FLEXIQ™ – REDEFINING FLEXIBLE RISER INTEGRITY MANAGEMENT

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Abstract

FlexIQ™ is a complete offering in the arena of flexible riser integrity management from the strategic alliance of INTECSEA and Innospection. This partnership looks to redefine the approach to flexible riser integrity management by offering the best in inspection and computational simulation techniques as part of an Integrity Management Framework. This, in turn, leads to a significant improvement in understanding operational risk and enables a fully integrated service for inspection, analysis and data management. An overview and benefits of the offering will be presented:

- Risk-based integrity management and inspection planning
- State-of-the-art annulus testing of flexible risers
- Visual and MEC-FIT™ Inspection
- Dynamic riser simulation using detailed, multi-layered finite element models with FLEXAS™
- Intervention planning and construction management
- Life of field riser analysis and model updates

Introduction

In pipeline integrity the development of inspection methods, in particular In-Line Inspection tools, and the corresponding integrity assessment methods have been developed in parallel over many years. New inspection equipment was developed with respect to what defects are potentially dangerous. Failure analysis and fracture mechanics is used to establish reasonable PODs and minimum allowable defect sizes. Conversely assessment methods are more and more tailored to the data that they are based on. Defect grouping algorithms are developed such that an ILI report can be the basis. Also a measurement error of an inspection instrument is considered, when probabilistically calibrated factors are given in assessment codes like in DNV RP-F101 [1].

For the inspection as well as for the condition assessment of flexible riser pipe the situation has thus far been different. The reason for this is twofold. Condition assessment was mainly based on fatigue analysis leading to lifetime predictions. This of course continues to be of major significance for flexible risers, but does not consider the formation of actual sizeable defects. Due to the complexity of a flexible riser structure the assessment of particular defects, however, is only possible with computationally effective FEM solutions. Such a solution has recently been introduced by INTECSEA with the Flexas™ Software.

On the Inspection side the possibility to detect and size defects on specific spots has also only recently been developed. The MEC-FIT™ inspection solution is such a method. It has been introduced by Innospection in 2012 and has fulfilled several inspections on flexible risers in the past years. Even though the actual scope of work has always been different from project to project, the task was to inspect a section of flexible pipe at a specific location and detect and size defects. The following will describe the two approaches, FLEXAS™ and MEC-FIT™, and will then introduce its combination FlexIQ™.

FLEXAS™

Finite element Analysis (FEA or FEM) for structural analysis is a well know method to calculate the strength of components under constant load. It is widely applied also in the design of offshore structures [3] as well as in the assessment of defects [4] in pressure vessels. Commercially available software, however, often fails in allowing to take into account the complexity of a flexible riser and at the same time to solve a problem in reasonable time. What makes flexible risers especially complicated are, just like in inspection problems, the number of layers the resulting possible interaction, the required fineness and the complexity of the loading conditions. Figure 1 shows same sample views of a model and the respective mesh. The left shows a flexible pipe and the right a defect introduced into one of the outer layers.

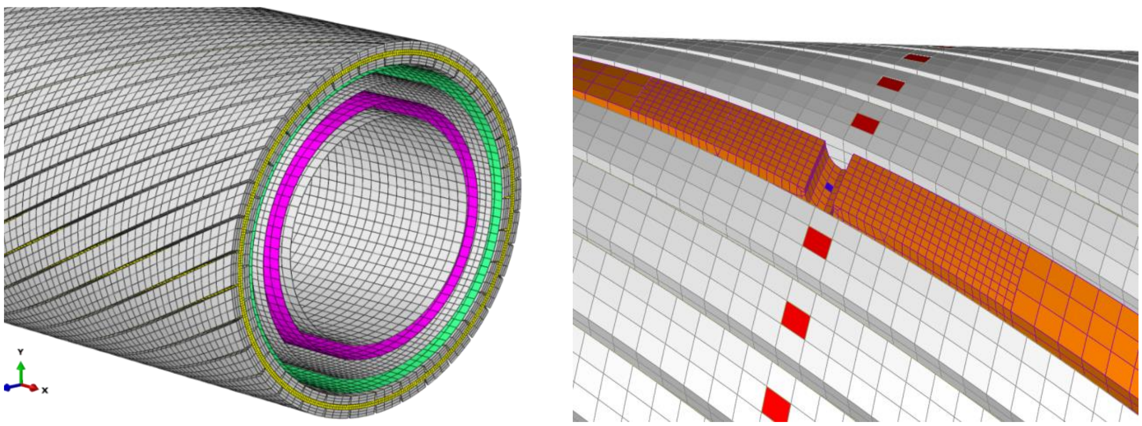

Figure 1: Sample models with mesh for solving flexible riser problems with FLEXAS™

The loading conditions for flexible pipe are especially difficult as the typical wave action, platform motion and currents a riser is subject to consists of a wide spectrum of frequencies and amplitudes. These need to be considered over a reasonable length of the flexible. A sample of the stress-input is given in Figure 2.

To achieve the goal of carrying out these complex calculations and to do so in a reasonable time frame, methods beyond the state-of-the art have to be implemented. One of these methods is Nonlinear Dynamic Substructuring (NDS) [5]. It is a method for efficient computation of nonlinear simulations with detailed models and environments – a requirement for accurate armour stress computations and fatigue life predictions.

In summary FLEXAS™ NDS solver is the only available tool that enables efficient global and local scale simulations of flexibles with detailed models and environments.

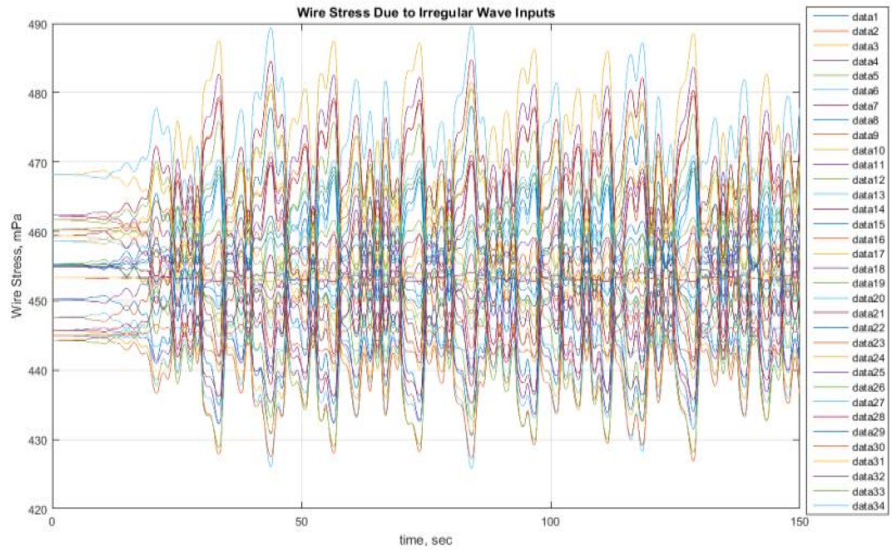

Figure 2: Typical stress input as calculated by irregular waves

MEC-FIT™

The MEC-FIT™ inspection technology is an adaptation of the well proven MEC-inspection method to flexible risers. Some details have been published before [2]. In essence MEC is an eddy current technology that is applied to a magnetized steel structure. This allows extracting information from within the component and not just the surface. Phase analysis and magnetization level control allow distinguishing signals from different layers. Again the complex structure of the flexible necessitates adjustment of the inspection analysis to wire lay angles, wire thickness and outer sheath thickness. What makes this electromagnetic technique especially interesting for the inspection of flexible riser pipe is its sensitivity not only to metal loss, but also to cracks, elastic stresses and plastification of the material. Metal loss may be a result of corrosion, cracking can be due to fatigue, but also due to sulfur stress cracking, stresses can originate from bending, overbending may lead to plastification.

In addition the wire structure can be examined. Permanent bending and unbending would not only lead to a local fatigue, but can also lead to a permanent rearrangement of wires. It is well understood now, that such a rearrangement also poses a significant integrity issue of the pipe.

It is, however, quite a challenge to distinguish all of the above effects from one another in a single measurement. Hence, the MEC-FIT™ system usually scans a portion of pipe at least twice with different settings. The eddy current settings, the orientation of motion and magnetization then depend on the exact scope of the inspection. If the task is, as an example, to inspect a 45° structure for metal loss defects in the armored layers and the inspection is to be done in the splash zone, then the MEC-HUG™ scanner as shown in the left of Figure 3 can be employed. If, as another example, the task is rather to inspect the armored layers for crack-like defects in a 55°-structure in the sag-bend, then the modified MEC-Pipe crawler is employed.

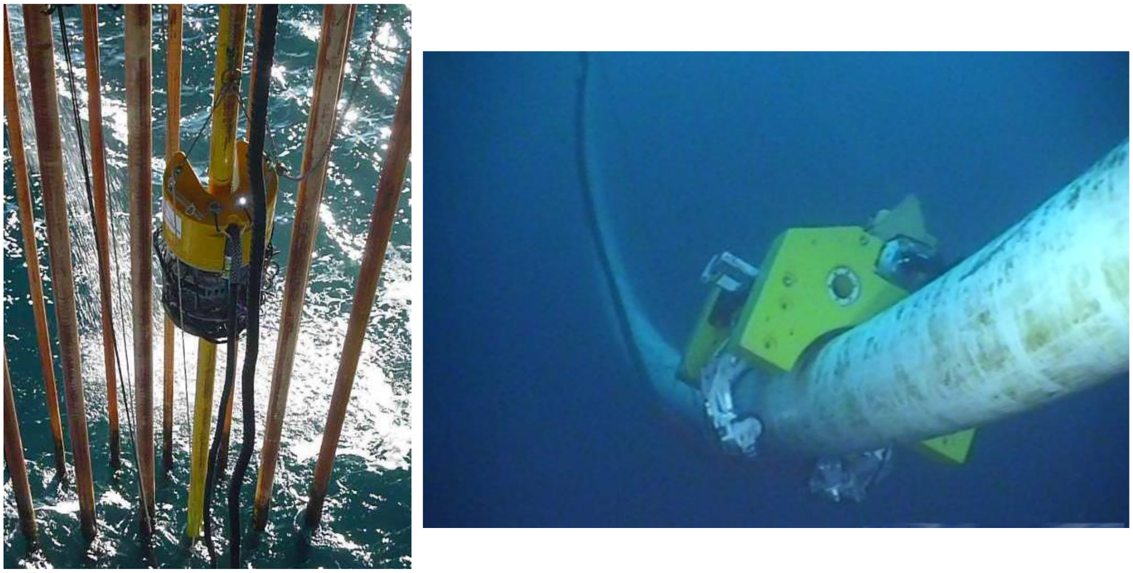

Figure 3: Different configurations of the MEC-FIT™ technology for different inspection tasks.

What is possible in terms of finding local defects like cracks or corrosion in flexible risers with the MEC-FIT™ is illustrated in Figure 4 and Figure 5.

Figure 4: Demonstration of crack detection in flexible risers

Figure 4 shows artificial cracks in a mock-up for demonstration and calibration purposes. The upper two photos show two crack-like slots introduced into the wire with different crack depth and orientation, the lower photos show the mock-up as a whole to test the sensitivity of the method to find cracks in defined layer configurations. Again the calibration is done by matching the wire structure with the one under investigation.

Figure 5 shows the signals thus obtained. The deeper cracks are the higher the amplitude. The amplitude of the signal also rises with the separation of the wire, should it be cracked all the way through. Hence signal length and amplitude are investigated to set up a calibration curve and to size the cracks. It is also visible from Figure 5 that the location of a crack can be well defined with respect to a datum point.

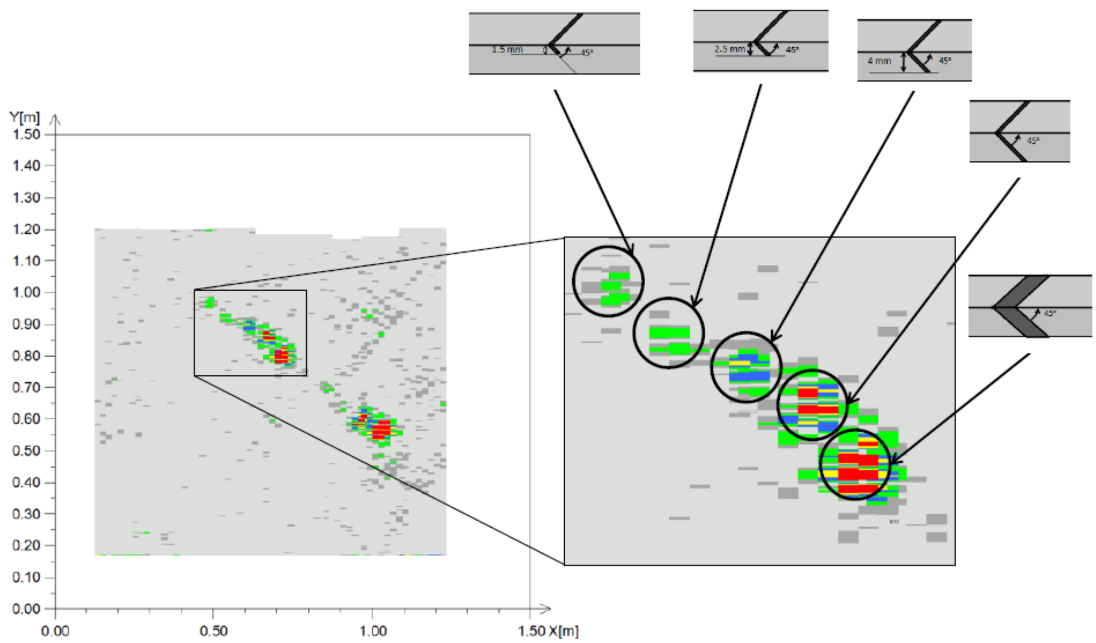

Figure 5: Signals obtained from cracks in the armor layer

Not only is the inspection equipment configuration tailored to the needs of the inspection task, but so is the analysis. Figure 6 show an example view of data taken from a subsea section of a flexible riser. The left of Figure 6 shows the overview of several scans taken over a distance of 5 m. The upper right images show more detailed views, while the lower right shows the corresponding image of the actual eddy current signal. Note that the signals shown on the overview image show a clear pattern. A signal of specific shape is repeated at a specific distance an always at the same orientation. The pitch between these signals is exactly the pitch of the helically wound wire. So the same wire is affected whenever is runs through the same circumferential position. This indicates that a manufacturing related stress was induced. It is corroborated by the signal shape.

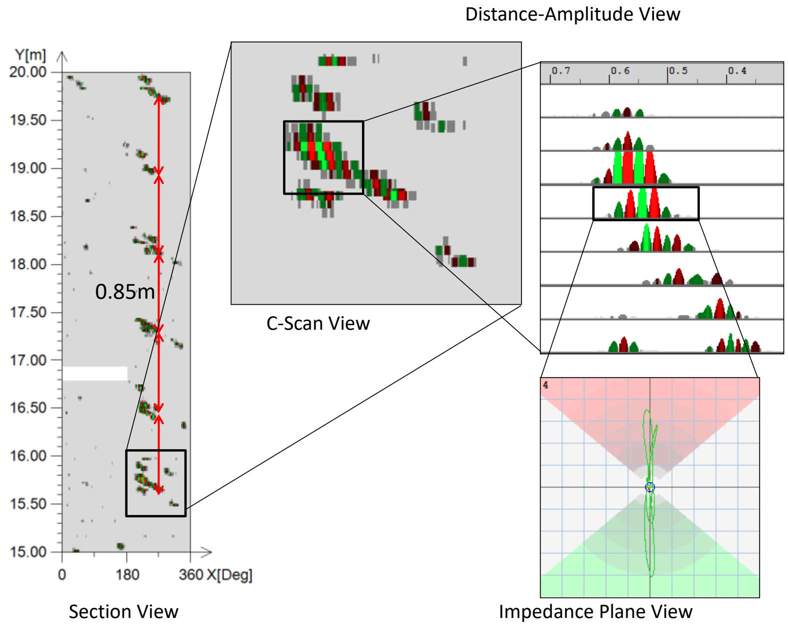

Figure 6: Sample view of data from a subsea portion of a flexible riser with different levels of detail.

A different example is shown in Figure 7. In this case the detection of gaps between single wires in the armor layer was the task of the inspection. The figure compares the situation at two points in time about one year apart. The earlier inspection on the left, the latter on the right. The two upper lines show the signals obtained from scanning three shorter sections of the flexible.

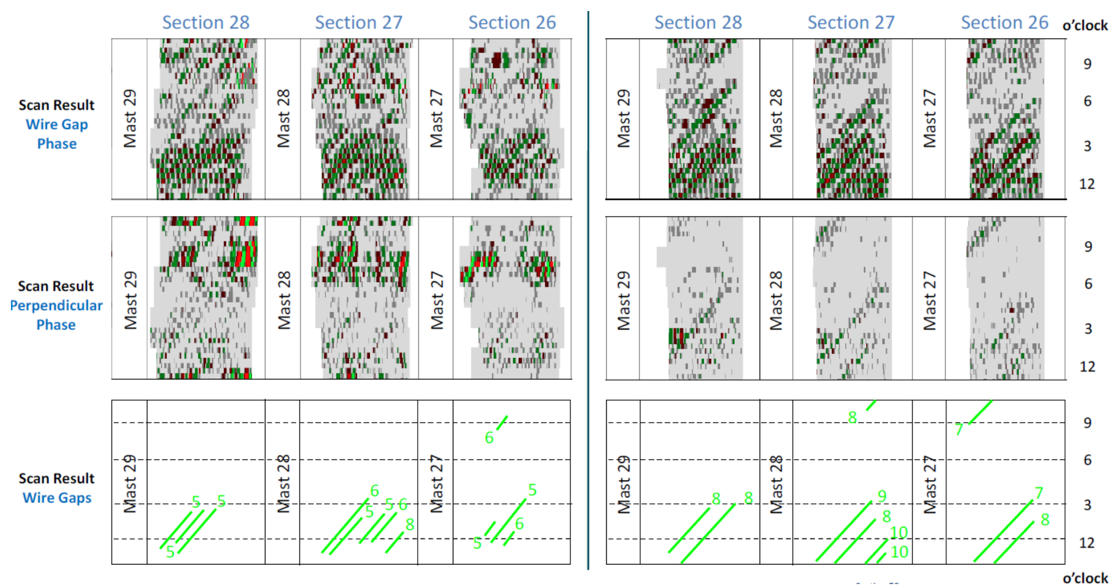

Figure 7: Comparison of wire gaps over a period of less than one year.

The two lines of data screen shots just show different views on the eddy current data. Detailed analysis allows determining and sizing wire gaps. They are visible in the upper line. The lowest line shows the result of the analysis, which is an indication of a wire gap and a size, i.e. a width of the gap in mm.

It is visible from the figure that the wire gaps are found at the same location and also with similar sizes. A small rearrangement of gaps is visible, which is attributed to the constant bending motion of the flexible that has taken place in the meantime.

The combination of FLEXAS™ and MEC-FIT™

As it is apparent from the two above examples, MEC-FIT delivers exactly the kind of data that is required for further integrity assessment. Local and structural defects are detected. Hence, a combination of the two technologies yields considerable added values to the integrity assessment of flexible risers.

Also vice-versa the possibility to simulate the stress conditions of flexibles is considerably improved if a priori stress conditions in the structure are known and input. So far, stresses are not quantified, but areas of stresses are detected. A rough quantification is envisaged for the future. In addition, if several defects are found, the simulation would require input as to whether these defects affect a single wire in the layer or several adjacent ones. And finally if gaps are detected a limit width at which these gaps become dangerous need to be established. Tools like FLEXAS™ can give reliable forcasts about these limits. In reverse, it can be calculated what kind of information inspection solutions like MEC-FIT™ should deliver.

Together with Annulus Testing and Risk-based integrity management a complete integrity circuit is set up. This concept of continuous integrity assertion is shown in Figure 8. This service is offered as FlexIQ™.

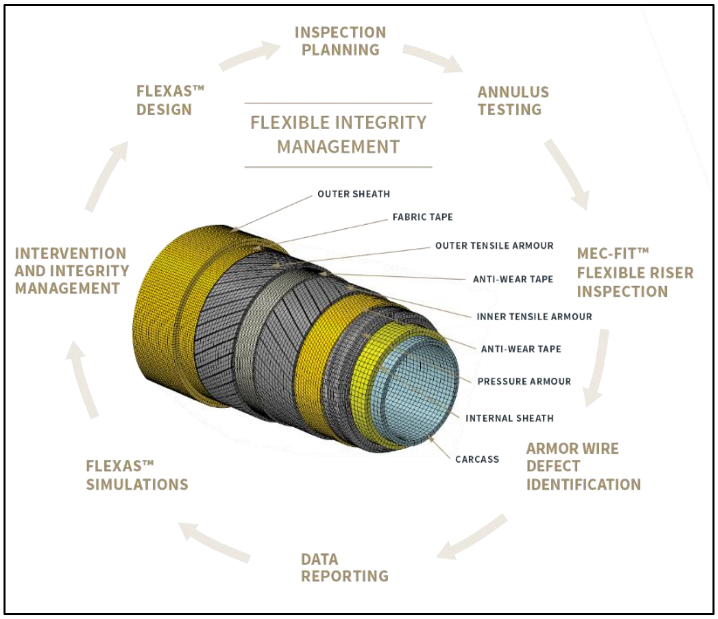

Figure 8: FlexIQ™ – The continuous cycle of integrity assertion.

Conclusion

FlexIQ™ offers a fully integrated service for inspection, analysis, and data management. It is now possible to apply methods of continuous integrity assessment to flexible risers just the way it is known to rigid pipe. In consequence a continued service of flexible riser will become possible, where lifetime of an asset does not depend on its age but its condition.

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