Innovative Flexible Riser Monitoring
Brian D. Taylor
Agenda

- Background
  - Goals of Flexible Integrity Management System
  - Flexible Riser Threats
- FlexAssure: Monitoring
  - Overview
  - Development and Qualification
  - Benefits and Limitations
  - Case Study
- FlexAssure: Curvature Monitoring
  - IntegriStick
  - Remnant Life Assessment
- Final Remarks
Goals of Flexible Riser Integrity Management System

- To improve **integrity and reliability**
- **Prevent failure** through early anomaly detection
- Enable **safety assessment** monitoring and maintenance
- To accurately assess **remaining service life**
Flexible Riser Threats

Unbonded Flexible Risers
DAMAGE & FAILURE CASES, GROUPED BY PIPE LAYER / COMPONENT
SureFlex JIP 2017

- Carcass
- Internal Damage - Pigging
- Internal Pressure Sheath
- Armours
- Annulus Flooding
- Outer Sheath
- End Fitting Leak / Failure
- Ancillary Equipment
- Global Pipe Defect

Number of Occurrences

<table>
<thead>
<tr>
<th></th>
<th>Damaged (failure initiator)</th>
<th>Failed - Leak</th>
<th>Failed - Rupture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass</td>
<td>25</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Internal Damage - Pigging</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Internal Pressure Sheath</td>
<td>40</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Armours</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Annulus Flooding</td>
<td>120</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Outer Sheath</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>End Fitting Leak / Failure</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Ancillary Equipment</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Global Pipe Defect</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Oil and Gas UK

relate to annulus and armour wires condition
Flexible Riser Threats Monitoring

FLEXASSURE™
Flexible Riser Monitoring System

1. INTEGRIPod™ located on riser below bend-stiffener
   - Multiple sensors recording riser movement and response

2. Second INTEGRIPod™ on flexible connector recording vessel movement. Will also detect the presence of gas or hydro-carbons in the I-tube

3. Intelligent software processing. Software will sound alarms at pre-defined threshold values

4. Satellite or internet communication to shore.

armour wires
annulus
• Wire break causes structural vibration and acoustic emission

• Five sensors (basic configuration):
  • Acceleration X/Y/Z
  • Gyroscope (axial rotation)
  • Transducer

• Data Analysis Methodology
  • Threshold level defined per sensor
  • If 4/5 sensors above threshold:
    • Potential break and alarm raised
    • Confirmation by human evaluation
FlexAssure: Development and Qualification

Operator promoted development of multiple technologies:
- Inspection and monitoring
- Built-in and retrofit

Pulse Qualification Tests:
- Lab Tension-Tension Test
- Lab Dynamic Fatigue Test
- Offshore Background Noise Test
FlexAssure Development

Tension-Tension Static Test

- Only Static Tension Loading
  - No Pressure
  - No Bending

- Range of sensors were used in the test to capture as many parameters of riser failure as possible.

- Sensors not marinised (prototype).

- Cables and connectors designed for laboratory tests.

- Sensors logged directly to computer.
FlexAssure Development
Tension-Tension Static Test Methodology

- Improved understanding
- Different technologies trialled
- Cuts induced controlled break

Armour Wire
Break Initiated
Note: Failure threshold defined based on offshore background noise recorded at a later test stage
FlexAssure Development
Dynamic Fatigue Test Arrangement

- Same sensors with removal of extra arm extension
- Introduction of similar marinised version
- Introduction of reference (vessel) sensor
- 1.5 years of testing
- Weekly reports of events
- Gamma ray inspection
  - At damage 0.3 > no breaks
  - At damage 0.8 > no breaks

Pipe Region
Dynamic Fatigue Test Results / Conclusions

- **Blind Test**
  - Number of breaks identified during dissection was only communicated after disclosure of detected breaks

- **All breaks detected**
  - 45 breaks
    - ~4 in the inner armour layer
  - Lab estimate based on acoustic measurement was 10-20
FlexAssure
Benefits & Limitations

Key Benefits
 Early detection of events leading to progressive armour wire failure prior to catastrophic failure
 Retrofit System
 Marinised
 Intrinsically Safe

Associated benefits
 Motion and acoustic record can be used for further operational response evaluation and fatigue tracking
 May be integrated with permanent annulus monitoring

Limitations and Challenges
 Only detects a potential failure event as it occurs, cannot retrospectively identify a failure.
  ✓ Magnetic inspection tool typically recommend to set base line and validate eventual breaks identified (e.g. GE/MAPS).
 Max detection range/distance is unknown.
  ✓ Failures expected near B. Stiff.
 Background noise/acceleration may lead to “detection failure” or “false alarms”.
  ✓ Multi sensor and human evaluation to address that.
FlexAssure: Case Study

- External Turret FPSO
- Water Depth 970m
- Hang-Off Above Water
- System retrofitted to installed risers
- 5 risers being monitored
FlexAssure: Case Study

Data screening and validation

- Threshold definition per sensor (and riser)
  - 5 standard-deviation used as starting point
  - Green events: 1 sensor above thresholds.
  - Red events: 4 of 5 sensors above thresholds – alarm.

- Log Rate 2000/s;

- Statistics and record 1/s (std-dev, min, mean, max);

- Reference Sensor
  - Located on turret outer radius. Relative acceleration between risers hang-off and reference sensor during FPSO pitch and roll will be different.
FlexAssure: Curvature Monitoring Remnant Life Assessment

- INTEGRISTick – Dynamic Curvature Sensors
- Attached to outside of riser
- Measures change in riser curvature in two planes
- Results used to calibrate global/local models
- First installation on a flexible planned Dec 2018
FlexAssure: Curvature Monitoring Remnant Life Assessment

- Measured curvature and angles – identify trends
- Combined with measured environmental data
- Additional input for remnant life assessment
- Reduction of conservatisms
Final Remarks

- Flexible risers have complex failure modes
- Tensile armour wires are key structural component
- FlexAssure provides innovative monitoring solution:
  - Provides early detection of potential failure events
  - Avoids catastrophic failure
  - Can be retrofitted on existing riser system
  - Combination of sensors suit, fatigue tracking and further operational evaluation
Questions?
Thank you!

Pulse Structural Monitoring
Brian D. Taylor
Phone: +44 7711 842 649
Brian.taylor@pulse-monitoring.com