INSPECTION OF FLEXIBLE RISER PIPE WITH MEC-FIT™

By: K. Reber, Innospection Germany GmbH, Stutensee, Germany
A. Bönisch, Innospection Ltd., Aberdeen, UK

Abstract

Flexible pipes are by nature complicated in design with its many varying material types, corresponding to challenges in the inspection and integrity evaluation of the pipes.

The anticipated concerns of the flexible pipe operators are defects such as cracks, corrosions, erosion and fatigue in the different layers of the wires under various tensional stress levels. While the inspection techniques currently available in the market are able to inspect only the near side layers for wire disruptions, the far side layers remain uninspected.

Developed by Innospection, MEC-FIT™ is a Flexible Riser Inspection Tool using a patented technology that combines direct magnetic field lines with eddy current field lines, thus allowing a deeper penetration into the various armored layers. This technique enables the selection of the layers to be inspected, or alternatively allows the optimisation of the inspection for a specific layer from which a defect signal is received. The tool is capable of detecting defects such as cracks, corrosions, material fatigue and general wall loss.

Unlike traditional inspection methods, this system requires no couplant or annular flooding.
Deployed from an ROV, the inspection data is transmitted in real time via the ROV's main umbilical back to the inspection computer at the ROV control unit.

Introduction

Flexible riser pipe or unbounded flexible pipe becomes more and more popular for applications in the offshore oil and gas industry. Initially merely intended for the use of flexible risers in rough sea, this type of pipe type is now also used for flow lines and other subsea applications. It is often also part of a platform to platform connector pipeline, in combination with regular rigid piping. In this context flexible riser pipe has also been intelligently pigged. However, due to the special structure of flexible riser pipe, most defects will not be revealed to intelligent pigs. Hence, flexible riser pipe, although it could be considered piggable in terms of passage, is not inspectable.

Flexible riser pipe is manufactured of layers of metallic strings (armoured wires) and helically wound interlocking wires (pressure armour). For tightness and external protection layers of PE or similar polymers are used. The typical configuration of a flexible riser pipe is shown in Figure 1.

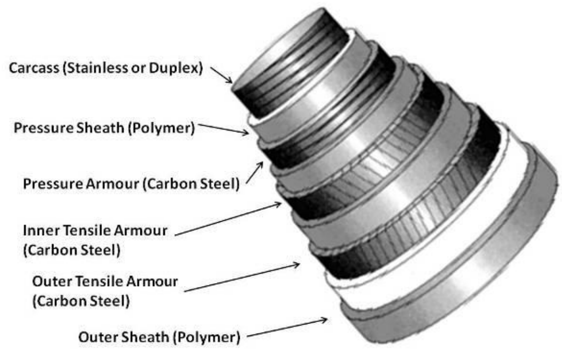

Figure 1: Typical configuration of flexible riser pipe

Flexible riser pipe is hence a challenge to the inspection service industry and several joint industry projects have been launched to tackle this problem [1, 2 and 4]. The multi-layered structure of the flexible riser pipe presents a problem for most of the typical NDT-Technologies employed in regular steel pipe. While Ultrasonic based technologies often have the advantage of yielding information also from non-metallic material, the coupling between different layers often prevents a complete picture. Electromagnetic methods, in contrast, will select conductive material, while other material, like polymers will not be considered. The subject remains an area of active research, but solutions targeting specific concerns are now available.

Defects in flexible riser pipe

The flaws and defects that flexible riser pipe may suffer from are quite manifold. As a matter of fact raising the issue with different operators it is likely that the mentioned issues will differ widely.

However, a few main concerns have risen. In particular as the lifetime of flexible riser pipe is deemed to be governed by fatigue-life, fatigue related defects are expected. While macroscopically fatigue will result in a reduced material strength, microscopically it will be the emergence of cracks that constitute a possible route to failure. With the armoured layers designed to take the main part of the bending stresses, this layer would be most prone to cracking.

In addition inevitable damages in the outer sheath will lead to the ingress of water. This can cause corrosion in the outer layers of the tensile armour. Finally any overbending of the pipe can lead to an unlocking of the pressure armour or to fatigue cracking in the clamping parts of the pressure armour. Further defects like erosion have been reported.

Pigging flexible riser pipe

As mentioned previously the uneven inner surface of a carcass does not render flexible pipe unpiggable. Intelligent pigs have passed through flexible pipe many times. No major problem has been reported. Concerning defect detection, the inspection is very much limited to the inside, i.e. the carcass. Distortions and changes in the structure, unlocking etc. usually become visible in such surveys. However, MFL as well as UT-based intelligent pigs have a limitation in penetrating further into the pipe. In principle MFL could still detect larger defects in the inner layers, but the resolution would be reduced. Precaution shall be taken when using MFL-tools with carbon steel brushes in stainless steel carcasses. A metallurgical investigation is required to avoid “after-rust”.

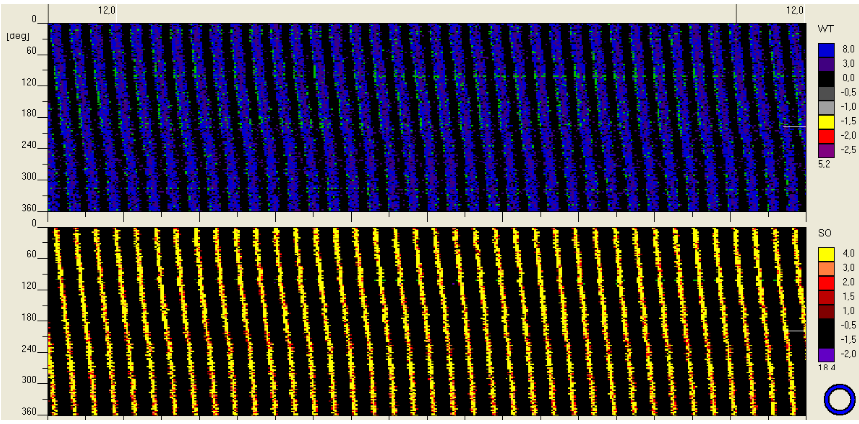

Figure 2: View of a flexible riser pipe by a UT Wall thickness tool. Courtesy of NDT Systems & Services AG using LineExplorer UM™

Prior technologies

One of the most often applied techniques is radiography [1, 3]. While this technique shows high resolution images, the ease of deployment is somewhat limited. It may turn out to be an excellent verification technique. Another electromagnetic technology is MAPS [4]. This technology is currently in use for monitoring the condition of flexible riser pipe at fixed positions. Finally UT pulse-echo is also employed from an ROV [2]. This technique is mainly used for the detection of flooded annuli.

Application of Eddy Current Technology

Standard eddy current instrumentation is only sensitive to the surface of a metallic material. Even this can be quite a benefit for the inspection of flexible riser pipe [5]. However, modifications of the standard eddy current technologies allow for the inspection of deeper structures. At Innospection magnetically biased eddy current has been found to be a versatile method for the inspection of ferritic steel structures. The technology is also known under the trade name of SLOFEC. For the modification and adaptation to flexible riser inspection it is now known as MEC-FIT™.

The idea of MEC-FIT™ is to use an eddy current coil on ferromagnetic material and to magnetise the section of ferritic steel components 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 defects embedded in the material 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. Obviously one difference to MFL is that the level of magnetisation should be adjusted. In contrast in MFL the magnetisation level should always be as high as possible.

One of the most defining aspects of flexible riser pipe is the presence of wires or strings running helically around the pipe. This has a fundamental impact on electromagnetic NDE methods. The question of the scanning and magnetisation direction needs to be considered. Several configurations can be conceived. A certain level of magnetisation needs to be achieved; hence the magnetisation cannot deviate too much from the direction of the wires. There are at least two wiring directions. For mechanical reasons only axial and circumferential scanning are reasonable. In addition the employed probes usually yield a strong signal for the gaps between the wires. Refer to Figure 3 for a sample measurement of 4 mm thick armour wires, 12 mm in width and a gap of app. 2 mm.

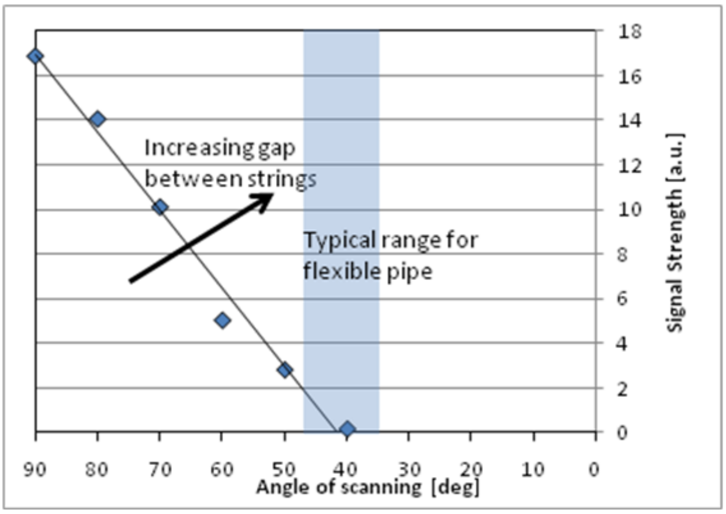

Figure 3: Signal of gaps between wires as a function of scanning direction measured versus the pipe axis.

Typical flexible riser pipe has angles between 35º and 45º. With the two layers wound in opposite directions an angle of 45º would be a crossing of the layers at right angles. As can be seen in Figure 3 the probes are designed such that the signal of a gap just disappears at the typical angle. It is known that the gaps are not at all uniform in flexible riser pipe. It may be interesting to be able to detect larger gaps in the armour layer. Larger gaps do not necessarily constitute a defect, but it may be used as a reference location in a structure that may appear very homogeneous otherwise.

Another question is the implication of the magnetisation direction. In general this will be parallel to the scanning direction. The wire structure has a fundamental impact on the magnetisability of the structure. A finite element study has been carried out to determine this impact. A typical configuration is shown in Figure 4.

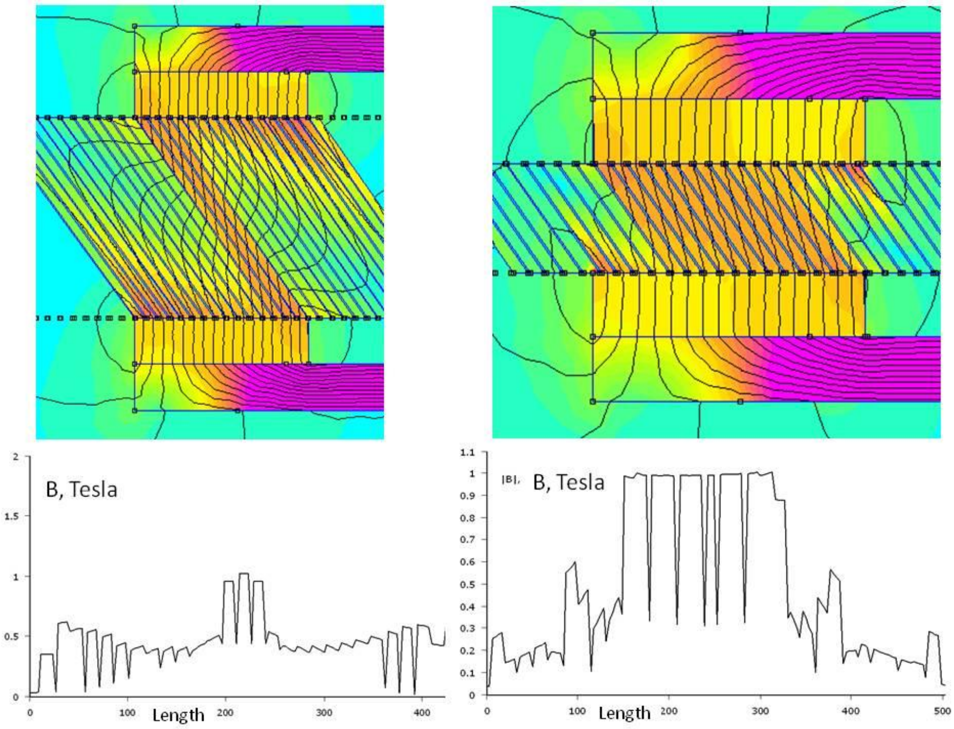

Figure 4: Comparison of different magnetization devices on the wire magnetization

The upper part of the picture shows different configurations of the magnetisation device. In particular the width to length ratio has been altered. The lower diagrams show the respective magnetisation level. The area of homogeneous magnetisation is too small in the configuration on the left.

Calibration of equipment

The calibration for MEC-FIT™ is usually carried out on a calibration piece with artificial defects. As an electromagnetic method, the calibration is always with respect to known sample defects under the same conditions. For a simple steel pipe, the relevant parameters for calibration are the wall thickness and the lift-off. In some cases the material would also make a difference, but carbon steel does not vary too much. Compared to regular steel pipe, flexible riser pipe obviously is much more complex. The parameters that need to be considered when calibrating flexible riser pipe are:

- Thickness of layers and interface layers
- Lift-off (here thickness of the outer sheath)
- Angle of armor layer versus the pipe axis
- Magnetization level

Different levels of magnetisation can approximately be measured by the magnetic stray field above the magnetised specimen. For this reason magnetic Hall sensors have been mounted into the eddy current probes. They allow monitoring the magnetic stray field. The field is then directly related to the wall thickness of the steel layers, the lift-off and the magnetisation level. With the first two held constant, the signal can be used to control the magnetisation level. Also by monitoring the value and keeping the magnetisation level constant, any unexpected changes in the structure of the pipe should become visible. The level of magnetisation can be changed with a patented rotary magnet device. It is depicted in Figure 5.

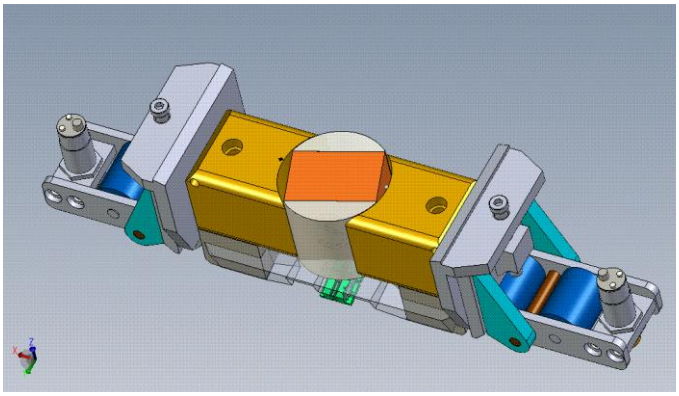

Figure 5: Patented design for the adaptation of the magnetization level

By rotating the magnet the field can be changed from zero to a maximum level. Measurements are shown in Figure 6 for various pipe configurations. Also the open circuit, i.e. the device removed from any steel material is shown. It can be seen, that once a pipe type is chosen, the Hall device can be used to verify the magnetic flux level.

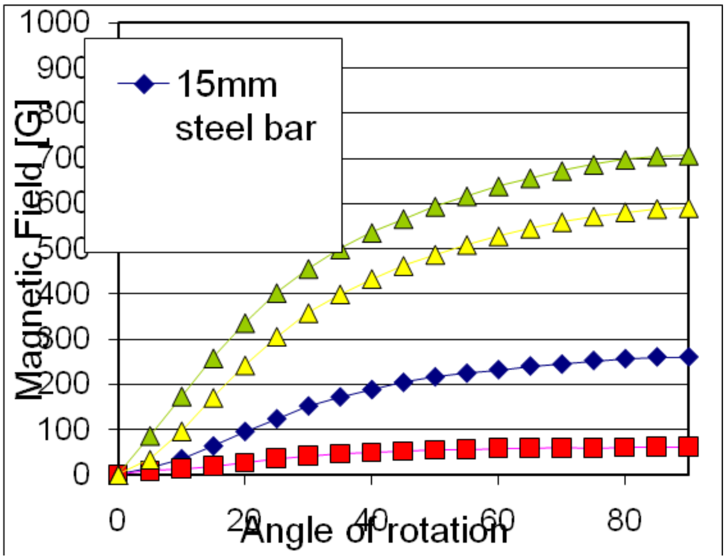

Figure 6: Magnetic field measured by the Hall sensor for different structures as the magnet is "turned on"

In addition the values can be combined with the information of the open circuit. This will allow calculating a value directly proportional to a permeability. This value does of course not only include material permeability but also geometry effects. The result is shown in Figure 7.

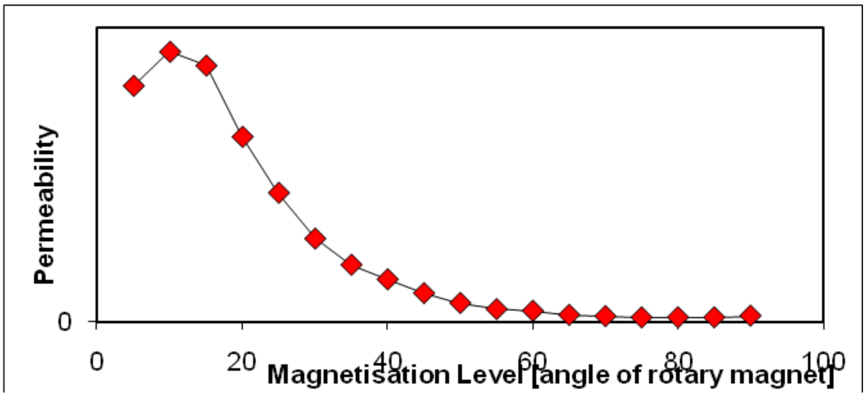

Figure 7: Calculated "permeability" in arbitrary units. It is a combination of material and geometrical effects.

The maximum signal is expected at the steepest slope of this curve. This would be around 20º turning angle. Experimentally this could be verified. For the calibration of defects the magnetization level will be set to the optimum level with lift-off and wall thickness fixed. It can be seen in Figure 6 that this value can also be interpolated once sufficient experimental data is obtained.

With regards to calibration for defect sizing, artificial defects can be used if the "electromagnetic environment" is comparable. This means that material properties and configuration should be similar as in the actual pipe.

For gaining experience with the device, testing on actual defects in riser pipe is very important.

Figure 8 shows the signals of a scan of the complete surface of a flexible riser pipe of app. 2 m length. This particular flexible pipe has been in service for many years and was known to be flooded. Radiographic inspection has revealed an unlocking of the ξ-wire. Depicted are the signals as the scan was performed along the axis. The axis of the pipe is from left to right. The figure is a mosaic of several scans and displays the full circumference in the vertical extent.

The area with the presumed unlocking is found in the center of the picture, where signals extend in the vertical direction. Also two stripes running from the lower left to the upper right show larger gaps in the armored wire. It is well known that in flexible riser pipe the armored wires are not equally spaced, but the gap size can vary. With larger gap size the gap will yield a signal as shown in Figure 3.

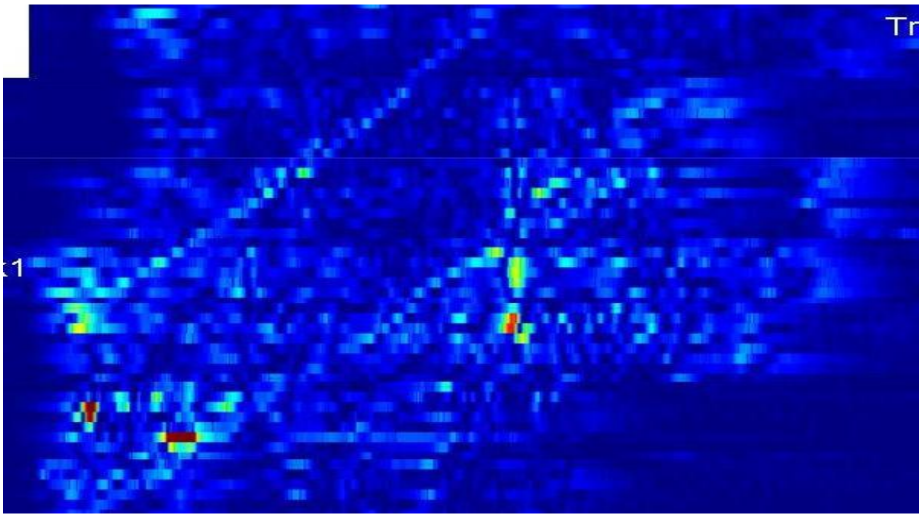

Figure 8: Surface of a flexible riser pipe that has been in service for many years and was known to be flooded. Radiographic inspection has revealed an unlocking of the Zeta-wire.

Operational aspects

One of the advantages of electromagnetic testing over ultrasonic testing is that the surface preparation does not require as much scrutiny. Usually cleaning is achieved by water jetting. The nozzles can be mounted on a crawler tool as shown in the left in Figure 9. Water jetting results in a quite clean surface. Often a simple scraping action may yield sufficient results. The magnetization unit with the sensors is mounted on wheels. Wheels will prevent the metallic parts from touching the Outer sheath in order to avoid any damage. The unit is hung into a frame with drives to move the scanning unit around the pipe. The unit is shown on the right in Figure 9.

Figure 9: Left: The scanner inside the frame of the MEC-FIT unit. Right: A different sub-sea scanner unit is equipped with nozzles for a prior cleaning operation

The tool is deployed with an ROV as shown in Figure 10. Data is routed through the umbilical of the ROV and received top-side for immediate analysis.

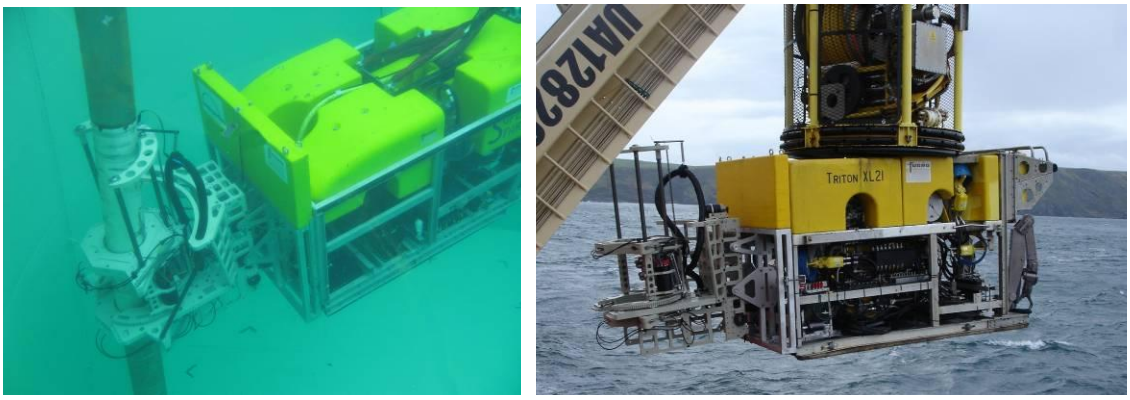

Figure 10: Deployment of the inspection tool by ROV (Together with Fugro)

To scan the compete surface the scanner will move up and down and rotate around the axis such that the pipe is covered by a meandering path. To move to the next location the tool can climb up and down on the riser.

Conclusion

MEC-FIT offers a unique possibility to scan larger areas of the surface of flexible riser pipe for several kinds of defects. The deployment is relatively easy. As the measurement is carried out with a moving device, absolute rest is not required. The unconventional layered structure will only pose a problem for inspection for deeply imbedded small defects, like cracks in a zeta-wire or in deep water pipes with four armoured layers.

References

[1] FlexiRiserTest 2010. The FlexiRiserTest Project is a collaboration between the following organisations: Computerised Information Technology (CIT) Ltd, Technical Software Consultants (TSC) Inspection Systems Ltd, Naftosol SA, Wellstream International Ltd, Petrobras, EuroNDT Ltd, Zenon SA, Research Institute Juelich and TWI Ltd. This project is managed and co-ordinated by TWI Ltd, and is partly funded by the European Commission under the Horizontal Research Activities Involving SMEs: Cooperative Research Programme reference COOP-CT-2006-032680.

[2] Riser End of Life JIP headed by Flexlife: 2010

[3] Automated radiographic inspection of flexible risers: A Feasibility Study, R.Mallett et.al., TWI, Insight Sep 2005

[4] HOIS JIP headed by ESR Technology, see for instance: Update on HOIS JI work… Integrity Management of unbounded flexible pipelines, Pittodrie Hotel Inverurie, 27th November 2008.

[5] Force Institute /Flexible-pipe-monitoring/specialisedndtservices