Flexible Riser Integrity Assessment with Advanced MEC-FIT™ Technique

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CONTENT

- Flexible Riser NDT techniques, Inspection to Assessment

- MEC Technique
  (Overview from SLOFEC to MEC......Background, applications)

- MEC-FIT Flexible Riser Inspection
  - Technical Overview / Detection Tests
  - Application tools
  - Case Studies
  - Outlook

- QUESTIONS
Flexible Riser Inspection to Assessment

Flexible Riser Inspection Deployment

Flexible Riser Inspection Operation

Defect Detection
(cracks, pitting, wire misalignment)

Data Reporting

Risk / Life Time Assessment by FEM Analysis (FLEXAS™)

Flexible Riser Inspection to Assessment
## FLEXIBLE RISER - NDT TECHNIQUES

Overview of existing external deployed NDT techniques for Flexible Riser Inspection

<table>
<thead>
<tr>
<th>PRINCIPLE</th>
<th>DETECTION</th>
<th>DEPLOYMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ultrasonic</strong></td>
<td><strong>MAPS-FR</strong></td>
<td><strong>Digital Radiography (DRT)</strong></td>
</tr>
<tr>
<td>Pulsed echo ultrasound technique, (Electromagnetic) Magnetic Field stress measurement caused by cracked wires</td>
<td>Full cracked through wires on outer wire layer</td>
<td>External radiography technique, static spot RT shots (mainly top side yet)</td>
</tr>
<tr>
<td>Flooded annulus, Thickness of outer tensile armour wire (only if flooded)</td>
<td>Mounted collar, No couplant / flooding required</td>
<td>Cracks, Corrosion (limited min wall loss detection) Loss of interlock</td>
</tr>
<tr>
<td>External Scan Annulus Flooding / Couplant required</td>
<td></td>
<td>Subsea Operations yet limited Static shot film (CT potential for future inspection)</td>
</tr>
<tr>
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BACKGROUND TECHNIQUE

Principle MEC™ (Magnetic Eddy Current)
Magnetic Field controlled High Frequency Eddy Current

Detection of far side defects

Detection of near side defects

Dense Data Information & Mapping with sensor arrays

Separate mapping external / internal condition or complete.
MEC™ (Magnetic Eddy Current ….extended technology to SLOFEC): Electromagnetic NDT technique, fast scanning, high POD for isolated pits / general corrosion (e.g. MIC), inspection through coatings, low prep. required

**Pipe Scanning**
WT range: up to 1”

**Vessel Scanning**
WT range: up to 33mm

**Tank Scanning**
WT range: up to 30mm through coating up to 10mm

**Riser & Caisson Scanning**
WT range: up to 30mm through coating up to 15mm

**Micro Biological Corrosion (MIC/SRB)**
Amonium Chloride Salt Corrosion
General Corrosion / CO2 Corrosion
Corrosion / Cracking
BACKGROUND TECHNIQUE / APPLICATIONS

Splash Zone Inspection Tools
(Riser / Caisson / Structure)

Subsea Pipelines Inspection Tools

Flexible Riser / Riser / Mooring Line Inspection Tools
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MEC-FIT™ Inspection Focus

- External scan, detection in 2 (up to 3) layers
  - corrosion (pitting/general)
  - cracking
  - wire misalignment / gaps

- Signal separation in layers, defects / wire gaps

- Scanning
  - <37° wire: in axial orientation,
  - >37° wire: in circumferential orientation

- Fast external scanning

- No couplant required

Pressure Armour wire Layer
2nd Armour wire Layer
1st Armour wire Layer
Defect detection by induced electromagnetic field change analysis by controlled high Frequency Eddy Current

Flaws in wires causing electromagnetic field changes – detected by eddy current field changes in analysis of the signal phase, amplitude and signal pattern with field strength analysis

Comparison of different magnetization levels at the different wire layers, varying with field strength to determine layer with issue.
Evolution Steps

Feasibility Test
at 10inch Coflexip Riser Sample with existing Pipe scanner

- penetration depth with the existing scanners and sensors.
- detectability of various material dishomogenities
- distinction between defects and other caused indications
- signal pattern distinction defects / armour layer edge effects.
- possible capabilities of fatigue detection & analysis
**External scan tests at Flex Riser Stress Sample**

**Advantage:** Real flaws without damaging upper layer

**Result:** Scanned through polyethylene layer
- Detected indications – verified cracks

**Flexible Riser End of Life JIP**

(4” Gas Lift Riser Segments, 8” Oil Export Riser Segments)

**External scan tests at Flex Riser sample – major indication from unlocked Zeta-Wire**

**Information:** analysis of field penetration from outside through to pressure armour layer

**Result:** detected area compared to DRT (Oceaneering)
MEC-FIT Evolution Process

Wire gap indication vs defect indications

- Increased wire gap
- Crack simulation (mechanical introduced)
- Localised pitting (externally machined)

Signal Phase separation
MEC-FIT Evolution Process

MEC-FIT TESTS/ VERIFICATIONS
Localised Corrosion or Crack Detection / indication repeatability

Cracking simulation indications

Localised pit simulation indications

Wall Loss

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Detection tests at flat bed with Flexible structure simulation

Tests performed at flat Flexible Riser layer simulation for Crack and general wall loss detection

Detection of wall loss defects in single wire and cracks in single wire
### Tests / Signal analysis

- **Local wall loss**
- **Wire thinning**
- **Wire crack**

### 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>x</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>x</td>
<td>310°</td>
<td></td>
</tr>
<tr>
<td>6 Far side ml in solid Pipe</td>
<td>x</td>
<td></td>
<td></td>
<td>310°  (90° for SLOPEC)</td>
<td></td>
</tr>
<tr>
<td>7 Near side ml in solid pipe</td>
<td></td>
<td></td>
<td></td>
<td>310°  (90° for SLOPEC)</td>
<td></td>
</tr>
</tbody>
</table>

**Signal Catalogue (2014)**

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Artificial defect - crack in single wire in second wire layer
wire gap closed for the scan

Test Defect: machined crack in second armour layer

Tight Cracking and Natural Corrosion simulation by Flawtec
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
Flexible Riser Inspection with MEC-FIT™

MEC-FIT™ scanner units deployment diversity:

ROV deployment
MEC – Hug V1

ROV & Top side deployment
MEC – Hug V2

WC & Inspection Class ROV deployment
MEC – Combi Crawler types

Manual deployment for top side inspections
MEC – M-PS150 & 200
MEC-FIT Case Studies

North Sea Project

Inspection from top side to ~ -30m

Flexible discovered with polyethylene damage in area caused operator to assess wire condition of main flexible riser and neighbor risers
Operation of Flexible Riser scanning with top side deployment

Rope access support to launch the tool.

Driving by hydraulic motorised system

Maximum umbilical length for top side deployment: 70m

Coverage with magnet off

Depth corrected for sensor array to tool top offset approx. 1m
Verification of MEC-FIT technology for inspecting
- a 15°-flexible pipe structure
- detection of wire misalignment
- differentiation of wire misalignment vs defects
Missing wire & defects in both layers

Scanning in axial orientation – influence of detection at different wire angle

15° 35°

Scanner lift off increase vs pipe OD

- With increases lift-off the signal will get weaker, but not disappear
- The magnetisation will decrease, but the signal does not depend on it

MEC-FIT Case Studies

Verification tests at flat bed simulation

Scanner lift off increase vs pipe OD

MEC-FIT • FIT Case Studies

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North Sea Project

Inspection from top side area below connector

Main focus to detect localized pitting corrosion on 1\textsuperscript{st} & 2\textsuperscript{nd} tensile armoured wire
External Scanning below connector, access from scaffold with hand held scanners

Preparation tests: Artificial metal loss defects on flexible riser with 9mm coating

MEC – P19 Scanner
150mm coverage with 8 sensors
Electromagnet with DC Power up to ~ 1.5T

Taped riser - manual scanning of ~ 2m section
North Sea Project – Wire Crack Detection

External inspection of 55 degree wire Flexible Riser

Flexible Riser set up:

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

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Crack Simulation Depth (perpendicular projection)

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<th>Crack Simulation Depth</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>
</table>

Test Defects

Assembly of the structure

Flexible Wire set up

Picture Defect 3

Picture Defect 6
Signals of defects in outer tensile layer far-side.

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

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

Relation crack Depth vs amplitude

Detection Conclusion

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<tr>
<th>Defect Position</th>
<th>Detectable Size in % of wire thickness</th>
</tr>
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<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>
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</table>
MEC-FIT Case Studies

Global Simulations with MEC-FIT™ Damage Data integrated in the FLEXAS™ System for Risk Analysis

Finite Element Model

Stress Plot

— Magnetic Eddy Current – Flexible Inspection Tool (by Innospection)
**MEC-FIT Case Studies**

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

External inspection of flexible riser sections in the Drag Chain set up to analyse 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 to determine individual wire gaps.

High resolution encoded drive of the scanner allowing precise definition of the wire edges and distance to neighbor wire.

Additional: Scanner device to be designed flat to overcome tight gap to close flexible risers
MEC-FIT Case Studies

Flexible Riser Scanning Top side at the bulk head of the drag chain for detection & monitoring of wire gaps

Test scans – signal phase focus on wire edge

Simulation sample with defined gap distances & scanner manually operated at tests.

Developed flat scanner for outer tensile layer detection reach

Gap Analysis: three classes of gap sizes.
R&D, Ongoing Evolution Process

- ANNULUS FLOODING DETECTION
  Ongoing development of annulus flooding detection (capacity measurement)

- 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.

- HIGH RESOLUTION & HIGH CONTRAST CT/DR
  Engineering analysis with Deepscan Integration of high resolution & high contrast CT/DR in subsea scanners
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THANK YOU FOR YOUR ATTENTION

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