Flexible Riser Integrity Assessment with advanced MEC-FIT™ technique

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Flexible Riser Inspection with MEC-FIT™

CONTENTS

- External Inspection of Flexible Riser
- MEC Technique
- MEC-FIT Flexible Riser Inspection
- Case Study
- Next Steps
Unbonded Flexible Pipe

- outer plastic sheath
- anti-wear tape
- inner carcass
- tensile armors
- pressure armor
- internal plastic sheath
### 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>Internal carcass</td>
<td>Collapse</td>
<td>Load</td>
</tr>
<tr>
<td>Inner liner smooth bore</td>
<td>Collapse</td>
<td>Load</td>
</tr>
<tr>
<td>Internal pressure sheath</td>
<td>Rupture</td>
<td>Thinning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strain</td>
</tr>
<tr>
<td>Pressure armors</td>
<td>Loss of interior breakage</td>
<td>Stress</td>
</tr>
<tr>
<td></td>
<td>Collapse</td>
<td>Load</td>
</tr>
<tr>
<td>Tensile armors</td>
<td>Breakage</td>
<td>Stress</td>
</tr>
<tr>
<td></td>
<td>Buckling</td>
<td>Load</td>
</tr>
<tr>
<td></td>
<td>Wire disorganization</td>
<td>Displacement</td>
</tr>
<tr>
<td>Anticollapse sheath</td>
<td>Rupture</td>
<td>Strain</td>
</tr>
<tr>
<td>Antibuckling tape</td>
<td>Birdcaging</td>
<td>Stress or strain</td>
</tr>
<tr>
<td>Outer sheath</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

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Reasons for Inspecting

- Immediate integrity assurance due to presence of known defects (i.e. breached sheath, filled annulus)
- Future integrity assurance / asset lifetime extension
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Principle MEC (extended from SLOFEC)
Magnetic Field controlled High Frequency Eddy Current

Detection of far side defects
- Magnetic Field Lines
- Signal Response

Detection of near side defects
- Eddy Current sensor
- Signal Response

controlled Magnetic field

- New Sensor type with field strength measurement
- Field strength control / analysis (retentivity point)
- higher Eddy Current Frequency
- higher sensitivity at increased stand

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Background Inspection Techniques & Tools

Splash Zone Inspection Tools
(Riser / Caisson / Structure)

Subsea Pipelines Inspection Tools

Flexible Riser / Riser / Mooring Line Inspection Tools
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# Flexible Riser Inspection Techniques

<table>
<thead>
<tr>
<th>NDT solutions for external Flexible Riser Inspection</th>
<th>Ultrasonic</th>
<th>MAPS-FR</th>
<th>Digital Radiography (DRT)</th>
<th>MEC-FIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultrasonic</strong></td>
<td>Pulsed echo ultrasound technique, Ext. scan under water, slow</td>
<td>(Electromagnetic) Magnetic stress measurement technique, static ext. mounted, measurement in ± 15m from monitor</td>
<td>detection of: fatigue failure, through cracked wires</td>
<td>Electromagnetic technique (Magnetic/Eddy Current Field), dynamic fast scan</td>
</tr>
<tr>
<td></td>
<td>detection of flooding of annulus, thickness of outer tensile armour only if flooded</td>
<td>no penetration through outer layer</td>
<td>detection of: Cracks, Corrosion (limited min wall loss detection) Loss of interlock (X-ray Computed Tomography Very high resolution single line scan)</td>
<td>detection of: Corrosion (pitting), Cracks Wire misalignment detection in 1(^{st}), 2(^{nd}), (partly 3(^{rd}) layer)</td>
</tr>
<tr>
<td></td>
<td>Couplant required,</td>
<td></td>
<td></td>
<td>No couplant required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Requires calibration</td>
</tr>
</tbody>
</table>
MEC-FIT Evolution Tools

Scanner types & deployments

Scanner head (pole shoes & sensor array)

Top side deployable tools

MEC – Hug V1
(WC ROV deployable)

MEC – Hug V2
- Top side deployable 70 umbilical
- WC Class ROV deployable

Manual Scanner (hand held)

MEC – Combi Crawler
- WC & Insp. Class ROV deployable

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MEC-FIT™ Background Technique

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

a further development of the SLOFEC™ technique
Comparison of different magnetization levels on the wire magnetization

Magnetisation Level

MEC-FIT Background Technique

Magnetisation Unit

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Depiction of wire gap. With the magnet on additional wires of the lower internal layer become visible (Pipe 6).
MEC-FIT Evolution Process

Signal Phase Analysis - Relevant Indications vs irrelevant indications

General Eddy Current Signal to colour mapping production

Defect Indication vs Non-Defect Indication - Raw data analysis

Reporting for standard 35° type flexible riser inspection

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MEC-FIT Evolution Process

Tests / Signal analysis

- Local wall loss
- Wire thinning
- Wire crack
- Localised drilled defects from inside out

Signal analysis catalogue

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>Loop Magnet off</th>
<th>Loop Magnet intermediate</th>
<th>Loop Magnet On</th>
<th>Phase</th>
<th>Change Mag. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gap upper level</td>
<td></td>
<td></td>
<td></td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>2 Cut wire Lower layer</td>
<td></td>
<td></td>
<td></td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>3 Grinding on upper wire</td>
<td></td>
<td></td>
<td></td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>4 Cut wire Surface (crack like)</td>
<td></td>
<td></td>
<td></td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>5 Mat. in-homogeneity</td>
<td></td>
<td></td>
<td></td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>6 Far side ml in solid pipe</td>
<td></td>
<td></td>
<td></td>
<td>310° (90° for SLGPEC)</td>
<td></td>
</tr>
<tr>
<td>7 Near side ml in solid pipe</td>
<td></td>
<td></td>
<td></td>
<td>310° (90° for SLGPEC)</td>
<td></td>
</tr>
</tbody>
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Signal Catalogue (2014)
Effect of Wire Lay Angle on Detection Capabilities

15° lay angle

55° lay angle

Signal Strength [a.u.] vs Angle of scanning [deg]
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North Sea Project – Wire Crack Detection

External inspection of 55 degree wire Flexible Riser

Flexible Riser set up:

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<th>Thickness</th>
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<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. Fi41</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. Fi41</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
MEC-FIT Case Studies

Flexible Riser – subsea (UK)
Crack Detection Tests at 55 degree wire angle 13

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Flexible Wire set up

Picture Defect 3

Picture Defect 6

Flexible Wire set up

Assembly of the structure

Test Defects

<table>
<thead>
<tr>
<th>Crack Simulation Depth (perpendicular projection)</th>
<th>Crack Type A</th>
<th>Crack Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Angle</td>
</tr>
<tr>
<td>1.5mm (30%)</td>
<td>1</td>
<td>45°</td>
</tr>
<tr>
<td>2.5mm (50%)</td>
<td>2</td>
<td>45°</td>
</tr>
<tr>
<td>4.0mm (80%)</td>
<td>3</td>
<td>45°</td>
</tr>
<tr>
<td>5.0mm (100%) (tight)</td>
<td>4</td>
<td>45°</td>
</tr>
<tr>
<td>5.0mm (100%) (wide)</td>
<td>5</td>
<td>45°</td>
</tr>
</tbody>
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Flexible Riser – subsea (UK) Crack Detection Tests at 55 degree wire angle

Signals of the defects in the near side of the outer tensile. The right shows a sketch of the defects.

Defects 3 (80%, 45°) and 4 (100%, 45°) with magnet on (left) and off (right)

Signals of defects in outer tensile layer far-side.
Flexible Riser – subsea (UK) Crack Detection Tests at 55 degree wire angle
Signals of the defects in inner tensile layer (by different blind tests, wires changed)

Detection Conclusion

<table>
<thead>
<tr>
<th>Defect Position</th>
<th>Detectable Size in % of wire thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Near side defect</td>
<td>Outer tensile layer</td>
</tr>
<tr>
<td>Far side defect</td>
<td>Outer tensile layer</td>
</tr>
<tr>
<td>Near side defect</td>
<td>Inner tensile layer</td>
</tr>
<tr>
<td>Far side defect</td>
<td>Inner tensile layer</td>
</tr>
</tbody>
</table>

Relation crack Depth vs amplitude
MEC-FIT Case Studies

Inspection Class ROV deploying MEC-FIT™ Scanner

Scanning in circumferential direction

Big guy watching the scene ...

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R&D, Ongoing Evolution Process

- MEC Automatic analysis algorithm
  Ongoing development eddy current signal analysis algorithm and integration into assessment software

- HD camera integration to scanner
  Integration of HD camera systems for outer sheath condition assessment

- HIGH FIELD EDDY CURRENT SENSORS
  Penetration through the stiffener material and Polyethylene coating. Target to detect defects at surface of outer armoured wire in focused area.
- Inspection is an integral part of the process for flexible pipe lifetime extension.

- The MEC-FIT™ technique is capable of detecting defects such as single & multiple wire cracking, corrosion and wire disorganisation in 2 (3) wire layers.

- Demanding projects including inspection of a flexible having a 55° wire structure and a 15.3mm thick outer sheath have been mastered.

- Different inspection tools implementing the MEC-FIT™ technique are available for various tool deployment requirements.
THANK YOU FOR YOUR ATTENTION

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