November 2016

eJournal

ptj Pipeline Technology Journal

www.pipeline-journal.net
ISSN 2196-4300

Extensive Pipeline Opportunities

Dr. Klaus Ritter
Editor in Chief

Dear Reader,

The Pipeline Technology Journal (ptj) is relaunching its services for the global pipeline community. In 2017 ptj will focus on current and upcoming high-end pipeline technologies and provide its readership with a condensed overview of innovative and practical products and services available to the market.

Therefore, in six issues with different emphases the Journal will report about new pipeline technologies regarding

- Planning / Construction / Rehabilitation,
- Operation,
- Maintenance,
- Offshore,

and relevant comprehensive Topics. To stay up-to-date with the technological development, all topics are updated yearly with the latest developments, products and services. This will enable pipeline professionals from all over the world to stay informed about the current state of technology at a glance. In addition, the ptj newsletter will provide the global pipeline community with relevant news and announcements from the industry. It will be sent every two weeks.

The mission of ptj is twofold: It first intentions to archive and catalogue the existing knowledge whether textual, auditory, or visual. Secondly requests to create new content, and foster the growth and development of the already available knowledge classified in categories. For this purpose, a searchable web-database containing all published articles within the ptj will go online and will serve as a pool for relevant pipeline technologies. Thus, interested readers can make the most out of ptj extensive pipeline related content.

The ptj is the next hub for pipeline technologies from around the world, serving as reliable source of information for pipeline professionals.

The 12th Pipeline Technology Conference (ptc), taking place in Berlin from 2-4 May 2017, is not far away anymore. The conference will feature lectures and presentations on all aspects surrounding oil, gas, water and product pipeline systems. One of the new focus topics at ptc 2017 will be "Pipeline Construction". Make use of this opportunity and get involved now, as participant, exhibitor or speaker.

Many cities in Africa, Middle East and South Asia suffer from their crumbling and poorly maintained pipeline, pipe and sewer infrastructure. Thats why we have decided to take a next stop with our portfolio and to develop a new conference and exhibition directed towards this promising markets. In 2017, we will hold for the first time the Pipeline-Pipe-Sewer-Technology (PPST)Conference & Exhibition in Cairo, Egypt. People, excellence and innovation are key factors of this international platform to build a different and better future – for Egypt, the wider MENA region and the world.

We are working constantly to uphold the continuous exchange within the international pipeline community. You are welcome to make use of the extensive opportunities we created. Kindly find additional information on our websites or contact us directly via mail:

- eitep@eitep.de
- www.pipeline-journal.net
- www.pipeline-conference.com
- www.pipelinepipesewer.com

Yours,

> Dr. Klaus Ritter, President EITEP Institut

GAZPROM DISCOVERS NEW FIELD ON SEA OF OKHOTSK SHELF:

Gazprom has reported a new gas and condensate field in the Sea of Okhotsk, near Russia’s Sakhalin island.

The company was drilling an exploration and appraisal well, as part of the Sakhalin III project, when the discovery was made.

As part of the Sakhalin III project, Gazprom is engaged in exploration of three licensed blocks: Kirinsky, Ayashsky, and Vostochno-Odoptinsky. Within the Kirinsky Block, the company also discovered Yuzhno-Kirinskoye and Mynginskoye fields.

TECHNICAL ARTICLES

NOVEMBER 2016
EDITION 12

GENERAL TOPICS

THIS ISSUES COMPLETE CONTENT

NEWS

INDUSTRY AND PRACTICE

TECHNICAL ARTICLES

RESEARCH / DEVELOPMENT / TECHNOLOGY

REPORTS

CONFERENCES / SEMINARS / EXHIBITIONS

Calgary / Canada

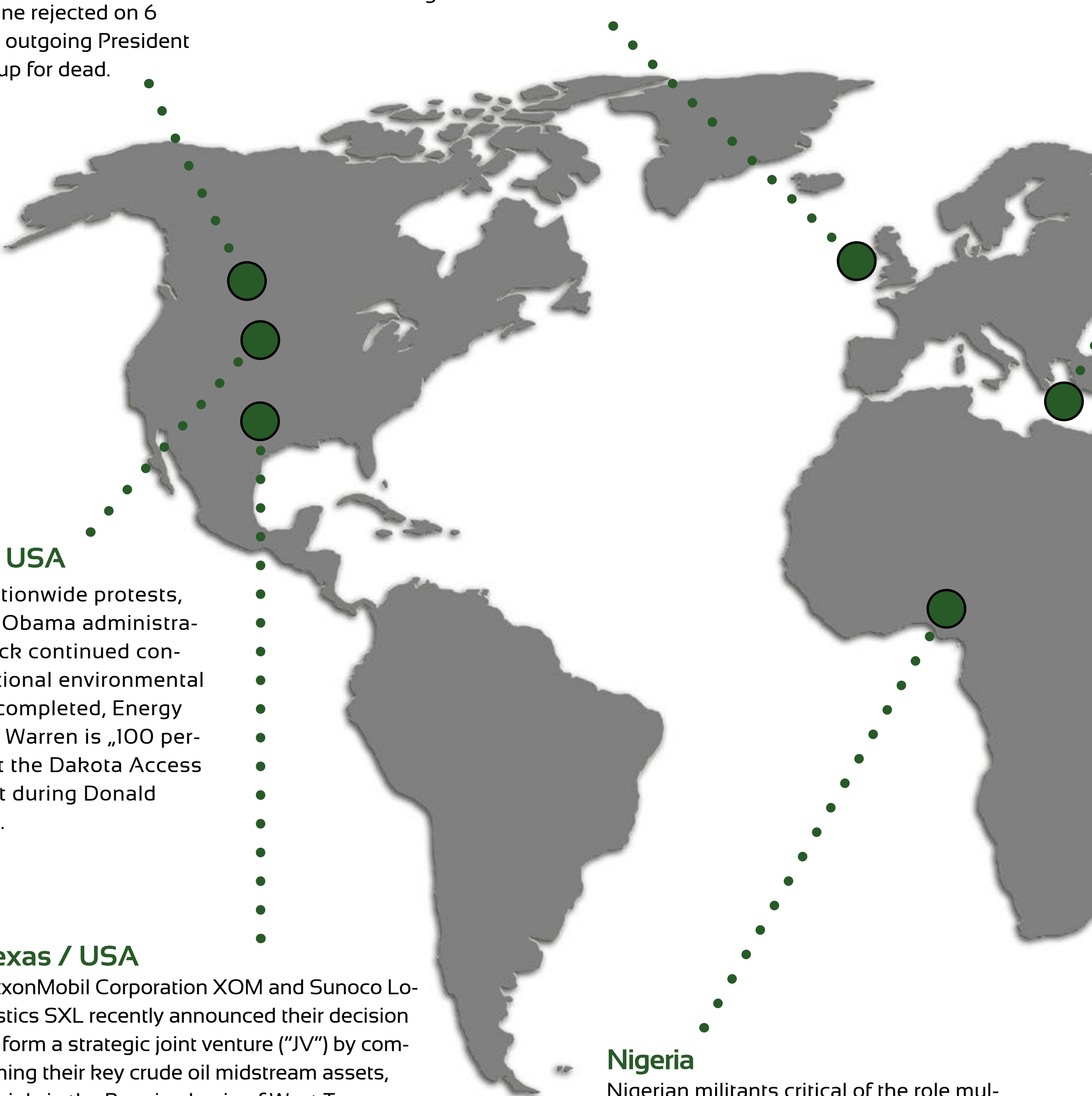
Calgary-based TransCanada is hopeful that the Trump win in last week's election will resuscitate the oft maligned Keystone XL pipeline rejected on 6 November 2015 by outgoing President Obama and given up for dead.

Page 12

Dublin / Ireland

The route of the € 1.2 billion, 170 km water pipeline from the Shannon River to Dublin and the midlands has been published in Ireland. Some 550 landowners will be affected by the construction.

Page 11



North Dakota / USA

Despite growing nationwide protests, rising costs and an Obama administration decision to block continued construction until additional environmental studies have been completed, Energy Transfer CEO Kelcy Warren is „100 percent" confident that the Dakota Access pipeline will be built during Donald Trump's presidency.

Page 11

Texas / USA

ExxonMobil Corporation XOM and Sunoco Logistics SXL recently announced their decision to form a strategic joint venture ("JV") by combining their key crude oil midstream assets, mainly in the Permian basin of West Texas. Alongside the transaction, ExxonMobil and its associates will enter into a preferred provider agreement with the JV.

Page 11

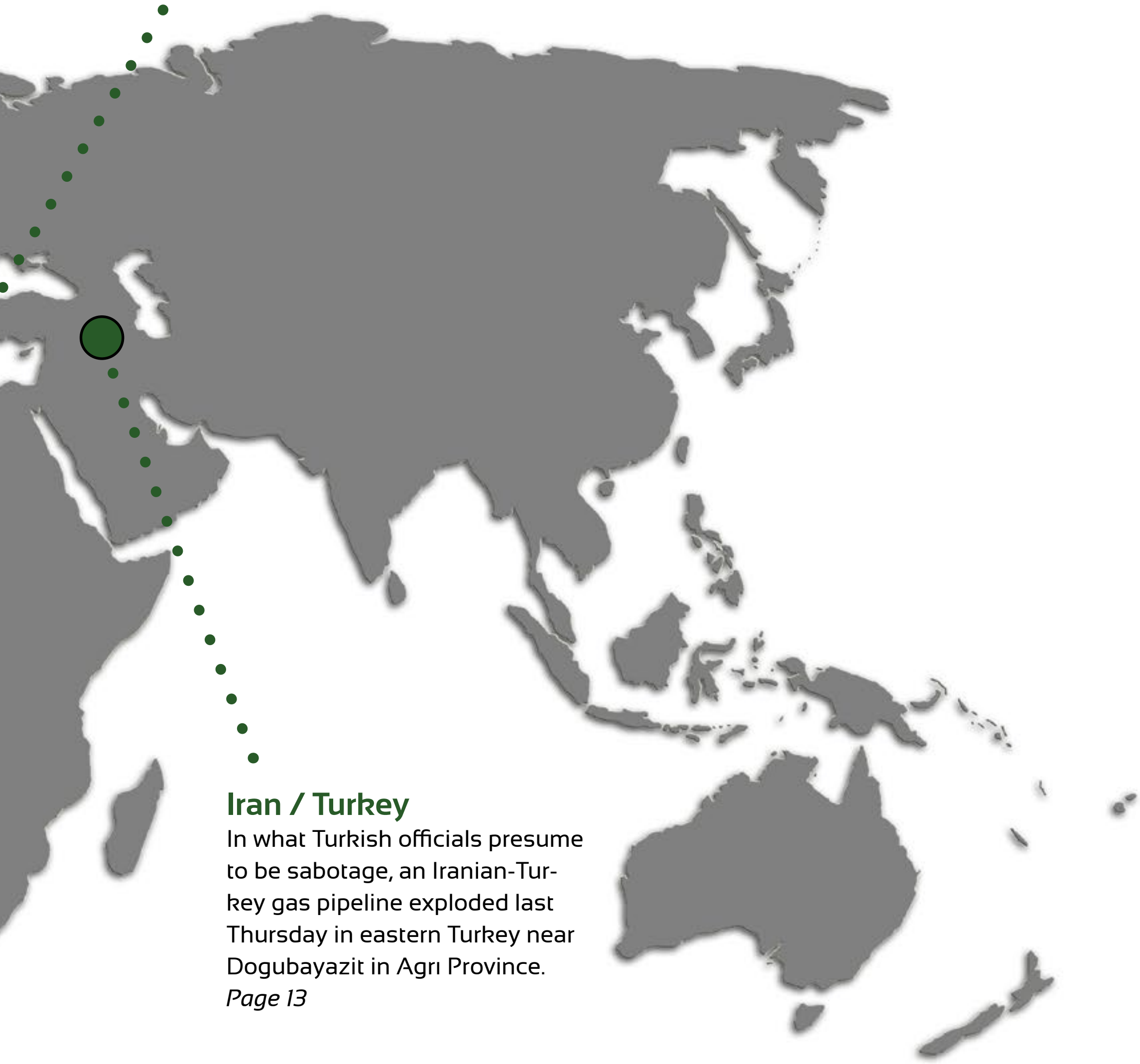
Nigeria

Nigerian militants critical of the role multinational energy companies are playing in the oil rich Nigerian delta have bombed a Chevron-operated export pipeline at Escravos in Warri South Local Government Area of Delta State.

Page 12

Mediterranean Sea

The European Commission has determined after authorizing a feasibility study on a natural gas pipeline from the Leviathan offshore gas field via Cyprus to Greece would cost about $5.7 billion.
Page 13



Iran / Turkey

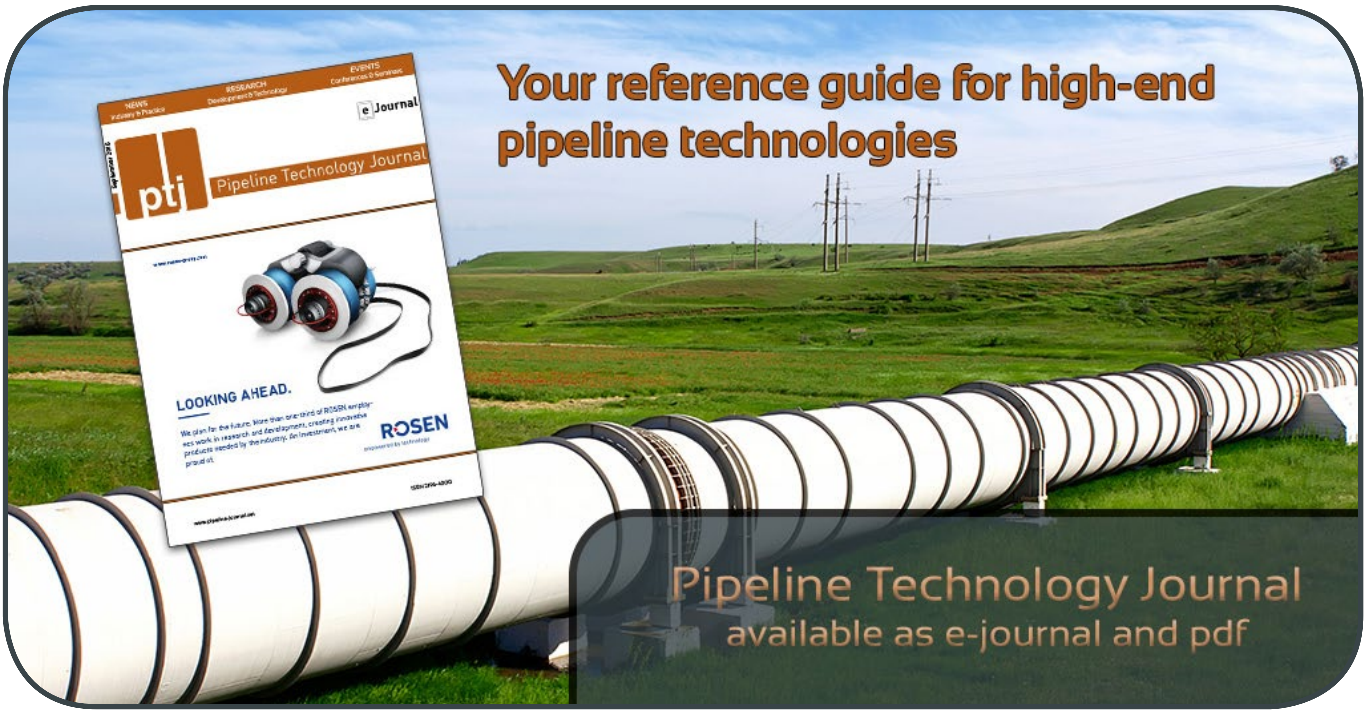
In what Turkish officials presume to be sabotage, an Iranian-Turkey gas pipeline exploded last Thursday in eastern Turkey near Dogubayazit in Agrı Province.
Page 13

WORLD NEWS

RELAUNCH:

The Pipeline Technology Journal as reference guide for high-end pipeline technologies

SYSTEMATICALLY COLLECTED STATE-OF-THE-ART TECHNOLOGIES AT A GLANCE



The Pipeline Technology Journal (ptj) is relaunching its services for the global pipeline community. In 2017 ptj will focus on current and upcoming high-end pipeline technologies and provide its readership with a condensed overview of innovative and practical products and services available to the market.

Therefore, in six issues with different emphases the Journal will report about new pipeline technologies regarding Planning / Construction / Rehabilitation, Operation, Maintenance, Offshore, and relevant comprehensive Topics. To stay up-to-date with the technological development, all topics are updated yearly with the latest developments, products and services. This will enable pipeline professionals from all over the world to stay informed about the current state of technology at a glance. In addition, the ptj newsletter will provide the global pipeline community with relevant news and announcements from the industry. It will be sent every two weeks.

The mission of ptj is twofold: It first intentions to archive and catalogue the existing knowledge whether textual, auditory, or visual. Secondly requests to create new content, and foster the growth and development of the already available knowledge classified in categories. For this purpose, a searchable web-database containing all published articles within the ptj will go online and will serve as a pool for relevant pipeline technologies. Thus, interested readers can make the most out of ptj extensive pipeline related content.

The ptj is the next hub for pipeline technologies from around the world, serving as reliable source of information for pipeline professionals.

ExxonMobil and Sunoco in New Midstream Joint Venture

ExxonMobil Corporation XOM and Sunoco Logistics SXL recently announced their decision to form a strategic joint venture ("JV") by combining their key crude oil midstream assets, mainly in the Permian basin of West Texas. Alongside the transaction, ExxonMobil and its associates will enter into a preferred provider agreement with the JV.

Sunoco, with an 85 percent share, will be majority owner and operator of the JV assets. ExxonMobil will hold the remaining 15 percent.

Sunoco will contribute its Permian Express 1, Permian Express 2 and Permian Longview and Louisiana Access pipelines to the JV. ExxonMobil, for its part, will contribute a Texas-Louisiana pipeline as well as its Pegasus pipeline, which runs from Texas to Illinois.

Part of the Pegasus pipeline is shut down, a result of a rupture in 2013 in Arkansas causing $57 million worth of damage.

With West Texas Intermediate (WTI) and Brent crude currently trading at $44.59 and $45.82 per barrel, respectively, both companies are looking to bolster their cash position.

Water Pipeline Being Planned in Ireland

Water Pipeline Being Planned in Ireland (Shutterstock / somsak suwanput)

The route of the € 1.2 billion, 170 km water pipeline from the Shannon River to Dublin and the midlands has been published in Ireland. Some 550 landowners will be affected by the construction.

Given anticipated water shortages in the near future, Irish Water, the utility, says the project will supply 330 million litres a day to Dublin and the midlands, equivalent to "125 Olympic-sized swimming pools" daily.

Irish Water cites forecasts that the population of the Greater Dublin Area will rise from 1.5 million, as it was recorded in the 2011 census, to 2.1 million by 2050.

The project does have its detractors: the River Shannon Protection Alliance said Dublin had no shortage of raw water but "insufficient treated water", and argued that eastern groundwater supplies should be explored.

Energy Transfer Sees Dakota Access Pipeline Going Forward Soon

The protests against Dacota Access Pipeline take place in the area around the Cannonball river (Bryan Boyce / Wikipedia)

Despite growing nationwide protests, rising costs and an Obama administration decision to block continued construction until additional environmental studies have been completed, Energy Transfer CEO Kelcy Warren is „100 percent" confident that the Dakota Access pipeline will be built during Donald Trump's presidency.

The 1886 km, 30 inch diameter pipeline, is 84 percent completed, with all but 1000 more feet to cover.

Native Americans and environmentalists say the pipeline could threaten the water supply of millions and disrespect sacred lands.

Obama administration officials have requested that Energy Transfer voluntarily stop construction underneath Lake Oahe. Yet there is no readiness to change course, particularly since the company has received all necessary permits from the Army Corps of Engineers.

Warren donated $103,000 to Trump's campaign and Trump has minor investments in Energy Transfer. When asked if he has ever spoken to Donald Trump about the pipeline, Warren said that he ‚has never met the man."

TransCanada has hope for Keystone XL Pipeline

TransCanada has hope for Keystone XL Pipeline (Marc Nozell / Wikipedia)

Calgary-based TransCanada is hopeful that the Trump win in last week's election will resuscitate the oft maligned Keystone XL pipeline rejected on 6 November 2015 by outgoing President Obama and given up for dead.

TransCanada said it was „"evaluating ways to convince the new administration on the benefits, the jobs and the tax revenues this project brings to the table."

Opponents -- and there have been many -- say the 1,897 km, 30 inch diameter pipeline requires too much energy. In addition farmers and ranchers fear damage to water supplies in the event of a leak and oppose the use of eminent domain to take land for a project that would have no direct benefit for them. The very arguments one hears concerning Dakota Access.

TransCanada counters that Keystone would bring tens of millions of dollars in tax revenues to counties along the proposed route that are in dire need of an economic stimulus.

Nigerian militants shut down Chevron Export Pipeline in Nigeria

Nigerian militants critical of the role multinational energy companies are playing in the oil rich Nigerian delta have bombed a Chevron-operated export pipeline at Escravos in Warri South Local Government Area of Delta State.

The so-called Niger Delta Avengers have warned Chevon as well as other international oil companies to heed to its warnings not to effect repairs to their bombed facilities pending the outcome of ongoing negotiations or dialogue with the people of the Niger Delta. The Avengers have said they want to force multinationals out of the oil-producing Niger Delta because careless production has impoverished residents through massive pollution that has destroyed fishing grounds and agricultural fields.

Deji Haastrup, the General Manager, Government, Public and Policy of Chevron, refused to confirm or deny the attack when contacted yesterday.

Nigerian militants shut down Chevron Export Pipeline in Nigeria

The EU Takes A Serious Look at the Leviathan Giant Gas Field

The European Commission has determined after authorizing a feasibility study on a natural gas pipeline from the Leviathan offshore gas field via Cyprus to Greece would cost about $5.7 billion.

This was reported by Shaul Meridor, Director General of the Israeli Ministry of Natural Infrastructures, Energy and Water Resources. Meridor met in Athens with his counterparts from Greece, Cyprus and Italy and a senior official from the EU Energy Commission. All meeting participants expressed the desire to carry on with the project and the European Commission has recognized the pipeline as a Project of Common Interest (PCI).

The length of the pipeline examined in the feasibility study would be 1,300 kilometers - 200 kilometers in deep waters from the Leviathan field to the Cypriot gas fields and Cyprus itself, 700 kilometers to Crete, and 400 kilometers to the Greek mainland. The pipeline's diameter would be either 24 or 32 inches in various sectors and it could supply 16 BCM annually.


(Shutterstock / esfera)

Given the European preference to diversify its sources of energy and particularly its desire to wean itself from being overly dependent on Russia for natural gas, the Israelis are hopeful that the Leviathan basin will capture European attention and help supply Europe for many years to come.

Explosion Disrupts Iranian Gas Pipeline into Turkey

In what Turkish officials presume to be sabotage, an Iranian-Turkey gas pipeline exploded last Thursday in eastern Turkey near Dogubayazit in Agrı Province.

"Iran's gas flow to Turkey has temporarily stopped because of a blast by some opposition groups inside Turkey around 1830 GMT on Thursday night," Majid Aghai, an official from the Iranian Interior Ministry, said.

Sabotage is common on pipelines leading into Turkey from Iran and Iraq, where the Kurdistan Workers' Party (PKK) armed group is based. The collapse of the cease fire between Turkey and the PKK has led to renewed violence between the two sides.

The PKK has fought a three-decade-old insurgency that has killed more than 40,000 people.

Pipeline Technology Journal

www.pipeline-journal.net
ptj@eitep.de

Publisher
Euro Institute for Information and Technology Transfer GmbH
Am Listholze 82
30177 Hannover, Germany
Tel: +49 (0)511 90992-10
Fax: +49 (0)511 90992-69
URL: www.eitep.de

President: Dr. Klaus Ritter
Register Court: Amtsgericht Hannover
Company Registration Number: HRB 56648
Value Added Tax Identification Number: DE 182833034

Editor in Chief
Dr. Klaus Ritter
E-Mail: ritter@eitep.de
Tel: +49 (0)511 90992-10

Editorial Board
Advisory Committee of the Pipeline Technology Conference (ptc)

Editorial Management & Advertising
Design & Layout
Admir Celovic
E-Mail: celovic@eitep.de
Tel: +49 (0)511 90992-20

Editorial Staff
Dennis Fandrich: fandrich@eitep.de
Mark Iden: iden@eitep.de

Terms of publication
Six times a year, next issue: January 2016
Paper deadline: January 6th 2016
Advert Deadline: January 6th 2016

DEEPWATER NDT TECHNOLOGY FOR PIPES AND TUBULAR STRUCTURES

Dr Yoann Eras Lage > TWI Ltd
Graham Edwards > TWI Ltd
Børre A. Børretzen > Dacon AS
Dr Slim Soua > TWI Ltd
Dr Tat-Hean Gan > TWI Ltd

Abstract

A new NDT inspection technology to inspect pipes and tubular structures for deepwater has been designed. This technology designed by SubCTest prototype has been conceived by the SMEs in order to exploit a new market with the potential for huge growth – NDT for off-shore subsea structures.

The SubCTest system consists in a ROV deployed NDT collar employing two technologies: Long Range Ultrasonic Testing (LRUT) and Electromagnetic Acoustic Transducer (EMAT). Once the LRUT detects a defect on a subsea pipe or structure the EMAT will investigate the severity of the defect. LRUT covers a length of pipe simultaneously which makes the inspection less time consuming. The collar has been built and tested in a water tank and now the project is at a development stage to take it to demonstration level. Once the collar reaches this stage it will be deployed under sea using a work-class ROV to test subsea pipes.

The SubCTest prototype will allow the demonstration and validation of LRUT and EMAT technologies inspection underwater and establish a lead in the emerging market of deepwater structure inspection. In addition, will provide NDT services and components to oil/platform operators and potentially to the offshore wind turbine sector.

INTRODUCTION

The majority of oil and gas production in European waters takes place from fixed platforms that normally comprise of a steel tubular structure (jacket) permanently anchored (through a series of piles) to the seabed that supports a topside above the sea level, comprising of different modules for accommodation, power generation, pumping and initial product processing etc, as illustrated in Figure 1. Beneath the platform are a complex network of pipelines and risers bringing oil and gas to the surface.

About 300 platforms exist in the North Sea and over 50% of them are older than 25 years and beyond their original design life. About 150 platforms have permanent manning levels in excess of 20 people. Further life extension of these platforms and an increase in technical duty (eg tie-ins to other oil and gas fields) will be required in the future [1]. It is widely acknowledged that undiscovered oil and gas reserves in the North Sea can only be found using improved production techniques by extending the lives of existing installations and from future deepwater fields [2] and that sub-sea NDT inspection capability is an important strategic element in this approach to maximise future oil supplies.

Figure 1: North Sea oil platform as seen from MS Oosterdam, clearly showing the steel jacket structures supporting the top-side modules

As mentioned, the need for new NDT techniques arises from the fact that older offshore installations were designed to earlier technical standards which have since been superseded and their conditions have significantly deteriorated during service. Historically, much of the inspection and NDT has been on the top-side, pressure and structural components and comparatively little sub-sea NDT and inspection has taken place on the vital support jacket structure, much of which has now exceeded its design life. At this stage, few techniques for underwater inspection are available and most of them need divers to operate the systems, resulting in high cost services and high health and safety risks. Another limitation with deepwater human intervention is the short allowable operation times and the limit for deep diving certification beyond 60 metres (technical diving) by authorities. The operating oil companies, are themselves under increasing pressure from the regulatory authorities, to reducing diver operations, because of safety issues [Norwegian case awarded €3.7million compensation to 3 divers [3-4]].

Strong fluctuations in the oil price recorded during the last decade have also been a decisive factor influencing the offshore asset structural integrity management, forcing companies to reduce operational expenditures (OPEX) and in some cases completely overhaul in important aspects of the their own strategy for securing structural integrity by introducing new, more efficient NDT technologies, such as LRUT.

Approximately 2.5 billion tonnes of oil are processed in the world each year. Of that about 30,000 tonnes is leaked or spilled into the world's oceans annually [5-6]. The failure of a jacket sub-sea support leg, cross member or flow-line could mean the catastrophic failure of the entire platform with immense environmental and economic consequence and is currently considered by the oil majors to be an, 'un-thinkable' accident. Apart from the lost production, the cost of environmental pollution, adverse public relations and legal and regulatory proceedings on the offshore oil & gas industry would be immense and would probably run into many hundreds of millions of Euros.

It is reported by BP [7] that there are approximately 6,500 oil & gas offshore installations across the industrial world, many of which will be expected to operate well beyond their original design life. Although many of the fixed structure installations are in relatively shallow waters (eg inshore Gulf of Mexico) the trend in offshore exploration is to go further into deeper waters (eg Gulf of Mexico - Deep Water, offshore West Africa and offshore Brazil, ie the so called Golden Triangle). In these regions harsher weather conditions will be experienced and the environmental and economic consequences of structural failure will be dramatic.

Although the current economic situation of the Oil & Gas sector does not present the best conditions for investment in new technology, companies continue to participate as end-users or customers for new innovative solutions as presented by this project SubCTestDEMO.

New NDT techniques remotely operated or even automated underwater are crucial therefore for the extended life of offshore structures currently operated and in a deepwater offshore future.

NDT TECHNOLOGICAL CHALLENGE

Existing NDT equipment and techniques are also limited by the water depth and do not lend themselves to sub-sea depths below about 25 – 30 metres and generally rely on divers applying visual inspection and electromagnetic techniques for surface examination.

The original SubCTest project included Automated Ultrasonic Phased Array Ultrasonic Testing (PA-AUT); Alternating Current Field Measurement (ACFM); and Long Range Ultrasonic Testing (LRUT) brought improvements regarding previously identified NDT technique limitations in their underwater application. Some of these enhancements are listed below:

- a simplified PA-AUT scanning technique using multi-skip ultrasound beams to insonify the welds in jacket node joints;
- new developed prototype ACFM system, marinised sensors & techniques for automated robotic surface examination of sub-sea welds for fatigue cracks;
- new developed prototype LRUT system, marinised sensors & techniques for detection of corrosion in sub-sea oil & gas flow lines & export/import lines;
- ultrasonic marinised piezoelectric transducers tested for depth up to 450metres;
- new inspection head/transducer LRUT collar deployed by an ROV and validated to TRL6.

Although all these improvements provided significant advancements in weld inspection subsea, the present project SubCTestDEMO is more focused in underwater corrosion detection adopting previously developed LRUT underwater technology that may be developed to a more robust unit as well as a new technology development using Electromagnetic acoustic transducer (EMAT) for local circumferential scanning in a tubular section.

SUBCTEST CONCEPT

As previously mentioned, this SubCTestDEMO project has been conceived by the SMEs with the intention of exploiting a new market with potential for huge growth – NDT for offshore subsea structures, by using part of the technology already developed in SubCTest project and to deploy that technology at depths down to 100 meters. The SubCTest technology may as well be very useful in the shallow part as we call the splash zone, from + 10 meters down to – 30 meters.

The SubCTestDEMO project will allow the SMEs to demonstrate and validate their system for the purposes of establishing a lead in this emerging market and, in addition, provide NDT services and components to oil/ platform operators. The SubCTestDEMO project will use an already developed LRUT prototype as background and will develop a new NDT EMAT system, both to be deployed by a commercial ROV work-class C.

This project proposes to use the LRUT technique for long range corrosion detection on a 12" nominal size pipe, complemented with a new system based on EMAT technology, for more focused corrosion assessment. The EMAT technique was investigated in the previous project, but was not implemented.

In following Figure 2 the TRLs (Technology Readiness Levels) of the components of the LRUT inspection manipulator are presented.

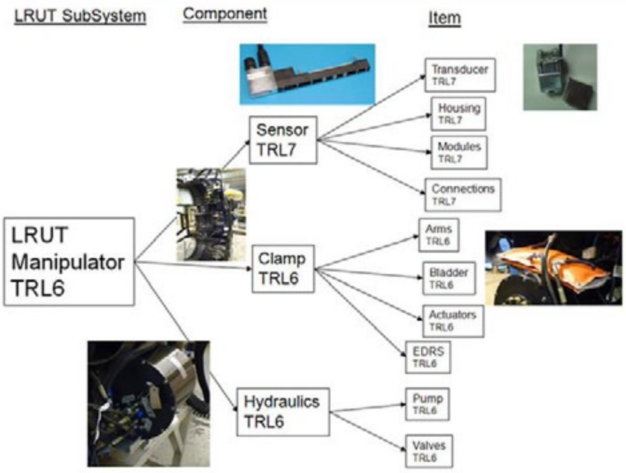


Figure 2: TRL of LRUT inspection manipulator

SubCTest Demo, will demonstrate a robust NDT system that will reliably inspect a variety of sub-sea structures, including jacket braces and nodes, risers, flow lines and mooring chains. Validation of the LRUT and EMAT manipulator systems (clamping and scanning respectively) will be demonstrated and an analysis of the accuracy achieved will be conducted in real subsea environment at the end of the project. Validation procedures will test both the reliability and robustness of the NDT system within prescribed offshore structures.

SUBCTESTDEMO TECHNOLOGIES

As stated before, the developed underwater NDT prototype uses two distinct NDT techniques: the first, a clamping manipulator integrating LRUT techniques to perform long range defect detection and the second, a scanning manipulator integrating EMAT techniques to perform local corrosion detection. In the following subsections the two techniques, LRUT and EMAT are presented respectively.

LRUT SYSTEM

The LRUT transducer clamping manipulator will be used for long range inspections on 12" pipe using guided ultrasonic torsional waves. This system was specifically developed for detection of corrosion in jacket support structure legs, cross members and flow lines. When in position, the LRUT transducer ring generates an ultrasonic wave that propagates down the pipe for several tens of metres in either direction. Corrosion/erosion or significant weld defects cause the emitted ultrasonic pulse to be reflected back to the transducer ring that then enables the extent and axial/circumferential position of the defect to be determined.

The LRUT clamping manipulator is already fully developed, as you can see in Figure 3 and was deployed for underwater trials and tested using an observation class ROV (from DACON AS) system, see Figure 4. This technique is at TRL6 targeting to reach a higher TRL with this current SubCTestDEMO project.

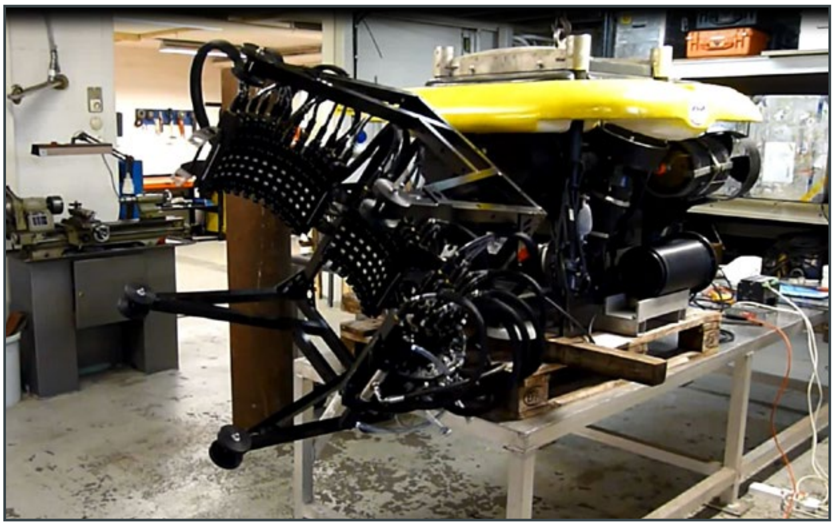


Figure 4: LRUT clamping manipulator deployed for underwater using an observation class ROV system (from DACON AS)

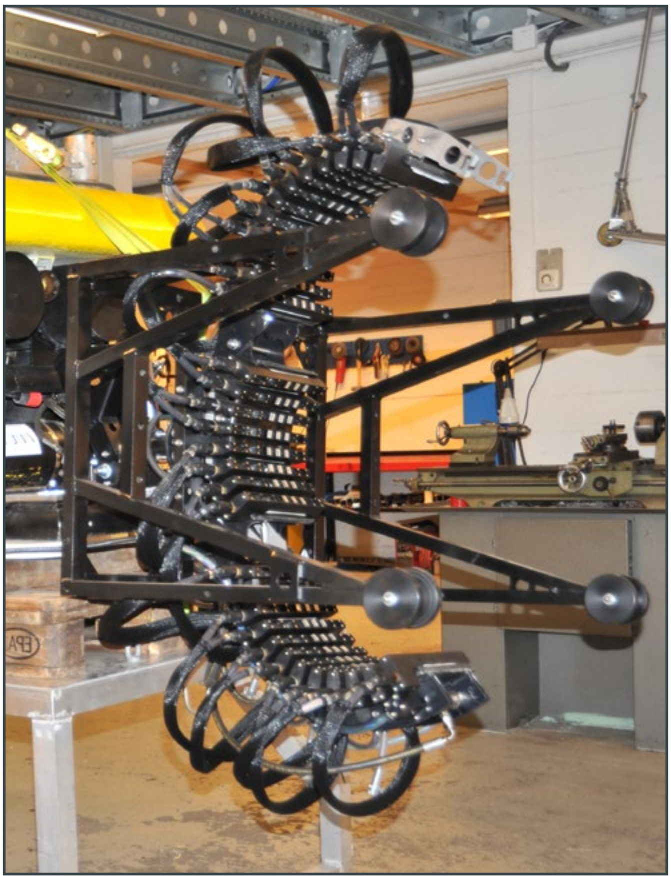


Figure 3: LRUT clamping manipulator

The LRUT technology used is a marinised version of the LRUT collar used in the commercially available LRUT equipment as seen in Figure 5, from Plan Integrity Limited; namely 'Teletest Focus'. This was the first commercially available system to utilise long-range guided wave ultrasonic testing for detecting corrosion in pipelines. The technique therefore has proven reliability.

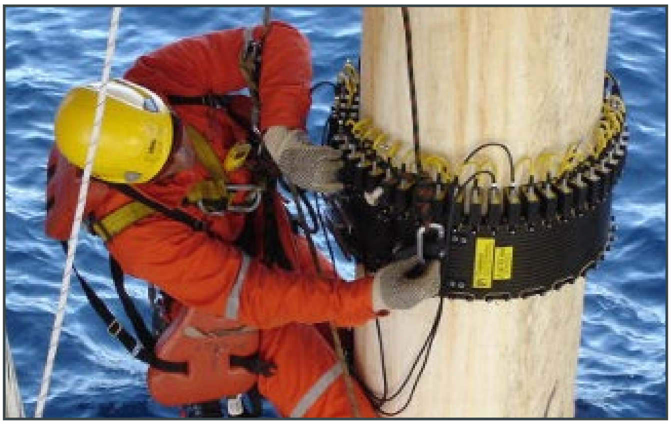


Figure 5: Plan Integrity Limited, Teletest Focus application

The most significant difference on this new system is the marinised version of the shear acoustic transducers which have been developed specifically for underwater applications, Figure 6.

Figure 6: Marinised acoustic shear transducer

The principal defining parameter of the LRUT clamping manipulator is the diameter of the pipe to be tested, following the oil & gas American National Standards Institute (ANSI) that was adopted to be a 12'' diameter pipe. Normally, a pipeline will be one diameter only, eliminating the need to change collar sizes underwater.

The next defining parameter for the LRUT clamping manipulator is the type of guided wave modes to be generated [8]. There is a choice of two:

1. Longitudinal waves (Figure 7 (a)) are generated by a forward-backward motion of the transducers along the pipe axis. By consulting the dispersion curves of velocity vs frequency available in literature for the specific pipe material-diameter-wall thickness combination, it can be shown that at the ultrasound frequencies being used (20-60KHz), two longitudinal wave modes exist, the L(0,1) and L(0,2). Two wave modes occurring together in the pipe leads to complications in signal interpretation. The L(0,1) is therefore suppressed, because it is more highly dispersive (velocity vary with frequency) than the L(0,2) wave. This is achieved by having an additional ring of transducers oscillating in anti-phase. On the other hand, signal resolution is good using longitudinal waves and the reflected flexural waves (F(1.3)) are relatively non dispersive.

2. Torsional waves (Figure 7 (b)) are generated by a forward-backward motion of the transducers around the pipe circumference. From the same set of dispersion curves, it can be seen that torsional waves are non-dispersive and within the ultrasound frequency range being used, there are no other torsional wave modes to interfere with signals. However the reflected flexural waves (F(1,2)) are relatively dispersive.

Torsional waves were selected for SubCTestDEMO and therefore the transducers are orientated circumferentially. The transducer modules allow the transducers to be removed and replaced axially, if L-waves are chosen as the preferred mode. Both wave modes require two sets of transducer rings around the pipe, working in anti-phase to destructively interfere with the wave propagating in the opposite direction to the forward test direction. The phasing is then reversed to propagate the waves in backward test direction. The longitudinal wave operation requires a third ring to remove the L(0,1) mode.

The installed software controls all settings, including finding the appropriate velocity on the dispersion curve, giving inputs about pipe material, diameter and wall thickness and setting the pulse delays for destructive or constructive interference with the given ring separation.

The final defining parameter is the pressure that must be applied to individual transducers to be coupled ultrasonically to the pipe. This coupling improves with pressure up to a limit, but excessive pressure can cause damage to the transducer, this value pressure can be easily tuned with the experience of the operator.

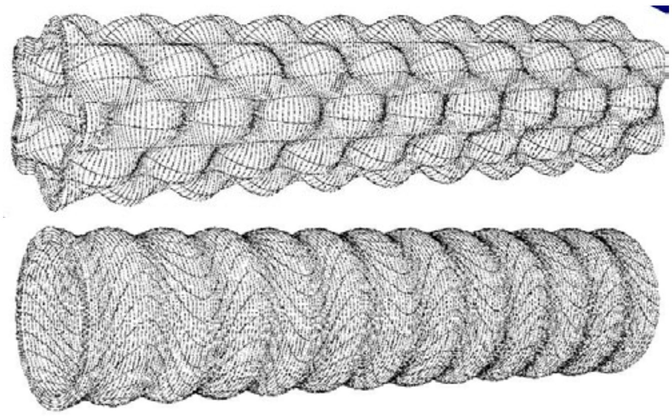


Figure 7: guided wave modes: (a) [above] Longitudinal waves and (b) [below] Torsional waves

EMAT SYSTEM

The EMAT scanning system to be deployed in a ROV workclass C will represent a first attempt for this type of technology. The marinised versions of these periodic permanent magnets (PPM) EMAT transducers are currently in progress and very small deviations are expected from the results obtained to their commercial available solution. In Figure 8 the experimental setup adopted for a non marinised version is presented. This system will be used to complement the LRUT system to perform circumferential scanning in small sections of the 12'' pipe length, around 100 mm wide.
The primary aim of including an EMAT to complement

the measurements performed with the LRUT collar is to provide a method to evaluate with accuracy the detected defect by the LRUT. This will require moving the EMAT sensors to the position of the LRUT indication in order to scan them with the EMAT.

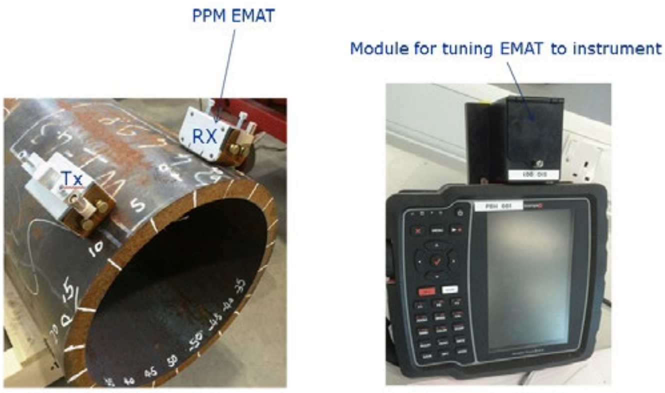


Figure 8: Experimental setup for corrosion defect detection with PPM EMAT sensors

The EMAT system presented is a commercial inspection system from Innerspec Technologies.

Some advantages of these EMAT sensors are:

- good sensitivity to corrosion losses on both internal and external diameters of the pipe;
- no contact needed with the surface to perform the inspection, allowing inspection through light rust, scale and various coatings;
- sensor can be marinised without losing considerable sensitivity, good for underwater application;
- allows inspection of irregular surfaces;
- can be used to inspect most ferrous and non-ferrous metals.

A commonly used method of evaluating pipe corrosion is to use Lamb or Shear Horizontal (SH) waves that are propagated circumferentially around the pipe. For circumferential propagation, the test range is relatively short, just over 1m for a 12" AINSI schedule pipe, allowing higher frequencies, 100KHz to 500KHz to be used with greater resolution for evaluating indications.

The Lamb waves are dispersive, that is to say their phase and group velocities are different and vary with frequency. Interpretation of A-scan signals becomes difficult and also shows the presence of a Shear Horizontal (SH) wave, the fundamental SH0. This is not dispersive.

The technique for using the SH0 waves will use two PPM type EMATs, one for transmit, the other for reception. These will be placed on one side of the pipe. There will be SH0 wave pulses travelling in both directions from the EMAT, each giving rise to a possible reflection signal from a discontinuity.

There will also be two through transmission signals from the pulse propagating directly from the transmitter to the receiver; one taking the short path, the other taking the long path. If these discontinuities are on the diametrically opposite side of the pipe, the reflection signals will coincide with the transmitted signal. The two can be distinguished by either moving the transmit to receive EMATs further apart or moving them 90 degrees around the pipe.

According the technical description of the EMAT system, their scanning manipulator system needs to be finalized to proceed with further sensitivity assessments and real test conditions.

LRUT UNDERWATER PROTOTYPE

As presented above, the LRUT clamping system is fully developed and ready to deploy in a commercial work-class C ROV, Figure 9. The LRUT manipulator is in the form of a bracelet, with a mechanism to clamp the rings of the LRUT transducers down and around the pipe, once they have been positioned by the ROV.

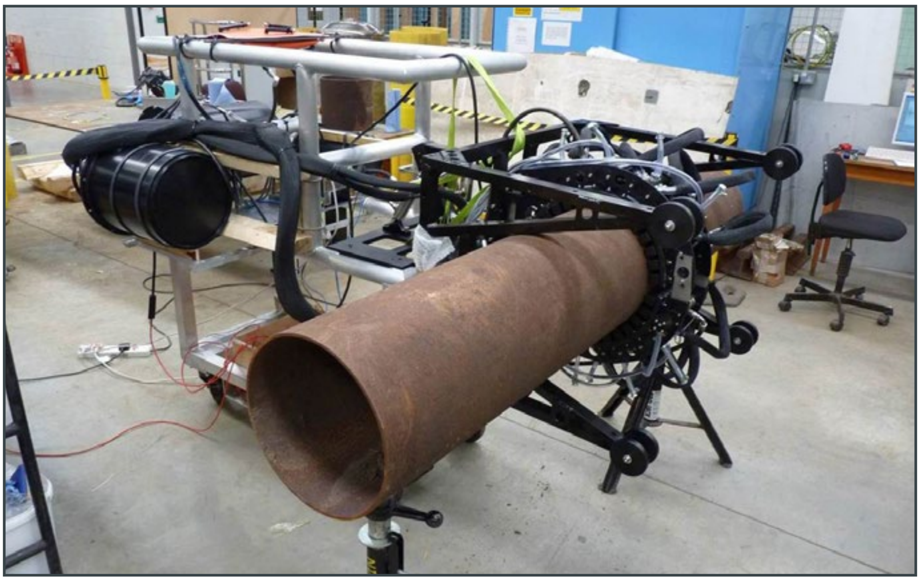


Figure 9: LRUT clamping system, mounted in a testing frame

The fully developed LRUT clamping system will integrate all the systems needed for operation after positioning by the ROV on to the pipe.

The subsystems existing in the LRUT clamping are listed as follow:
- NDT collar – with marinised sensors for LRUT inspection;
- Hydraulic system – with own hydraulic pump and valves allowing to the manipulator to rotate, close, lock and inflate collar;
- Electronic pod – containing all electronics needed to perform the inspection, controls and a computer with all the software's regarding the already mentioned systems.

The operation of the LRUT system is almost independent to the ROV, needing only an Ethernet communication line to connect to the surface and a low voltage power supply for electronics and pump.

All the features mentioned for this system make this underwater NDT prototype a competitive tool, easy to use and suitable for installation on a range of underwater vehicles, including commercially available ROVs.

SYSTEM OPERATION

The eventual LRUT operational procedure will need to be integrated with the ROV. It is normal for a training exercise to take place before the inspection, which might be completed within an ROV simulator. The ROV pilot will be in charge of the operation at all times, with the LRUT test operator following his instructions.

With regard to the integration of the LRUT and EMAT procedures, the latter is for evaluation purposes only. LRUT is able to detect anomalies in the pipe wall over test ranges of up to 50-60m either side of the transducer collar and locate them to within ±100mm. However, LRUT is unable to identify the type of anomaly, which may be corrosion, erosion, dents, cracks or any other discontinuity. As the auxiliary NDT method to evaluate accurately the defect, the prototype uses the SH-wave method, created using EMATs. The EMAT system allows the operator to perform small region scanning complementing the results obtained from the LRUT clamping system that covers large regions. The EMAT system will able to cover circumferential scanning sections approximately 100mm in width.

Regarding the defect evaluation procedure the SH-wave relies on a comparison of signal from unknown defect in the pipe with known machined reflector in a reference pipe. This known machined reflector may be a machined flat to represent corrosion, or groove to represent a crack, or side drilled hole to represent a pit. The use of reference pieces for calibration is standard practice in ultrasonic NDT. In practice, the design of reference pieces must follow an engineering critical assessment of the pipeline to establish the critical defect types and sizes and therefore the size and nature of implanted reflectors.

FUTURE FINAL TRIALS

The final SubCTestDEMO trials envisage demonstrating the operational system in real environmental and operation conditions before the end of the project. These final trials will take place during the middle of 2016 in the shores of Loch Linnhe, a sheltered sea loch in the west highlands of Scotland. The loch has many features which mean that the testing environment is close to what can be found offshore.

Figure 10: Loch Linnhe photo

The sea loch bed hosts numerous wrecks and structures – several sunken army vehicles, a concrete inspection block and an oil platform frame replicate. These features are at depths of around 20m just off the pier. The loch drops to depths of 100m and 150m within around a mile.

Parameters	
Maximum depth	150 m
Temperature	6-11 °C
Flow rate	0-2 knot (0.5-1 m/s)

Table 1: Loch Linnhe features

CONCLUSION

This paper has presented a new underwater NDT tool inspection based on LRUT and EMAT technologies for pipes and tubular structure inspections. The successful implementation and exploitation of this new tool will be crucial to the oil & gas industry regarding the underwater assessment of structural integrity. This will play an important role between end-users and customers allowing them to perform inspections in deepwater, with low human risks and decreasing their cost operation for strategy of structural integrity.
The LRUT clamping manipulator has been fully implemented and ready to be deployed with commercial work-class C

ROV. To complement this system, which can detect a defect in the range 100 m but with low resolution, a new scanning inspection system continues to be developed. This new system based on EMAT technology will allow the inspection tool to scan the defects circumferentially and around 100mm in pipe length with higher resolution.

The improvements presented so far promises great potential for the offshore sector.

SUBCTESTDEMO - RESEARCH FOR SMES

The present work is part of the SubCTestDemo project that aims to implement the technology demonstrated at the end of the preceding Research for SMEs project SubCTest. The purpose of the SubCTestDEMO project is to accelerate the pace of the technologies towards commercial maturity. The original project SubCTest, 'Development of novel Non Destructive Testing (NDT) techniques and autonomous robots to be deployed by Remote Operating Vehicles (ROVs) for the sub-sea inspection of offshore structure welds' was submitted in the call FP7-SME-2001-1 Research for the Benefit of Small to Medium Size Enterprises (SME's) and received the grant agreement number 222174. The new SubCTest-DEMO is a two year project started in October 2014. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 605969.

References

[1] - HSE, Hazardous Installations Directorate - Offshore Division. Structural Integrity Strategy, Rev.1 September 2005;
[2] - Lessons learned from offshore design in the North Sea. www.dnv.com;
3 - International Herald Tribune, Disabled North sea oil divers win compensation case against Norwegian Government, 10 August, 2007;
4 - Long Term Effects of Diving - Neurologic Effects, www.medscape.com/viewarticle/408486_8;
5 - US Coast Guard Pollution Incident Statistics, www.uscg.mil/hq/gm/ncm/response/stats/Summary.htm;
6 - Council Directive 92/43/EEC, 21st May 1992 'Conservation of natural habitats and of wild flora and fauna', last update 8th July 2003;
7 - BP Marketing Report, 2005;
8 – G. Edwards, Detection of corrosion in offshore risers using guided ultrasonic waves, 6th International Conference on Offshore Mechanics and Arctic Engineering, OMAE 2007, San Diego, California, 10-15 June 2007.

Authors

Dr. Yoann Eras Lage
TWI Ltd.
Project Leader
Condition and Structural Monitoring
yoann.lage@twi.co.uk

Graham Edwards
TWI Ltd.
Consultant
Condition and Structural Monitoring
graham.edwards@twi.co.uk

Børre A. Børretzen
Dacon AS
Managing Director
Borre.Borretzen@dacon.no

Dr. Slim Soua
TWI Ltd.
Section Manager
Condition and Structural Monitoring
Slim.Soua@twi.co.uk

Dr. Tat-Hean Gan
TWI Ltd.
Business Group Manager
Integrity Management Group
tat-hean.gan@twi.co.uk

DISSECTION AND ANALYSIS OF RETIRED FLEXIBLE PIPES – KEY FINDINGS AND LESSONS LEARNED

Damir Tadjiev > Wood Group Kenny UK Limited

ABSTRACT

As part of the recent field infrastructure upgrade project on one of the deep water developments, all flexible risers and a number of flexible jumpers have been removed from service. Five riser sections and one jumper section, which had been in service from 10 to 15 years, have been dissected onshore to investigate the condition of different layers to gain a better understanding of in-service degradation mechanisms. Since some of the risers were damaged in service, the dissections also aimed to confirm the condition of the layers in the vicinity of the damage locations. In addition, post-retirement testing of riser ancillary equipment, tethers and buoyancy modules, was carried out.

This paper discusses the key findings and the lessons learned, some of which are summarised as follows:

- Out with the areas of major outer sheath damage the layers of flexible pipes showed little degradation;
- The anti-wear tapes removed from the risers, which had been operating in a harsh dynamic environment, experienced little, if any, degradation. This was the case even at the fatigue hot spot locations, i.e. bend stiffener locations;
- Two gas relief valves from the jumper were found to be blocked with debris;
- When marine corrosion of the armour wires occurred it was found localised in areas of outer sheath damage. The extent of damage to the armour wires was more severe at the areas of high oxygen replenishment, i.e. bend stiffener locations;
- General corrosion of armour wires at the locations remote from outer sheath damage locations was found to be minimal (worst case implied 0.026 mm/year);
- Dissection findings for the flexible riser section which had a steel repair clamp showed that long steel repair clamps may not fully seal the damage location on a riser, especially if installed on a dynamic section;
- The post-retirement testing of the buoyancy modules and tethers showed little, if any, degradation, which suggests that ageing is not a concern.

The paper also includes a discussion on possible application of the findings from retired flexible pipe dissections.

Pipeline - Pipe - Sewer - Technology

Conference & Exhibition on Oil, Gas, Water and Waste Water Transportation in Africa, Middle East and South Asia

FIRST ANNOUNCEMENT / CALL FOR PAPERS

Cairo, Egypt

17-19 Sept. 2017

an EITEP event

Euro Institute for Information and Technology Transfer

Local Partner

AHK Deutsch-Arabische Industrie- und Handelskammer
German-Arab Chamber of Industry and Commerce
الغرفة الألمانية العربية للصناعة والتجارة

INTRODUCTION

Inspection of a flexible pipe and the associated ancillary equipment in service is normally limited to external General Visual Inspection (GVI) and Cathodic Protection (CP) survey. As a result, an ongoing integrity assessment for the majority of its layers has to be based on accepted degradation models. Dissection of a flexible pipe is a form of a post retirement inspection, which enables direct assessment of flexible pipe layers. It is undertaken following removal of a pipe from service due to failure, integrity concerns or as a result of field infrastructure modification works, with the purpose of:

- Investigating the cause of failure (pipe failed in service);
- Checking how the layers of a flexible pipe performed in service and comparing the findings against predictions and models used during the design (pipe removed from service).

In both cases the findings help inform any fitness for service assessment of the other pipes operating within the same field. In addition, if communicated to the flexible pipe manufacturer, dissection findings may enable improved design of new flexible pipes. Dissection findings can also be used for life extension assessment of flexible pipes operating under similar conditions [1].

Post retirement testing of riser ancillary equipment helps to understand degradation of the ancillary components in service. This paper presents the key findings and lessons learned from the dissection and analysis work that has been undertaken recently for one of our clients. The purpose of the work was to:

1. Gain a better understanding of in-service degradation mechanisms in flexible pipes;
2. Confirm the condition of the layers at the locations which had been known to be damaged in service;

In addition, post-retirement testing of riser ancillary equipment, tethers and buoyancy modules, has been carried out to determine if their performance has changed over time.

The findings of the dissection and analysis of flexible pipes as well as post-retirement testing of riser ancillary equipment may be of interest to those who are involved in integrity management of flexible pipes as well as flexible pipe manufacturers.

METHODOLOGY AND SCOPE

Dissection has been carried out on six test pieces, removed from four risers and one jumper as shown in Table 1. Each test piece was approximately 5-6 m long. Four riser test pieces were cut from the bend stiffener area. For two of the risers, locations of damage had been identified to be in the bend stiffener area when in service (R1 and R2). For the other two risers, locations of damage had not been known in service and the bend stiffener areas have been chosen because this is where the highest bending stresses occurred in service (R3 and R4). An additional test piece from the R2 riser was cut from the area which was damaged and clamped on installation (remote from bend stiffener region). For the jumper, the test piece was cut from the wellhead end because this is where the highest operating temperatures would have occurred in service (J1).

To facilitate dissection the test pieces were mounted on telescopic vertical jacks, with both ends strapped (see Figure 1). To aid recording of the findings every layer was marked with four reference lines along the pipe lengths; the lines were equally spaced around the pipe circumference and had distance markings. During dissection each layer was subject to visual inspection from inside and outside. In addition, a spot microscopic examination and mechanical testing were carried out for carcass and armour wires, while Corrected Inherent Viscosity (CIV) testing and cross profile measurements were carried out for the pressure sheaths. Microscopic examination aimed to quantify general corrosion (all dissected risers were flooded or partly in service), while CIV testing aimed to ascertain ageing of the PA-11 material. For the jumper, the scope also included vent port communication test and function testing of the gas relief valves (GRVs).

Figure 1: Mounting of Flexible Pipes for Dissection

Pipe (test piece)	Description of layers	Operating conditions	Background information
R1 10 inch production riser	316L carcass PA-11 inner and outer sheaths Carbon steel wires (sour rated) PA-11 anti-wear tapes	40-45°C 15 barg at LAT	10 years in service, annulus flooded to waterline for last 5 years (routine annulus vacuum testing)
R2 11 inch water injection riser	Duplex carcass PA-11 inner and outer sheaths Carbon steel wires (sour rated) PA-11 anti-wear tapes	25-30°C 180 barg at LAT	10 years in service, annulus flooded from day 1 (outer sheath damage near touch down), operated with failed bend stiffener for 1.5-2 years
R3 10 inch production riser	316L carcass PA-11 inner and outer sheaths Carbon steel wires (sour rated) PA-11 anti-wear tapes	45-50°C 15 barg at LAT	15 years in service, annulus partly flooded from day 1, bend stiffener partly replaced half way through service life
R4 8 inch production riser	316L carcass PA-11 inner and outer sheaths Carbon steel wires (sour rated) PA-11 anti-wear tapes	40-45°C 15 barg at LAT	15 years in service, annulus partly flooded for 7 years
J1 8 inch production jumper	316L carcass PA-11 pressure sheath Carbon steel wires (sour rated) PA-11 anti-wear tapes Insulation HDPE outer sheath	55-60°C 50 bara	15 years in service, relatively high operating tem-peratures when compared to the other production jumpers within the field.

Table 1: Summary of Test Pieces

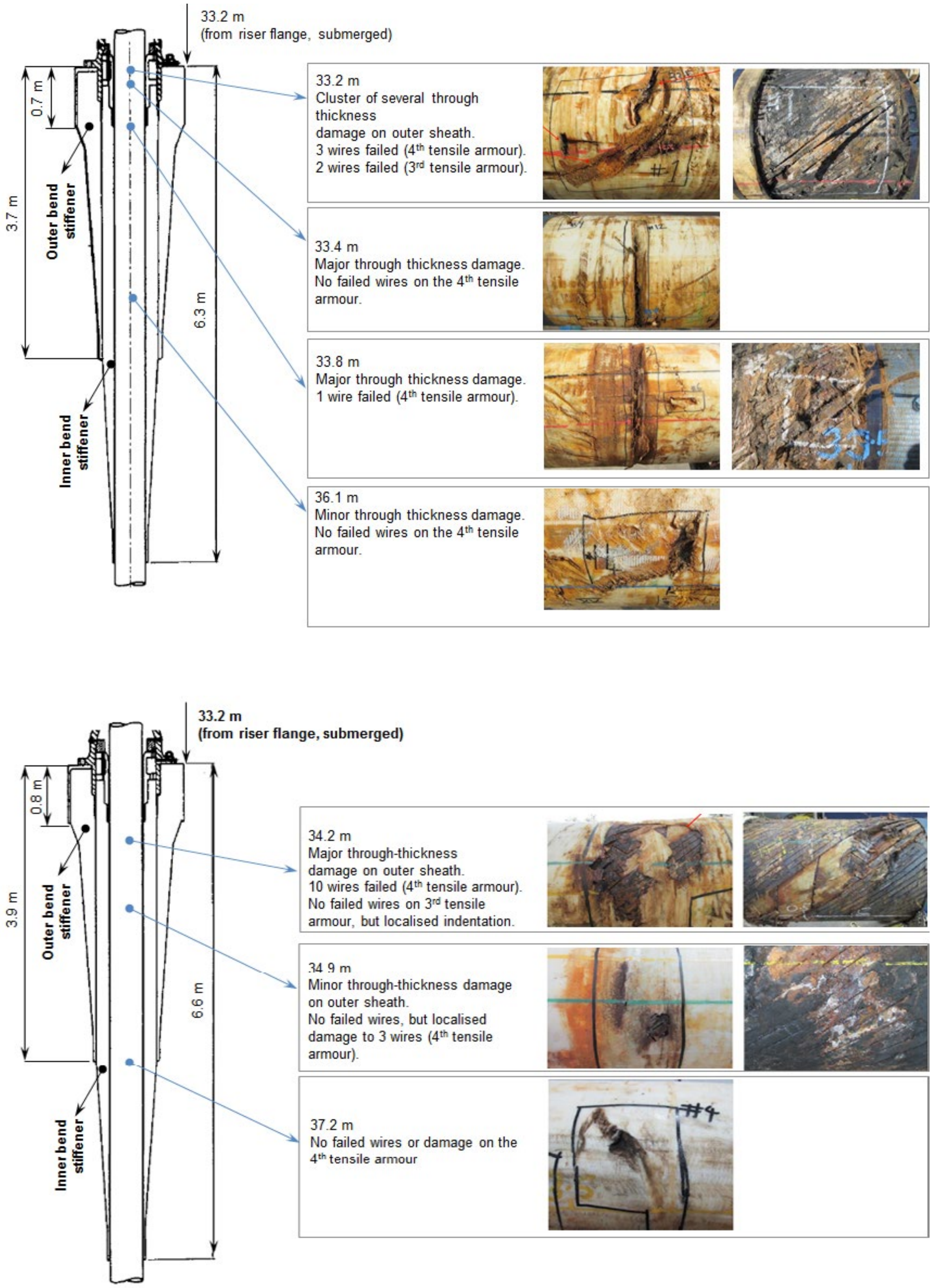


Figure 2: Mapping of Major Damage Locations on R1 (top) and R2 (bottom)

Post retirement testing of four buoyancy modules and a number of tethers has also been performed. For the buoyancy modules, the scope included visual examination, buoyancy testing, water absorption and hydrostatic crush test. For the tethers, the scope included visual inspection, full scale break testing (selected tethers) and internal examination of representative samples.

KEY FINDINGS AND LESSONS LEARNED

OUTER SHEATH

Major damage to the outer sheath was identified on the test pieces removed from the R1 and R2 risers, and this was of a mechanical nature, as shown in Figure 2. In both cases major damage was within the riser bend stiffener area but out with the fatigue hot spot location (tip of the outer bend stiffener in Figures 2 and 3). No damage was identified on the outer sheaths of the test pieces from the R3, R4 and J1.

The outer sheath damage on the R1 riser was identified in service by the routine riser annulus vacuum testing. The annulus pressure testing following the annulus vacuum testing suggested that damage was in the bend stiffener area, and visual examination of the outer sheath during dissection confirmed this to be the case. The damage is thought to have been caused by the failed bend stiffener monitoring system components (see Figure 3), which were known to have been compromised while in service.

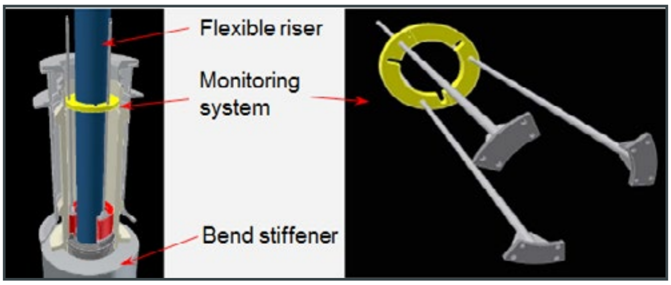


Figure 3: Bend Stiffener Monitoring System Components

The outer sheath damage on the R2 riser is thought to have been caused by the failed inner bend stiffener (see Figure 4), which lead to wear (abrasion) of the outer sheath against the outer bend stiffener and, consequently, exposing the outermost tensile armour layer to oxygenated marine environment. Microscopic examination of the wires showed some evidence of plastic deformation, which could have been due to excessive bending of the riser at the bend stiffener location following slippage of the inner bend stiffener. Slippage of the bend stiffener was identified during the routine GVI; however damage to the outer sheath was only identified during the dissection process. Routine annulus vacuum testing was not carried out through the service life of the riser (riser damaged on installation, see Table 1); however doing so would have identified the outer sheath damage at the bend stiffener area when it occurred.

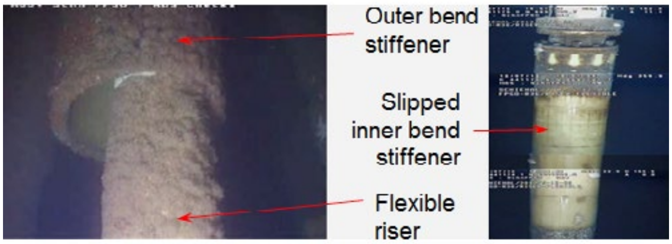


Figure 4: Slipped Inner Bend Stiffener on R2 (circa 150 meters below waterline)

ARMOUR WIRES

Significant corrosion and broken outer tensile armour wires were identified in the areas of major outer sheath damage on the test pieces from the R1 and R2, as shown in Figure 5.

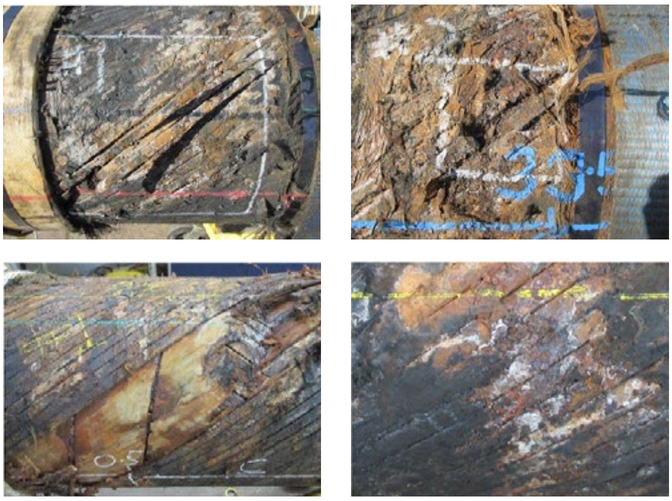


Figure 5: Major Outer Sheath Damage on the Outermost Tensile Armour Wires of R1 (top) and R2 (bottom)

In the areas remote from these locations, the armour wires were found to be in good general condition, with minimal general corrosion, as shown in Figure 6 (a and b). Similarly, the armour wires on the test pieces from the R3 and R4 (partly flooded) were found to be in good general condition, with little minimal general corrosion, as shown in Figure 6 (c and d).

Spot microscopic examination has been carried out on the wires removed from riser sections (all risers were flooded or partly flooded in service). This identified some pitting (see, for example, Figure 7). However, this did not exceed 300-325 microns, as shown in Table 2. The highest average wall loss, assuming surface roughness of a virgin wire at 20 micron, implied a corrosion rate of 0.026 mm/year (see Table 3). It is acknowledged that corrosion had not been linear – the data in the public domain suggests that it is high initially, but decreases over time due to the built-up of corrosion products (FeCO3) which form protective films [2]. It is also acknowledged that microscopic examination covered a limited surface area; however the measurements are consistent with the figures reported in the public domain for long term corrosion (0.015-0.025 mm/year [2, 3]). The wires from J1 were also examined, but minimal pitting was identified; since dissection findings indicated that annulus was not flooded in service, it is believed that pitting occurred due to annulus flooding when the jumper was cut subsea prior to removal.

In addition to microscopic analysis, an attempt has been made to quantify wall loss rate for the wires in the locations of major outer sheath damage. Considering that the damage on the R1 riser was identified 5 years before it was removed from service, complete loss of four wires on the outermost tensile armour (4 mm thick) occurred at an average rate of 0.8 mm/year (assuming loss at single surface). And, considering that the inner bend stiffener slippage on the R2 riser occurred 1.5-2 years before the riser was removed from service (damaged identified 1.5 years before, but last inspection showing no damage undertaken 2 years before), complete loss of the wires on the outermost tensile armour (5 mm thick) occurred at an average wall loss rate of circa 2.5-3.3 mm/year (assuming loss at single surface). For the R1 riser it was concluded that the main failure mechanism for the wires was marine corrosion exacerbated by highly oxygenated environment. For the R2 riser it was concluded that the failure mechanism was a combination of marine corrosion in highly oxygenated environment and wear/abrasion (against outer bend stiffener). The difference in the extent of outer tensile armour layer damage observed in the areas of major outer sheath damage on the R1 and R2 test pieces is attributed to the extent of outer sheath damage (smaller exposed area on the R1) and the difference in the failure mechanisms.

Industry experience shows that flooding of a flexible riser annulus leads to reduced fatigue life, especially for high pressure water injection and gas risers [4]. It is also known that the bend stiffener area is the most critical in terms of damage due to fatigue loading (i.e. fatigue hotspot). From the dissection findings for the R1 and R2 risers, where major damage was identified in the vicinity of the fatigue hotspot area, it was concluded that the most damage to the tensile armour wires occurred as a result of marine corrosion exacerbated by highly oxygenated environment. It was impossible to conclude on the extent of fatigue contribution on the failed wires due to the extent of corrosion. However, for both risers, it was concluded that the initial damage to the outermost tensile armour layers could have created initiation sites, which changed the fatigue failure mode from "crack initiation driven" as might be expected of undamaged wires to "propagation driven" with reduced fatigue life.

Flexible pipes are fitted with a CP system designed to provide protection from marine corrosion for the exposed armour wires in case of outer sheath damage. The dissection findings suggest that CP systems did not provide protection to the areas of major outer sheath damage on R1 and R2. This is likely to be due to the fact that both areas were remote from the locations of the anodes (circa 700 m) and "shielded" by the bend stiffeners.

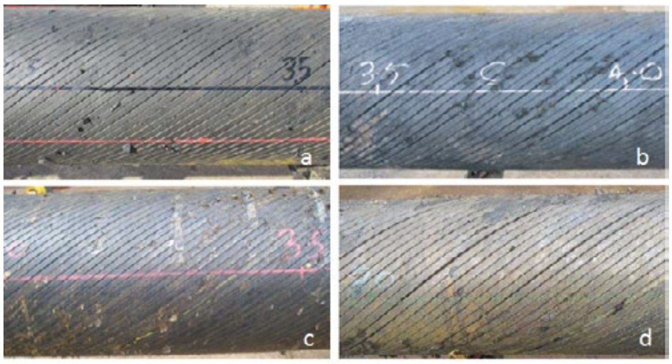


Figure 6: Outermost Tensile Armour Wires Remote from Areas of Outer Sheath Damage on R1 (a) and R2 (b), and Outermost Tensile Armour Wires on R3 (c) and R4 (d)

Sample	Maximum measured pit depth (micron) from spot microscopic examination[1]					No of samples examined
	Pressure armour	1st tensile armour	2nd tensile armour	3rd tensile armour	4th tensile armour	
R1	150	60	325	90	70	4
R2	85	85	80	200	80	4
R3	100	80	200	150	300	4
R4	70	60	70	80	70	4

Table 2: Summary of Microscopic Examination

1. Measured pit depth equates to maximum height between one peak and one valley consecutive.

Sample	Nominal wall thickness, mm	Measured wall thickness, mm	Height of "ridge", mm	Creep, %	CIV, dl/g
R1	7	7.5	10	-	2.10-2.19
R2	10	9.5	11.5	5	2.07-2.16
R3	7	7.5	11	-	2.00-2.11
R4	5.5	6.0	9.5	-	1.88-1.99
J1	5.5	6.2	10	-	1.39-1.67

Table 3: Summary of Calculated Wall Loss Rates

1. Corrosion rate calculated as (measured pit depth –surface roughness for new wire) / period with flooded annulus; where surface roughness for new wire was assumed at 20 micron as per the design documentation.

Visual inspection of the armour wires from the R2 riser area which was covered by a repair clamp in service showed moderate localised marine corrosion (see Figure 8). Corrosion was less severe when compared to that observed in the areas of major outer sheath damage (see Figure 5). The latter is consistent with the fact that the damage to the outer sheath was identified and clamped shortly after the occurrence (circa 1 month), and location of the damage was at circa 400 m below the waterline (i.e. less oxygenated environment). Considering that the repair clamp was fitted promptly, the observed corrosion under the clamped area suggests that the clamp did not fully seal the damaged location – presumably because the rigid clamp was relatively long and located on a dynamic section of the riser (near to touch down).

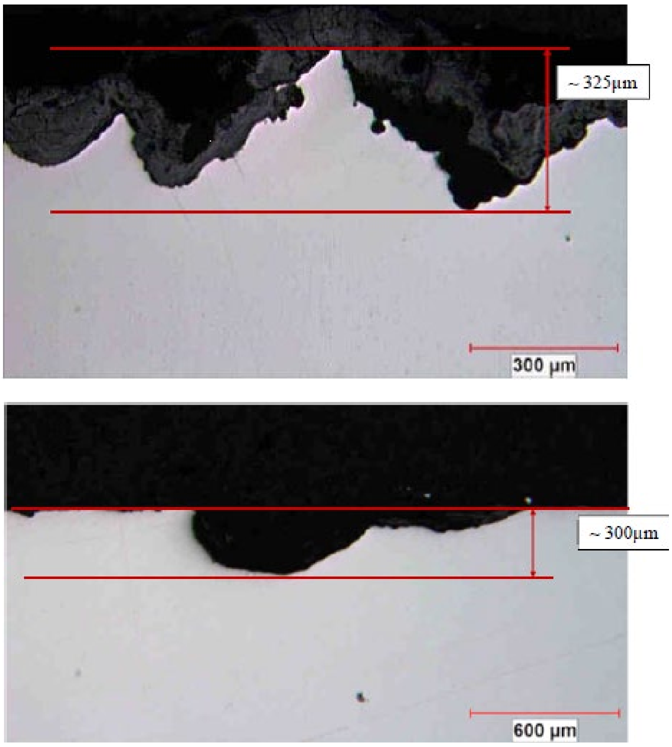


Figure 7: Examples of Pitting Measurements: 2nd Tensile Armour Wire from R1 (top) and 4th Tensile Armour Wire from R3 (bottom)

Figure 8: R2 Repair Clamp Area (Subsea)

RISER ANTI-WEAR TAPES

The anti-wear tapes on the test pieces from all risers were found in good general condition, with regular distribution and no signs of wear, as shown in Figure 9. This is despite the fact that the risers had been operating in harsh environment for 10 (R3, R4) to 15 (R1 and R2) years. Some damage was observed at the locations of major through thickness outer sheath damage on the R1 and R2 test pieces, but this was due to external factors rather than in-service degradation (see also Figure 2).

The annuli of the R1 and R2 risers were flooded to the waterline, while the annuli of the R3 and R4 risers were partly flooded when in service. During ongoing risk assessment of failure mechanisms, cracking was not considered to be a high risk due to the relatively low operating temperatures. Examination of the anti-wear tapes during dissection confirmed this to be the case.

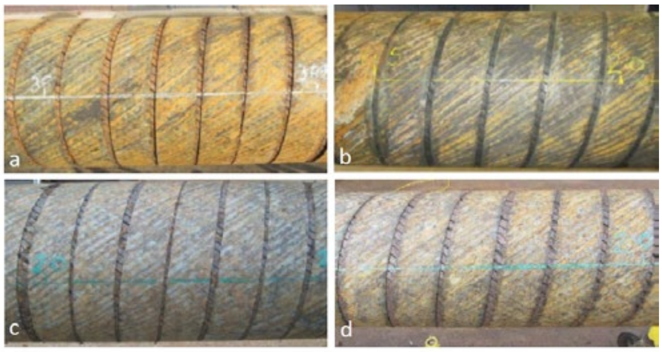


Figure 9: Outermost Anti-Wear Tapes of a) R1 b) R2 c) R3 and d) R4

PRESSURE SHEATH

Spot microscopic analysis identified no evidence of reduction in wall thickness due to creep for the pressure sheaths from production pipes, although minor reduction (5%) was identified for the pressure sheath of the high pressure water injection riser (see Figure 10 and Table 4). This is consistent with the fact that none of the pipes experienced pressures and temperatures out with the design limits when in service as well as the fact that the water injection pipe operated at relatively high pressures. As can be seen from Figure 10, during factory acceptance testing, the pressure sheath filled the gaps between the pressure armour wires forming "ridges", but this is a known phenomenon which has no effect on the performance of the layer in service.

From Table 4 it can also be seen that CIV tests showed minimal ageing for the pressure sheaths samples from the risers and some ageing for the pressure sheath sample from the jumper. This is consistent with the fact that the risers were subject to relatively lower temperatures when in service (see also Table 1). The results from the CIV tests were in good agreement with the in-service PA-11 ageing predictions undertaken in accordance with API 17TR2 [5].

Sample	Nominal wall thickness, mm	Measured wall thickness, mm	Height of "ridge", mm	Creep, %	CIV, dl/g
R1	7	7.5	10	-	2.10-2.19
R2	10	9.5	11.5	5	2.07-2.16
R3	7	7.5	11	-	2.00-2.11
R4	5.5	6.0	9.5	-	1.88-1.99
J1	5.5	6.2	10	-	1.39-1.67

Table 4: Pressure Sheath Analysis and Testing

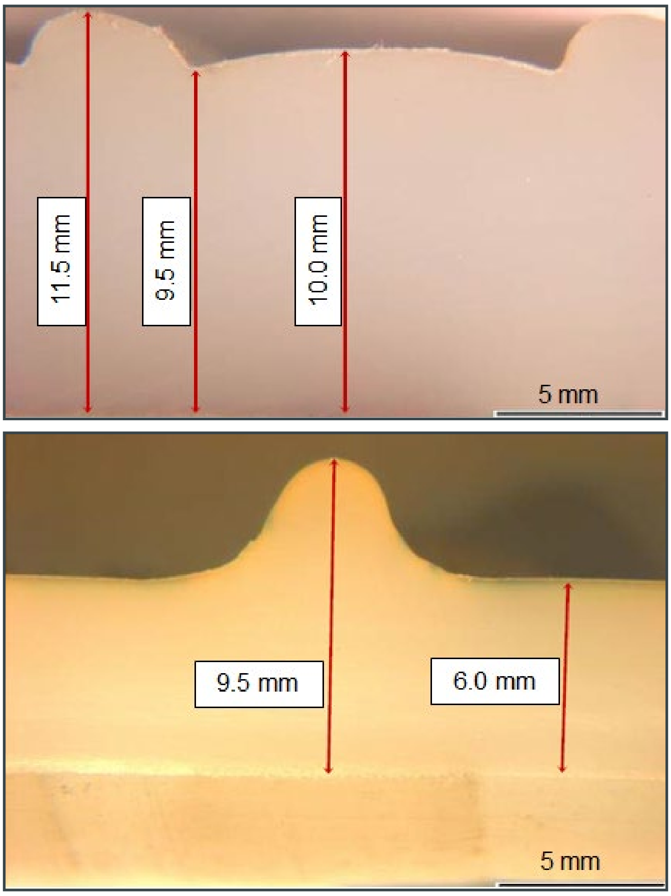


Figure 10: Pressure Sheath Profile from R2 (top) and R4 (bottom)

CARCASS

The carcass layer removed from all test pieces was found in good general condition with no damage observed. Some evidence of erosion was observed on the inner surfaces of the carcasses from production risers (see Figure 11), which was considered to be consistent with the sand levels and flowrates recorded in service. The absence of carcass defects is consistent with experience from similar riser systems in the North Sea [1]. A large number of carcass tearing and collapse incidents have been reported recently for the risers removed from offshore developments in the Norwegian sector of the North Sea [6]; they were associated with multilayer PVDF pressure sheath material, which was not used on any of the risers discussed in this paper.

Figure 11: Inner Surface of Carcass from R1 (left) and R3 (right)

SUMMARY OF DISSECTION FINDINGS

Summary of dissection findings is presented in Table 5. It can be seen that out with the areas of major outer sheath damage the layers of flexible pipes showed little degradation.

Significant corrosion and multiple failed outer tensile armour wires were identified in the bend stiffener areas of the two risers (R1 and R2). Although the outer sheaths at these locations were known to be damaged when the risers were in service, the failure of the armour wires was only identified after recovery and dissection of the risers. This suggests that, for a flexible riser with damaged outer sheath in the vicinity of a splash zone area (oxygenated environment), proactive integrity management requires consideration of an inspection technique that enables prompt identification of any wire damage or breakage (e.g. stress measurement).

JUMPER VENT SYSTEM

Vent port communication test has been carried out on the end-fitting from the J1 jumper. This involved removal of the GRVs, then connecting hoses with a supply of compressed air, as shown in Figure 12 (let). The cut surface opposite the end fitting was dosed in clean soapy water and then air was gradually introduced into the hoses (< 1 bar). Air bubbles started forming within 1-2 seconds, thus confirming communication between the vent ports and the jumper annulus, as shown in Figure 12 (right).

Figure 12: J1 Vent Port Communication Test: Hose Arrangement (left) and Air Bubbles Confirming Positive Communication (right)

The GRVs removed from the end-fitting were subject to pressure testing to confirm their functionality, and both failed to open (two tests, up to 4 bar and up to 6 bar maximum pressure, respectively). Further examination of the GRVs showed accumulation of debris, as shown in Figure 13. Accumulation of marine growth and/or soil in the GRVs of flexible pipes over time has been acknowledged by the industry [7].

The standard differential pressure setting for the gas release valve is known to be 3.0±0.5 bar. However, it is also known that, due to the manufacturing tolerance relating to the differential pressure setting for the valves, gas will only be released from one of the GRVs. Considering this and the fact that the last routine GVI did not identify any outer sheath damage on the J1 jumper, it was concluded that one of the two GRVs on the other end of the jumper was operational when the jumper was in service.

Flexible pipe layer Layer	J1 jumper (wellhead end)	R1 riser bend stiffener area	R2 riser clamped area (touch down)	R2 riser bend stiffener area	R3 riser bend stiffener area	R4 riser bend stiffener area
Carcass	• No unlocking • No pitting • No cracks or breaks	• No unlocking • No pitting • No cracks or breaks • Localised polished areas (external)	Out with the scope of work	• No unlocking • No pitting • No cracks or breaks • Localised polished areas (external) • No wear (internal)	• No unlocking • No pitting • No cracks or breaks • Localised polished areas (external) • No wear (internal)	• No unlocking • No pitting • No cracks or breaks • Localised polished areas (external) • Surface scratches (internal)
Pressure sheath	• Carcass rigidly held • No cracks • No creeping into pressure armour or carcass • No significant ageing	• Carcass rigidly held • No cracks • No creeping into pressure armour or carcass • No significant ageing	Out with the scope of work	• Carcass rigidly held • No cracks • No creeping into pressure armour or carcass • No significant ageing	• Carcass rigidly held • No cracks • No creeping into pressure armour or carcass • No significant ageing	• Carcass rigidly held • No cracks • No creeping into pressure armour or carcass • No significant ageing
Pressure armour	• No unlocking • Limited (general) corrosion • No pitting • No cracks or breaks	• No unlocking • Limited (general) corrosion • No pitting • No cracks or breaks	Out with the scope of work	• No unlocking • Limited (general) corrosion • No pitting • No cracks or breaks	• No unlocking • Limited (general) corrosion • No pitting • No cracks or breaks	• No unlocking • Limited (general) corrosion • No pitting • No cracks or breaks
Tensile armour	• No abnormal gaps or overlap • Minimal (general) corrosion • No cracks or breaks	• Major mechanical damage and significant corrosion at the locations of through thickness external sheath damage otherwise no cracks or breaks, no abnormal gaps or overlap and minimal (general) corrosion	• Moderate corrosion at one location of through thickness external sheath damage (outermost layer only), otherwise no cracks or breaks, no abnormal gaps or overlap and minimal (general) corrosion	• Major mechanical damage and significant corrosion at the location of major through thickness external sheath damage, otherwise no cracks or breaks, no abnormal gaps or overlap and minimal (general) corrosion	• Minor damage (dents) and minimal corrosion at 3 locations (outermost layer only). • Minimal (general) corrosion • No cracks or breaks • No abnormal gaps or overlap	• Minor damage corresponding to the location of through thickness external sheath damage (outermost layer only), otherwise no cracks or breaks, no abnormal gaps or overlap and minimal (general) corrosion
Anti-wear tapes	• Regular distribution • Good general condition	• Damage at one of the locations of through thickness external sheath damage (outermost layer), otherwise regular distribution and good general condition	• Regular distribution • Good general condition	• Damage at the location of major through thickness external sheath damage (outermost layer), otherwise regular distribution and good general condition	• Regular distribution • Good general condition	• Regular distribution • Good general condition
High strength tape	• No breaks or disorganisation • Good general condition • Localised staining	• Major damage and disruption at the locations of through thickness external sheath damage (outermost layer), otherwise no breaks or disorganisation • Localised staining	• Major damage and disruption at the locations of through thickness external sheath damage (outermost layer), otherwise no breaks or disorganisation • Localised staining	• Major damage and disruption at several locations (outermost layer), otherwise no breaks or disorganisation • Localised staining	• No breaks or disorganisation • Good general condition	• Minor damage corresponding to the areas of through thickness external sheath damage and comparatively large gasps between tensile armour layers (presumably due to armour layer relaxation at the pipe end) • Localised staining
Outer sheath	• Surface scratches/scuffs • No through thickness damage	• Numerous locations of through thickness damage • Surface scratches/scuffs • Staining from bend stiffener	• Two locations of significant through thickness damage, one of which was reason for clamping • Surface scratches/scuffs	• One major (full circumference) and two minor through thickness damage • Surface scratches/scuffs • Staining from bend stiffener	• Surface scratches/scuffs • Staining from bend stiffener	• One location of (minor) through thickness damage • Surface scratches/scuffs • Staining from bend stiffener

Table 5: Summary of Dissection Findings

Note: Green colour coding is used for the layers where no damage or degradation was identified, amber colour coding is used for the layers where some (minor) damage or degradation was identified and red colour coding is used for the layers where major damage or degradation was identified.

MECHANICAL TESTING OF WIRES

For each test piece, four wires from every armour wire layer were subject to tensile and hardness testing. The wires were tested in "as removed" condition (de-greased but not polished). Review of the test results showed mechanical properties comparable to those of a virgin material. This suggests that surface pitting observed on the wires (see Table 2) had no adverse effect on the mechanical properties of the wires. Recent studies show that the fatigue strength of the wires can reduce significantly as a result of pitting corrosion [8]. However, the effect of pitting on fatigue performance of armour wires has not been investigated as part of this work.

RISER ANCILLARY EQUIPMENT

The dominant long term threats related to buoyancy modules and tethers in service are reduction in buoyancy and ageing/fatigue, respectively [9].

All four buoyancy modules passed the water absorption test (<2% water absorption in 24 hours) and buoyancy tests confirmed sufficient buoyancy following 10-15 years in service (see Table 6). Successful hydrostatic crush tests as well as even distribution of macro spheres confirmed adequate design of the modules tested (see Figure 14).

From Table 6 it can be seen that the findings for the R1 module indicated buoyancy marginally below the specified buoyancy (7.5%). Considering that water absorption tests were successful, the latter is thought to be the result of a measurement error (modules were tested in half shells).

Visual inspection of the tethers identified some localised damage areas on the eye bearing points of some of the tethers (see Figure 15). Damage was concluded to be mainly service related (abrasion against bollard), although it might have been caused during handling of the tethers. Full scale tests showed break loads in excess of the specified minimum break loads for all tested tethers. Therefore, it was concluded that localised damage does not necessarily compromise the integrity of the tethers in service.

USE OF DATA FROM RETIRED PIPE DISSECTIONS

Findings from dissection of retired flexible pipes as well as the post-retirement testing of riser ancillary equipment can provide valuable input into life extension assessment of flexible pipes (see, for example, [1]). This is of particular importance when considering time-dependent failure threats, assessment of which for a pipe in service is purely based on the accepted degradation models and design assumptions. Such failure threats include:

- Erosion of carcass in production flexible pipes;
- Ageing of PA-11 pressure sheath in production flexible jumpers, especially when operating temperature exceeds 60°C;
- Creep of pressure sheath in high pressure dynamic flexible risers (bend stiffener area);
- General corrosion of armour wires in flexible pipes with flooded annuli;
- Fatigue of armour wires in dynamic flexible risers with flooded annuli;
- Wear and ageing of anti-wear tapes in dynamic risers;
- Vent system failure (blockage) in production flexible pipes;
- Ageing of buoyancy modules and tethers in service.

Riser	Net buoyancy per module (end of service life), kg	Measured buoyancy per module (seawater), kg	Period in service, years
R1	1167	1080	10
R2	1629	1637	10
R4	745	804	15
R5[1]	1160	1274	15

Table 6: Buoyancy Test Results
1. This riser was not dissected, but ancillary equipment was subject to post retirement testing.

Figure 13: J1 GRV Examination: Debris Contained within GRV (left) and Magnified Image of the Central Bore (right)

Figure 14: Distribution of Macro Spheres in R1 (Left) and R4 (Right) Buoyancy Modules

Figure 15: Damage at Soft Eye Bearing Points of R1 Upper Tether Clamp Tethers

Dissection and analysis of flexible pipes removed from service enables direct condition assessment of different layers, which improves our understanding of various in-service degradation and ageing mechanisms. Life extension assessment of a flexible pipe can particularly benefit from such data, because dissection findings can be used to challenge the conservatism applied at the design stage. Therefore, it is considered of significant benefit to consider dissection and analysis of flexible pipes removed from service as part of the ongoing Integrity Management Strategy of an operating offshore asset.

In addition, the findings from dissection of retired flexible pipes as well as post retirement testing of riser ancillary equipment may be used to improve design of new flexible pipe systems. However, the latter will be possible only if the findings, including information on the operational history throughout service life, are communicated to the flexible pipe manufacturer.

Finally, if shared in the public domain, the findings from dissection of retired flexible pipes can improve our understanding of how different riser systems behave when subject to different environment and operating conditions. Such information can also aid fitness for service assessment of the riser systems operating under similar conditions.

CONCLUSIONS

Out with the areas of major outer sheath damage the layers of flexible pipes showed little degradation.
For a flexible riser with damaged outer sheath in the vicinity of a splash zone area (oxygenated environment), proactive integrity management requires consideration of an inspection technique that enables prompt identification of any wire damage and breakage (e.g. stress measurement).

Routine riser annulus vacuum testing should be considered for the risers flooded to waterline, when damage location is remote from a splash zone area (subsea). Doing so will enable prompt identification of outer sheath damage in the vicinity of the splash zone area, where wall loss of amour wires can be significant due to the highly oxygenated environment.

The CIV values obtained from the direct assessment of PA-11 pressure sheaths correlated well with the API 17TR2 predictions. This suggests that ageing calculations can be used as a means of a proactive integrity management of internal sheath.

The post-retirement testing of the buoyancy modules and tethers showed little, if any, degradation, which suggests that ageing of such equipment in service is not a concern.

The findings from dissection of retired flexible pipes and post retirement testing of the riser ancillary equipment can provide valuable input into the life extension assessment of flexible risers. Therefore it is of significant benefit to consider dissection and analysis of flexible pipes removed from service as part of the ongoing Integrity Management Strategy of an operating asset.

NOMENCLATURE

CP	Cathodic Protection
CIV	Corrected Inherent Viscosity
GRV	Gas Relief Valve
GVI	General Visual Inspection
HDPE	High Density Polyethylene
LAT	Lowest Astronomical Tide
PA	Polyamide
PVDF	Polyvinylidene Fluoride

ACKNOWLEDGMENTS

The author would like to thank Mark Murray, John Picksley and Adrian Ledingham of Wood Group Kenny UK Ltd. for their valuable input during the preparation of this paper.
The author would like to thank Jeremy Allen, Chris Minton and Peter Jones of Minton, Treharne & Davies Ltd. for carrying out the dissections of the pipes.

References

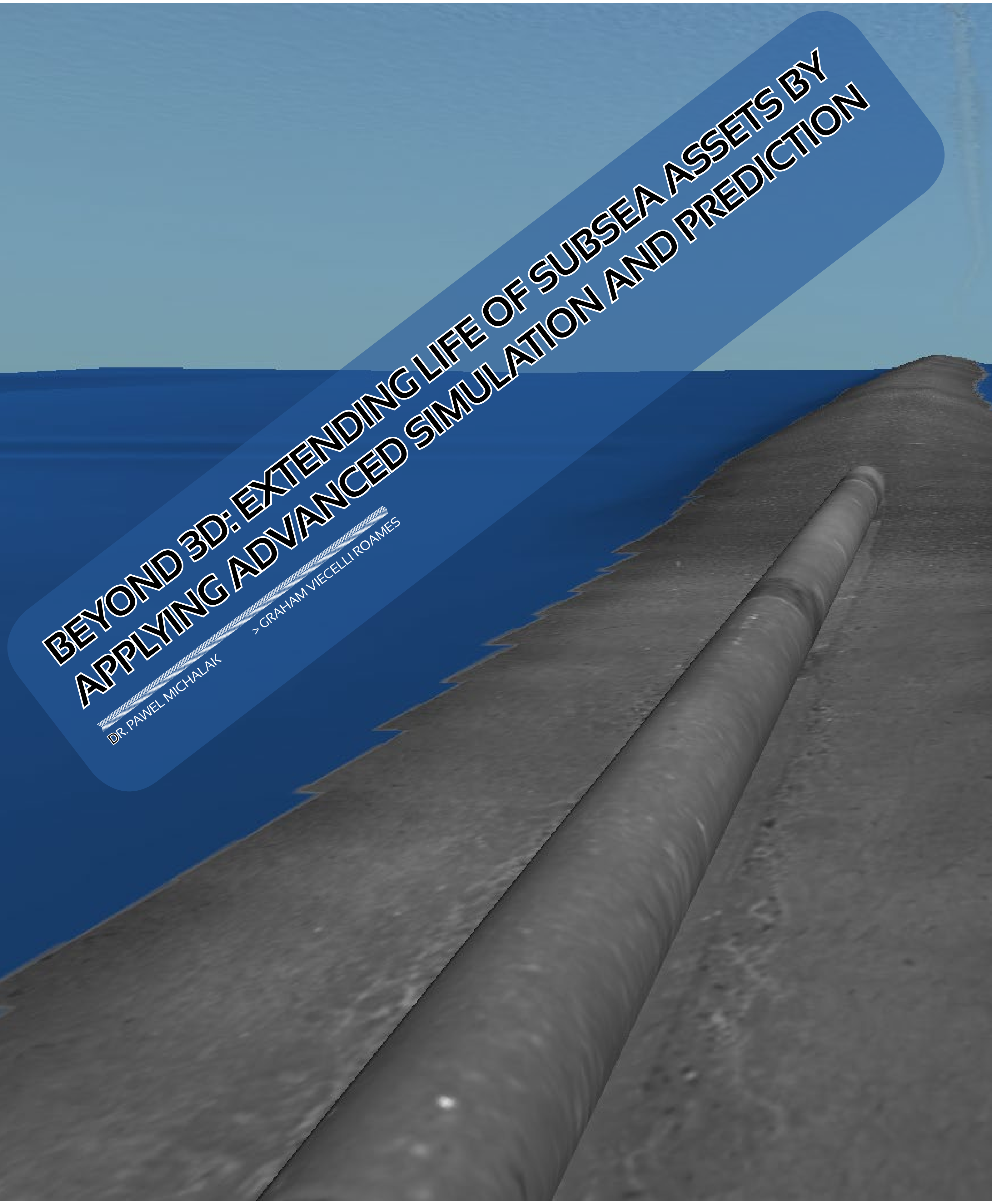
1. Damir Tadjiev "Life Extension of Dynamic Flexible Risers – A Case Study", presentation at the Pipeline Design and Integrity Seminar jointly hosted by SUT and The Hydrographic Society in Scotland, 17/06/2015.
2. Richard Clements "Corrosion Assessment Prediction for a Confined Flexible Pipe Annulus", Wellstream International Limited.
3. OMAE2003-37473: Clements R., Ethridge A. "Corrosion Testing of Armour Wire in Simulated Annulus Environments of Flexible pipelines - An update", Offshore Mechanics and Arctic Engineering 2003.
4. SureFlex JIP Report "State of the Art Report on Flexible Pipe Integrity", WGIM/MCSK Doc. No. 2-4-5-013/SR01, Rev. 02, 26/08/2010.
5. API TR 17TR2 "The Ageing of PA-11 in Flexible Pipes", 01/06/03.
6. OMAE2014-24154: Skjerve H., Kristensen C., Muren J., Søfferud M., Engelbreth K., "Findings from Dissection and Testing of Used Flexible Risers", Offshore Mechanics and Arctic Engineering 2014.
7. Riser End of Life JIP Report, Flexlife Ref. FLX-JIP-001, Rev. 03, 30/05/2013.
8. OMAE2015-41624: Leira B.J., Lotveit S.A., Berge S., Fergestad D., Langhelle N., "Qualified Assessment for Lifetime Extension of Flexible Risers", Offshore Mechanics and Arctic Engineering 2015.
9. API RP 17L2 "Recommended Practice for Flexible Pipe Ancillary Equipment", 1st Ed., 2013.

Author

Damir Tadjiev
Wood Group Kenny UK Limited
Lead Pipeline Integrity Engineer
Mail: damir.tadjiev@woodgroup.com

BEYOND 3D: EXTENDING LIFE OF SUBSEA ASSETS BY APPLYING ADVANCED SIMULATION AND PREDICTION

DR. PAWEL MICHALAK
> GRAHAM VIECELLI ROAMES



Abstract

As humans, we see the world as one, two or threedimensional. Many will recognize the fourth dimension (4D) as time, which while not measured in terms of Euclidean space can be represented by the detectable change in state of a given object between two points in time. In that sense we cannot see in 4D but as asset managers and operators we experience asset performance and risk implications from it, and in a geospatial context it is more commonly understood through the application of change detection. While 3D addresses the questions 'What is the object and where is it?', 4D asks 'How did it change?'.

Given the limitless potential of commoditized cloud computing, sophisticated deep learning computer algorithms, next generation data acquisition platforms, and access to the number of accurate realtime environmental data streams, we are now able to move subsea asset management into the fifth dimension (5D). This postulates all possible scenarios of change between two objects or locations. Now we are asking 'How could it change?'. Offshore pipeline owners can now optimize their IRM management strategy to meet certain cost or risk targets by simulating environmental conditions and performing a risk based analysis. This consequently leads to narrowing down the inspection program to high risk areas based on pipeline structural information, subterrain data, live metocean stream, fishery activities, shipping lines traffic etc.

Knowing the current status and predicting future behaviour of an infrastructure network is key to reducing the probability of failure. The method to realistically interpolate the state of assets between surveys and to reliably predict how assets and environment will change in the future is therefore of the highest importance. The onshore utilities benefit from 40% savings over traditional IRM methods (Sharma, 2016) when using these novel improvements. They also observe a corresponding reduction in the probability of failure and lead time for repairs and maintenance.

ASSET MANAGEMENT PARADIGM

Currently, traditional asset management practices and associated, offshore IRM activities are the primary mechanisms available to asset operators for ensuring the reliability of an infrastructure network. Managers perform inspection campaigns at discrete time intervals of varying regularity. They assign schedules according to the code, legislative requirements, and asset requirements based on past experience. Calibrated hysteresis models can predict the state of an asset and potentially reduce the frequency of inspections. However, not all infrastructure networks are maintained to the same degree of diligence, such advanced methods are costly and therefore uncommon.

Each inspection campaign collects a large volume of data capturing important properties of the asset and its surrounding environment. Detected anomalies or defects receive further assessment including engineering analysis such as fitness for service. If the anomaly or defect does not comply with code requirements, the structure may require repair or changes to the operating conditions. Those changes may depend on even further assessment such as flow assurance simulations. Importantly, each process/task occurs separately as discontinuous campaigns, potentially by separate engineering consultancies, each with specific, finite objectives. This can lead to inaccuracy in the assessment.

Integration of results from multidisciplinary teams or multiple consultancies directly impacts the quality of the overall solution. This occurs due to different data availability and handling practices for each discipline. Engineering evaluations heavily depend on the quality of the data. Unfortunately, in most cases only the bare minimum of data is available in order to, contradictorily, ensure asset safety and protect the intellectual property (IP). This leads to simplified assumptions that limit the usefulness of each outcome and present barriers to accurate engineering assessments. The effect of those assumptions reduces the accuracy of integrated problems involving complex crossdisciplinary tasks or multiple contractors.

Transforming the output of an engineering assessment into a costeffective solution for the client requires knowledge, experience, and skill. Engineering consultancies depend heavily on the ability of individual personnel to provide this. Long term and experienced employees have valuable prior knowledge of defect assessment and client specific data. They are required for identifying and extracting feature attributes. The quality of an engineering assessment depends on the collective competence of finite allocated personnel.

High quality engineering advice is only possible when the raw data and processing outcomes are available to all parties involved. Increasing the effectiveness of multidisciplinary solutions for complex infrastructure networks, therefore, depends heavily on the availability and sharing of data, which in turn has a positive effect on the reliability of the asset.

BALANCING COST AND RISK

Ensuring a low probability of failure begins with a robust design, followed by competent asset management and sufficient IRM investments through life. Industry members generally consider design codes and standards for offshore infrastructure as conservative. But failure statistics from operational oil and gas infrastructure, as reported by various organisations such as the International Association of Oil and Gas Producers (IOGP) (OGP, 2010) and Det Norske Veritas (DNV) (DNV, 2009), are not aligned with the nominal probability or the intention (OGP, 2014, Palmer, 2013) of the relevant design codes and standards (DNV, 2013).

A primary factor behind this discrepancy is that ensuring a low probability of failure is costly. When production becomes a higher priority than preventative maintenance or repair, higher levels of risk are perceived as acceptable and the number of failures increases.

The nominal probabilities for design are based on industry expertise iterated over many decades of experience, and "… are not intended to be compared to an annual probability of occurrence…:" (DNV, 2013). Instead, they express the inherent level of safety in the system. This is a misleading situation (Palmer 2013).

A connection between the level of reliability in a design and its corresponding reliability must exist during operation. Otherwise the reliability of a design cannot be honestly justified. Given their iterative origins, the industry must consider the nominal values as targets for assessing the effectiveness of operational IRM activities. The failure statistics alone indicate that the current IRM strategy is significantly underachieving the target reliability specified by the design. Loss of containment analysis provides a telling example.

A cursory analysis of loss of containment (spill events) for offshore oil and gas infrastructure in the Gulf of Mexico (BSEE, 2011: original data source: U.S. DOI/BOEMRE Oil Spill Database, February 2014) appears in Figure 1 and 2. Figure 3 breaks down the causes of failure. Regional government regulatory authorities (PHMSA, 2016) have comparable statistics for onshore oil and gas infrastructure.

These statistics demonstrate that while some improvements exist in safety and reliability, large scale lossofcontainment events continue to occur. They also reinforce the failure of conventional IRM to ensure the ongoing reliability of infrastructure during its operational life. The cost of failure (Gaddis, 2007) is potentially devastating for both asset owners and other stakeholders. These stakeholders include the environment and local populations. The current balance point in IRM activities needs to shift in favor of reducing the annual number of failures and their associated costs.

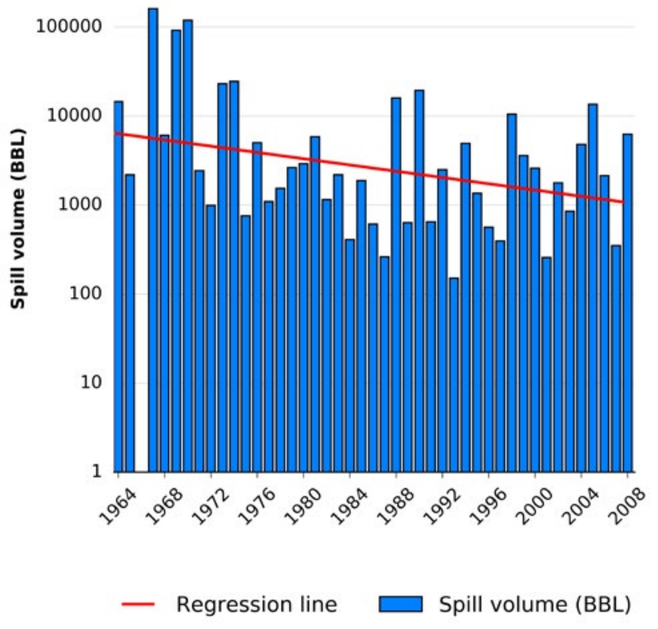


Figure 1: Spill volume for the Gulf of Mexico, 1964 2008 (BSEE, 2011)

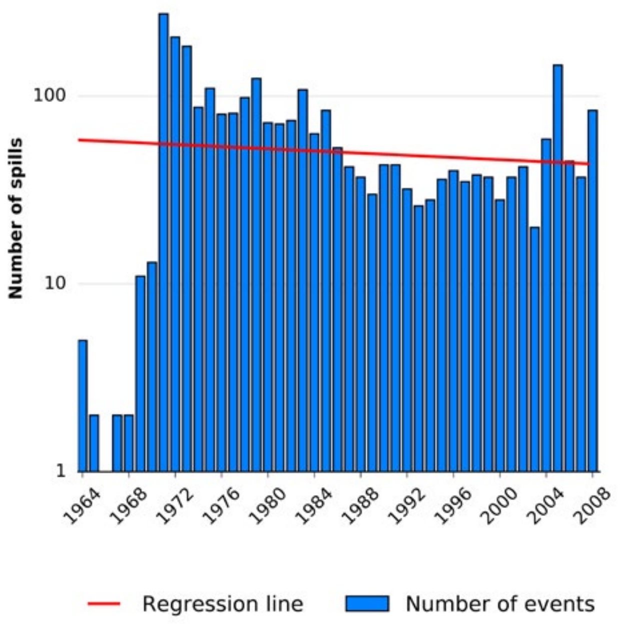


Figure 2: Spill incidents for the Gulf of Mexico, 1964 2008 (BSEE, 2011)

TECHNOLOGY CATALYSTS

In order to produce highly accurate advice, asset management and assessment need a continuous process. They must have available in its entirety, with adequate detail, the current status of an asset at all times. Indirect monitoring of assets, for instance, through predictive modelling and simulations safely reduce the required frequency of field inspections. This minimizes the number of expensive offshore campaigns.

Automation of data handling, processing, modelling and analysis add even further reductions. The onset of reduced cost cloud computing as a commoditized resource provides significant advances in online data storage and sharing. The cost of performing high volume computations is now trivial. It is especially so when compared to the cost of personnel. Leading edge applications operate on a central platform as external plugins. The plugins provide additional functionality to the core service through the use of Application Programming Interfaces (API). Taking full advantage of this technology is key to providing accurate engineering advice at significantly reduced cost.

Traditional restrictions placed on data sharing and data access can disappear (whilst still ensuring the highest security standards). External collaborators can now process data held in cloud storage through an API interface.

A single source repository protects and maintains the asset owner's IP and centralizes maintenance. This approach brings the most value in maintaining data availability through progressive stages of an asset lifecycle from design through

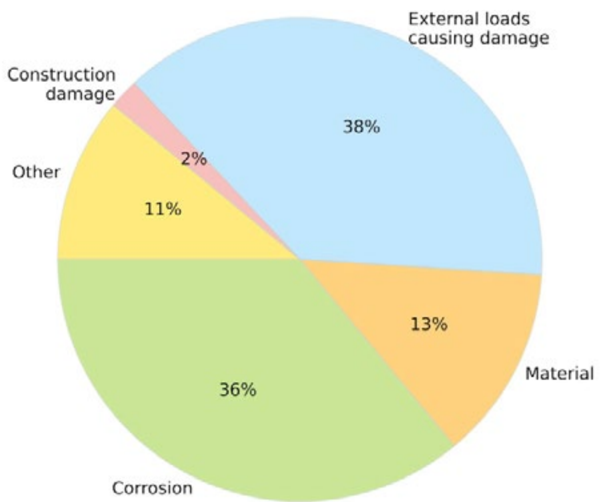


Figure 3: Cause of failure of offshore oil and gas infrastructure in the Gulf of Mexico (BSEE, 2011)

manufacture, installation and operation to eventual end of life. Progressive automation of data processing and modelling provides cost reductions in analysis. Detection and identification of anomalies and defects such as sandwaves, lateral buckling and freespans, dents, coating imperfections and anode depletion can also be made from sensor data without manual intervention.

By assigning realworld physics properties to the modelled assets and environment, accurately simulating the asset behavior under changing operational and environmental conditions becomes possible.

Figure 4: Raw pipeline images (AUV)

Processes higher up the value chain can also be automated such as engineering assessment of defects, alerts for remedial action, or further human assisted processing. Any higher level automated processes is subjected to manual review using known data, or training sets, prior to being trusted. Convergence is achieved once the confidence interval of an automated algorithm reaches and exceeds the equivalent manual process. This is possible because the algorithm provides a measureable improvement in accuracy. Assessment and improvement of the performance of an automated algorithm is a huge advantage, especially when applying computational neural networks (CNN).

ADVANTAGES TO ASSET OPERATORS

The outcome of a single source data platform integrated with automated data acquisition, handling, processing and analysis constitutes the ability to create a virtual embodiment of an asset of such fidelity that it can be used to monitor the asset in between scheduled inspections. Calibrated hysteresis models are updated in real time through a continuous improvement process with information from monitoring, regular external and internal inspection data as well as any available geophysical and geotechnical data. This leads to reduced uncertainty in the original inputs and increased accuracy of future predictions.

The dynamic behaviour of the asset against ongoing or upcoming events can therefore be assessed with a high level of confidence such that potential failures are identified before they occur.

For instance, a rupture due to high stress during a storm might be predicted based on expected metocean conditions resulting in a temporary shutdown and avoided loss of containment. The status of the asset during the storm may also be simulated in real time within a structural reliability assessment such that the risk of loss of containment following the storm is identified and available to the operator prior to continued operation. Such predictions can be used to identify regional assets of greatest risk following extreme events and hence coordinate inspection campaigns, ensuring that costly offshore operations are optimised.

Further benefits, such as life extension and operations flexibility, can be derived from a modelled asset. Once the model of an asset is available, it can be replicated in a testing environment where hypothetical changes to the operating conditions or environment are examined. Changes to offshoreprocessing conditions such as temperature or pressure can be applied and their effect on the asset behaviour observed. Updates to local fishing and shipping activity can be visualised and the consequence of impact on the asset determined.

ROAMES PLATFORM

For industries that depend on reliable infrastructure, the key challenge is to maintain an ongoing understanding of the assets and the world around them. The described methodology (patent pending) already serves asset owners globally, as part of the Roames platform. The concept allows power utilities across Australia, the United Kingdom, and the United States to achieve 40% savings on traditional practices managing critical infrastructure using Roames. Predicting the response of an asset under changing conditions assists in commercial decisions such as a new subsea tiein or changes to production.

The entire lifecycle of an asset is modelled at any stage with different changes to the present and future processing conditions in order to extract the maximum useful life. Asset owners and operators can therefore optimise an asset for extended life, production or other economic drivers as required, based on the current market conditions. They can respond faster to changing market conditions, with increased operating reliability, reduced cost and reduced probability of failure.

Thanks to the open access philosophy, Roames serves as an asset assessment and management environment for infrastructure owners, engineering and consulting firms, and data acquisition companies.

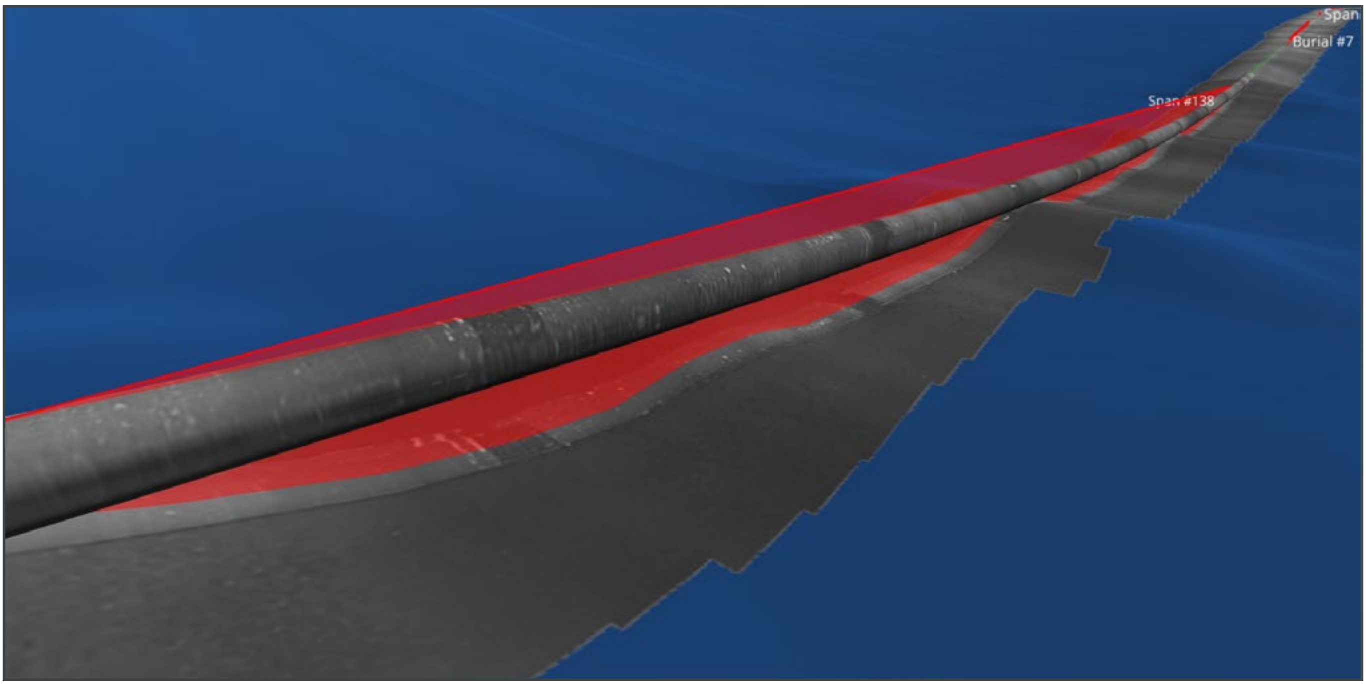


Figure 6: Web based Roames visualization of the physics enabled pipeline model created automatically using data collected using an AUV (location: North Sea)

References

BSEE (2011): All Petroleum Spills ≥ 1 Barrel from OCS Oil & Gas Activities by Size Category and Year, 1964 to 2013, 2011.
DNV (2009): Recommended failure rates for pipelines, DNV Reg. No.: 20091115, 2009.
DNV (2013): Offshore Standard DNVOSF101. Submarine Pipeline Systems, DNV, 2013.
Gaddis (2007): Fullcost accounting of coastal disasters in the United States: Implications for planning and preparedness, Ecological Economics, pp. 307318, Vol. 63, 2007.
OGP (2010): Riser and Pipeline Release Frequencies: Risk assessment data directory, OGP report 434 No. 4, 2010.
OGP (2014): Workshop proceedings. Reliability of offshore structures Current design and potential inconsistencies, OGP Report No. 486, 2014.
Palmer, A. (2013): 106 and all that: What do failure probabilities mean?, Journal of Pipeline Engineering, pp. 269271, Vol. 12, No. 4. 2013.
Perrons (2015): Data as an asset: What the oil and gas sector can learn from other industries about "Big Data", Energy Policy pp. 117121, Vol. 81, 2015.
PHMSA (2016): Pipeline incident 20 year trends, Pipeline Hazardous Materials Safety Administration, 2016.
Sharma (2016): Roames is game to boost STEM interest, The Australian, March 8th 2016.

Author

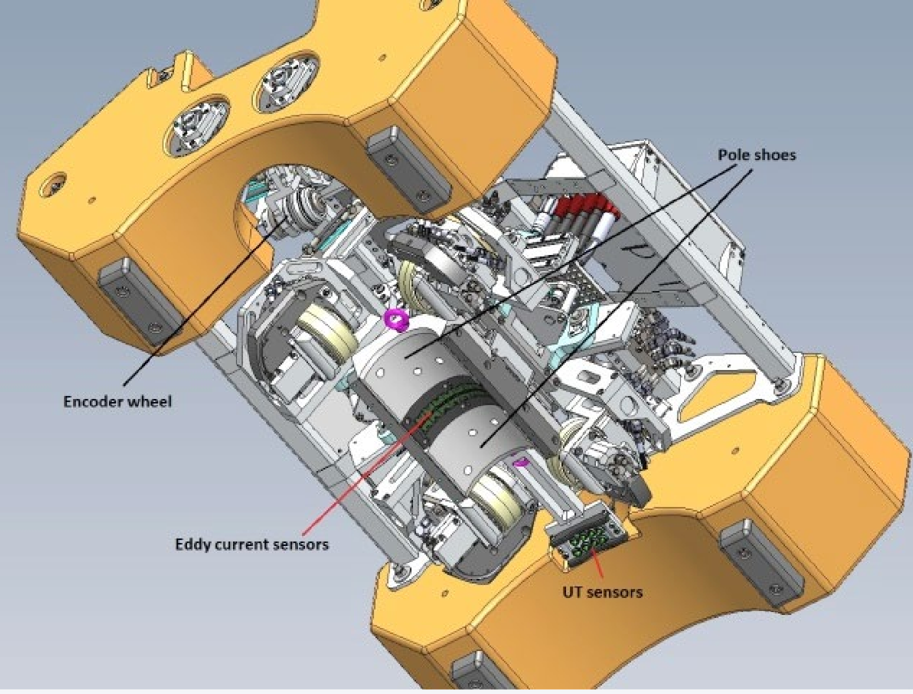
Dr. Pawel Michalak

Fugro Roames

Executive General Manager /

Global Product Manager

Mail: pawel.michalak@roames.com



INSPECTION OF SUBSEA PIPELINES WITH THE MEC™-COMBI CRAWLER

K. Reber, Innospection Germany GmbH
S. Hartmann, Innospection Ltd.
A. Boenisch, Innospection Ltd.

Abstract

The inspection of subsea pipelines in particular flow lines and gathering lines has recently moved into the focus of offshore integrity engineers. Contrary to most long-distance export pipelines many of these lines are unpiggable. While some of these lines can be inspected with tethered internal inspection tools the only inspections options until recently for the majority of lines were visual testing, CP-surveys and local defect monitoring. With the MEC™-Combi Crawler system it is now possible to gather integrity information to a level of accuracy that can be compared to in-line inspection, but is obtained by external scanning. This level of accuracy permits carrying out defect assessment based on the inspection data. It does not require any further verification as compared to general defect screening methods. Several case studies are presented that show how the MEC™-Combi Crawler is adapted to fit to the specific inspection task.

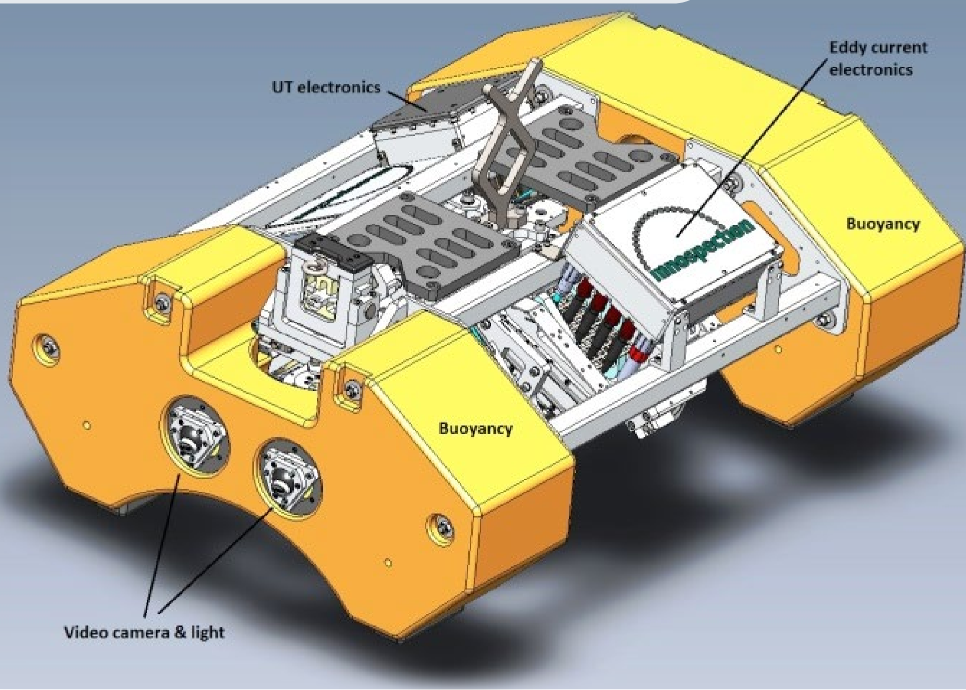


Figure 1: The MEC™-Combi Crawler tool for the inspection of subsea pipelines

DESCRIPTION OF THE MEC™-COMBI CRAWLER TOOL

The MEC™ Combi-Crawler pipe scanner is designed and built for high performance inspection applications that are tailored to a specific inspection requirement. It can be equipped with laser triangulation sensors to measure the profile of a pipe, with UT sensors to measure wall thickness and eddy current sensors for various applications.

The most versatile inspection technique is a combination of eddy current sensors with a DC-Magnetisation known under the name Magnetic Eddy Current technique (MEC™) or sometimes SLOFEC. With these technologies the pipe crawler allows for the detection of internal and external metal loss defects at a rather high scanning speed. Additionally the UT sensor array allows for a corrosion mapping of the covered area.

The scanner head with a MEC™ sensor array covers 180 mm circumferentially, meaning that a number of axial runs are to be taken with overlap to have 360° coverage of the full pipe. For a 6" pipe with ~200 mm diameter this would require four scans to complete the full 360° coverage. Several views of the tool are shown in Figure 1 and Figure 2.

The UT sensor array also consists of eight sensors. The sensors are staggered to allow for a closer circumferential sensor pitch. The distances driven are measured with an encoder-wheel both in axial as well as in circumferential direction. An umbilical is connected to the tool for supply of electrical and hydraulic power by the ROV. In addition the eddy current and UT signals are routed to a top-side data-acquisition system via the ROV umbilical.

Figure 2: The MEC™-Combi Crawler on site

MAGNETIC EDDY CURRENT

The idea of Magnetic Eddy Current (MEC™), which has been developed further from the SLOFEC-technique, is to carry out an eddy current inspection under the influence of a DC magnetic bias-field. Eddy current sensing is a traditional method for the inspection of metallic surfaces. Through the introduction of a magnetic bias field, the sensing coils are also sensitive to far-side defects. The idea is shown in Figure 3.

In the presence of a metal loss defect, the magnetization level changes also on the near-side at the defect location. This will lead to a change in the eddy current response, which can be calibrated to the defects size.

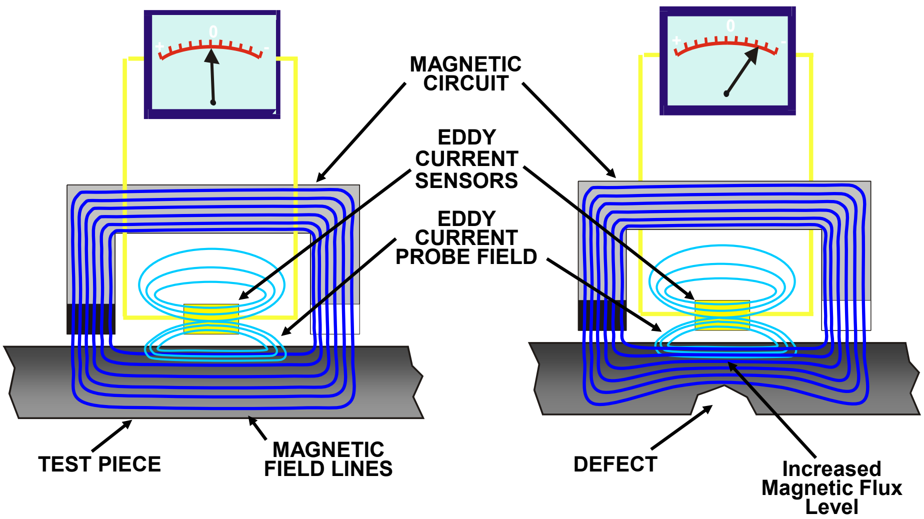


Figure 3: Principle of the MEC™ technology (Magnetic Eddy Current) also known as a further developed technique from Saturation Low Frequency Eddy Current (SLOFEC)

For near-side defects the method works as a traditional eddy current method.

Again as an eddy current-based method the interaction of the sensor with the pipe surface is via electromagnetic induction. The interaction principle works over distances depending on the relation of sensor size to coating thickness. Ferromagnetic layers would shield the sensing field, but thin conductive non-magnetic layers can be penetrated.

In principle an enlarged scaling of the sensor would allow for large distances between sensor and pipe surface. The distance from sensor to ferromagnetic surface is often also just referred to as "lift-off". At least for non-conductive material a coating would act just like an increased air-gap. This is of course the main big difference to ultrasonic testing.

CASE STUDIES

To illustrate the inspection technique and the deployment possibilities of the MEC™-Combi Crawler, a few case studies shall be presented. At Innospection Magnetic Eddy Current (MEC™) in combination with UT spot checks has been found to be an adaptable testing technology for the various tasks described above.

UNPIGGABLE SUBSEA PIPELINE

In this project the task was to inspect an unpiggable subsea pipeline. It was deemed possible that the pipeline suffered from top-of-the-line corrosion.

The MEC technology was chosen, because it is especially sensitive to localized pitting, also small pitting. Hence the focus was on the top position for inspection. The coating consisted of a 3-layer Polyethylene with a thickness of a few mm. Sections of several meters were to be inspected.

A rough cleaning had to be performed prior to inspection. The inspection tool is a modified MEC™-Combi Crawler. It is seen lying in front of a Work class ROV in the left of Figure 4. Again it is equipped with buoyancy to ensure no resulting torque is exerted on the tool when running on the pipeline. This allowed to tool to also run stable in the 11 and 1 o'clock position even without clamping arm.

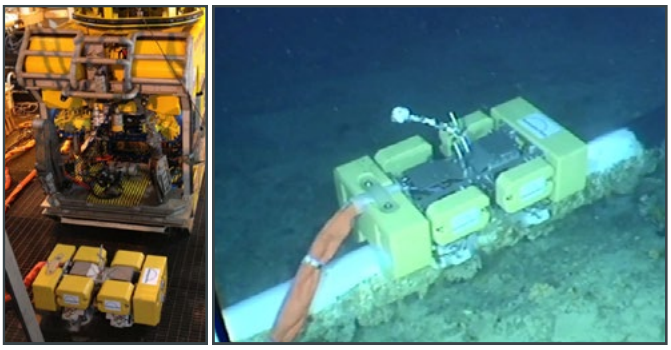


Figure 4: Left: the inspection tool (modified MEC™-Combi Crawler) lying in front of a work class ROV. Right: Tool deployed on subsea pipeline scanning over the pipeline

The right in Figure 4 shows the tool running on the pipeline performing an inspection using MEC™ and UT Wall thickness measurements. The tool remains connected with the ROV over an umbilical. The data is transferred through the ROV in real-time.

INSPECTION OF FLEXIBLE PIPE FLOW LINE

Often flexible pipe is used as flowlines for the ease of deployment. This pipe type cannot be addressed by ILI inspection not because of the piggability of the pipeline, but rather because of its structure. In principle this pipe type can also suffer from corrosion and cracking just like rigid pipeline. In some cases, however, it is not so much metallurgical defects that are of interest, but wire misalignment defects.

In a specific project the aim was to find wire rearrangement that has taken place underneath the outer protective coating. Wire misalignment is a potential integrity threat to flexible pipe, as the strength of the pipe is only given with a proper arrangement of all wires in all layers. The exact appearance of the wire structure was to be defined first, and then potential wire rearrangement defects were investigated in a test sample. In the end the effect of increased lift-off had to be understood.

The latter was important as the lift-off was not only increased because of the coating, but was also varying because of the curvature of the pipe. For any scanner, be it internal or external, it becomes difficult to follow a cylindrical surface as soon as the cylinder is curved. The method was required to be rather insensitive to a change in lift-off.

Again Magnetic Eddy Current was chosen. For the same reasons explained earlier this method is able to sense over a relatively large stand-off. For the detection of wire disorganization the exact signal strength is not so important. It is more the structure or morphology that is relevant.

Through amplification a change in lift-off can be compensated and the obtained signals at different lift-off are equivalent. The upfront testing was done on a flat sample that represents the structure of a flexible riser. The set-up is shown in the left of Figure 5.

A PVC-layer of 9 mm represents the outer sheath. For the testing a hand-scanner can be used. The photo shows the MEC™-P19 in a flat configuration. The lift-off of the scanner or the addition of PVC-layers can change the overall stand-off. The right shows the results for some possible wire disorganization defects. The signal image is placed over the

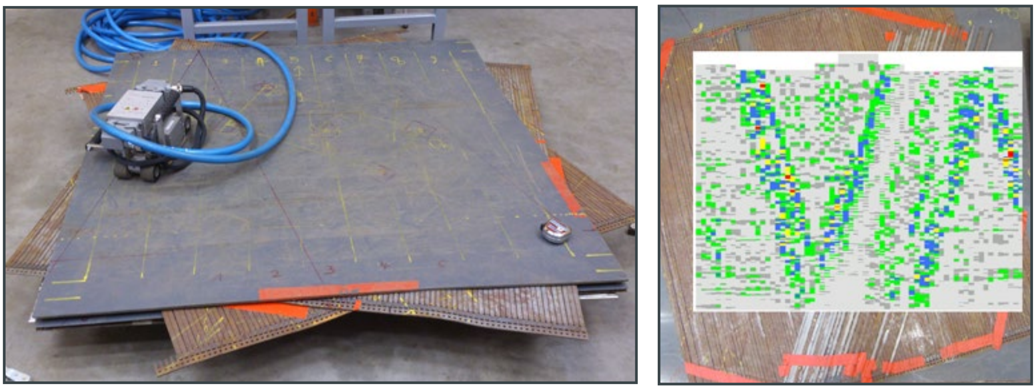


Figure 5: Set-up for testing of wire disorganization defects on a flat sample (left) and results for loose wires and wire gaps (right)

wire photo to show the corresponding positions. Of course the signals were obtained with the sheath-layer in place. To the left there is a larger gap in a layer. To the right there is a structure with loose wires and variable gap arrangement. As pointed out before it was important to carry out this measurement through large and variable stand-off, because of the flexible pipe outer sheath and the bending of the pipe.

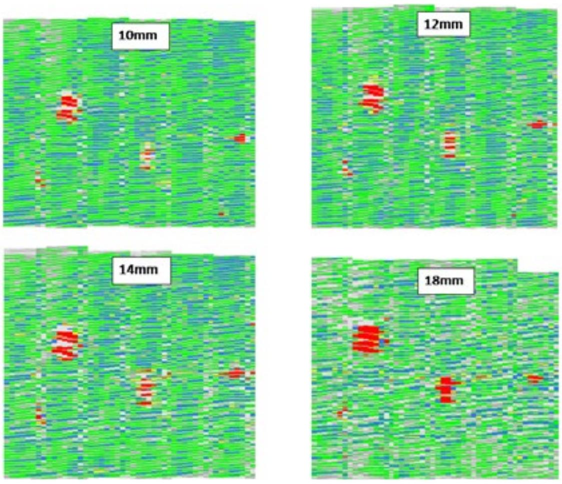


Figure 6: Obtained signals with different lift-off as indicated

Figure 7: The MEC™-Combi Crawler on a flexible pipe carrying out the measurement

Figure 6 shows the signals obtained from a certain flexible pipe structure under different stand-off values. The signals shown in red are metal loss defects and were not of interest in this project. A typical stripe pattern is visible showing an intact flexible structure.

The structure is visible from 10 mm stand-off (sensors close to outer surface of the pipe) to 18 mm (sensors lift-off in an in-side bend). The signals have to be adjusted in gain, but remain similar over this range of change in lit-off. This allowed for the inspection of wire disorganization defects even in this adverse condition.

Figure 7 shows the MEC™-Combi Crawler carrying out such an inspection on a subsea flowline consisting of a flexible pipe. Wire misalignment was not detected, which allowed for continued operation of the pipeline.

FULL CIRCUMFERENCE INSPECTION OF SUBSEA PIPELINE

In this project several subsea flowlines had to be inspected that were assumed to suffer from internal channeling corrosion. No inspection had been done so far and the lengths of the lines were in a range of 5 to 10 km. They connect subsea manifolds to a production platform. The pipelines were 6" and 8" diameter. As channeling corrosion is predominantly expected in the 6 o'clock position the full circumference had to be scanned. The line was coated with a 3 mm 3-layer PE coating. The water depth changed from 250 to 450 m. The wall thickness was ½".

Because of the coating, the UT sensors had to be checked for the suitability for this purpose. UT sensors were positioned with a pitch of 9.3 mm and a stagger of 22 mm to allow for higher resolution scanning. The use of MEC™-Sensors in the presence of a PE coating had already been established in earlier projects. A full scale wet-test was carried out in the Ocean-Lab at Newburgh North of Aberdeen. The purpose of such a test is to verify not only the inspection technology, but also the maneuverability of the crawler on the pipe.

The MEC™-Combi Crawler was hooked up to a work-class ROV as shown in Figure 2. Altogether four sections have been selected along the stretch of the pipeline for inspection. One section was typically 6 to 8 m in length. The selected sections were assumed to be representative with respect to the corrosion condition. For instance the elevation high and low points of the line were selected for inspection. In these areas the seabed was removed by water suction. About ½ meter below the pipeline was required to allow for the crawler to reach the 6 o'clock position.

Figure 8: View of the pipe and the seabed after intervention. The picture is taken from the camera on the crawler

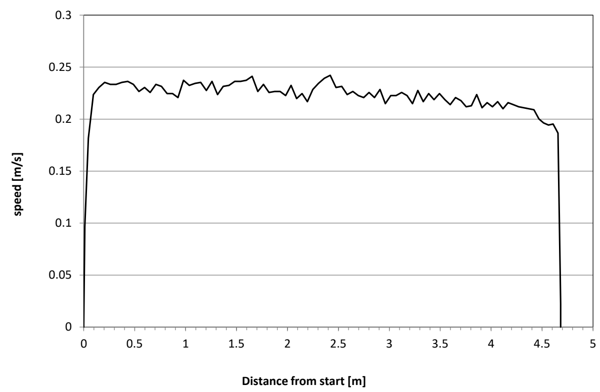


Figure 9: Speed profile of a scan

Because of the closely packed UT sensors the full circumference was scanned with approximately 12-15 scans. This resulted in a high redundancy of the MEC-measurement. In some cases a defect signal was scanned by five different tracks. The quality of the inspection data depends on the smoothness of the ride over the pipe surface. A good indication of this is the speed profile. After the acquisition of the data speed profiles are investigated with respect to accelerations. A sample speed profile is seen in Figure 9. It shows a rather constant scanning speed of 0.2-0.25 m/s throughout the scan. The complete scanning of a section was achieved within ½ to 1 hour. The results have revealed channeling corrosion in all inspected sections. However, some sections were more affected than other. Lines of corrosion were visible, very much as expected. A sample report page is shown in Figure 10. There are four data views altogether. From left to right there is the MEC view on internal corrosion, the MEC-view on external corrosion, the UT view on the wall thickness and the UT view on the sensor stand-off. The internal MEC data shows a line of corrosion at the 6 o'clock orientation often known as "channeling" or "6 o'clock corrosion".

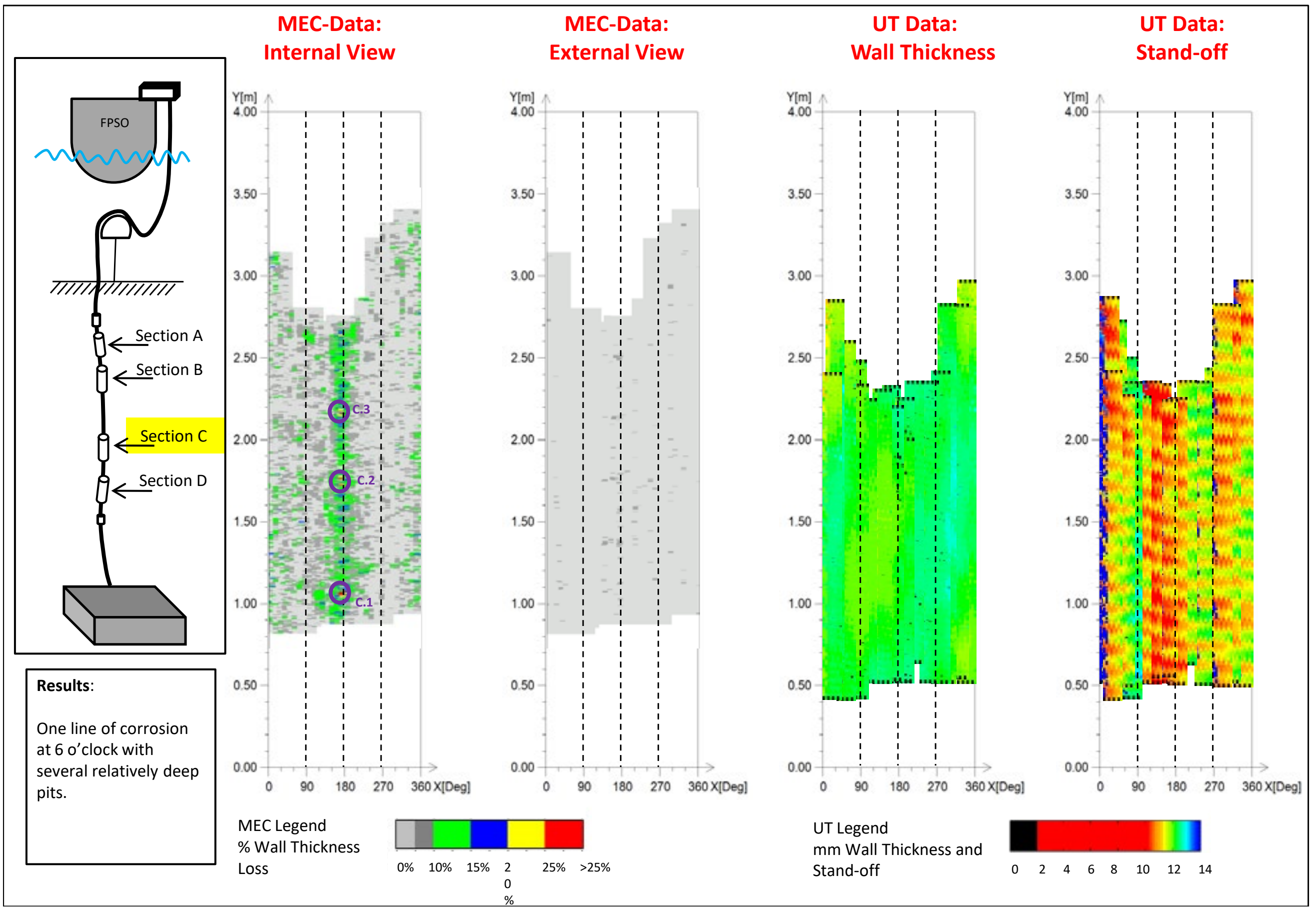


Figure 10: Sample report page for full circumference inspection of pipeline on the seabed

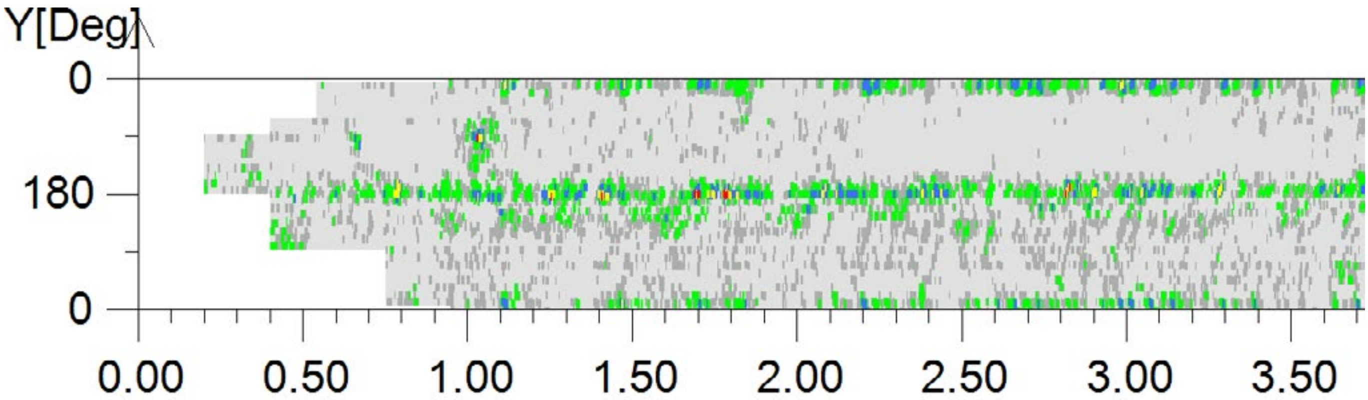


Figure 11: Full view of internal defects with MEC™

These lines of corrosion do not need to concentrate at 6 o'clock. It depends on the flow regime and the water levels in multi-phase pipeline what the o'clock position is. However, the lines will be symmetric to the vertical line. This is what has been found in this inspection. The UT data is more sensitive to the gradual changes, while the MEC-data is more sensitive to localized pitting. In essence they two measurements complement each other. Distance from start [m]

Figure 11 shows another example of the internal MEC data. It demonstrates the level of detail and the location accuracy that can be achieved. Single defects can be reported in terms of defect depth, length and width. With respect to a datum point the location of the defect can be given within cm of the actual location. This is comparable to what an In-Line inspection tool can achieve.

CONCLUSION

Subsea pipelines need to be inspected just like on-shore pipelines. While export pipelines have been inspected with ILI for many years now, a suitable inspection solution for non-piggable flowlines is now also being introduced. These external inspection solutions may not yet be as standardized as ILI is, but the level of reliability of the data is comparable.

The presented MEC™-Combi Crawler has successfully been used under very different circumstances and for different inspection tasks. In particular the MEC™-Inspection is quite suitable for underwater applications as it is fast compared to other external methods and at the same time robust with respect to cleanliness and surface conditions.

Authors

Konrad Reber
Innospection Germany GmbH
Director Research and Development
Mail: k.reber@innospection.com

Sebastian Hartmann
Innospection Ltd.
Sales & Business Development Manager
Mail: s.hartmann@innospection.com

Andreas Boenisch
Innospection Ltd.
Founder & Director
Mail: a.boenisch@innospection.com

PIPELINE - PIPE - SEWER - TECHNOLOGY

Conference & Exhibition on Oil, Gas, Water and Waste Water Transportation in Africa and Middle East

PREVIEW

600+ DELEGATES

100+ EXHIBITORS

40+ DIFFERENT NATIONS

The civilized world has constructed some 3.5 million km of high pressure pipelines for oil, gas and water over the last 100 years - about 25,000 km of new pipelines are added every year. On the side of medium and low pressure pipe networks for gas and water distribution, district heating and cooling as well as sewers for waste water disposal we are talking about roughly 25 million km. The annual construction of new lines is estimated at 30,000 km. According to statistics the length of the supply and disposal network within different economies correlates very closely to their economic success. The largest networks could be found in the industrialized countries of North America and Europe. But poorly constructed and uneconomically operated, leaking pipeline, pipe and sewer networks are major cost drivers and can damage the environment.

In many places around the world water losses are extremely high and damaged sewers pollute the ground water. Losses in the district heating and cooling networks are also a waste of financial resources and gas leakages could even lead to serious and fatal accidents.

Organizations all around the world work on technical solutions for safety improvements, maximum reliability, economic efficiency and environmental protection of supply and disposal systems. The Pipeline - Pipe - Sewer - Technology Conference & Exhibition (PPST) intends to further appropriate solutions and the international exchange of experiences.

Please take a closer look at the following pages and get involved now - send in your presentation suggestion and reserve your place at the accompanying exhibition. I look forward to seeing you in Cairo.

Yours,

Dr. Klaus Ritter
Pipeline Technology Conference Chairman
Pipeline Technology Journal Editor in Chief
President of EITEP

CONFERENCES / SEMINARS / EXHIBITIONS

12TH PIPELINE TECHNOLOGY CONFERENCE

02-04 MAY 2017, ESTREL CONVENTION CENTER, BERLIN, GERMANY

ptc

Save the Date!

For Europe's Biggest Pipeline Conference and Exhibition

CONFERENCES / SEMINARS / EXHIBITIONS

EVENT CALENDER

Pipeline Technology Journal - Issue 01/2017	23rd January .2017	Worldwide
Pipeline Pigging and Integrity Management	27-02 - 02.03.2017	Houston, Texas
12th Pipeline Technology Conference (ptc)	02-04 May 2017	Berlin, Germany
Pipeline-Pipe-Sewer-Technology (PPST)	17-19 September 2017	Cairo, Egypt

Pipeline Technology Seminar (Cairo, Egypt)

Pipeline life-cycle extension strategies

Get a deeper insight into the success story of decades of failure-free and economic pipeline operation

27 February 2017
AHK Mena Office
Cairo, Arab Republic of Egypt

Your Course Director
Heinz Watzka

Former Positions:
Managing Director Technical Services, Open Grid Europe (Germany's largest pipeline operator)
Vice President Maintenance, Ruhrgas
Technical Manager, TAL Oil Pipeline
Project Engineer, ILF Consulting Engineers