INSPECTION OF UNUSUAL PIPE TYPES WITH EDDY CURRENT TECHNOLOGIES

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Abstract

Regular high-strength carbon steel pipe is the most often used pipe type for nowadays on-shore and off-shore pipelines. However, for many tasks special pipe types or modifications are employed. These pipe types are designed to give higher resistance to corrosion, like cladded pipe or pipe with thick coating, to give better mechanical flexibility, like flexible pipe or to allow for the transport under higher temperature like heat-insulated pipe.

As the inspection method strongly depends on the type of pipe and the type of degradation mechanism, regular inspection methods are usually not applicable. This is the case for internal as well as external pipe inspection. It has been found that eddy current technologies are indeed a very versatile method to design tailor-made inspection instruments. It is a common misconception that eddy current is only sensitive to surface defects.

The paper will describe the advantages of eddy current inspection methods. Methods are classified to show that in fact the methods vary considerably with respect to their field of application. Three case studies are presented, where bespoke instruments have been designed to inspect pipe types that have previously been considered non-inspectable due to their unusual nature.
Also it is described how methods that are currently used externally would be employed in an intelligent pig.

Introduction

The in-line inspection (ILI) industry has seen the birth and demise of many different inspection technologies. From the current perspective it seems that Magnetic Flux Leakage (MFL) and Ultrasonic inspection have achieved a status of “standard applications”. Over the recent years also EMAT (Electro-Magnetic Acoustic Transducer) Technology has found its way in the ILI industry and it seems that it will persist, as it addresses problems that have been outside of the technical feasibility of ILI so far.

When comparing ILI applications with other areas of non-destructive testing (NDT) it becomes apparent that eddy current inspection technology, that is found almost everywhere else, does not seem to have a suitable place in the ILI world. As a matter of fact eddy current pigs have been built in the past. The main objective has been to inspect oil pipelines or other pipelines under high cyclic loading for internal crack-like defects. This task is today performed by ultrasonic pig, that also allow for the detection of external cracking. The main reason for the absence of eddy current pigs is the inability of regular eddy current technology to inspect the volume of high wall thickness pipes of ferritic steel.

The testing of the near side surface is often not sufficient in the Oil and Gas-industry. The extent to which the volume of the material can also be tested depends on three parameters:

- The conductivity of the material
- The permeability of the material
- The measurement frequency

Eddy current inspection in essence consists of the measurement of the inductivity of a coil. If the coil is close to the specimen to be inspected its inductivity thus depends on the above mentioned parameter. Any degradation of the material in the vicinity of the coil would be detected as a change in conductivity or permeability.

The parameters determine the depth to which eddy currents penetrate into the material and hence whether the method is more sensitive to far side defects. Standard eddy current measurement, i.e. coil impedance measurement, thus remains sensitive to the surface only for magnetisable, i.e. ferritic steel. Alterations of the parameter need to be sough to be also sensitive to far side defects, wall loss or mid-wall defects. On the other side the possibility of eddy current testing to be used in any conductive material represents a great advantage over magnetostatic methods, which are only applicable for permeable material. Altogether three types of modifications can be identified to render eddy current more versatile.

Techniques

Remote Field Eddy Current

The Remote Field Eddy Current (RFEC) inspection is an eddy current method to allow for inspection of ferromagnetic pipe. It has been pointed out by Teitsma [1] that it is especially suitable for the inspection of non-piggable pipe. It has not been employed for in-line inspection mainly due to the reason, that the inspection speed is limited. For the inspection of unpiggable pipeline, however, often cable operated tools are employed. Cable-operated tools inspect at a much slower speed as compared to in-line inspection tools. Moreover, RFEC measurement is more forgiving with respect to lift-off and changing diameter.

RFEC-tools have been used for the inspection of heat exchanger and pressure tubes and have been proposed to inspect pipelines for stress corrosion cracking [2]. They have also been used to inspect the casing of oil and gas wells [3]. Russel Technology has introduced commercial RFEC pigs [4]. Their application in the oil and gas industry is restricted mainly due to the limitations in speed.

Pulsed Eddy Current

The idea of Pulsed Eddy Current (PEC) is to use a signal pulse. The propagation of such a pulse in a conductive material can be described as a diffusion process with a certain propagation speed. At the rear wall the reaction of the conductive layer suddenly stops. Measuring the diffusion speed to the rear wall allows for a quantitative wall thickness calculation. This is the idea of Pulsed Eddy Current (PEC), as it has been developed by Shell Global Solutions [5]. The accuracy of an ultrasonic probe is not being reached, but being an electromagnetic method, it does not require a couplant.

SLOFEC

The idea of SLOFEC is to use an eddy current coil on ferromagnetic material and to magnetise the section of pipe at the same time. The magnetisation has several effects. It changes the permeability of the material. Hence the penetration depth increases. At the same time changes in permeability due to different flux distribution become visible. With these effects also far side defect can be picked-up with eddy current sensors.

The principle of measurement is related to MFL-measurement, but the set-up works at lower magnetisation levels. Since only moderate levels of magnetisation are required, the method works to higher wall thickness pipe, or through several millimetres of coating thickness.
The following will show different applications on pipe systems. Some are not used for external inspection, but could in principle work from the inside as well.

Applications

In general the correct design and careful production of eddy current sensors is the key in obtaining valuable measurement. Many parameter like coil size, wire gauge, number of turns, measurement frequency and source gain are important parameters to be determined. In particular there are many eddy current coil types each suited for a specific inspection task. It requires a certain level of experience to determine the right configuration.

Metallic coating or cladding

One pipe type that is still difficult to inspect is ferritic pipe with a non ferritic but metallic layer. In some configuration that metallic layer may be on the outside as in cladded riser pipe. In other configurations this cladding may be on the inside as in cladded pipe for sour service. Often the task is to measure through the metallic layer into the ferritic layer of the pipe and to test for metal loss or crack-like defects.

on the left side shows a sample test pipe with a cladding of Monel on the outside. For the detection of corrosion in the inner ferritic layer the conductive Monel layer would need to be overcome. Special eddy current configurations with respect to the above mentioned parameter allow finding these defects. What made this project especially difficult was the fact that defects had to be detected close to or within girth welds. As internal pigging and axial scanning from the outside usually leaves the weld uninspected or at least badly inspected, the direction of scanning has to be altered. A scanning movement in the circumferential direction will improve the situation considerably. For in-line inspection a circumferential movement is hardly possible. Hence an external inspection tool was designed to scan the pipe on the outside. This tool is shown on the right side of .

Figure 1: Monel cladded pipe on the left and an external inspection device made by Innospection

An equivalent situation exists if internally cladded pipe is to be inspected from the inside. For this type of pipe an in-line inspection solution would be ideal that can inspect also for the external ferritic part for external corrosion or for corrosion in the annulus between the two layers. A sample pipe is shown in . The thin internal cladding is visible. In this particular pipe there is also an insulation layer between two carbon steel layers. The pipe type is known as pipe-in-pipe. At the girth welds only the inner pipe is present. This section was chosen for the test.

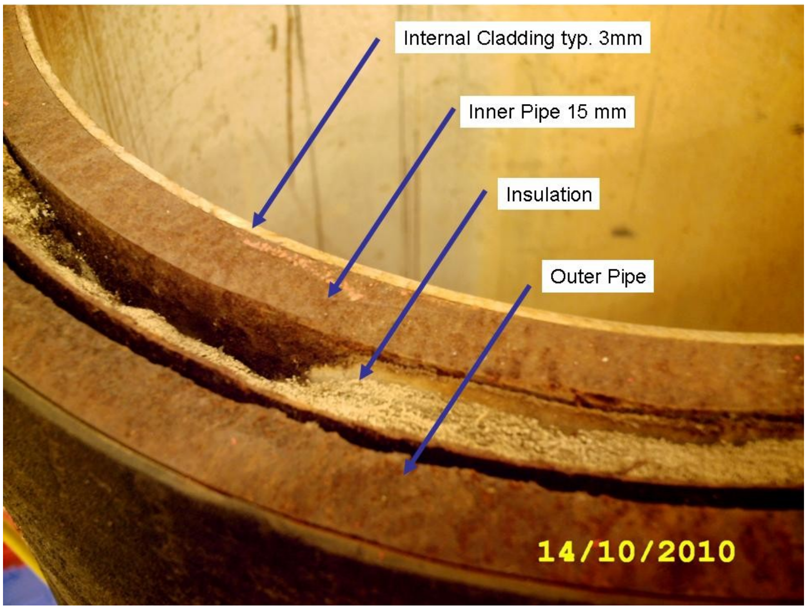

Figure 2: The cladded pipe consists of an inner CRA layer. In this particular pipe there is also an outer ferritic layer. Test defects were in the inner ferritic pipe.

The general test set-up is shown in . The external defects are shown on the left side. They are put into the inner of the two pipes shown in . At this position the outer pipe is reduced and merged to the inner pipe. In the center a girth weld is visible. The inspection device is shown on the right side of . It does not cover the whole inner circumference. However, full 360 deg tools are feasible as the magnetization units would be similar to MFL inspection tools.

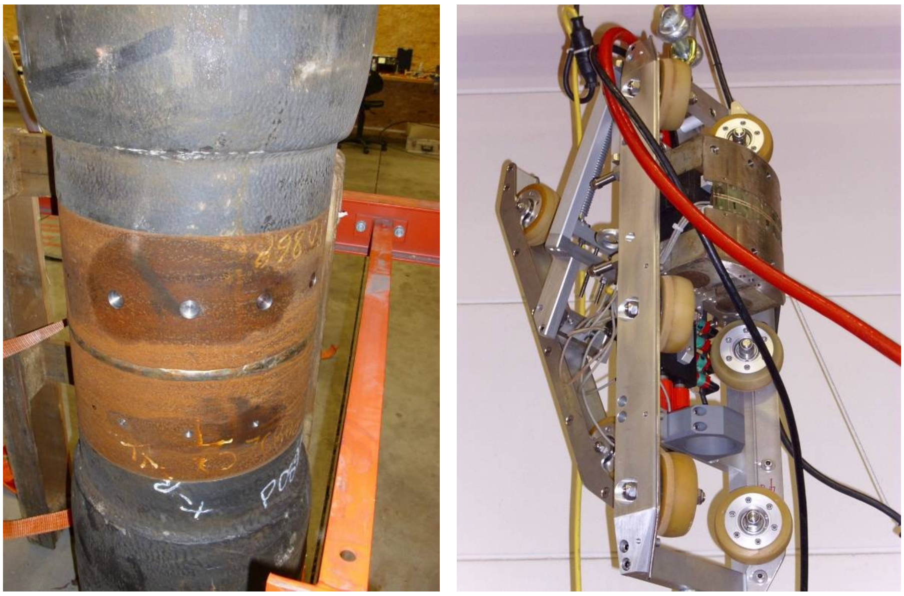

Figure 3: Test set-up with external defects in a cladded pipe and inspection device used for the test

The signals are shown in . What is shown are eight sensors that are mounted in an array. The signals are plotted in amplitude versus distance. The color coding reflects additional information about the signal phase. The detected defects and features are marked on the figure. In principle all defects have been found. The smallest has been 12 mm in diameter; the shallowest was 13% loss of wall thickness.

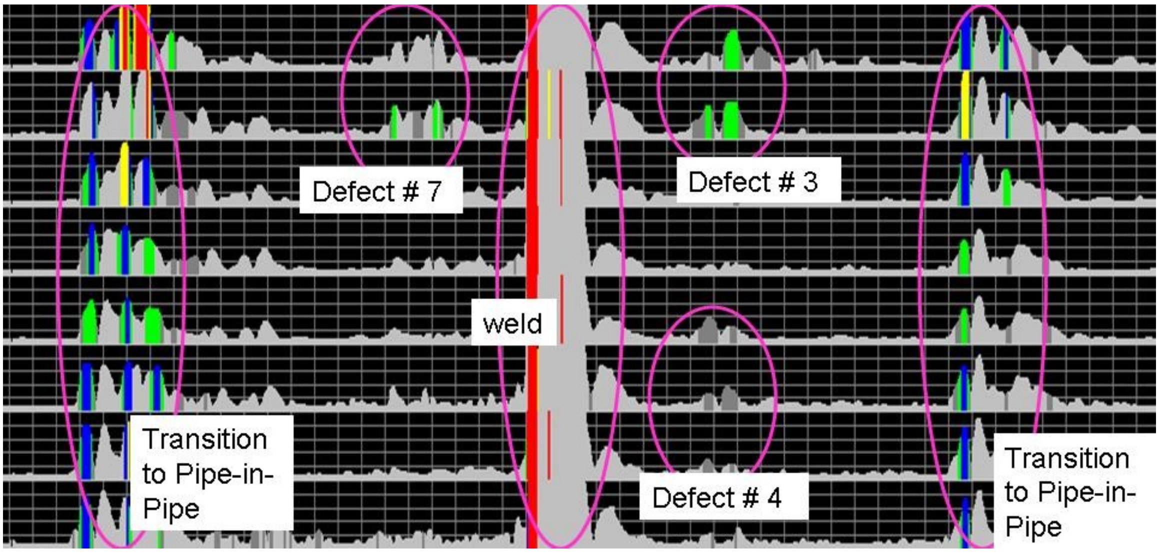

Figure 4: Detected eddy current signals in cladded pipe

Flexible riser pipe

Another pipe type of unusual configuration is flexible riser pipe. The multitude of different steel layers and materials represents a major challenge to inspection. A typical layer structure is shown in . Internal and external inspection techniques have been looked into. For now the external inspection method seemed to be quicker to realise. It will be presented here. However, internal methods that can be deployed like a tethered pig are also investigated.

Figure 5: Typical appearance of a flexible pipe

The newly built tool is shown in . On the right side the tool is in the workshop for testing. On the left side a tank test is shown. The tool consists of a scanning unit that is moved up and down on the pipe by hydraulic power. To cover the whole circumference the scanner can be moved around the pipe. It will be deployed using an inspection type ROV. Clamps will tighten it to the pipe to ensure smooth motion during inspection. The design was aiming at making the tool as light as possible for simple deployment.

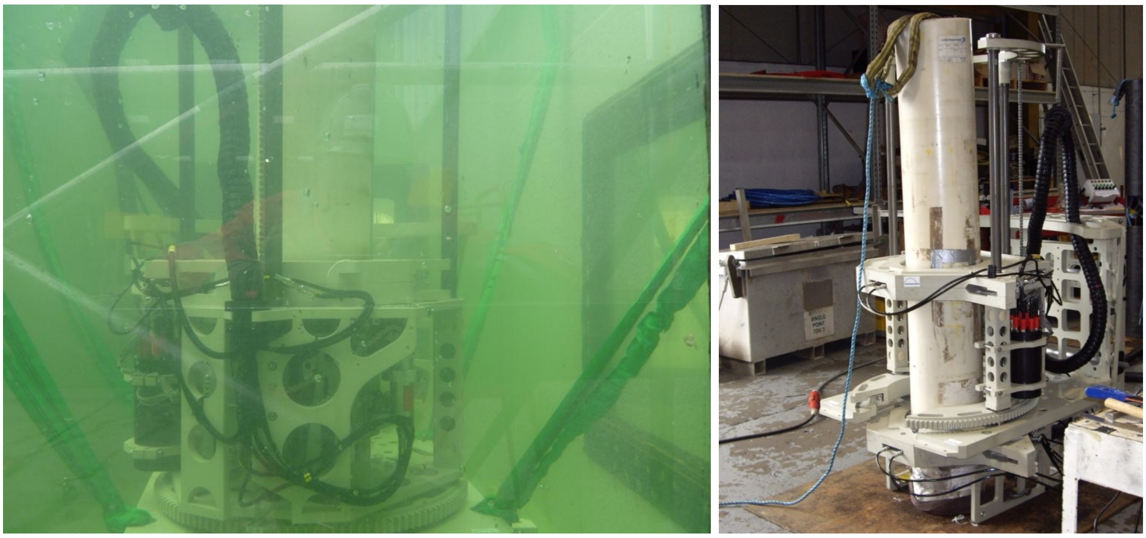

Figure 6: Newly built inspection tool for flexible risers

Typical defect signals can also be obtained on a flat test sample as shown in . A small artificial defect in an armored layer is seen on the left. The layer structure can be imitated. Especially the layer orientation is important. Signals are obtained as shown on the right of .

Figure 7: Testing and calibration for certain defect types and sizes can be done on a flat sample.

The signal obtained from the defect shown in on the left is shown in the inset of the right part in . It is measured through a 10mm thick coating. This is the typical outer coating thickness of flexible riser pipe. The defect does not need to be in the near side of the upper layer. The employed method finds defects also in the lower layers.

A sample measurement on a flexible riser pipe is shown in the lower part of Figure 8. Some defects like flat bottom holes and a deep notch representing a crack-like defect have been put in the first armored layer. These defects are also detected as shown in the lower part of Figure 8. Note that the scanning was done in different direction; signals on the picture are turned upside down.

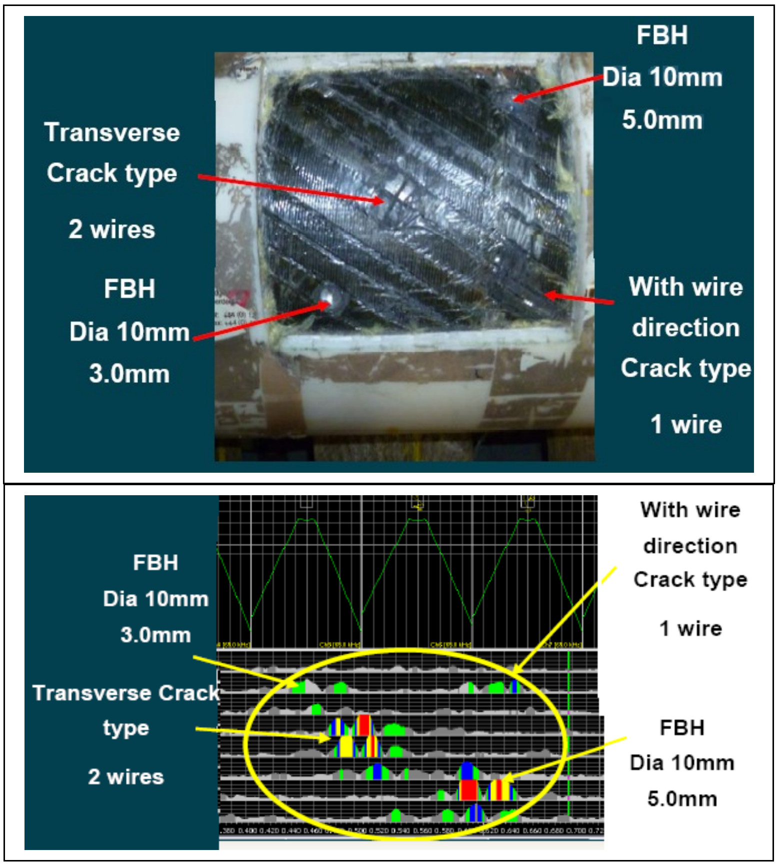

Figure 8: Upper part: artificial defects in a flexible riser pipe; Lower part: The signal obtained from defects in a flexible riser pipe.

Conclusion

Eddy current non destructive testing really consists of a variety of different methods. All of these methods can be tailored for some application. In particular magnetically biased eddy current is suitable for many applications in the oil and gas industry. For In-line Inspection it offers unique opportunities. For instance cladded pipe or flexible riser pipe may be inspected.

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