IN-LINE INSPECTION OF PIPES USING CORROSION RESISTANT ALLOYS (CRA)

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ABSTRACT

The global market conditions influence the extraction of resources onshore as well as offshore, whereby particularly offshore exploration pipelines need to cope with high temperatures and pressures as well as products containing corrosive elements. This leads to potentially higher corrosion rates in a high temperature environment. Pipelines made of ferritic steels are susceptible to corrosion attack, especially if specific types of medium are transported in the line or the pipe is situated in a critical environment.

The industry is addressing this issue through various means, also including the development of new materials and pipe types. More and more corrosion resistant materials like stainless steel are used, e.g. duplex steels or different types of corrosion resistant alloy (CRA) pipes. Over the past 30 years thousands of kilometers of CRA pipelines are laid and there is still a growing demand.

However, in the carbon steel but also in the CRA layer different types of defects and/or features can appear, whereby the ILI technologies so far focus on carbon steel pipes. This paper will give an overview of state-of-the-art ILI technologies to inspect mechanically and metallurgically bonded CRA pipes. The challenges for inspection of the carbon steel and the CRA layer, for different ILI technologies will be presented.

Key words: Corrosion Resistant Alloy, CRA, In-line Inspection, ILI, inspection, stainless steel, mechanically bonded, metallurgically bonded, pipeline, pipe, offshore

INTRODUCTION

The global trend of exploring for oil and gas focuses more and more on offshore production. Onshore as well offshore pipelines are usually made of ferritic steels which are susceptible to corrosion attack. A critical environment like high temperatures and pressures as well as product containing corrosive elements lead to potentially higher corrosion rates. This attack can occur from the inside affecting the internal pipe wall, or the outside effecting the external pipe wall. The latter is often experienced in an offshore environment for instance in the splash zone of a riser.

A critical environment within a pipeline can occur after the drilling and production start and consist of high temperature of the medium and corrosive elements like hydrogen sulfide (H2S). The temperature of the medium is higher than the surrounding temperature of the water. This high temperature differences lead to a condensation of the gas at the top of the pipe. This droplet condensation can typically cause small and deep metal loss like top of line corrosion (TLC). TLC usually occur between 10h and 2h as shown in figure 2 and 3 and for the first hundreds of meter to kilometers.

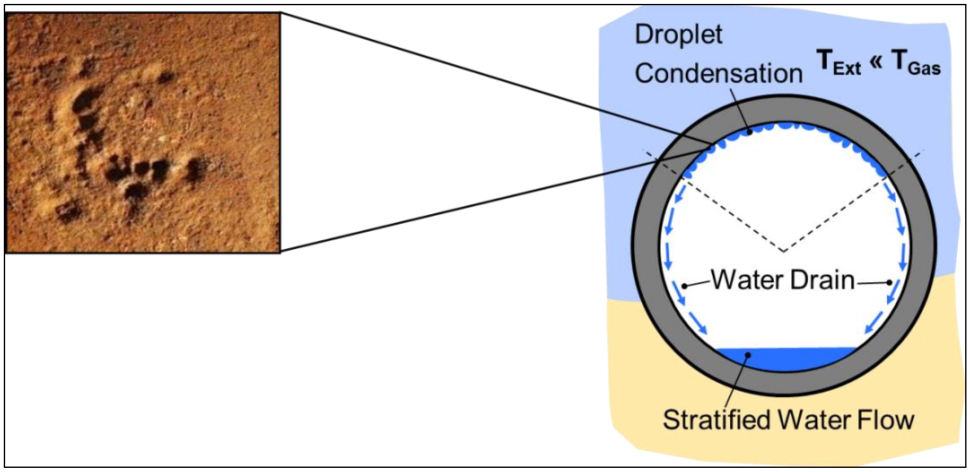

Figure 1: Top of line corrosion

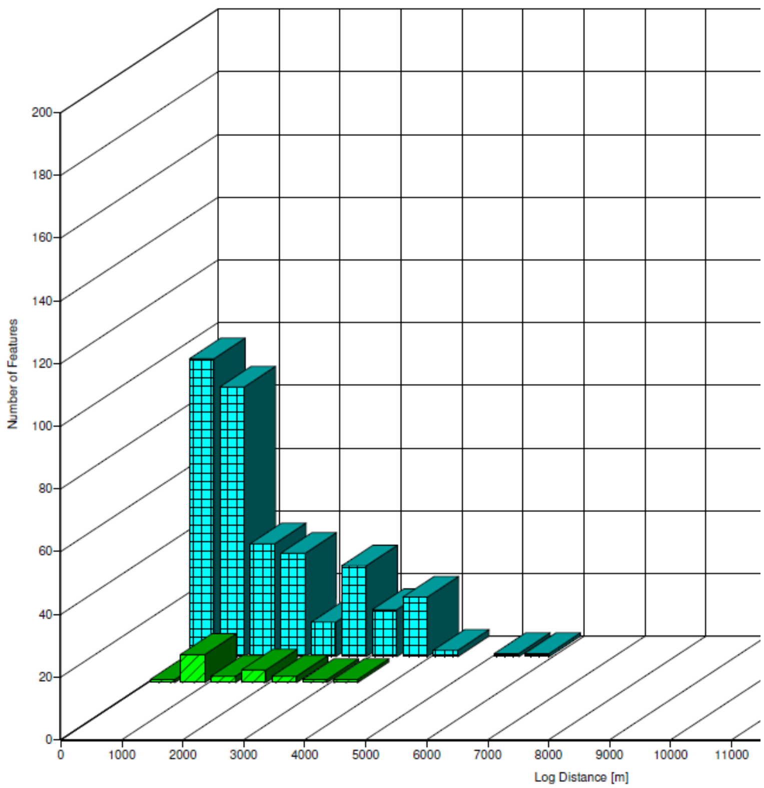

Figure 2: Typical allocation of features (1)

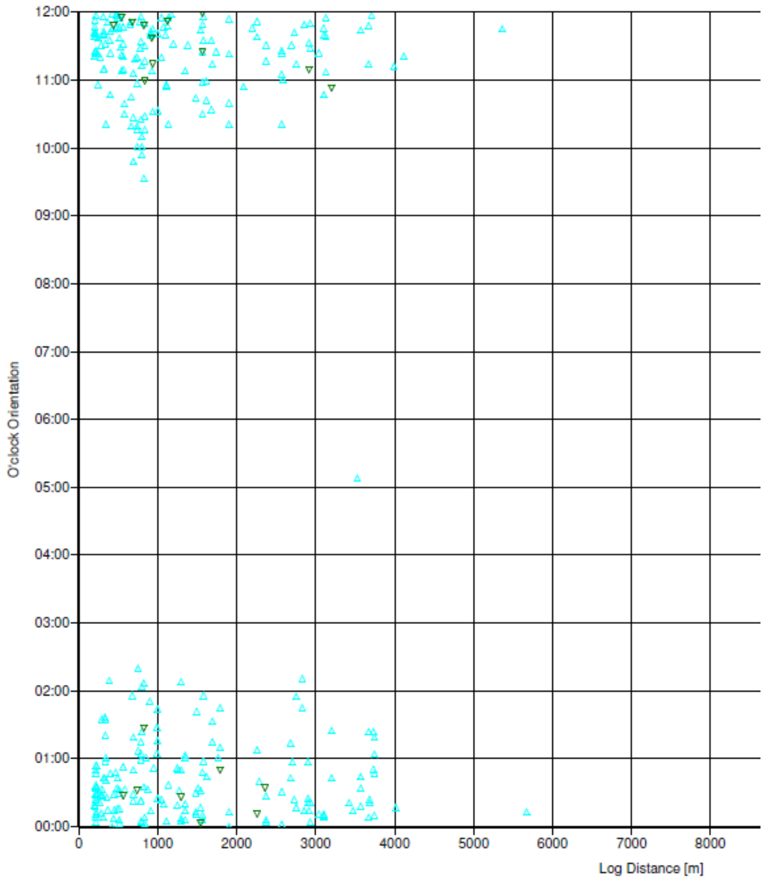

Figure 3: Typical allocation of features (2)

The industry is addressing this issue through various means. This includes the development of new materials and pipe types. Corrosion resistant materials like stainless steel are used, e.g. corrosion resistant alloys (CRA) with high chromium content, duplex steels or different types of corrosion resistant alloy pipes. Today many thousands of kilometers of pipe are being designed and manufactured with CRA being installed, at least partially. Especially CRA is used for offshore gas pipelines [1]. To ensure that ILI solutions for a specific new offshore pipeline are available, DNV-OS-F101 recommended that in-line inspection is already taken into account during pipeline design phase (Front End Engineering & Design – FEED) [2]. This paper describes which state-of-the-arte ILI technologies can be considered and used.

Types of CRA Pipes

Considering the economic, corrosion resistant alloys pipes are an optimal solution. Cladded respectively lined pipelines are carbon steel (e.g. X-65, X52) pipelines with an inner or outer cladding or lining of stainless steel (e.g. alloy 825, 316L) depending on use. The stainless steel is in direct contact with the carbon steel without space in-between. This wear and corrosion protection solutions enables a more effective and longer operation time of the pipelines. The thickness of the inner stainless steel layer ranges typically from 1 to 7mm, where in the most cases 3mm – 4mm are applied.

The approach in cladded or lined pipe is to protect the pressure bearing ferritic steel with a protective layer of a corrosion resistant alloy, usually an austenitic stainless steel, represented in figure 4. Based on the manufacturing process, there are basically two different types of corrosion resistant alloys pipes:

- Metallurgically bonded = cladded pipe
- Mechanically bonded = lined pipe

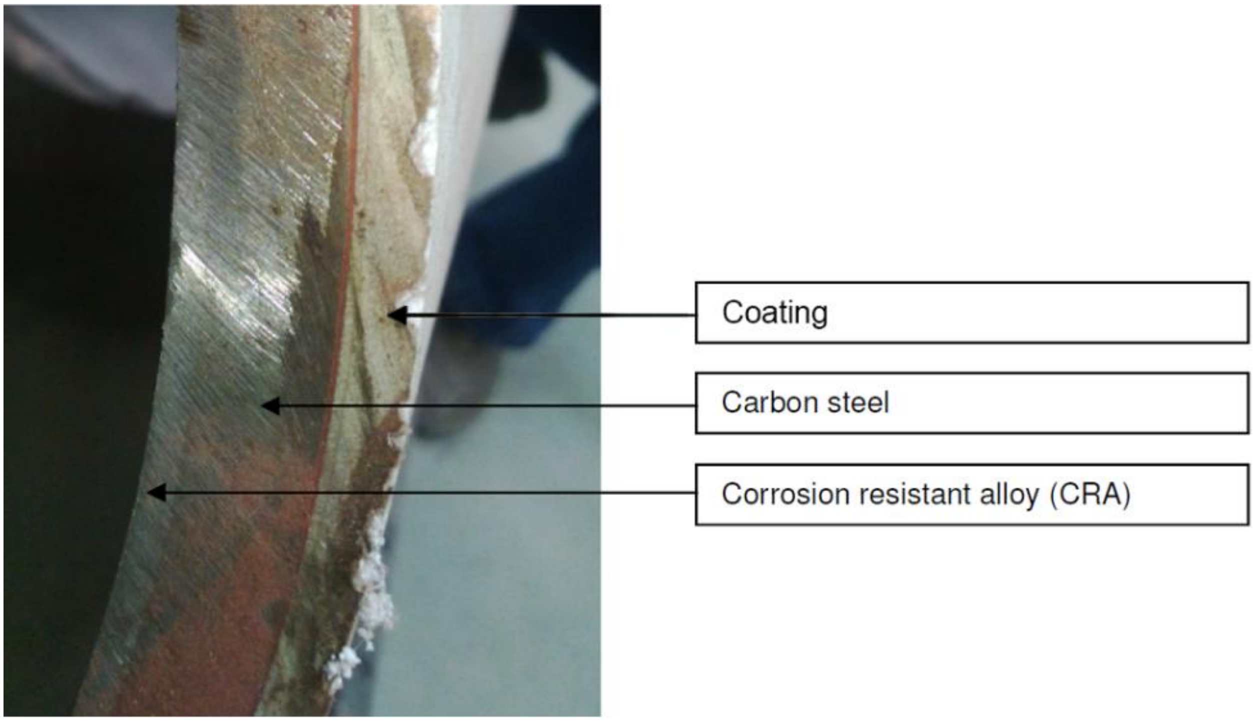

Figure 4: CRA pipe showing carbon steel and CRA layer

The production process for cladded pipelines cause a metallurgical bonding between carbon steel and the corrosion resistant alloy. Here the materials are bonded by means of mechanical forces and undergo a controlled heat treatment. The application of a cladding process yields a metallurgical bonded pipeline, which means, that there is a molecular connection of the metals. The carbon steel and corrosion resistant alloy plates are joined firmly by diffusion bridges.

Mechanically lined pipes are produced by using e.g. hydroforming processes. The hydraulic pressure expands the corrosion resistant pipeline respectively the liner to the carbon steel pipeline. The expansion forces cause an interference stress between the corrosion resistant alloy and the carbon steel pipe. This production process is usually combined with a seal weld or a weld overlay at the ends of the pipeline to prevent moisture. These bimetal pipes are also called line pipe and consist of e.g. alloy 316L, 904L, 825 or 625. Furthermore other manufacturing processes can be used to produce mechanically bonded pipes. These processes determine the interface of the CRA and carbon steel.

Moreover weld overlay is applied at the ends of pipe spools and e.g. in bends. The overlay welding process is used to obtain a fusion between a coating and a substrate surface. This system is primarily used in bends, installations and at the ends of pipe spools, but it would be applicable for nearly all wear and corrosion endangered installation or applications. Due to the welding process a rougher inner pipeline surface can occur. CRA pipelines are described e.g. by PALMER and KING [3].

Summarized, there are basically two different types of CRA pipelines where additionally different CRA materials are used. This means, that there are different combinations which have to be considered.

Possible Defects and Types of Features

Dependent on the specific types of medium which are being transported in the line, the possibly critical environment and the temperatures and pressures, different defects or features can occur.

In many cases an external coating on the carbon steel protects the pipeline. Nevertheless this coating cannot completely prevent, that the carbon steel gets into contact with the environment. Therefore external corrosion respectively external defects can arise at the carbon steel.

Furthermore internal erosion, corrosion or corrosion at the transition from carbon steel to the corrosion resistant alloy can be in place. Additionally there could be defects at the interface of carbon steel and stainless steel which were created during the manufacturing process and influence the bonding.

Moreover there could be cracks within the stainless steel or carbon steel and pitting features in the corrosion resistant alloy. Also geometric deformations like dents, wrinkles or buckles, especially in lined pipes, and other defects like bonding flaws can occur. For this purpose Figure 5 and 6 show the possible defects of the carbon steel in corrosion resistant alloy pipe materials. Due to this it is necessary to inspect corrosion resistant alloy pipelines. Inline inspection technologies provide a solution for this need.

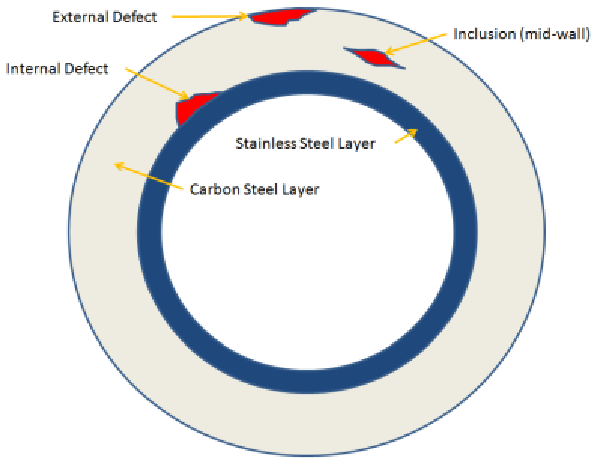

Figure 5: CRA Pipeline with defects

Figure 6: CRA Pipeline with defects (2)

STATE-OF-THE-ART ILI TECHNOLOGIES IN FOCUS

Introduction

Due to the possible defects and features that can appear in corrosion resistant alloy pipes as described in section 2, it can be necessary to inspect such pipeline with an inline inspection tool. Different types of tools utilizing different non-destructive testing technologies are available.

Magnetic Flux Leakage Technology

General

The principle of magnetic flux leakage (MFL) involves the magnetic saturation of a ferromagnetic sample, here the pipe wall. Powerful permanent magnets are utilized to temporarily magnetize the pipeline steel. Internal and external anomalies influence the magnetic flux density in the pipe wall, yielding a leakage field. This is measured by sensors with hall effect elements.

These sensors additionally detect the lift-off, which describes the distance between sensor and pipeline that can vary during the inspection. With these sensors internal and external anomalies can be distinguished.

The magnetic field acts in three dimensions with axial, radial and circumferential components. Every scalar component of the flux field contains a magnitude which determines the metal loss.

A certain range of magnetization is necessary, to get sufficiently high magnetization (so-called magnetic saturation) of the pipe wall for accurate flaw recognition and sizing and to get high resolution data which enables a comprehensive analysis of the pipeline integrity.

Under normal conditions (no flaws present) the magnetic flux can travel through the pipeline undisturbed. In the presence of internal or external metal loss, the flux "leaks" out of the pipe wall and is recorded.

The magnetic flux leakage inline inspection tools are designed to detect general metal loss within a pipeline, caused by e.g. corrosion, manufacturing or during construction of the pipeline. The magnets are mounted onto the ILI tool in a certain manner, which defines the direction of the resulting permanent magnetic field and hence whether the tool employs so-called axial or circumferential MFL.

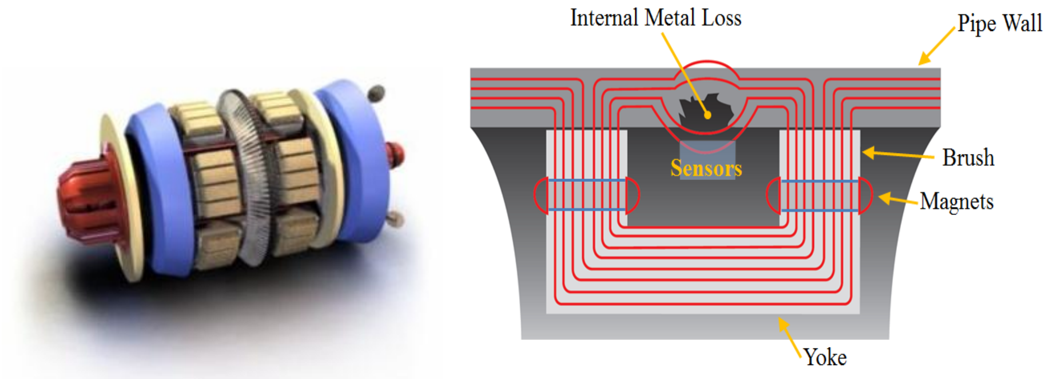

Figure 7: RoCorr MFL-A Tool and flux line distribution

Results of full-scale tests at ROSEN Technology and Research Center

The following test setup was used for full-scale testing of MFL ILI tools performing a pull-through test at ROSEN Technology and Research Center (RTRC) in Lingen, Germany:

- 08 in spool
- 6 meter length
- Cladding with Inconel alloy 825
- 10mm wall thickness of carbon steel
- 3.9mm wall thickness of CRA
- 4 types of features were included (lateral dimension 24mmx24mm)

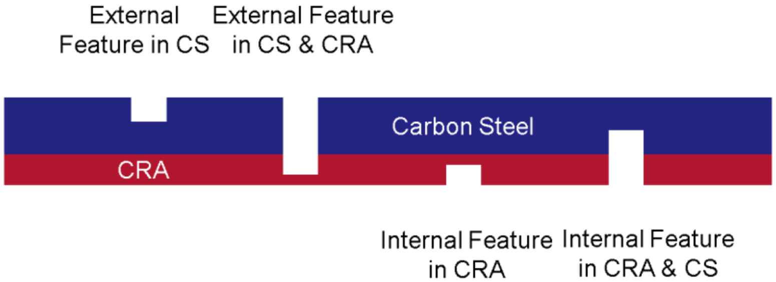

Figure 8: Schematic picture of types of features

The first feature is a 6.5mm deep, external defect in the carbon steel at 5300mm at 4:00. The axial MFL channels, pictured as lines, react clearly and enable a data evaluation with a metal loss of 65%. According to the carbon steel thickness of 10mm, 65% metal loss match to a 6.5mm deep feature. The color plot shows the internal eddy current lift-off sensors of the MFL ILI tool and don't react, due to the fact, that this is an external defect, correctly. The detection and the sizing work within the performance specifications.

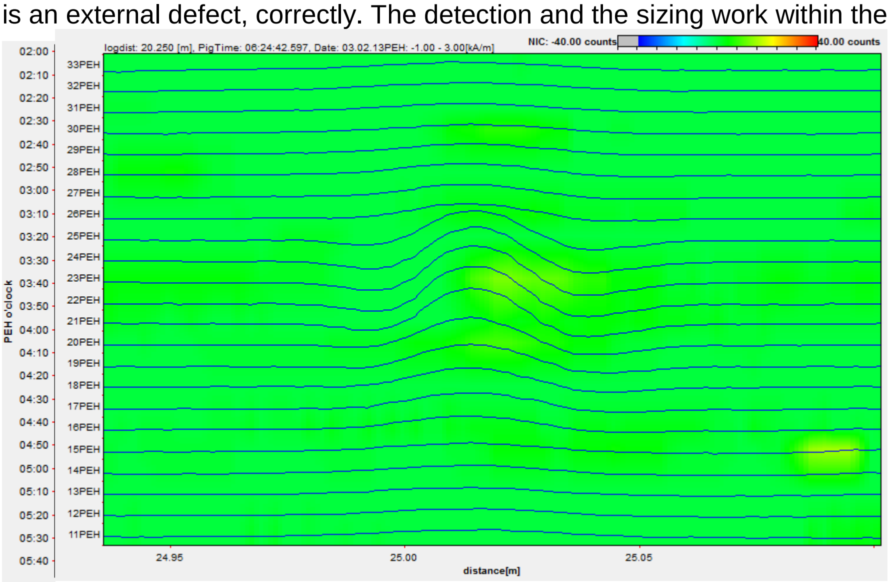

Figure 9: MFL data plot of feature one

The second feature is a 13.0mm deep, external defect in the carbon steel and CRA at 800mm at 10:00. The axial MFL channels, pictured as lines, react clearly and enable a data evaluation with a metal loss of 100%. According to the carbon steel thickness of 10mm, 100% metal loss match to a 10mm deep feature. The metal loss in the CRA isn't detected by the MFL tool. This is exactly what was expected, due to the non-magnetic, austenitic structure of the CRA. The color plot shows the internal eddy current lift-off sensors of the MFL ILI tool and don't react, due to the fact, that this is an external defect, correctly. The detection and the sizing work for the carbon steel within the performance specifications. But this confirmed that MFL doesn't work for inspection of the CRA.

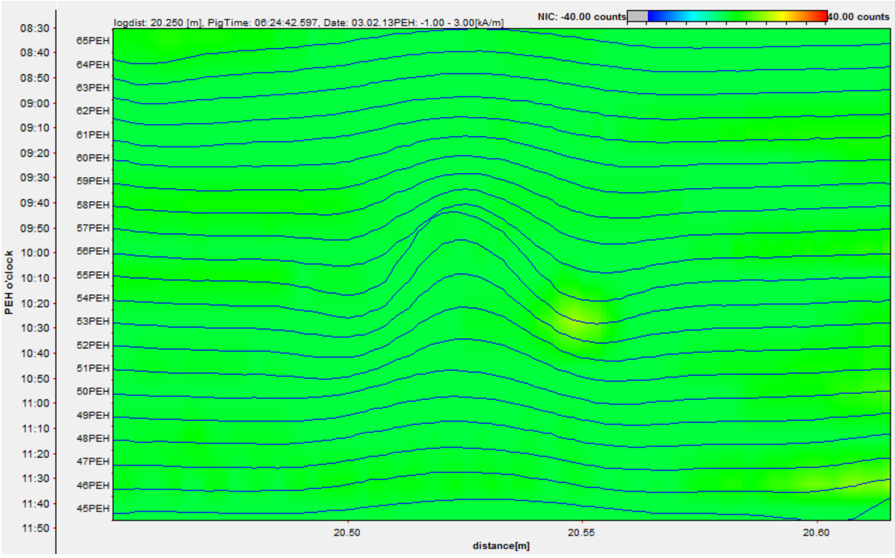

Figure 10: MFL data plot of feature two

The third feature is a 3.0mm deep, internal defect in the CRA and not in the carbon steel at 600mm at 10:00. The axial MFL channels, pictured as lines, doesn't react . The metal loss in the CRA isn't detected by the MFL tool. This is exactly what was expected, due to the non-magnetic, austenitic structure of the CRA. The color plot shows the internal eddy current lift-off sensors of the MFL ILI tool and react, due to the fact, that this is an internal defect, correctly. The detection and the sizing work for the carbon steel within the performance specifications. But this confirmed that MFL doesn't work for inspection of the CRA.

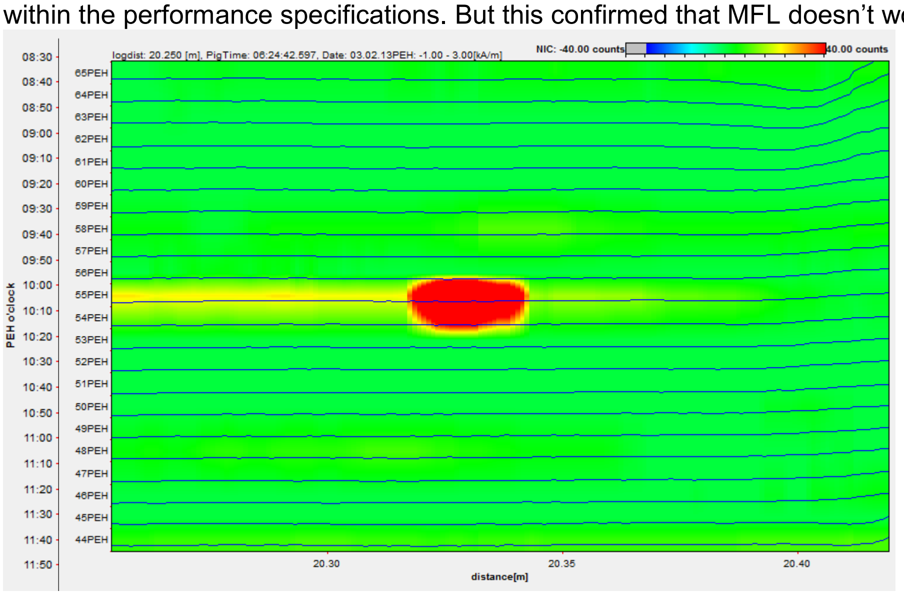

Figure 11: MFL data plot of feature three

The fourth feature is a 10.9mm deep, internal defect in the CRA and in the carbon steel at 5500mm at 8:00. The feature is 3.9mm deep in the CRA and go into the carbon steel 7.0mm deep. The axial MFL channels, pictured as lines, react clearly and enable a data evaluation with a metal loss of 70%. The metal loss in the CRA isn't detected by the MFL tool. This is exactly what was expected, due to the non-magnetic, austenitic structure of the CRA. The color plot shows the internal eddy current lift-off sensors of the MFL ILI tool and react, due to the fact, that this is an internal defect, correctly. The detection and the sizing work for the carbon steel within the performance specifications. But this confirmed that MFL doesn't work for inspection of the CRA. The red area at 6:10 to 6:50 is another internal defect, not detected by the MFL, because it is only in the CRA.

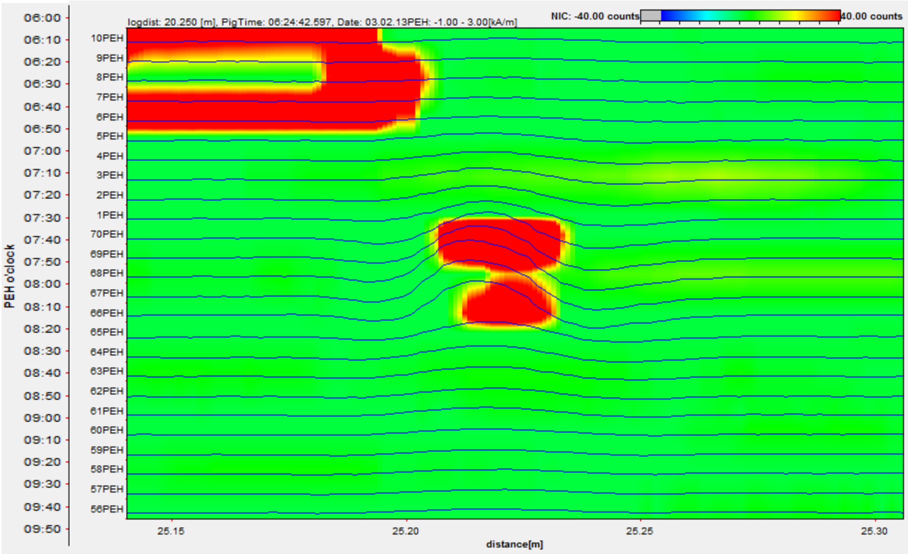

Figure 12: MFL data plot of feature four

<u>Résumé for CRA pipes</u>

The stainless steel layer respectively the corrosion resistant alloy does not influence the magnetic field directly, because the austenitic structure is not magnetic. However the thickness of the stainless steel layer causes a higher distance of the magnets and sensors from the carbon steel layer which indirectly influences the defect detection as described in the following. The stainless steel thickness basically constitutes sensor lift-off.

With FEM calculations and pull tests the decreasing of the magnetization over the pipeline wall thickness as show in Figure 13 was analyzed. Therefore the tools are limited regarding the maximum inspection wall thicknesses. The corrosion resistant alloy causes a sensor lift-off influencing the magnetization and, therefore, defect signals. Due to the austenitic structure (austenitic grain is not magnetic) of e.g. 316L, no geometric deformation, metal loss or cracks can be detected in the corrosion resistant alloy. The thicker the corrosion resistant alloy, the lower is the maximum allowable carbon steel thickness. To achieve full magnetization throughout the whole wall, the inspection velocity needs to be reduced compared to the standard case, i.e. inspection without corrosion resistant alloy.

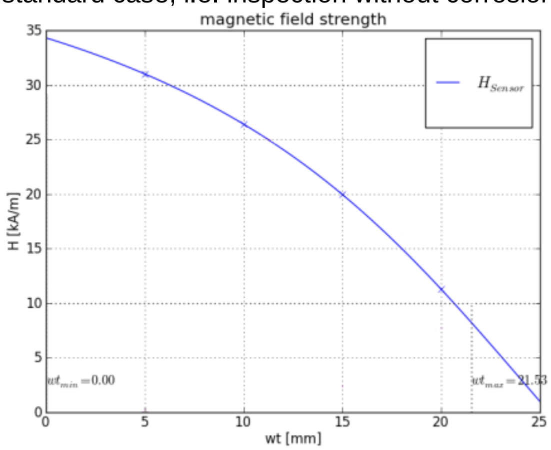

Figure 13: magnetic field strength vs. wall thickness

In the following Figure the decrease in magnetization due to lift-off is shown. Here the magnetization decreases by 1-2 kA/m per 1 mm lift-off. Correspondingly the amplitude decreases with increasing lift-off, thickness of corrosion resistant layer respectively, which needs to be considered for the inspection of specific pipeline.

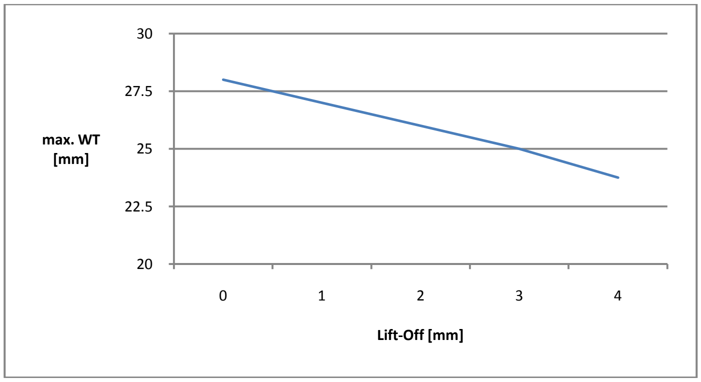

Figure 14: maximum wall thickness vs. lift-off

Moreover a decrease in magnetization due to velocity has to be considered as MFL is affected by so called speed effects. Lift-off increases this effect. Therefore the maximum allowable tool velocity for pipelines with corrosion resistant alloy is typically lower than for non-corrosion resistant alloy pipelines.

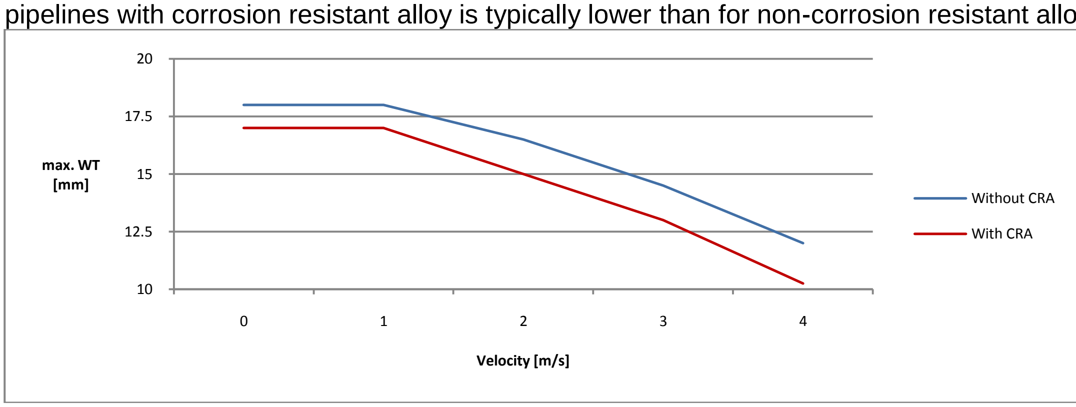

Figure 15: maximum wall thickness vs. tool velocity

ROSEN MFL in-line inspection data obtained from corrosion resistant alloy pipelines so far confirm these outlines. Furthermore a special tool setup regarding friction and material properties, to optimize the run behavior could be necessary and has to be taken into account.

In conclusion a calibration of the tool for the specific pipeline with corrosion resistant alloy via pull tests is necessary. The detection of features in the carbon steel is possible according to these test and sizing a well, but there could be circumstances for which sizing could be influenced.

Eddy current technology

General

For geometric deformation mechanical caliper with an electronic angle sensor are used. Moreover touchless eddy current sensors are used for extended geometry inspections.

Eddy currents (ECs) are created when a moving conductor experiences changes in a magnetic field, as well as when a stationary conductor encounters varying magnetic fields. Both effects are present when a conductor moves through a varying magnetic field. ECs will be generated wherever a conducting object experiences a change in the intensity or direction of the magnetic field at any point within it, and not just at the boundaries.

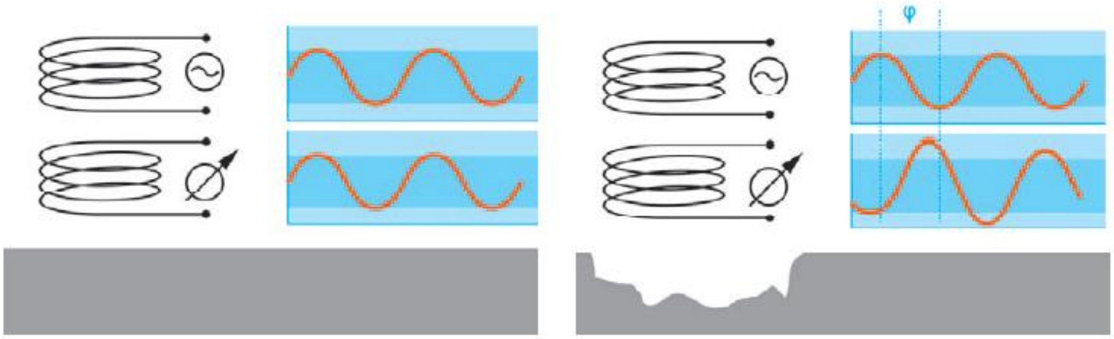

Figure 16: Principle of eddy current

The circulating currents set up in the conductor are due to electrons experiencing a Lorentz force that is perpendicular to their motion. In the case of a varying applied field, the induced field will always be in the opposite direction to that applied. The same will be true when a varying external field is increasing in strength. However, when a varying field is falling in strength, the induced field will be in the same direction as that originally applied, in order to oppose the decline.

<u>Results of full-scale tests at ROSEN Technology and Research Center</u>

The same test setup was used for full-scale testing of eddy current ILI tools performing a pull-through test at ROSEN Technology and Research Center (RTRC) in Lingen, Germany, as for MFL.

The first feature is a 6.5mm deep, external defect in the carbon steel at 5300mm at 4:00. The color plot represented the eddy current channels. No channel react, due to the fact, that this is an external defect. This is exactly what was expected, because the eddy current sensors are designed to detect internal metal loss and not external defects.

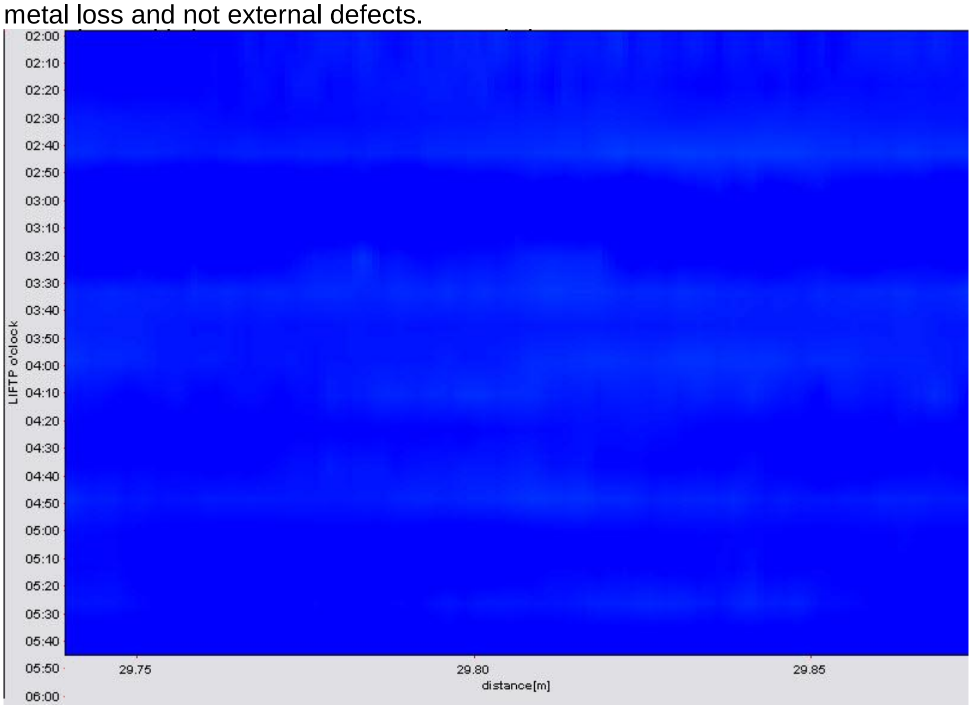

Figure 17: EC data plot of feature one

The second feature is a 13.0mm deep, external defect in the carbon steel and CRA at 800mm at 10:00. The color plot represented the eddy current channels. No channel react, due to the fact, that this is an external defect. This is exactly what was expected, because the eddy current sensors are designed to detect internal metal loss and not external defects.

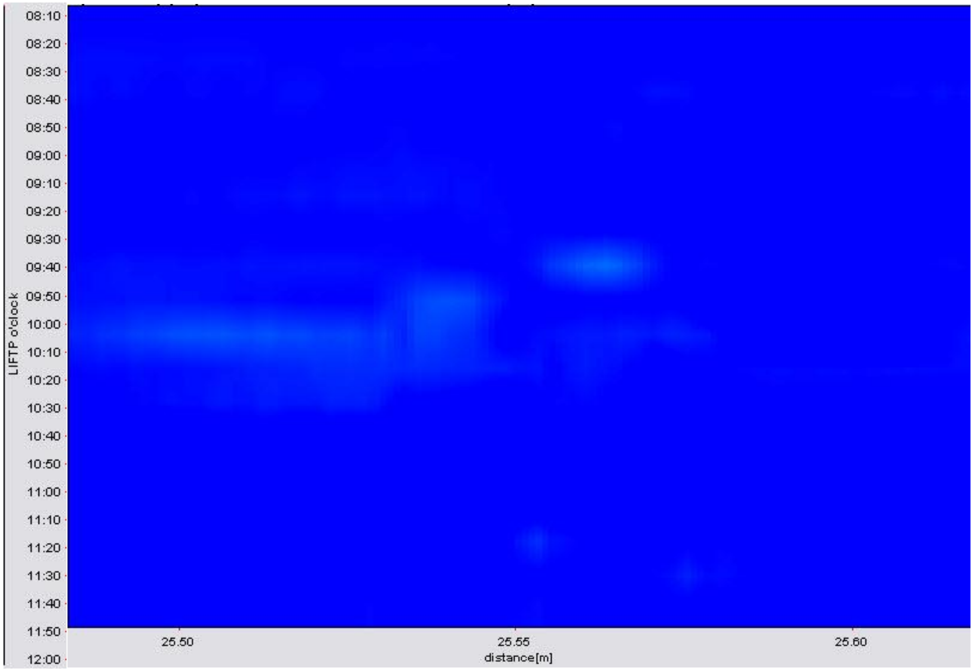

Figure 18: EC data plot of feature two

The third feature is a 3.0mm deep, internal defect in the CRA and not in the carbon steel at 600mm at 10:00. The color plot represented the eddy current channels. There is a clear reaction of the channels and the data evaluation confirmed the feature detection. The sizing regarding depth, width and length is to evaluate for every material and run conditions (e.g. tool velocity). In general, the standard performance specifications cannot be applied and individual, pipeline specific tests have to be done to determine the performance specifications.

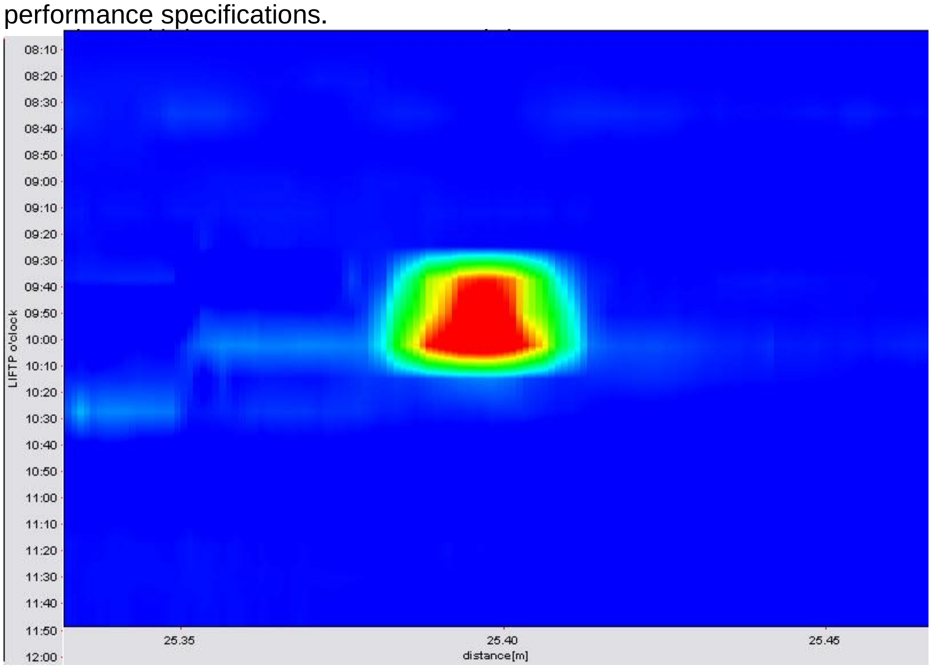

Figure 19: EC data plot of feature three

The fourth feature is a 10.9mm deep, internal defect in the CRA and in the carbon steel at 5500mm at 8:00. The color plot represented the eddy current channels. There is a clear reaction of the channels and the data evaluation confirmed the feature detection. The sizing regarding depth, width and length is to evaluate for every material and run conditions (e.g. tool velocity). In general, the standard performance specifications cannot be applied and individual, pipeline specific tests have to be done to determine the performance specifications.

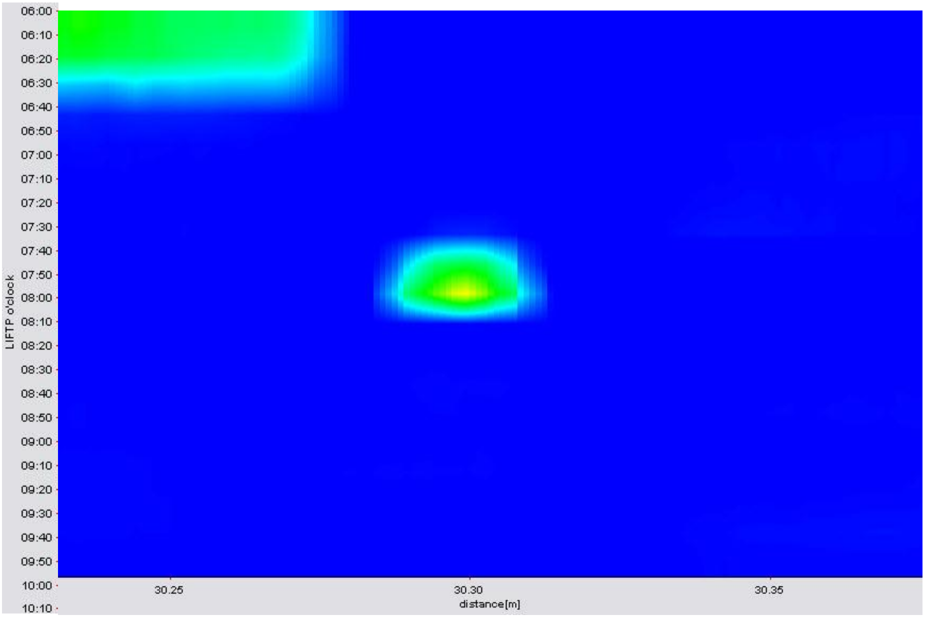

Fig. 20: EC data plot of feature four

Résumé for CRA pipes

The eddy current tool measures small internal metal loss features, such as pitting corrosion, with the eddy current component while the caliper component is used for measuring corrosion of larger areas (general internal corrosion).

In principle, this is applicable to the corrosion resistant alloy material too. Since CRA is still conducting, but due to its austenitic character non-magnetic, the same measurement principle as for carbon steel applies. But for CRA a sensor calibration with the used corrosion resistant material (e.g. alloy 825) has to be done before the inspection. Therefore a pull test with original tool and pipe is necessary.

In conclusion a calibration of the tool for the specific pipeline with corrosion resistant alloy via pull tests is necessary. The detection of features in the CRA should be possible, but sizing could be influenced. This is under current development and evaluation.

Ultrasonic technology

General

Ultrasonic technology (UT) measures the pipeline wall thickness and/or detects cracks, depending on the orientation of the transducer towards the pipe wall. Thereby sound waves propagate through materials by vibrating the particles that make up the material. An ultrasonic transducer is used to generate these ultrasonic waves directly in the sensor probe that propagates through the coupling medium (liquid) and the pipe wall. The transducer also records the reflections caused by the front wall and the back wall.

The differences in the arrival times of these reflections are directly related to standoff, distance between the transducer and the pipe wall, and wall thickness. On the basis of the reflections of the ultrasonic wave, the thickness of the wall can be assessed and a distinction can be made between internal and external metal loss.

Traditional ultrasonic testing based on piezoelectric transducers is only applicable when a suitable liquid coupling medium is present between the transducer and the pipe wall. Only liquid pipelines can be inspected by the conventional UT ILI tools, unless batching techniques, which can be costly and complex, are considered. In order to use conventional UT in gas lines, long batches of liquid coupling agent, often spread over many hundreds of meters, are needed.

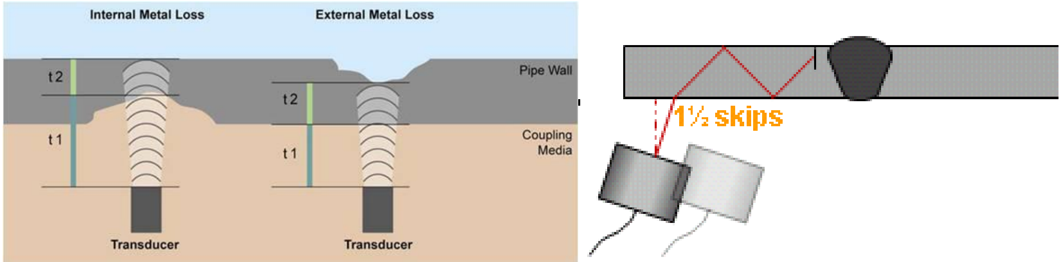

Figure 21: Ultrasonic principle (left metal loss, right crack detection)

<u>Results of full-scale tests at ROSEN Technology and Research Center</u>

The same test setup was used for full-scale testing of UT ILI tools performing a pump test at ROSEN Technology and Research Center (RTRC) in Lingen, Germany, as for MFL.

The first feature is a 6.5mm deep, external defect in the carbon steel at 5300mm at 4:00. The ultrasonic waves could negotiate the interface between the carbon steel and the CRA. This is exactly what was expected, because of the metallurgically bonding. The remaining wall thickness was measured with 6.2mm, what leads to a metal loss of 7.7mm according to the carbon steel thickness of 10mm. This differs from the actually metal loss of 6.5mm by 1.2mm. The detection works within the performance specifications, but the sizing was effected. The above plot on the left side shows the color plot of the remaining wall thickness, the bottom graph on the left pictured the echoes and the above diagram on the right side presented the time and amplitude of the back wall echoes. The results are listened additionally.

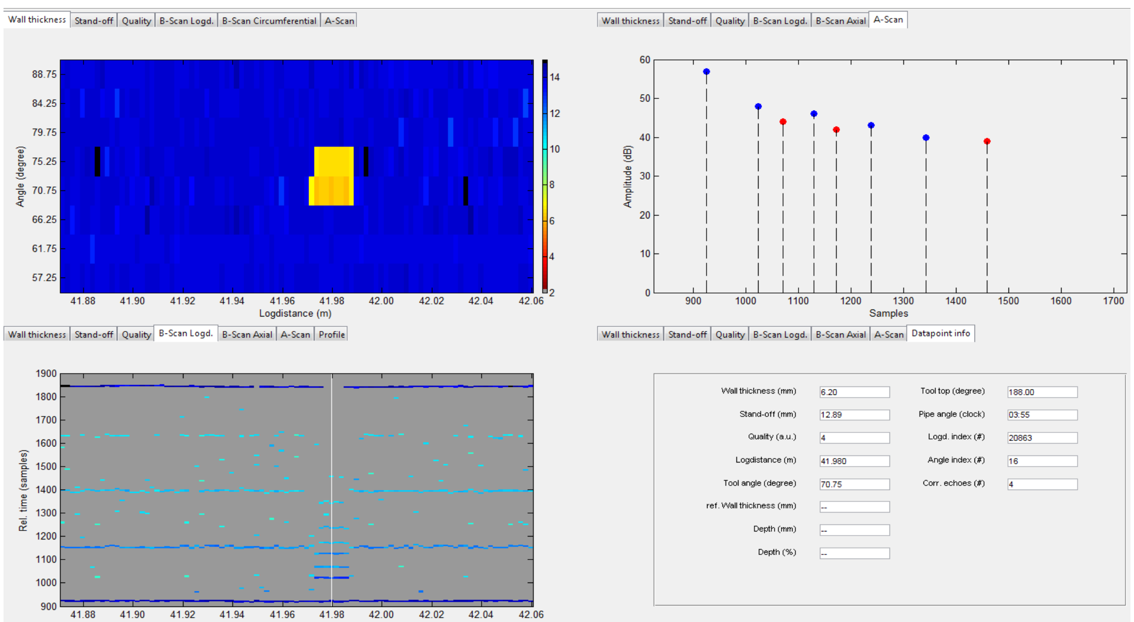

Figure 22: UT data of feature one

The second feature is a 13.0mm deep, external defect in the carbon steel and CRA at 800mm at 10:00. The ultrasonic waves could negotiate the interface between the carbon steel and the CRA. This is exactly what was expected, because of the metallurgically bonding. The remaining wall thickness was measured with 2.7mm, what leads to a metal loss of 11.2mm according to the carbon steel thickness of 10mm. This differs from the actually metal loss of 13.0mm by 1.8mm. The detection works within the performance specifications, but the sizing was effected.

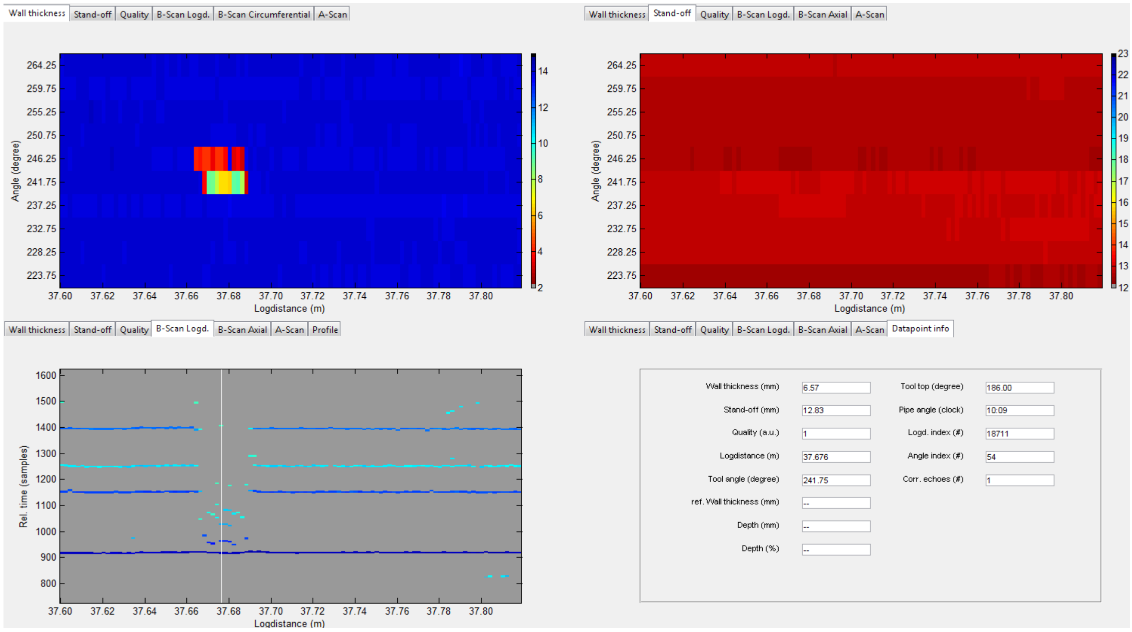

Fig. 23: UT data of feature two

The third feature is a 3.0mm deep, internal defect in the CRA and not in the carbon steel at 600mm at 10:00. The ultrasonic waves could negotiate the interface between the carbon steel and the CRA. This is exactly what was expected, because of the metallurgically bonding. The remaining wall thickness was measured with 11.1mm, what leads to a metal loss of 2.8mm according to the carbon steel thickness of 10mm. This differs from the actually metal loss of 13.0mm by 0.2mm. The detection and the sizing work within the performance specifications.

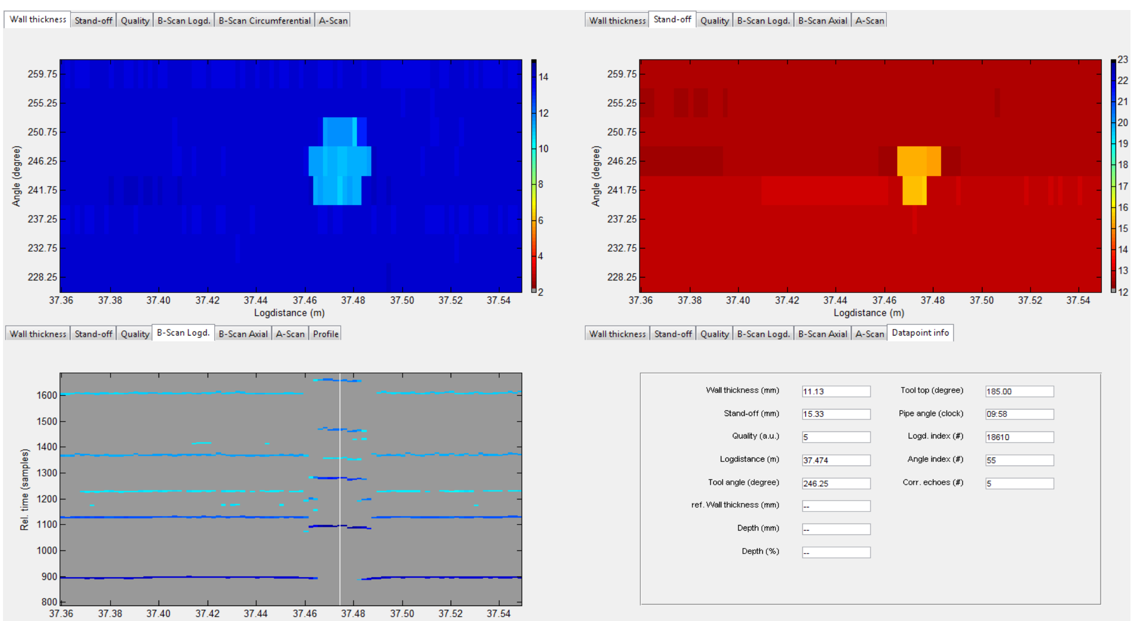

Figure 24: UT data of feature three

The fourth feature is a 10.9mm deep, internal defect in the CRA and in the carbon steel at 5500mm at 8:00. The ultrasonic waves could negotiate the interface between the carbon steel and the CRA. This is exactly what was expected, because of the metallurgically bonding. The remaining wall thickness was measured with 3.1mm, what leads to a metal loss of 10.8mm according to the carbon steel thickness of 10mm. This differs from the actually metal loss of 10.9mm by 0.1mm. The detection and the sizing work within the performance specifications.

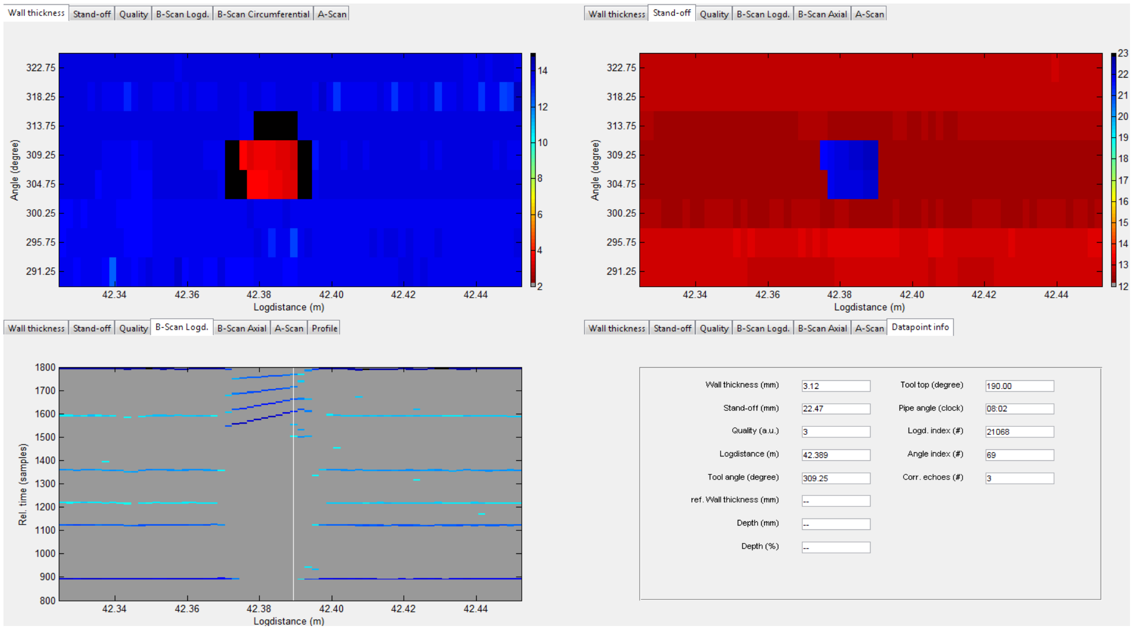

Figure 25: UT data of feature four

Results of laboratory tests at ROSEN Technology and Research Center

The following test setup was used for small-scale testing of UT sensors performing laboratory tests at ROSEN Technology and Research Center (RTRC) in Lingen, Germany:

- 06 in spool
- 0.5 meter length
- Lining with Inconel alloy 825
- 15.9mm wall thickness of carbon steel
- 5.0mm wall thickness of CRA
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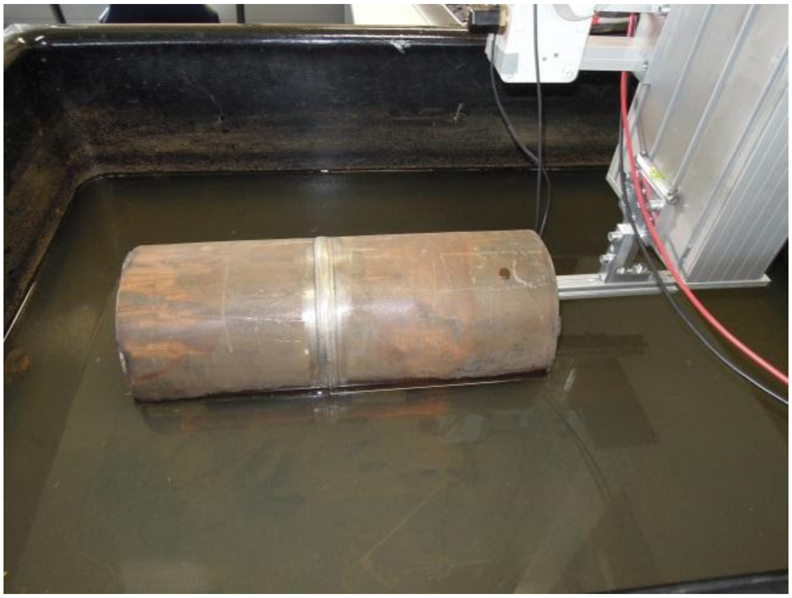
Figure 26: Test setup for test with ultrasonic sensors

The data display a clear visible front wall echo, marked with the green line and the back wall echoes which are marked with the blue line. The time of flight shows that only the CRA thickness of 5.0mm can be measured. The ultrasonic waves cannot negotiate the interface between the carbon steel and the CRA. This means, that an inspection of the carbon steel is not possible with UT.

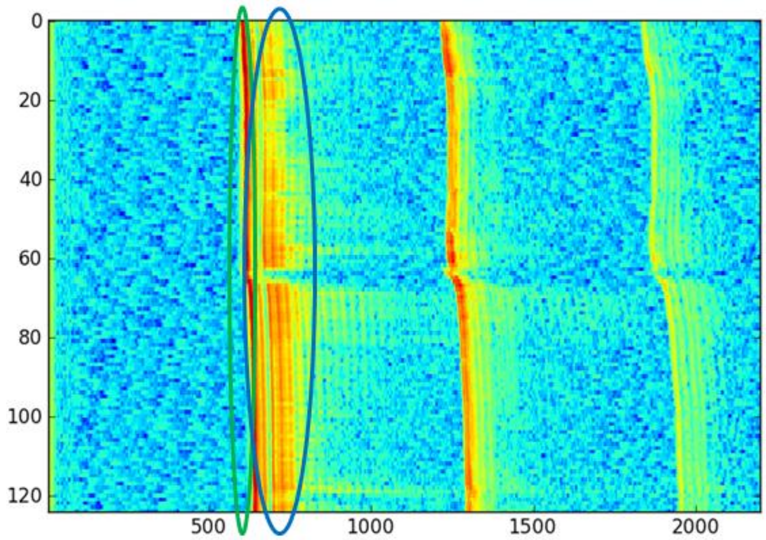

Figure 27: UT data for 6in pipe spool

The following test setup was used for another small-scale testing of UT sensors performing laboratory tests at ROSEN Technology and Research Center (RTRC) in Lingen, Germany:

- 16 in spool
- 0.5 meter length
- Cladding with stainless steel 316L
- 12.5mm wall thickness of carbon steel
- 3.0mm wall thickness of CRA
-

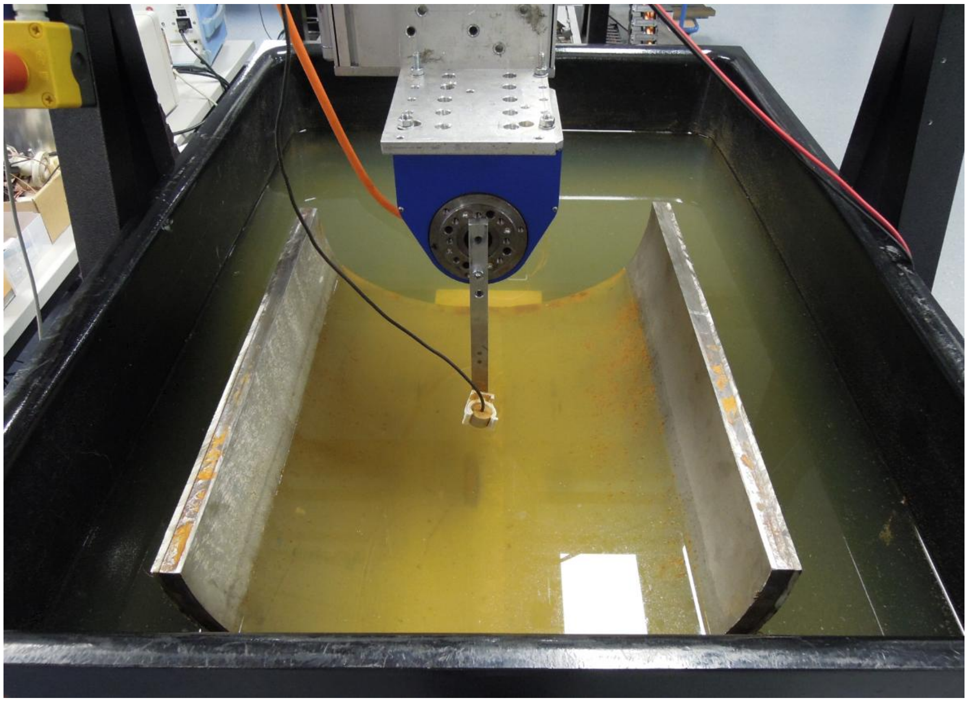

Figure 28: Test setup for test with ultrasonic sensors

The data display a clear visible front wall echo, pictured in dark red and the back wall echoes which are marked light red to green. The time of flight shows that the thickness of 15.5mm can be measured. The ultrasonic waves can negotiate the interface between the carbon steel and the CRA and the hole pipe wall can be inspected.

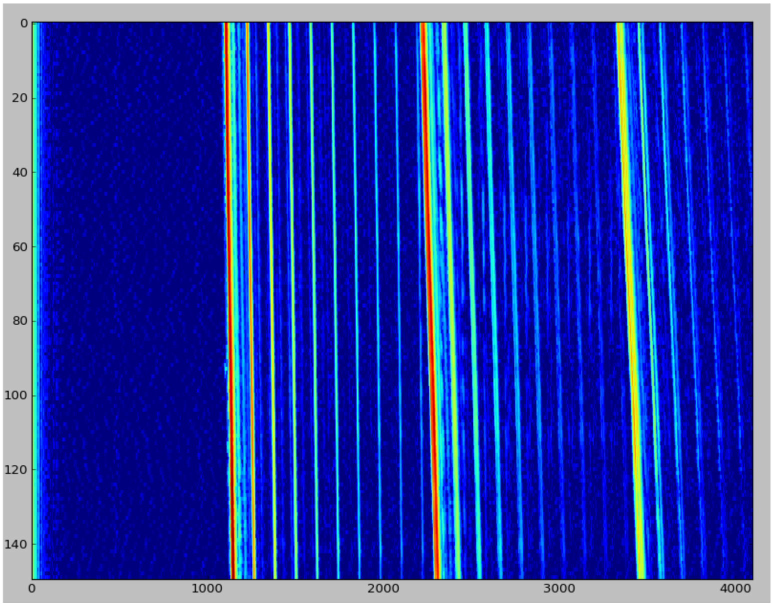

Figure 29: UT data for 16in pipe spool

With this test setup a crack detection test was performed as well, illustrated by the following Figure.

Figure 30: UT crack detection test setup with 16in pipe spool

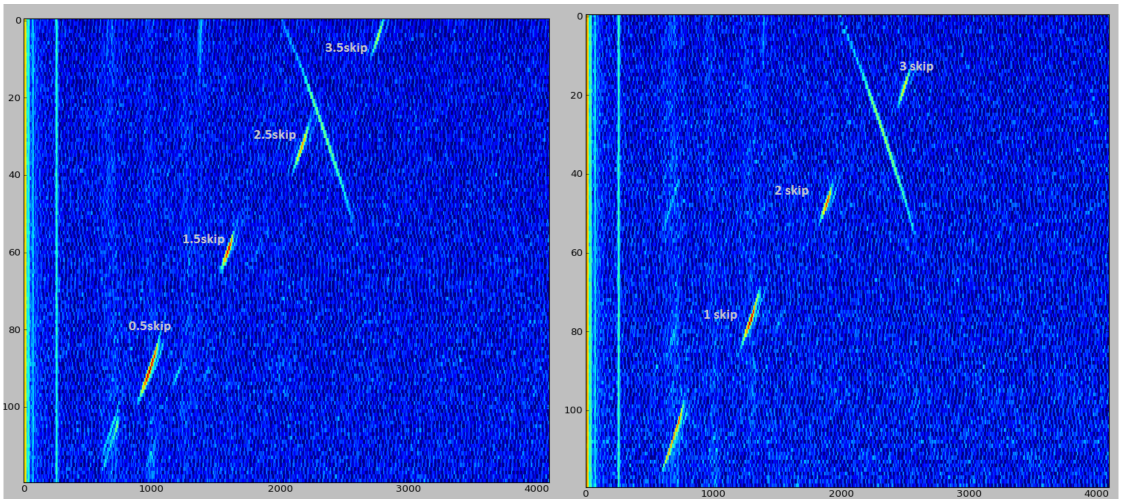

Figure 31: UT crack detection data for 16in pipe spool (left external, right internal)

Résumé for CRA pipes

Ultrasonic corrosion detection tools are designed to detect and accurately size defects like large areas of uniformly-corroded metal loss and laminations. Ultrasonic signals are influenced by so-called reflectors. It allows direct and highly accurate measurements of pipeline wall thicknesses. This technology can detect and accurately size defects for example, cracks and SCC. It is a direct measurement system for e.g. wall thickness.

The possibility to inspect a corrosion resistant alloy pipelines with ultrasonic depends on the type of corrosion resistant alloy. For mechanically bonded pipelines, the quality of the interface between the carbon steel and the stainless steel liner is important. The interface between the ferritic and austenitic steel may act as a reflector. UT signals are reflected by it and therefore UT doesn’t work for the inspection of the carbon steel. However, project specific analysis is recommended. Nevertheless the corrosion resistant alloy liner can be inspected with UT, which is confirmed by laboratory tests. In pipelines with overlay cladding the UT inspection capabilities depend on the inner surface roughness and the intersection of corrosion resistant alloy and carbon steel. Accordingly project specific analysis is recommended.

In case a metallurgical bonded cladding is applied an inspection with UT of the corrosion resistant alloy and the carbon steel should be possible. Due to the bonding the sound beam travels will likely travel through both the cladding and the carbon steel. The complete pipe can be inspected. The transition of cladding – carbon steel may cause an interface echo (depending on the sound velocities). In this case both cladding and pipe body can be inspected separately. A project specific analysis of the pipeline is recommended.

In conclusion a test of the tool for the specific pipeline with corrosion resistant alloy is necessary. The detection of features in the CRA should be possible, but detection of features in carbon steel depends on type of CRA and is not possible for mechanically bonded pipes.

CONCLUSION

Based on the commercial run, the full-scale pull-through and pump tests and the laboratory tests, for metal loss in the carbon steel, MFL is independently of the type of CRA pipe an option. But the mentioned restrictions have to be considered. UT is only an option, if a metallurgically bonded CRA pipe is used for the inspection of carbon steel. Standard UT ILI technology doesn't work for inspection of carbon steel for mechanically, internally bonded CRA pipes in the typically installed and tested pipe setup. For internal metal loss in the CRA eddy current can be used and alternatively UT, both with described restrictions. For using UT the thickness of the CRA should be above 2-3mm. This means that for metal loss detection a MFL and EC combination is recommended.

The detection of crack like features in the carbon steel is possible with UT in case metallurgically bonded CRA pipes are used. Otherwise, in case mechanically bonded pipes are used, standard UT technology which is used for ILI doesn't work in the carbon steel. MFL and EC are not designed for crack detection so far. Cracks in the CRA can be detected by UT, if the thickness of the CRA is above 2-3mm.

A geometric inspection is possible with standard geometry tools.

Summarized is an ILI of CRA pipes with current ILI technology possible, considering the above mentioned specialties and existing technologies, like MFL, EC and UT. The use of UT requires a liquid medium, which is typically not applicable is a gas pipeline. Therefore an individual analysis of the pipeline and an evaluation of applicable ILI technologies is recommended before an inspection.

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