Update on HOIS JIP work on flexible risers and MAPS-FR for monitoring armour wire integrity and detecting failed wires

Martin Wall, ESR Technology Ltd, Asset Integrity Group

John McCarthy, Maps Technology Ltd

HSE UK Industry Seminar, Integrity management of unbonded flexible pipelines, Pittodrie Hotel, Inverurie, 27 November 2008
Scope of talk

1. Update on HOIS work on inspection of Flexible risers
   Martin Wall, ESR Technology Ltd.

2. MAPS-FR for monitoring armour wire integrity and detecting failed wires.
   John McCarthy, MAPS Technology Ltd.
HOIS Joint Industry Project (JIP)

- HOIS is a well established JIP (1982)
- Members comprise oil and gas producer, NDT service companies, NDT equipment vendors, a regulatory authority (UK HSE)
- Managed by ESR Technology (formerly AEA Technology)
- >£400,000 annual programme
- Membership now a record 26 companies:
  - www.hois2000.com
Overview of HOIS work on Flexibles

- Initial review and limited experimental studies 1995
- FPSO and flexible riser working group established 2001
- Exchange of information on flexible risers
- Review and series of trials and evaluations (2004 to 2007)
- Ongoing exchange of information through FPSO &FR working group
Failure mechanisms

- **Tensile Armour Wire failure** particularly deepwater applications (“birdcaging”)
- **Polymer layers.** Failure of inner pressure barrier polymer layers leading to fluid ingress, corrosion fatigue of armour layers and outer sheath failure
- **Impact damage to outer sheath**
- **Pull-out** of inner sheath in end fittings
- **Lack of venting** or open subsea vent ports
- Often a *combination of circumstances* underlies failure
- End connections, areas of bend, around bend stiffeners and near sea bed are most common locations for failure
- **Individual factors** include poor repair, incorrect annulus testing, lack of venting, armour wire failure, armour wire corrosion due to water ingress, open sub-sea vent port, impact damage.
- **Inspection needs to detect any damage at an early stage and leave sufficient time for monitoring and intervention**
Typical inspection practice

- General visual inspection by ROV-mounted video camera
- Annulus and vent gas pressure monitoring and gas analysis
- Nylon or polyethylene degradation by coupon
- End fitting and annulus vent system inspection
- Internal visual inspection by cable operated video camera
- Regular leak testing and vacuum testing of the annulus
- *For flexible risers inspection and monitoring methods exist, that allow most “inspectable” failure mechanisms to be detected before they lead to shut-down and need for replacement.*
- *There is a need for better inspection or monitoring methods that allow the time for replacement to be determined more accurately than at present.*
The techniques trialed by HOIS have included the following:

- Microwave inspection (Evisive Ltd).
- Laser shearography (Laser Optical limited)
- Magneto Optical Imaging MOI (Advanced NDT)
- MAPS magnetic stress measurement (ESR)
- Active thermography (Thermal Wave inc) June 2006
- Magnetostrictive MSS Ultrasonic guided waves (NDT Consultants)

**Focus on inspection of tensile armour wires. 1m to 5m riser samples**

**Other techniques considered**

- Independent evaluation of trial results using SLOFEC on a Norsk Hydro riser sample (Innospection)
- Results from the DEEPSCAN X-ray tomography system which originated from an initial development by Statoil.
HOIS flexible riser inspection trials
HOIS flexible riser inspection trials

Continued
Other inspection methods

- Eddy current (CorrOcean) - Limited to the outer armour layer or the inner carcass. Problems with signal interpretation in multiple armour layers.
- Acoustic emission monitoring
- Radiography - Corrosion of armour wire and fractures of armour wires. Accessible parts of the upper part of risers, above sea level.
- AMFL special probe (electromagnetic method)
- X-ray and ultrasonics (UT) scanning device to detect armour wire disassembly
- Ultrasonics (UT) for polymeric layer degradation
- X-Ray and Gamma Ray Digital and linear Inspection accelerator radiography for end fitting (termination) Inspection
- Torsion and elongation monitoring
- Gas percolation monitoring (leakage) and on-line chromatography
- AGR Neptune UT mapping approach
- DNV Acoustic Resonance Technique
Conclusions
HOIS flexible riser trials

- The MAPS-FR technique was the most successful of the HOIS trials, detecting individual and multiple broken armour wires remotely. Now being developed by MAPS technology Ltd. for Petrobras.

- *Microwave inspection* and to a lesser extent *shearography* showed promise.

- Most methods had practical limitations.

- Several methods including thermography and shearography had difficulty in seeing through the outer polymer layer and most could not see beyond the first armoured layer.

- The trials on the MSS guided wave method (as used on wire ropes) were less promising than hoped. The signal was heavily attenuated by the outer polymer coating. Range achieved in practice unlikely to exceed 3m. Sensor strips need to be preinstalled below the outer polymer layer.

- *Electromagnetic methods (SLOFEC, AMFL, Corrocean ET)*, *acoustic emission (AE)* and *high energy radiography (LINAC, Deepscan)* seem the most promising of the methods trialed separately by HOIS members.
2. MAPS-FR for monitoring armour wire integrity and detecting failed wires.
MAPS-FR
Monitoring Riser Ligament Integrity

John McCarthy
Operations Director
MAPS Technology Ltd

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MAPS

- Patented magnetic method of stress measurement
  - multiple parameters
  - non-destructive, rapid
  - absolute biaxial stress
  - stress depth profiling
  - accurate to a few MPa

- Standard MAPS instrument
  - portable tool
  - verified against laboratory methods: X-ray & neutron diffraction, synchrotron X-ray, hole drilling, strain gauges.

Unique capability
Does it Work?

Validated against:
- Neutron diffraction
  - weldments & surface treatments
- X-ray diffraction
  - on aerospace bearing & rail heads
- Hole drilling
  - weldments & rail
## MAPS – Blind Trial on Rail Steel

<table>
<thead>
<tr>
<th>Load case</th>
<th>Applied stress (from strain gauges) (MPa)</th>
<th>MAPS result (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load case A</td>
<td>48.9</td>
<td>48.1</td>
</tr>
<tr>
<td>Load case B</td>
<td>19.6</td>
<td>18.9</td>
</tr>
<tr>
<td>Load case C</td>
<td>48.9</td>
<td>49.8</td>
</tr>
<tr>
<td>Load case D</td>
<td>67.7</td>
<td>68.2</td>
</tr>
</tbody>
</table>
MAPS-FR
Aim

• To monitor armour wire integrity within flexible risers and their end-fittings
• To be non-intrusive
• To work on new and in-service risers
MAPS-FR
HOIS

- Principle:
  - failed ligaments carry no load and so have different stress.
  - Detect failure by this stress difference
- Technique developed by MTL
- Technique demonstrated successfully through HOIS using single probe
MAPS-FR
Project with Petrobras

- Part of Petrobras project to develop and evaluate technologies for assessing topside ligament integrity
- MAPS-FR project started in July 2006
- MAPS-FR project due to complete in early 2009
- Laboratory trial in October 2007
- Laboratory assessment and offshore trial in early 2009
MAPS-FR
Laboratory trial
MAPS-FR
Laboratory trial
MAPS-FR
Laboratory trial

- Two types of test
  - Monitoring: static probe over ligament that fails. Before and after data available
  - Inspection: scan around riser. Deduce failed ligaments from single measurement

![Diagram of wires and measurement points](image)
MAPS-FR laboratory trial October 2007
Results of monitoring trial

-100
0
100
200
300
400
500
600
700
800
900

FR002 (wire coverage #64 to 70)

Time Counter

FR004 (wire coverage #6 to 12)

FR005 (wire coverage #21 to 27)

FR006 (wire coverage #35 to 41)

FR003 (wire coverage #50 to 56)

wire #9 cut
Scans made after cutting 4 outer layer ligaments and 2 inner layer ligaments while loading the riser at 900 kN
MAPS-FR
Laboratory verification and offshore trial

- MAPS-FR tool with 3 rings of 5 probes
  - Fully marinised
  - Communicates with shore using Ethernet
  - 3 rings provide a degree of redundancy
- Demonstrates MAPS-FR monitoring tool’s ability to detect wire breaks and ensure ligament integrity
MAPS-FR Software

- Two components
  - Offshore system in two parts:
    - gather data, analyse, store (FR Chef)
    - serve data to shore systems (FR Waiter)
  - Onshore configured to look for breaks and display (FR Eater)
MAPS-FR
Offshore trial

• Installation due early 2009
• Demonstrates MAPS-FR monitoring tool’s ability to operate and survive offshore
• Will validate design for use as part of Petrobras’ riser integrity strategy