particular attention was paid to the PU design on the tool front end. A previously used 2 cup design was no longer suitable, due to the potential for product bypass through the wye:

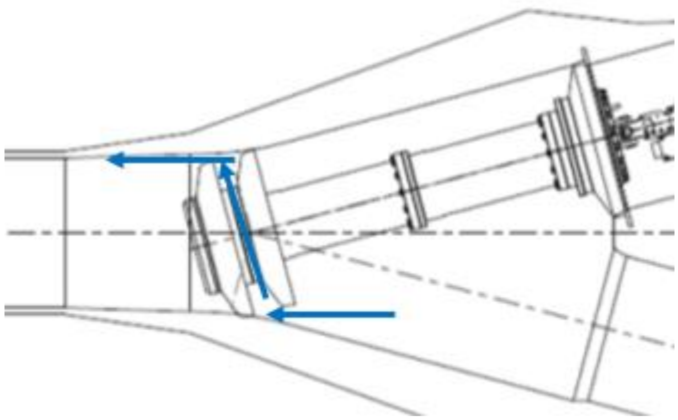


Figure 1: Tool bypass concerns with the previous design

The new design therefore accounted for this potential bypass path as follows:

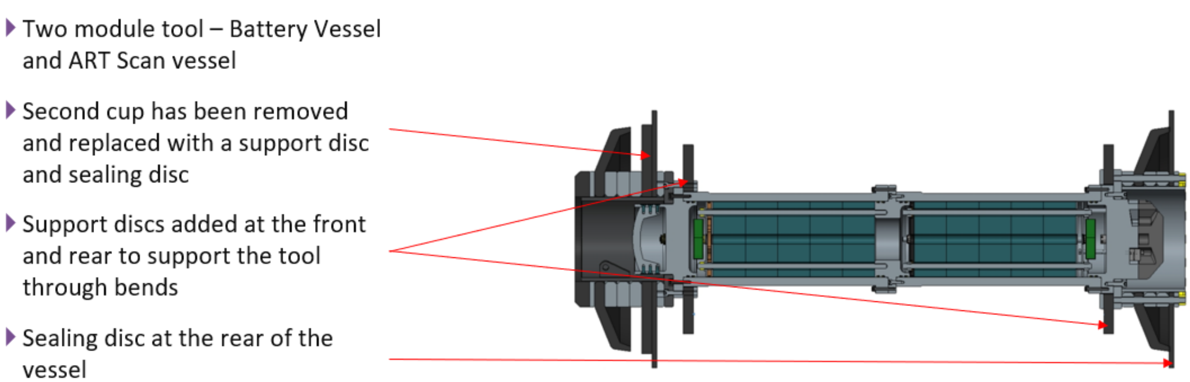


Figure 2: Reconfigured PU design

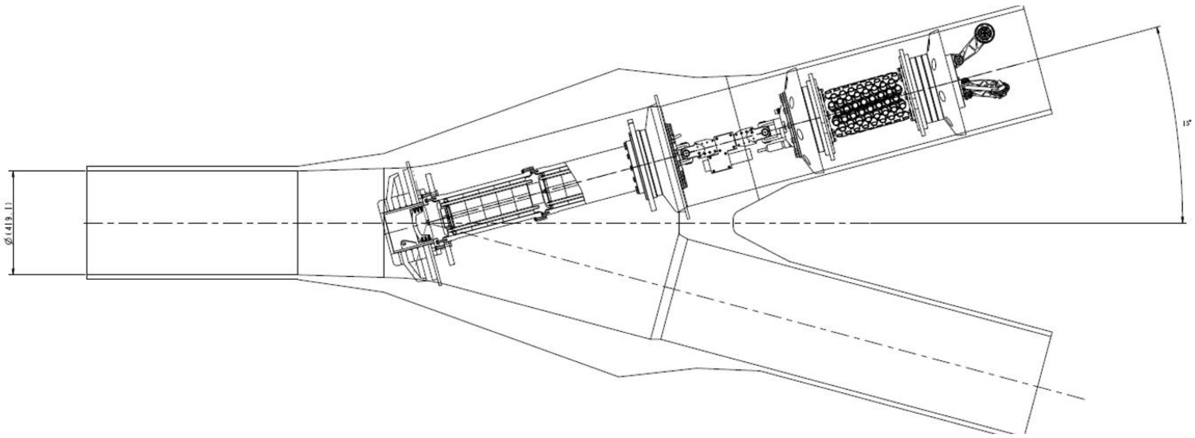


Figure 3: Reconfigured ART Scan tool modelling traversing the subsea wye

The opportunity for product bypass was then greatly reduced, providing a smoother transition through the wye.

Pigging Verification Programme

NDT Global arranged and completed an onshore pigging verification programme prior to mobilisation of the ART Scan tool. Nine wye passing trials were completed successfully.

The FAT acceptance criteria was "*To demonstrate repeatability, the ILI tools must successfully navigate through the test piece (including WYE) a minimum of twice without modification to the ILI tool or pumping regime. The test rig must include as a minimum one 5 metre lead in spool, one 5 D x 90' bend, a full-size model of the WYE and an exit spool*".

The initial disc configuration was revised through three iterations. The final disc configuration proved the ART Scan tool could traverse the wye section at low flow. The average ART Scan tool pigging differential pressure recorded was:

- ~0.4bar in the straight pipe spool
- ~0.2 – 0.6 bar in the wye section
- ~1.0bar in the 5D bend

The trials showed the ART Scan tool could be safely propelled through the pipeline and associated fittings (straight spools, wye and 5D bends) at:

- Minimum speed of 0.027m/s
- Minimum flow rate of 245l/min or 2156 bbls/d (UK).

In-field Run

In Q4 2019 the inspection of both pipelines was successfully executed, in one continuous run, and incident free.

The ART Scan tool was launched on the 21st November 2019 and received on the 30th November 2019. It passed through all pipeline fixtures, including the subsea wye, without any issues and was successfully 'caught' in the receiver trap basket.

Results

Two Final Reports were issued (one per pipeline) with all reporting completed successfully and in accordance to POF 2016 requirements. This allowed the customer to successfully confirm the pipelines integrity and safely enable continuous future operations.

Challenge # 2 – A Multi-Diameter, Deepwater Tie-back

Introduction

The requirement to inspect multi-diameter pipelines with significant variation in minimum and maximum bores is becoming increasingly common due to new tie-backs to existing assets. Conventional inspection techniques often rely on the sensors to be close to the pipe wall creating mechanical challenges to maintain that contact/distance.

Acoustic resonance technology has a typical stand-off (the distance between the sensor and the pipewall) of between 100-250mm compared to a typical stand off for a conventional ultrasonic tool of 15-20mm. This inherits ART with an unparalleled flexibility allowing not only the same electronics modules to be utilized over a wider range of pipeline diameters, but also to simplify multi-diameter developments.

In 2017 NDT Global (at the time Halfwave) where approached to investigate the inspection of a 16/24/28" oil export pipeline located offshore in the Gulf of Mexico. The 24" and 28" sections of the pipeline where pre-existing and there were very strong financial and technical motivations for selecting a 16" tie-back. The project required an integrity inspection solution as a mandatory parameter for the project milestones.

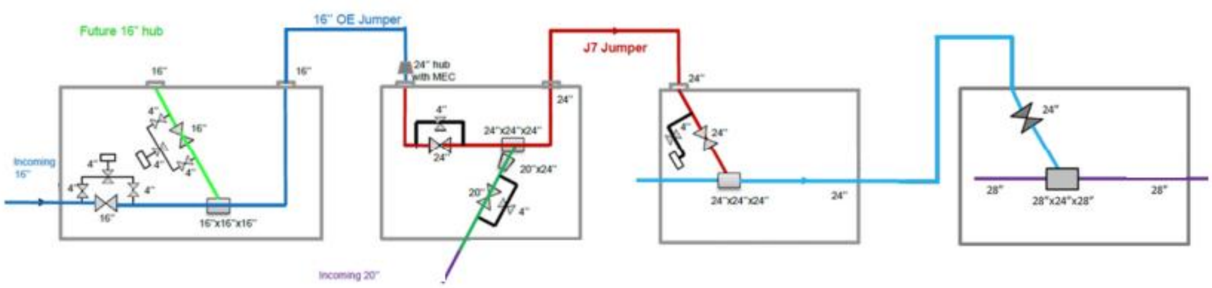


Figure 5: System Schematic

The Challenge

The first part of any development project requires the outlining of the key design challenges posed as part of the project. The primary areas of consideration when developing a multi-diameter inspection tool were the following:

- Drive through the various pipeline diameters ranging from 16" to 28" including passing a short section of 13" in the 16" section.
- Inspection data required was for the 16" and 24" sections.
- Passage through the multiple valves, 5D bends and wyes.
- Considerations for the application in deepwater and the associated pressure requirements for the pressure vessel, cables and sensors.

The Solution

Tool design

NDT Global worked closely with the pipeline operator to develop a bespoke solution based on ART. ART was originally selected based on its flexibility and the requirement to inspect heavy pipe wall in excess of 25mm.

The primary aspects for consideration for a multi-diameter application are how the tool can drive through the various diameters, but also the method of suspension to maintain centralisation of the tool body throughout the 16" and 24" sections.

Rather than following a narrow pre-determined path for the multi diameter aspect, NDT Global where aware they had the opportunity to evaluate multiple options for the drive and suspension mechanisms for the tool. Therefore, a thorough and diverse selection of tool designs where considered for further development at the concept evaluation phase. The solutions where evaluated in a number of different categories including the ability to traverse the various bore changes; the ability to pass the bends in the system; ability of the tool to provide centralisation and also the technical readiness level of the proposed solution.

Several options where considered, as shown in Figure 6, starting with solutions that used the existing ART core with a conventional FTL based suspension system in various configurations. However, all these options either had issues with passing the bends or providing a reliable centralisation method. Other, more abstract, solutions for the suspension methodology, including a PU-fin and whisk style approach, where also considered but, in the end, deemed to lack sufficient track-record to be considered further.

In the end the FTL suspension was selected as the best suspension methodology from a technical readiness level; its ability to navigate the system and to provide centralisation.

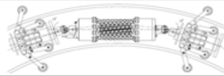
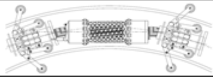
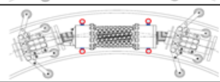
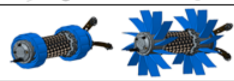
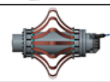
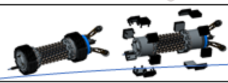
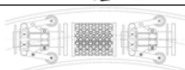
Concept Solutions		Feature and Capabilities					Concept Feasibility
		Bend	Bore	Centralization	Existing ART Core	Readiness Level	
Fixed interface, FTL wheels		✗	✓	✓	✓	✓	Feasible, however not recommended due to high risk of reduced inspection data quality
Single-point couplet, FTL wheels		✓	✓	✗	✓	✓	Feasible, however not recommended due to high risk of reduced inspection data quality
Semi-Rigid Link, FTL wheels		✓	✓	✗	✓	✓	Feasible, however not recommended due to high risk of reduced inspection data quality
Semi-Rigid Link, Support Rollers, FTL wheels		✓	✓	✗	✓	✓	Feasible, however not recommended due to high risk of reduced inspection data quality
PU-Fin		✓	✓	✓	✓	✗	Not recommended due to high risk related to functional performance and non-field proven concept
Whisk		✓	✓	✓	✓	✗	Not recommended due to high risk related to functional performance and non-field proven concept
Spring-loaded Bristles		✓	✓	✓	✓	✗	Not recommended due to high risk related to non-field proven concept, and centralization capabilities
Custom ART Scan Concept		✓	✓	✓	✗	✓	**Recommended solution**

Figure 6: Evaluation of Design Concepts

For the FTL system to pass the bands, a new ART sensor core was required to shorten the modules length, without having a negative effect on the performance specification i.e. by maintaining the overall sensor density. To achieve this the electronics, which are normally situated within the ART sensor core, had to be re-positioned to a dedicated electronics module.

The second challenge of the development was to develop a tow module to drive the tool through the various diameters. To provide sufficient flexibility through the bends and enough length to drive though the various wye pieces, the drive module was developed in two separate modules. Multiple cup/disc arrangement where considered and evaluated with pull through tests. The resulting drive arrangement consisted of two 16" seal discs, a single 24" buckle inducer seal disk and a single 28" buckle inducer seal disk fitted to each of the two drive modules.

Testing and assurance process

Assuring the performance of the tool is a critical step in any development project. Working with the operator NDT Global developed an assurance program to test all critical parameters of the new tool design. Testing of the tool was performed over two locations with factory acceptance testing performed in Bergen, Norway and final performance testing at the operator's facility in Houston.

The test rig in each location included the following key pipeline features:

- 16in wye section
- 16in 5D bend
- 24x28in wye section
- 16in, 24in and 28in mainline spools
- 16in – 24in expander

- 13.4in bore passing
- 16in and 24in blind performance spools

The primary objective of the testing campaign was to prove the passage traversing ability of the tool through the various diameters at the flow rates expected in the system. Differential pressures were expected to be low since the tool was expanding into each of the diameters, except for the short 13" restriction located in the 16" pipeline.

Resultant differential pressures ranged from a peak of 4 bar in the 13" restriction dropping to 2.5bar in the 16" straight sections and 0.1 bar in the 28" section - as shown in Figure 7, below.

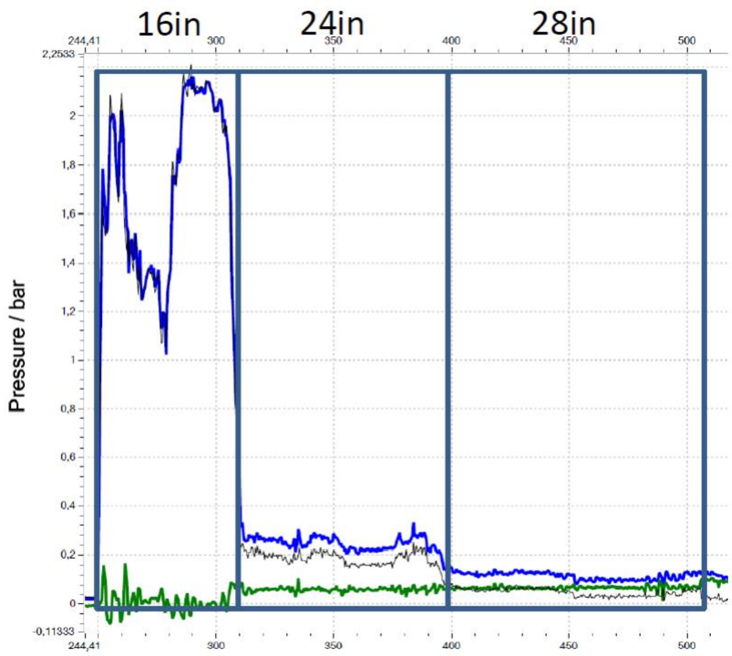


Figure 7: DP across the three diameters

Blow over tests where a necessary part of the scope to ensure drive through the line – particularly for the larger diameter 24" and 28" sections and to document the robustness of the sealing arrangement. The test rig setup is displayed in Figure 8 with the test spool connected with 2" inlets/outlets until the discs flipped. Resulting blow over pressures where 0.9 bar for the 24" section and 0.6bar for the 28" section.

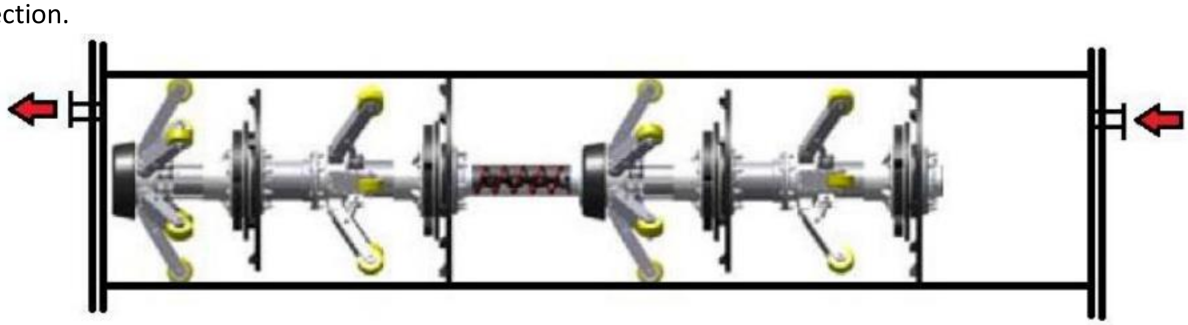


Figure 8: Blow Over Pressure Test Setup

In total over 70 pump tests, multiple blow over tests and pull through tests were conducted to prove both the passage passing abilities but also the tools performance specification. The resulting assurance process proved the tools performance repeatability. At the time of writing the tool has been fully signed off by the operator and awaits the inspection of the system.

Summary

The unique properties of ART provide it with an inherent flexibility for the world's most challenging pipelines. The low weight, low friction characteristics of the tool lends itself well to applications where pipeline throughput is low and, in combination, with the large stand-off requirements make ART ideal for challenging multi-diameter applications.

In both examples discussed in this paper, ART was selected due to the high wall thickness common in offshore pipelines, that could otherwise be a challenge for other technologies. By working closely with pipeline operators NDT Global was able to develop bespoke integrity solutions, with field proven technology, that was backed up with thorough and robust pigging assurance programs.

Acoustic Resonance Technology's combination of direct measurement, low friction and large stand-off represent a unique set of features for the unique pipelines of the world.