Pipelines that Walk

Back to the Future - 22 November 2018
What is Pipeline Walking?

Earliest recorded failure due to walking

- **1997** - North Sea operated by Amerada Hess
- Short flowlines operating at high temperature

**Incident**

- Worst affected flowline displaced axially by over 1.0 m per year
- Movement towards colder end
- Full bore rupture of tie-in spool

**Cause of Failure**

- Repeated heat-up & cool-down cycles - thermal transients
- Low axial resistance in soft to very soft clay
- Axial resistance is plastic (non-recoverable)
- Pipeline is “fully mobilised” expanding and contracting along its full length during heating & cooling

**Mitigation**

- Replace damaged tie-in spools
- Rock dump along flowlines in open trench

Tørnes, Ose, Jury & Thomson (2000) OMAE 5055
What is Pipeline Walking?

Recent recorded incident due to walking
- **2017** – Malampaya – Philippines operated by Shell
- Long flowlines with lateral buckles, operating at high temperature

**Incident**
- Flowline displaced axially by 28mm per cycle, 1.8m total
- Movement towards colder end, uphill & opposite to that expected
- Foundation displaced & concerns about integrity of jumper

**Cause of Incident**
- Repeated heat-up & cool-down cycles - thermal transients
- Low axial resistance in siliceous carbonate silt
- Pipeline is “fully mobilised” between lateral buckles
- Lateral buckles driving uphill walk

**Mitigation**
- Shut down production
- Engineer and novel mitigation system & install in 12 months
- Mitigate using PCM (pipe clamping mattress) - more later...

Frankenmolen, Ang, Peek, Carr, MacRae, White & Rimmer (2017) OTC 27185
1997 to 2017 – in twenty years what have we learned?

A Great Deal!
Drivers:

- Thermal Transients on re-start or shut-down
- SCR (Steel Catenary Riser) tension
- Seabed slope
- Liquid drop-out on shutdown

Carr, Sinclair & Bruton (2006) OTC-17945
Pipeline Walking – Understanding the Field Layout Challenges, and Analytical Solutions developed for the SAFEBUCK JIP

Bruton, Sinclair & Carr (2010) OTC-20750
Lessons Learned From Observing Walking of Pipelines with Lateral Buckles, Including New Driving Mechanisms and Updated Analysis Models

Bruton & Carr (2011)
OTC-21671
Overview of the SAFEBUCK JIP
Controlling Pipeline Walking - Chevron Tahiti - GoM
Stab and Hinge Over Suction Pile Attachments

Thompson, Zhang, Brunner, Qi, & Noel (2009) OTC 19858
Controlling Pipeline Walking - Greater Plutonio - Angola
Suction piles attached by chains to FTA

Jayson, Delaporte, Albert, Prevost, Bruton & Sinclair (2008) OPT
Attachment to allow retrofitting of anchors later in field life

Jayson, Delaporte, Albert, Prevost, Bruton & Sinclair (2008) OPT
Controlling Walking – Current Project
Mid-line Bridled Anchor Attachment
Anchoring Options for Pipeline Walking

- **Walking may be controlled by anchors**
  - Installed at the end of the pipeline (typically)
  - Mid-line anchors also installed
  - 'Unidirectional' (chain-attachment) or 'Fixed'

- **Several projects have installed pipeline anchors**
  - Typically suction piles - capacity of 50t to 350t

- **High levels of tension at shutdown are a concern:**
  - Route-curve instability & curve pull-out
  - Buckles pulling-straight – not reforming
  - Such instabilities observed in the field

- **Important drivers in the layout of a field development**
  - Several pipelines have required intervention to mitigate pipe-walking
Issue with SCR Tension due to Anchoring

Carr, Bruton & Leslie OPT 2003
Anchor Hold-Back Failure due to Accumulation of Tension

Example: Hold-back anchor - attachment failure
- Resulting in route curve pull-out (date unknown)
- Route curve pull-out has also occurred on another anchored flowline (without an SCR)
Design Uncertainties + Walking is affected by Lateral Buckling

**Influence**

- Not an issue, unless it occurs at:
  - first start up
  - shutdown

- Walking rate
- Feed-in to buckles

- Walking rate
- Number of buckles
- Feed-in to buckles
- Anchor loads

**Other uncertainties:**

- Lay tension
- Bathymetry, route & OOS
- Buckling triggers
- Pipe steel and coating data

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### Axial resistance

- **Breakout**
- **Residual**
- **Cyclic**
  - Consolidation hardening

### Lateral resistance

- **Breakout**
- **Residual**
- **Cyclic**
  - Soil berms

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### Operating Conditions

- **Fluid Density**
- **Thermal transients**
- **Steady state P&T**
- **Operating cycles**

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**Influence**

- Buckle formation
- Load in buckle

- Shape of buckle
- First load in buckle

- Cyclic fatigue
- Changes in shape that feed walking

- Walking rate
- Feed-in to buckles

- Walk/cycle
- Loads in buckles

- Cumulative walk
- Cyclic Fatigue
Understanding PSI - Geotechnical Advances in Understanding

University of Texas – Tilt-table

NGI (Norwegian Geotechnical Institute) - Oslo

UWA - Low Stress Shear

Axial test set up

Lateral test set up

University of Western Australia

Small-scale tests

Large-scale tests

Najjar, Gilbert, Leidtke, McCarron & Young (2007) ASCE
White, Westgate, Ballard, DeBrier & Bransby (2015) OTC26026
In-situ pipe-soil testing: model test in deep water fields West Africa & Australia

➢ Much effort expended in improving understanding and interpretation of Geotechnical data
➢ Improved methods for gathering Geotechnical data in development

White, Clukey, Randolph, Boylan, Bransby, Zakeri, Hill & Jaeck (2017) OTC-27623
The State of Knowledge of Pipe-Soil Interaction for On-Bottom Pipeline Design

Offshore in-situ tests
Monitoring Pipeline Walking – Current Best Practice

FTA (flowline termination assembly) with expansion sliders.
Graduated markings on side of sliders for measurement of expansion & walking
Magnet to record maximum reading
Monitoring Pipeline Walking – Prediction & Actual

- Compare actual walk with predicted walk based on end expansion for a range of axial friction
- Valuable lesson that axial friction increases with time
- Rate of increase in axial resistance needs quantifying

Operational monitoring and back analysis:
- Has provided valuable lessons for future projects
- Limited by snap-shot approach and poor monitoring records
**Continuous displacement monitoring would be much better**
- Less uncertainty, better calibration of walk
Anchoring Pipeline Technology APT – Joint Industry Project

- Intelligent application of modern analysis techniques
- Developing smarter strategies to simplify the design process
- Novel, simple-to-retrofit, low-capacity anchors
- "Wait and See" approach based on new Design Guidance
PARTICIPANTS:

Phase I – Scope Complete 2018

TASKS:

Task 1: State of the art review:
- Reviewed design challenges, drivers and mitigation applied on many international projects

Task 2: Geotechnical response of anchoring approaches:
- Provided force-displacement responses for the full range of anchor systems to identify most promising technologies, including evaluation of existing anchoring and restraint systems

Task 3: Impact of mitigation strategies on structural response:
- Evaluated structural response of pipeline-anchor combinations to identify the most promising mitigation strategies
- Evaluation of two real cases of pipeline walking and restraint solutions

Task 4: Integration into design process:
- Provided an outline of a simple & robust design strategy to guide the mitigation process

Task 5: Summary Report - Identify most promising technologies:
- Summarise work performed, identify areas for further investigation in APT Phase 2
Controlling Pipeline walking - low-capacity distributed restraint
Pipe-Clamping Mattress

APT supports the use of low capacity anchors such as the PCM

Frankenmolen, Ang, Peek, Carr, MacRae, White & Rimmer (2017) OTC 27185
Phase 2 - Scope of Work

1. **Development and testing of an innovative low-capacity plate anchor solution**
   - University based research into restraint systems (subsidised by government funding)
   - Generic interaction modelling by FEA to support testing and interpretation

2. **Engineering development of monitoring system for pipeline walking**
   - Continuous measurement to match directly with production P & T data
   - Low cost: simple to install, sufficiently accurate, easy data recovery and long battery life

3. **Engineering development of low-capacity pipeline clamp**
   - Sufficient restraining capacity to attach a ‘distributed’ anchor system, load for life of line
   - Easy to attach to pipeline by ROV with coating integrity maintained

4. **Tie-in Design to better accommodate large end expansion**
   - Tie-in design improvements to better accommodate cumulative end expansion
   - Defers need for walking mitigation

5. **Development of a Design Guideline**
   - Define methodology for observational method or “wait & see” approach
   - SRA to support design assessment methods and define acceptance criteria
   - Evaluation of real cases of walking and mitigation to support the APT approach
"And we can save 700 lira by not taking any soil tests."
For more information go to

www.crondall-energy.com