Structural Monitoring of Subsea Pipelines and Role in Reducing Mitigation Costs

Subsea Asia 2015 - Jakarta
24th November 2015

www.pulse-monitoring.com
Agenda

- Introducing Pulse
- Pipeline Span Monitoring
- Slugging Monitoring
- FIV Monitoring
- Summary and Questions
Introduction
Monitoring Systems

Motion

INTEGRIpod™
Standalone logger

INTEGRIpod™ AM
Acoustic logger

INTEGRIsensor™
Dynamic curvature

Strain

Interfaces

Software

INTEGRIpod™
Diver deployable holder for mooring lines

ASSURE™ software

Field proven systems

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Data Loggers

- Standalone
- Acoustic
- Hardwired
- Eexd

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Pipeline Integrity Monitoring Services

Overview

Free Spans
- Potential damage from VIV, FIV and slugging

Slugging
- Cyclic stress and inertial loading cause fatigue

FIV
- Increasing flow rates causing enhanced fatigue
Pipeline Span Monitoring
Pipeline Span Monitoring

Introduction

• Span- unsupported areas of subsea pipeline

• Two types of span that can cause integrity concerns:
  – Natural spans (pipeline profile / geometry of seabed)
  – Pipeline sleepers (installed to control lateral displacement and prevent pipeline buckling)

• Various potential fatigue damage
  – VIV (Vortex Induced Vibration), FIV (Flow Induced Vibration) and slugging
Pipeline Span Monitoring

Typical system layout
### Sensor Specifications*

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tri Axial Accelerometers</strong> X,Y and Z</td>
<td></td>
</tr>
<tr>
<td>Range [g]</td>
<td>± 2</td>
</tr>
<tr>
<td>Accuracy [m/s²]</td>
<td>+/- 0.001</td>
</tr>
<tr>
<td>RMS Noise [m/s²]</td>
<td>0.0003</td>
</tr>
<tr>
<td>Resolution [m/s²]</td>
<td>0.000005</td>
</tr>
<tr>
<td><strong>Tri Plane Angular Rate</strong> XZ, YZ and XY</td>
<td></td>
</tr>
<tr>
<td>Range [deg/s]</td>
<td>± 4</td>
</tr>
<tr>
<td>Accuracy [deg/s]</td>
<td>+/- 0.05</td>
</tr>
<tr>
<td>RMS Noise [deg/s]</td>
<td>0.008</td>
</tr>
<tr>
<td>Resolution [deg/s]</td>
<td>0.000001</td>
</tr>
</tbody>
</table>

### Communication Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Communication Ports</td>
<td>RS232</td>
</tr>
<tr>
<td>USB Port</td>
<td>For Data Download</td>
</tr>
</tbody>
</table>

*Based on INTEGRIPod Next Gen*
Vortex Induced Vibration
Pipeline Monitoring

Magnitude of Peak Response vs. Frequency

Logger 50
x/L = 1.000

Logger 51
x/L = 0.305

Logger 52
x/L = 0.257

Logger 53
x/L = 0.208

Logger 54
x/L = 0.160

Logger 55
x/L = 0.112

Logger 56
x/L = 0.000

INTEGRIPods

Schiehallion Event 91 - Magnitude of Peak Response vs. Frequency

Acceleration Amplitude (m/s²)

Frequency (Hz)
Pipeline Span Monitoring

Current monitoring

- Measures the speed and direction of ocean currents
- Battery Operated
- 20-30min recording per hour
Pipeline Span Monitoring
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>2µstrain RMS</td>
</tr>
<tr>
<td>Measurement Range</td>
<td>± 2,000µstrain</td>
</tr>
</tbody>
</table>

*Note: Above specification for pipe Ø between 6” and 11.75”*
Pipeline Span Monitoring
Sensor Interface Installation Methods

Motion

Strain

Current

Diver/ Topside

ROV
Pipeline Span Monitoring

Recent projects

- Humber Estuary Pipeline - 2005
- Pipeline bundle tow out & span monitoring - 2009
- Gas pipeline span monitoring - 2010
- Gas pipeline span slugging monitoring - 2012
- Gas pipeline span slugging monitoring - 2015
Case Study: Humber Estuary Pipeline

Overview

- Monitoring pipeline free span in river estuary
- Issue:
  - Client wanted to determine the flow velocities and directions that are incident upon the exposed section of pipe
  - Wanted to establish whether the pipeline is experiencing VIV and potential fatigue affects
- System
  - 2 x INTEGRIpod SM
  - 2 x current meters
Case Study: Humber Estuary Pipeline

Outcome

- No evidence of VIV was found to be present in either the cross-flow or in-line direction

- Typical VIV Spectrum

- Data monitored
Case Study: Pipeline Bundle Tow

Overview

- Monitoring of a pipeline bundle for response to towing and in service operations
- Issue:
  - Client required confirmation of the structural response and fatigue life
  - Part of design verification process
- System
  - 18 x INTEGRIpod SM
  - ROV deployable/retrievable
  - Continuous logging
Case Study: Pipeline Bundle Tow

Overview of Gravity Actuated Pipe

1.5km
Case Study: Pipeline Bundle Tow

Outcome

• Fatigue damage was accumulated during tow out
• Response was found to be within limits
• Proved analysis model was fairly accurate
Slugging Monitoring
Slugging

Introduction

- Occurs due to separation of liquids and gas in multiphase flow
- Causes cyclic loading leading to fatigue damage
- Certain infrastructure particularly susceptible to slugging:
  - Pipeline spans
  - Rigid jumpers
  - Sleeper crossings
- Can push structural utilizations above allowable limits
Case Study: Slugging Monitoring

Overview

- Monitoring of span on a gas flowline
- Issue:
  - Pipeline unsupported as it crosses subsea ridge
  - Vulnerable to fatigue from slugging & VIV
- System:
  - 6 x INTEGRIpod SM
  - 2 x INTEGRIstick
  - Record vertical & lateral structural response
  - ROV installable/ retrievable
High Speed Vibration Monitoring
Flow Induced Vibration (FIV)

Introduction

- Subsea vibration due to process excitation an increasing issue:
  - Higher flow rates
  - Increasing flexibility in pipework
- Particularly problematic on manifolds, jumpers and valves
- Issue may occur subsea with no obvious sign topsides
FIV Monitoring
High speed vibration sensors

Magnetic Sensor

Lightweight Sensor
Case Study: North Sea FIV Monitoring

Overview

- Monitoring a gas export pipeline in the North Sea
- Issue:
  - FIV inside pipe caused by trapped plug tool
  - A vibration monitoring system was requested for detecting the existence of such vibration
- System
  - High frequency monitoring system
  - Magnetic vibration sensor
  - 2 x INTEGRIpod SM High Speed logging continuously
Case Study: North Sea FIV Monitoring

Outcome

- System found high frequency vibration present
- Aided the operator to select a safe flow rate

Fast Fourier Transform (FFT) of the X-axis showing frequency of vibration
Pipeline Monitoring

Summary

• Purpose of monitoring spans:
  • Understand the motion and its cause (wave, current, VIV…)
  • Verify the design analysis and its operational integrity
  • Compare predicted motions to actual motions and calibrate actual structural response
  • Verify effectiveness of VIV strakes
Pipeline Monitoring

Reducing Mitigation Costs

- Pipeline span doesn’t necessarily mean excessive motion and fatigue, understanding this can save on mitigation costs.

- Example from an ongoing project:
  - A client in GoM has for policy to mitigate all spans > 20m long
  - By monitoring their spans they expect to have to monitor less spans and of longer length
Thank you!

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