INSPECTION OF PIPELINES THROUGH THICK COATING

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Introduction

The inspection of pipelines through high levels of coating remains a challenging task. In particular offshore pipelines often require a thick external coating for various purposes. Usually it is a combination of mechanical impact and corrosion protection. Hence, the configurations can be quite different. The external inspection of subsea pipelines and risers often complement or substitute an internal inspection by pigging.

An overview of available technologies is presented. The limitations of the technologies and their physical origins are discussed. Most of the principles are based on some kind of eddy current technique.

Several case studies of inspection through a thick coating are presented. In one case risers had to be inspected through as much as 12.7 mm (½”) of coating and with a wall thickness of up to 25.4 mm (1”). The high stand-off measurement usually conflicts with a high resolution of the scanned surface. Metal loss defects as small as 10 mm and as shallow as 10% have been found. In a different project a wire disorganisation of a flexible pipe had to be detected through a coating of 9 mm. In this case it was possible to show, how a regular signal pattern and its distortion by defects can lead to a sensitive detection of defects through a coating.

Existing Technology

One of the existing and matured technologies is guided wave UT. The idea of guided wave inspection technology is to introduce ultrasonic waves at an accessible part of the pipeline. Guided waves make use of the geometry of the pipeline. The waves are confined to the structure and thus propagate along the axis of the pipe. This confinement allows the waves to travel much farther than bulk waves. Hence, the technology is also called Long Range UT.

To properly excite this wave type a full circumference ring is clamped onto the pipeline externally. At this particular point any coating needs to be removed. The wave then travels in both directions, upstream and downstream, where potential defects like corrosion will lead to a reflection.

The range is usually stated to be up to 100m in both directions [1]. Many different modes of waves exist in a pipe geometry. The composition of these modes and possible mode conversions allow for an approximate size and orientation estimation of defects. A common aspect is, that an external coating will lead to a damping of the wave, thus reducing its range. Obviously, the method is stationary and it does not measure through a coating, but required access to the bare steel at some positions.

Another method that is able to cope with thicker layer of coating is Pulsed Eddy Current (PEC). The idea in PEC is to send a short pulse of current through an electrical coil and to investigate the response over time. Through the effect of electromagnetic induction the current will generate eddy current in a metallic surface in the vicinity. The generation of these currents will lead to a measureable transient response in the coil.

A pulse contains a broad spectrum of frequencies. The lower frequency range will lead to eddy currents propagating through the pipe wall. Due to the limit in wall thickness, the response will show a change in signal, once the eddy currents have diffused through the wall. The development of the Pulsed Eddy Current technique and its application to the Oil & Gas industry was driven by SHELL GLOBAL SOLUTIONS INTERNATIONAL [2].

As the relevant portion of the spectrum is also in the lower frequency range this method is also stationary. The thickness of coating that it can penetrate depends on the size of a coil and the nature of the coating. It has been used for the detection of corrosion under insulation (CUI) for thickness of 150mm and thin non-magnetic metallic coating [3]. Figure 1 shows a subsea instrumentation for PEC-Pipeline inspection and a depiction of inspection data [4].

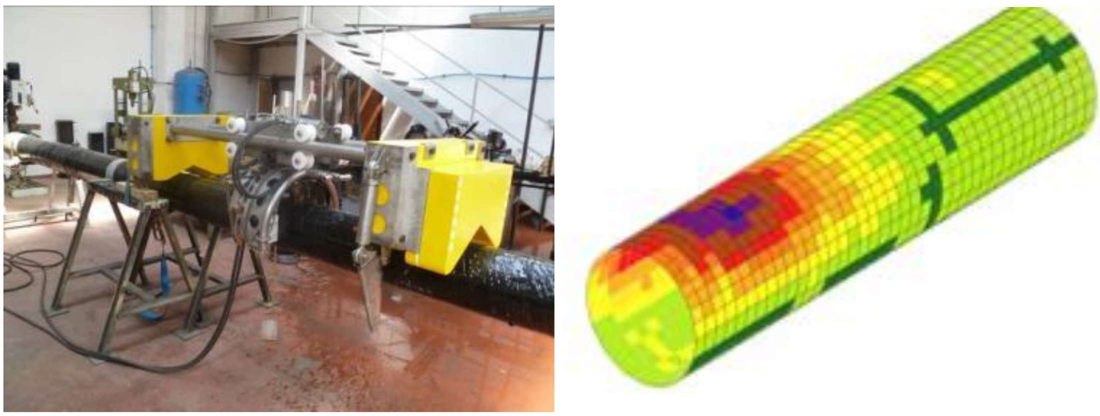

Figure 1: Left Subsea inspection device for PEC. Right: depiction of inspection results (by Impresub [4])

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 2.

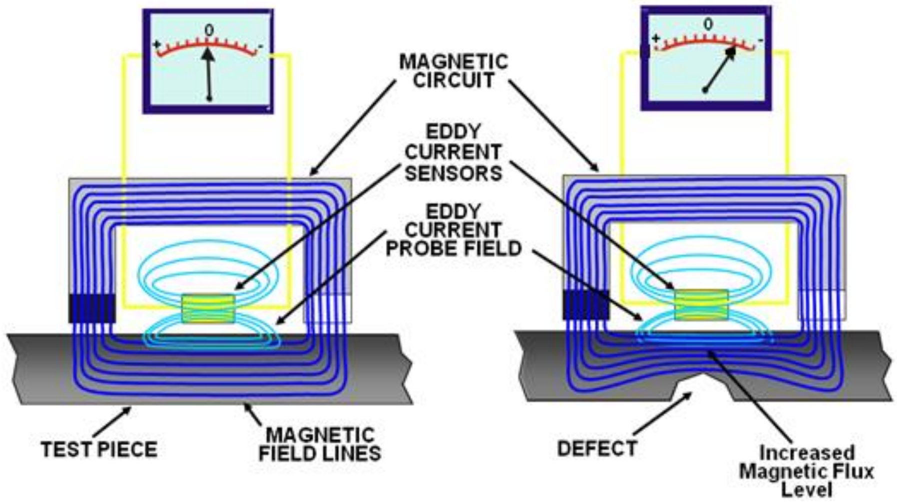

Figure 2: Principle of the MEC technology (Magnetic Eddy Current) also known as a further developed technique from Saturation Low Frequency Eddy Current (SLOFEC).

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. 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.

A larger size sensor would allow for an increased distance of the sensor from the surface. Larger sensors alone, however, would also lead to a reduction in resolution of the signal obtained from the scanned surface. This is why the exact shape of the magnetic field of the sensor interacting with the pipe surface is also of interest. A model obtained by 2D-FEM is shown in Figure 3.

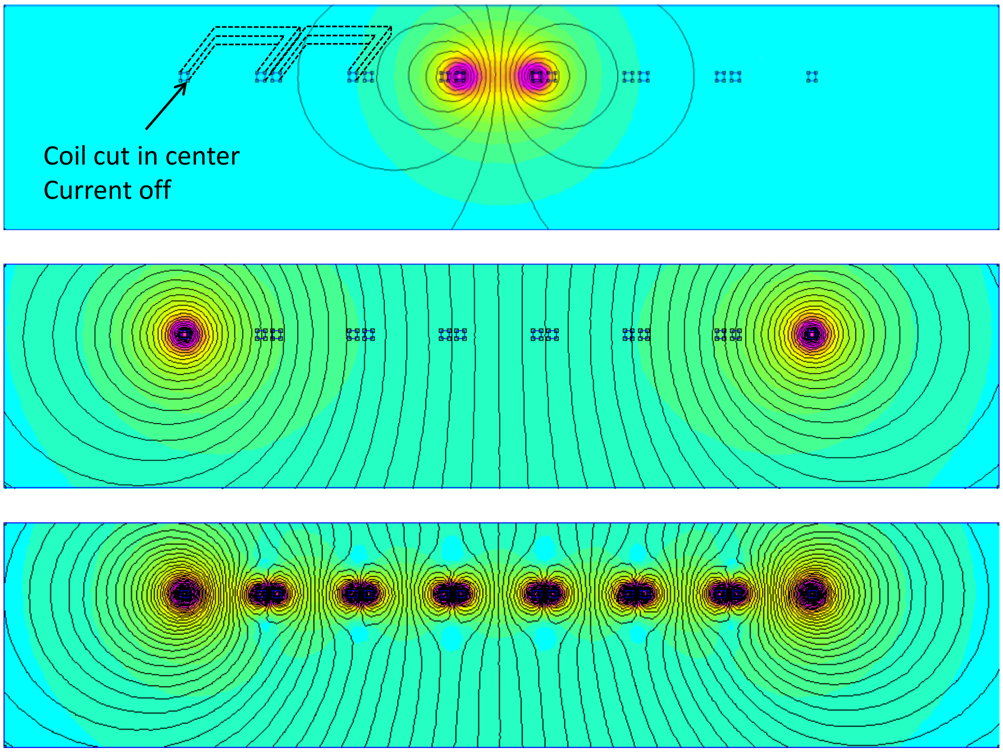

Figure 3: 2D modeled fields for a small, a large size coil and an array of coils

Figure 3 shows an FEM modeling of the magnetic field of a coil. The upper image shows a small coil with 10mm diameter. Field lines are shown in black, the magnetic field level in a color code. The model is for 7 coils. In the upper image the current for the center coil only is switched on. The field at a distance of 20mm (the lower edge of the image) is quite inhomogeneous and rather weak. For a larger coil (center image) the field is more homogeneous. The last image shows a model with an array of small coils. The overall field resembles the one of the large coil in homogeneity, but the multitude of coils allows for a higher resolution scanning at a relatively high distance.

Application for inspection of a riser with thick coating

In an actual project a riser pipe was to be tested for internal and external corrosion type defects. The steel wall thickness varied from 18 mm to 25.4 mm (1”). A polymer coating of 12.7 mm (½”) was present. Together with a 3mm lift-off of the sensors from the coating surface this led to some 15mm distance. The test pipe is shown in Figure 4.

Figure 4: Test pipe for the riser inspection with artificial defects. Internal defects were introduced through a hole on the opposite side.

For the introduction of internal defects a hole was cut into the pipe and defects were machined through this hole. After the introduction of external defects (center photo) the pipe was coated with a coating similar to the actual riser coating (right photo). It is essential that the coating resembles the original coating in terms of hardness. The movement of the tool on the heavily coated surface will be impeded, if the coating is too soft.

Figure 5 shows the MEC-MPS200+-Scanner which is used for this kind of inspection. Next to the MEC unit it can accommodate a water jetting cleaning device and an array of UT wall thickness sensors. It is operated with a electromagnet, which will also provide for an attractive force to the riser. This force is still suitably high even with a coating in the range of 12.7 mm (½") to safely make it stick to the pipe. Figure 6 shows the device in the vertical position on a riser sample (left) and on a riser (right).

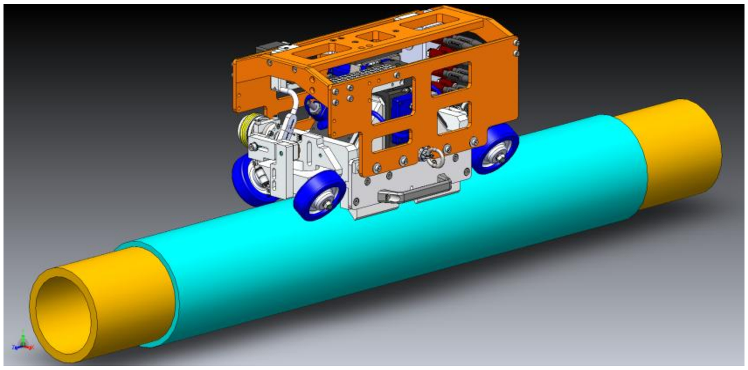

Figure 5: The MEC-MPS200+ System

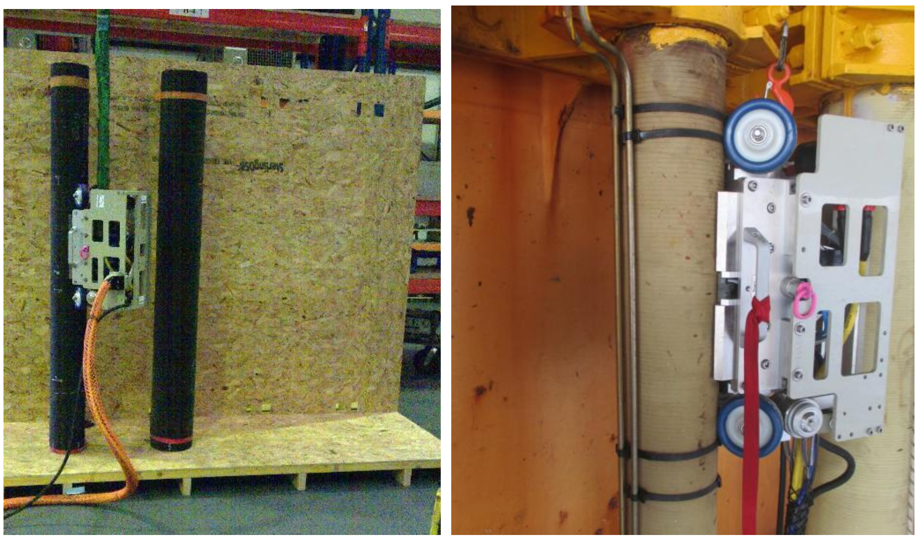

Figure 6: Arrangement with the MEC-MPS200+-tool for the inspection

(left on a test-rig, right offshore).

Data obtained in the test runs are shown in Figure 7. It shows a sequence of near-side (external) round-bottom metal loss defects with a diameter of 20mm. The coating of 12.7 mm (½") is present. The depth is stated in the image. Under favorable circumstances even 5% metal loss defects are visible. Defects with a metal loss of 10% or more show a probability of detection (POD) of 95% or better. The calibration needs to take the increased lift-off into account. The coating thickness should match the on-site thickness rather closely (± 2mm). In case of doubt a simple measurement of the outer circumference can help.

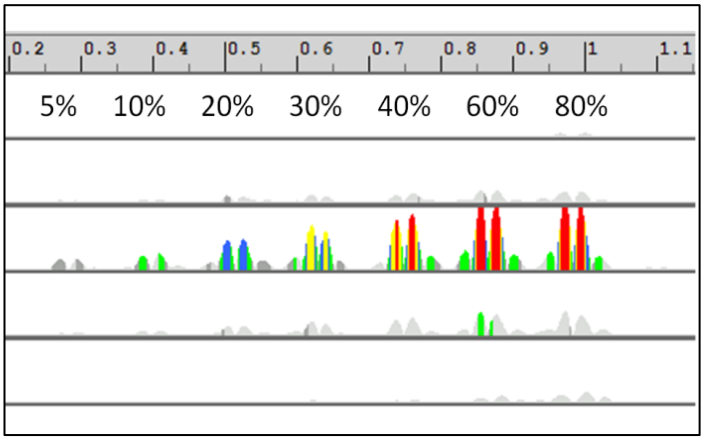

Figure 7: Sequence of 20 mm near-side defects in an 8"pipe of 23 mm wall thickness under 12.7 mm (½") coating.

Several risers from 6" to 20" diameter have been inspected in this manner.

Inspection of flexible riser

Flexible risers are also a type of pipe which requires a thick outer coating. Whatever inspection method is chosen, it does not have direct access to the surface of the metal components. The issue of inspecting flexible risers is complex and has been discussed before [3] in particular with respect to finding cracks and corrosion.

In some cases 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 risers, 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 vaying 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 8.

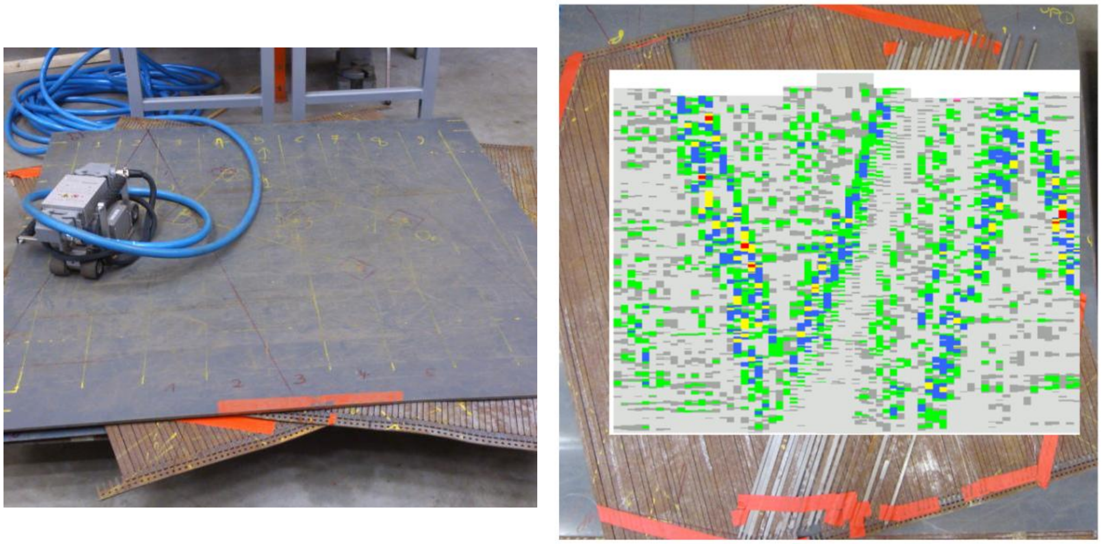

Figure 8: Set-up for testing of wire disorganization defects on a flat sample (left) and results for loose wires and wire gaps (right).

A PVC-layer of 9mm 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 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 9 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.

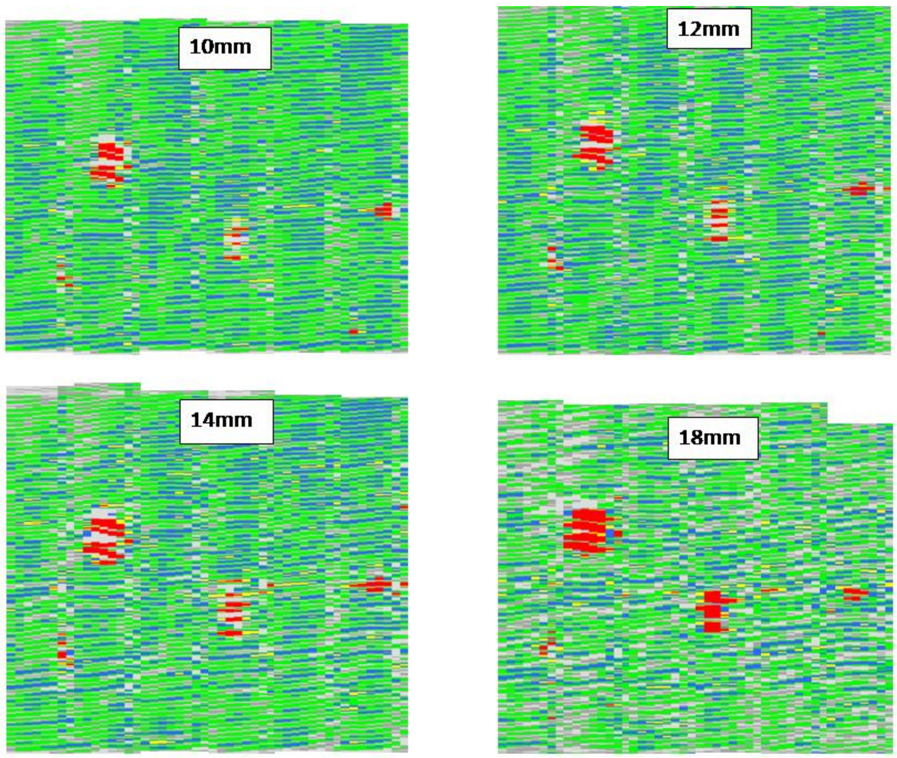

Figure 9: Obtained signals with different lift-off as indicated.

The structure is visible from 10mm stand-off (sensors close to outer surface of the pipe) to 18mm (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 10 shows the MEC-Combi-Crawler carrying out such an inspection.

Figure 10: The MEC-Combi-Crawler on a flexible pipe carrying out the measurement.

Conclusions

The Magnetic Eddy Current Technology offers a unique opportunity to carry out measurements through thicker layers of coating that Ultrasonic or Magnetic Flux Leakage inspection would not be capable of.
The technology has been successfully implemented for the inspection of pipes and pipelines in various environmental conditions in particular in offshore applications.

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