Flexible Riser Integrity Management & Lifetime Extension Support

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Flexible Riser Integrity Management & Lifetime Assessment

CONTENTS

- Challenges for Flexible Riser Integrity Management
- FlexIQ Offering
- Conclusions
Layer by Layer, functionality

- **Carcass** – Prevents collapse under hydrostatic pressure
- **Internal Pressure Sheath** – Acts as the boundary for the conveyed fluid
- **Pressure Armour** – Resists internal and external pressure in the hoop direction
- **Tapes** – For anti-wear, resisting wire movement and as a manufacturing aid
- **Tensile Armour** – Provides axial strength with some additional hoop strength
- **Insulating Layer** – Applied to reduce heat loss
- **Outer Sheath** – Protects against seawater ingress and external mechanical damage. Abrasion layers can be added for extra protection.
## Failure Modes (API 17J)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Primary Pipe Failure Mode</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal carcass</strong></td>
<td>Collapse (^{(1)})</td>
<td>Load</td>
</tr>
<tr>
<td><strong>Inner liner smooth bore</strong></td>
<td>Collapse (^{(1)})</td>
<td>Load</td>
</tr>
<tr>
<td><strong>Internal pressure sheath</strong></td>
<td>Rupture</td>
<td>Strain</td>
</tr>
<tr>
<td><strong>Pressure armors</strong></td>
<td>Loss of interior breakage</td>
<td>Stress</td>
</tr>
<tr>
<td></td>
<td>Collapse (^{(2)})</td>
<td>Load</td>
</tr>
<tr>
<td><strong>Tensile armors</strong></td>
<td>Breakage</td>
<td>Stress</td>
</tr>
<tr>
<td></td>
<td>Buckling</td>
<td>Load</td>
</tr>
<tr>
<td><strong>Anticollapse sheath (^{(6)})</strong></td>
<td>Rupture</td>
<td>Strain</td>
</tr>
<tr>
<td><strong>Antibuckling tape</strong></td>
<td>Birdcaging (^{(7)})</td>
<td>Stress or strain (^{(8)})</td>
</tr>
<tr>
<td><strong>Outer sheath</strong></td>
<td>Rupture</td>
<td>Strain</td>
</tr>
</tbody>
</table>

Source:
- Hans Out / Shell 2010, How to live with flexible pipe ever after?
- Krassy Doynov / ExxonMobil 2013, Improving standards and technology towards achieving robust design and safe operation of flexible risers
Flexible Risers in the North Sea

- Ageing assets
- Costs of exchanging a flexible riser can make production unviable
- Lifetime of an asset depends on age rather than condition
FEM in structural Integrity Assessment

- The most detailed method to calculate the strength of components under various kinds of loads

What is difficult about the modelling of Flexible Riser?
- Layer structure, number of surfaces, edge effects
- Small single wires
- Cyclic loading with complex spectrum of loads, wave action
- Friction in between layers
- Size of the structure in relation to size of stress concentrations
- Taking defect morphology into account for integrity assessment

Requires computational power and time!
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FlexIQ expands to all aspects of flexible riser integrity.
Magnetic Eddy Current (MEC) Principle

Magnetic field-controlled high frequency Eddy Current

Detection of far side defects

Signal Response

Magnetic Field Lines

Micro Biological Corrosion (MIC/SRB)

Ammonium Chloride Salt Corrosion

General Corrosion / C02 Corrosion

Corrosion / Cracking
Flexible Riser Inspection with MEC-FIT™

MEC-FIT™ – Magnetic Eddy Current Flexible Riser Inspection Tool

- Detection of corrosion, cracking, and misalignment in two (up to three) tensile armour wire layers by external scan
- Distinguish defects, wire gaps, and wire misalignment
- Scanning up to 35° wire in axial direction and >35° wire in circumferential direction
- Fast external scanning
- Electromagnetic technology, no couplant required
MEC-FIT™ Case Study 1

North Sea Project
Drag Chain Wire Gap Monitoring with MEC-FIT

External inspection of flexible riser sections in the Drag Chain set up to analyze wire gap changes in the bulk head area to monitor increasing wire gaps.

Verification target was to define the capability and repeatability of MEC-FIT determine individual wire gaps.
MEC-FIT™ Case 1 Study Results

Radiography Results

Innospection MEC-P7

[Image of radiography results and a diagram with annotations]
MEC-FIT™ Case 1 Study Results

Radiography Results

Innospection MEC-P7
MEC-FIT™ Case Study 2

North Sea Project – Wire Crack Detection

External inspection of 55 degree wire Flexible Riser

Flexible Riser set up:

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer Type</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Interlocked carcass</td>
<td>10.0 mm</td>
</tr>
<tr>
<td>2</td>
<td>Rilsan P40TL TP01 Pressure Sheath</td>
<td>11.0 mm</td>
</tr>
<tr>
<td>3</td>
<td>First Armour Layer, 55°, High charact. Fl41</td>
<td>5.0 mm</td>
</tr>
<tr>
<td>4</td>
<td>Rilsan (BF01) Anti-Wear Tape</td>
<td>2.5 mm</td>
</tr>
<tr>
<td>5</td>
<td>Second Armour Layer, -55°, High charact. Fl41</td>
<td>5.0 mm</td>
</tr>
<tr>
<td>6</td>
<td>Fabric Tape</td>
<td>2.3 mm</td>
</tr>
<tr>
<td>7</td>
<td>Rilsan 500TL TP08 External Sheath</td>
<td>13.0 mm</td>
</tr>
</tbody>
</table>

Target of the technique verification to detect tight cracking in single wire with expected orientation of 45° and 90° to the wire cross section. Cracking to be detected on the inner wire & outer wire layer.

Additional Task: MEC-Combi scanner deployed by Inspection class ROV from top of the installation.
FLEXAS™ Numerical Simulation

- More realistic simulations leading to increased accuracy for fatigue life predictions
- Incorporation of MEC-FIT™ detected damage into simulations
- Single integrated flexible riser global analysis with detailed multi-layer models and direct stress recoveries

Fully validated tool

- DeepStar qualification program
- Benchmarking against independent operator experiments
- Selected by NASA and qualified for mission-critical analysis for manned space flight
FLEXAS™ Numerical Simulation

Non-linear dynamic simulation of 20 pitch length (12m) flexible

Multi-layered, detailed finite element model

Irregular wave input for real-world conditions

Individual armor wire stress time-histories

Total Computation Time = 300 sec
DeepStar and ExxonMobil validation through FLEXAS™ local benchmarking

- Numerical benchmarking: 1 pitch length, 4 million DoFs, static
  - 1200+ stresses at armour wire locations were compared for axis-symmetric and bending cases with essentially ZERO differences

- Experimental benchmarking\(^1\): 8 pitch length, 32 million DoFs, cyclic loading
  - 238 computed armour strains were compared against strain gage measurements for axis-symmetric and bending cases resulting in very good agreement

\(^1\)Experimental work published by De Sousa Et al, OMAE2013-11384, OMAE2015-41436

FLEXAS solver is capturing the complex kinematics of the flexible’s helically wound layers resulting in excellent numerical and very good experimental comparisons
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FlexIQ - Conclusions

Best in class inspection and computational simulation

Accurate damage detection and impact on design life

Improved understanding of operational risk

A fully integrated service for inspection, analysis, and data management

Bottom line: we deliver insight, not just data.
THANK YOU FOR YOUR ATTENTION