Fighting fatigue

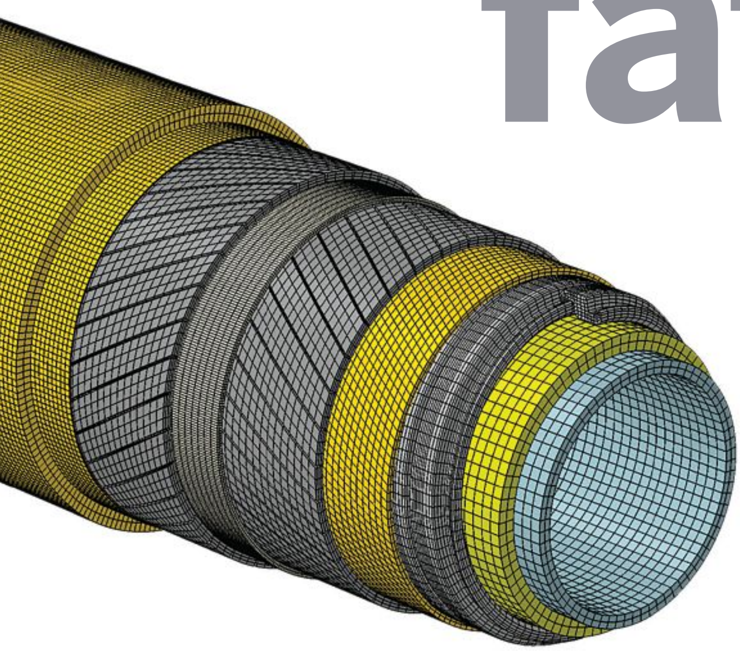

Figure 1: A typical flexible riser composition.
images from Intecsea.

Intecsea's Kirsten Oliver discusses a new flexible riser inspection tool created in partnership with UK-based Innospection.

Understanding the condition of flexible risers as they approach the end of their design life is not a straightforward exercise.

Flexible risers are designed with a discrete design life that includes significant safety factors to compensate for the uncertainties in degradation associated with the complex layer construction associated with tensile armor, pressure armor, inner carcass and outer protective layers.

The key benefits of flexible risers:

- Enabling a permanent connection between floating facilities and subsea infrastructure, where large motions are experienced.
- Cost-effective installation, ability to reel long lengths for transport and handling, and diverless installation, which enables deepwater installations.

However, this means flexible risers are put under complex dynamic stresses during operation, and one of the critical parameters in the design and continued operation is related to failure of the tensile armor wire layers because of fatigue.

When risers are initially designed, they have a significant in-built safety factor driven by the uncertainty in the fatigue life of the tensile armor wire layer. During early life, when the riser operates well within the design limits, basic inspection is carried out in line with a low risk categorization (e.g. DNV RP 206) (see Figure 2). This means there is often very little inspection testing or monitoring carried out.

As the riser approaches the end of its intended design life, this lack of operational integrity data makes life extension a challenge. Understanding the remaining fatigue life of the riser and establishing whether any degradation of the tensile armor wires has occurred has historically been both an analysis and inspection challenge.

Inspection

While there are many non-destructive testing (NDT) inspection tools on the market, they have had their limitations. Figure 3 summaries the comparative techniques.

The Innospection MEC-FIT inspection tool enables degradation (cracking and corrosion) to be detected in up to three layers of armor wire in both flooded and non-flooded annulus conditions. The tool can be deployed by inspection remotely operated vehicle or directly from the facility using a low capacity crane.

A client used MEC-FIT for a UK North Sea Project to inspect from the topside to about -30m on a flexible riser that had damage to the polyethylene outer sheath. The operator decided to assess the wire condition of the main flexible riser and neighboring risers.

Analysis

Finite element analysis (FEA) is the predominant method used to perform structural integrity assessments of complex components under various load combinations. Its application to the simulation of flexible risers is common during the design phase, as well as throughout the asset lifecycle in the form of life extension.

Flexible risers exhibit nonlinear behavior under bending, largely due to the stick/slip interaction between the pipe wall layers. However, capturing the highly nonlinear interactions in a compliant system that can undergo large 3D translations/rotations is currently limited by the computational efficiency of commercial FEA tools.

This limitation has historically precluded flexible risers from being assessed using high fidelity irregular wave fatigue methods, rather necessitating a regular wave approach with increased uncertainty and overarching assumptions. API RP 17B[1], Section 5.7.1 states: "The limitation of the regular wave approach is that the results can be difficult to interpret for systems whose response is strongly dependent on frequency. It is often impossible to determine whether the result is conservative or un-conservative, particularly in the case of flexibles where estimation of the natural periods can contain significant uncertainties."

Intecsea developed a simulation-based approach where nonlinear dynamic substructuring (NDS)[2] is leveraged for efficient computation of the large scale nonlinear simulations. This approach, enabled by a proprietary FEA solver (Flexas), has been fully validated for dropped object simulations[3] and for accurate prediction of detailed local stresses in unbonded flexible risers[4].

The technology uses simplified beam elements, and eliminates the need for additional local model analyses. Instead, the full detailed internal layer geometry is simulated either with global tension/curvature time-history inputs, or directly within the global riser configuration under irregular wave environments to extract wire stress time-histories[5].

The following example demonstrates how the conservatism in fatigue life calculations using regular waves (typical during design phase) can be quantified using an approach incorporating Flexas NDS.

The wire stresses were extracted from the following locations: the cross section under the bend stiffener, the wire corners' inner armors at 16 locations and wire corners' outer armors at 16 locations.

Post-processing of the wire stresses was carried out to generate fatigue spectra for both the irregular and regular wave cases to enable a comparison of wire damage ratios. Analysis demonstrates that the predicted damage from the regular wave cases is in the region of 6-7x greater than for the Flexas simulation based irregular wave cases. This equates to a potential 7x increase in fatigue life using the Flexas approach. Using Flexas irregular wave modeling increases confidence that the fatigue life can be extended for situations where the original design life has been compromised. While the Flexas simulation approach may be considered more accurate, it is specific to configuration and environmental loading and therefore needs to be assessed on a case-by-case basis; this is clearly a significant enhancement on the basic design premise regular wave analysis.

The Flexas approach has the additional benefit that damage can be incorporated into the detailed local model, and therefore any metal loss or cracking detected by the MEC-FIT inspection can be also be modeled. OE

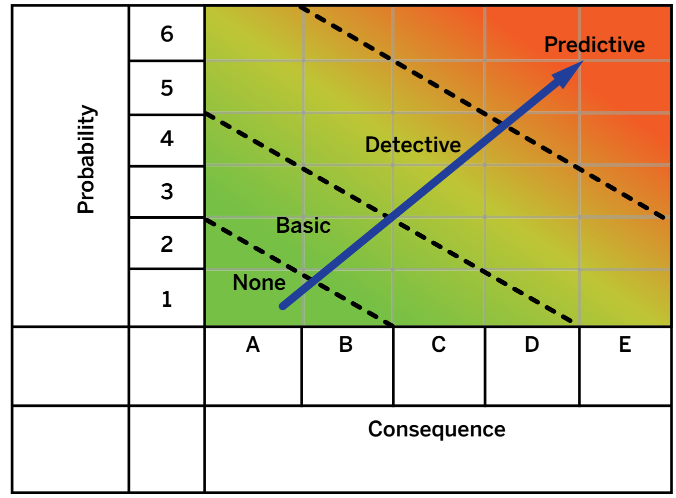

Figure 2: Example of risk-based integrity strategy (DNV RP 206)

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[1] API Recommended Practice 17B. Recommended Practice for Flexible Pipe.

[2] A Nonlinear Dynamic Substructuring Approach to Global Dynamics of Flexible Riser Systems, Arya Majed and Phil Cooper , ASME 2014, 33rd International Conference on Ocean, Offshore and Arctic Engineering Volume 6B: Pipeline and Riser Technology.

[3] Arya Majed (Intecsea), Antoine Dutertre (Total), iSOPE-2015, International Ocean and Polar Engineering Conference

[4] Michel W Dib, Philip Adrian Cooper, Shankar Bhat, Arya Majed (Intecsea) Offshore Technology Conference May 2013

[5] Majed, A., Cooke, N., Chinello, L. (Intecsea), Gomes, J. (DeepStar), Yiu, F. (Anadarko) and Kusinski, G. (Chevron), "New Generation Computational Capabilities in Nonlinear Dynamic Simulations of Flexible Riser Systems", OTC 2017, Houston, Texas.

Ultrasonic	MAPS-FR	Digital Radiography	MEC-FIT
Pulsed echo ultrasound technique	Electromagnetic stress measurement technique	External radiography technique	Electromagnetic technique (magnetic / eddy current field)
Ext scan under water, slow	Static ext. mounted measurement	Static spot RT shots	Dynamic fast scan
Detect flooding of annulus and thickness of outer tensile armor layer only if flooded	Detect fatigue failure and through cracked wires	Detects cracks, corrosion (limited min wall loss detection), loss of interlock in pressure armor layer	Detection of corrosion (pitting) cracks, wire misalignment in tensile armor later 1 and 2. Loss of interlock in pressure armor layer
Couplant required	No penetration through outer layer	X-ray Computed Tomography Very high resolution single line scan)	No couplant required but requires calibration

Figure 3: Comparison of NDT techniques. Source: Intecsea.