ROV Deployable Dynamic Curvature Sensor to Monitor Fatigue in Subsea Pipelines

December 1\textsuperscript{st} 2016

Subsea Asia 2016

www.pulse-monitoring.com
Agenda

- Introducing the Dynamic Curvature Sensor INTEGRISTick™
- Lessons Learned from not using an ROV Deployable Sensor
- ROV Deployable INTEGRISTick™
Introducing the Dynamic Curvature Sensor or INTEGRISTick™
Dynamic Curvature Sensor

**Sensor Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stick size</td>
<td>19mm OD – 506mm length</td>
</tr>
<tr>
<td>Weight</td>
<td>1kg approx. in air</td>
</tr>
<tr>
<td>Dynamic Strain Measurement Accuracy</td>
<td>1-2μstrain RMS</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>± 2,000μstrain</td>
</tr>
<tr>
<td>Note: Above specification for pipe Ø between 6” and 11.75”</td>
<td></td>
</tr>
</tbody>
</table>

- Unique & patented sensor. Won OTC Spotlight Award.
- Accuracy, when deployed by ROV, within ±8% accuracy of bonded strain gauges
- Allows dynamic bending stress to be calculated and hence fatigue damage to be calculated

www.pulse-monitoring.com
INTEGRIstick™
Dynamic Curvature Sensor

www.pulse-monitoring.com
**INTEGRIpod™ NEXT** Platform Key Features

**Best in class battery life by leveraging the latest in battery technology breakthroughs**

Can also go into a sleep mode and only trigger on threshold events of high activity.

**ARM™ processors are the standard across many industries because of the architecture’s focus on low power consumption while maintaining significant on-board processing capabilities which transform Pulse’s Next Gen products into “Smart Sensors”.

Independently verified precision MEMS gyroscopic sensors offers unrivaled precision and accuracy.

Configurable 4-Pole Butterworth filtering module allows fine-tuning to capture specific bands of low or high frequency signals.

All instrumentation can be streamed into Pulse’s ASSURE branded software for real-time processing, automated reporting, & analytics which gives you more operational insight into whether your critical assets are operating within design parameters.

Seamless integration with Pulse’s patented direct strain sensing technology or any 3rd party sensor (ex. Pressure, Temperature, or Heading) via the 24 dedicated channels accessible through wet mateable connectors.

The Next Gen platform can communicate over various connectivity options:

- Any below or a Hybrid Combo:
  - Standalone
  - Hardwired
  - Acoustic - has the capability to use any qualified acoustic modem system

Engineered and tested to comply with the most stringent internationally recognized standards regarding quality, safety, & performance.
Installation Examples

S (Standalone)

A (Acoustic)

H (Hardwired)

www.pulse-monitoring.com
Lessons Learned from Not Using ROV Deployable INTEGRISticks™
Lesson Learned #1: Uncertainty in the final sensor location post-installation. It is critical to have the strain measurement station as close to TDZ as possible. We could not relocate the sensor if the TDZ estimates were off. Also, a key challenge is determining the sensor orientation and transformation from local to global axis.

Mitigation #1: ROV install and retrievability of the strain sensor is crucial to be able to relocate it.
Lesson Learned #2: Pulse installed the instrumentation while the riser was being run on the Deep Blue for the Anadarko job. This puts the monitoring system in the critical path which can end up causing HSE issues if things are not done properly and also potentially slow down the riser installation process which costs the client money.

Mitigation #2: Re-Engineer the solution in a way that removes the need to be a part of the critical path.

www.pulse-monitoring.com
ROV Installable Strain Sensor

**INTEGRIpod™ NXT** Motion & Strain Measurement System

- Pulse has a unique design for a fully ROV deployable Motion & Strain Sensor Package

- Both the motion and strain sensors are deployed via (1) clamp assembly that uses standard ROV tooling

- This enables retrofitting of a direct strain monitoring solution onto a riser or installing the assembly “offline” from the initial riser installation and out of “critical path”
INTEGRIsick Qualification
4 Point Bending Test Fixture

Example Qualification Testing
Components Overview – INTEGRIstick
Calibration with Project Specific Riser Joint

<table>
<thead>
<tr>
<th>INTEGRIstick ID</th>
<th>Data Plot with best fit line</th>
<th>Strapping/Calibration Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>30083-45-04</td>
<td></td>
<td>1.0514</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INTEGRIstick ID</th>
<th>Pipe Orientation (deg)</th>
<th>Time trace plot - INTEGRIstick</th>
<th>Time trace plot - Strain Gauges</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td><img src="image1.png" alt="Time trace plot" /></td>
<td><img src="image2.png" alt="Strain Gauges" /></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td><img src="image3.png" alt="Time trace plot" /></td>
<td><img src="image4.png" alt="Strain Gauges" /></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td><img src="image5.png" alt="Time trace plot" /></td>
<td><img src="image6.png" alt="Strain Gauges" /></td>
</tr>
</tbody>
</table>
INTEGRIfick Qualification

4 Point Bending Test Fixture – Methodology Overview

- **Verification**
  - Static and Dynamic loading applied
  - Measurements from strain gauges are compared against the INTEGRIfick using the obtained calibration factors
  - Difference between the two measurements is evaluated for verifying the accuracy of the INTEGRIfick measurements
Pulse has a unique design for an ROV deployable Motion & Strain Sensor Package.

Both the motion and strain sensors are deployed via (1) clamp assembly that uses standard ROV tooling.

This enables retrofitting of a direct strain monitoring solution onto a riser or installing the assembly “offline” from the initial riser installation and out of “critical path”
• Qualified and installed ROV deployable strain monitoring solution for pipeline with fairings/strakes:
  – Pipeline unsupported as it crosses subsea ridge
  – Vulnerable to fatigue from slugging & VIV

• Opens up new retrofitable strain opportunities for Integrity Management
  – Pipelines
  – Jumpers
  – Risers
  – Other Subsea Infrastructure
Pulse Structural Monitoring
Steven Gauthier
Phone: +65 9722 5811
Steven.Gauthier@pulse-monitoring.com

Thank you!

www.pulse-monitoring.com