Permanent Weldless Deepwater Repair Strategies

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Introduction

• Speaker Introduction
  • Hydratight
  • Connector Subsea Solution
• Pipeline Repair Strategy
• Identify Damage – Root Cause Analysis
• Intervention Tooling
• Case Study
Part of the Actuant Corporation ($1.3B), Hydratight is a world leading engineering company who provide a range of specialist products and services to the Oil & Gas and Power Generation industries. Since 1901, our aim is to maximise safety and improve operational efficiency by supplying products and services that provide safe, reliable connections.

Subsea Pipeline Inspection, Maintenance & Repair Solutions:
- Mechanical Connectors, Clamps, Split nuts and remote bolt tensioning equipment
- Supplied worldwide over 20 years
- Repair, contingency, tie-in & construction for critical and non-critical applications
- Product DNV Type Approval for permanent pipeline repair
- 100% leak-free in-service record
Connector Subsea Solutions Overview

Connector Subsea Solutions (formerly AS Connector) is a technology leading company who provide complete deepwater inspection, maintenance and repair solutions for risers and flowlines. Since 2000, Connector has focused on supplying innovative, reliable and cost effective solutions to deepwater challenges.

Diverless Pipeline Inspection, Maintenance & Repair Solutions:
- Pipeline lifting and handling tools
- Coating and weld seam removal tools
- Pipe cutting tools
- Pipe end preparation and bevelling tools
- Lightweight and small footprint pipeline repair connectors
- Structural and leak sealing clamps
- Safety Clamps
- Riser cleaning and inspection tool
- Flexible retrieval tool
- Flexible Protection and Repair
Joint Collaboration

- **Formal Collaborative Agreement (signed May 2014)**
  - *Multiple peer contact*, ensuring an integrated alignment through all aspects of the business
  - *Fully Integrated offering*, reducing operation risk and optimizing delivery
  - *Profit Sharing*, ensuring lower cost solutions
  - *Combined technical offering*, providing over 45 years of subsea expertise in pipeline repair products and services.

- **Collaboration offers a complete combined system for SURF IRM including:**
  - Horizontal and vertical installation systems
  - Pipe handling and lifting tools
  - Pipe coating removal and end preparation
  - Mechanical connectors and clamps
  - Subsea power and control modules
  - ROV Customized and special tooling
Repair Strategy

1. Form Repair Team
2. Set-up Communication Lines
3. Collect Pipeline Data and Surveys
4. Identify Damage
5. Consult Marine Contractors
6. Consult Pipeline Intervention Companies
7. Isolation / Decommissioning
8. Stabilize Damage

9. Weldless/Mechanical
   - Develop Repair Strategy
   - Seek Approvals (Authorities etc.)

10. Deepwater/Remote Operated
    - Design Intervention Tools
    - Prepare Operational Procedures

11. Case Study
    - Re-commissioning
    - Offshore Repair
    - Logistics & Transport
    - Source & Commit Intervention Systems

Root Cause Analysis

Courtesy of IRM Systems LTD
## Identify Damage

### Root Cause Analysis

<table>
<thead>
<tr>
<th>Operation/activity</th>
<th>Hazard</th>
<th>Possible consequence to pipeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of pipeline</td>
<td>Dropped and dragged anchor/anchor chain from pipe lay vessel</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Vessel collision during laying leading to dropped object, etc.</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Loss of tension, drop of pipe end, etc.</td>
<td>Damage to pipe/umbilical being laid or other pipes/umbilicals already installed</td>
</tr>
<tr>
<td></td>
<td>Damage during trenching, gravel dumping, installation of protection cover, etc.</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Damage during crossing construction.</td>
<td>Impact damage</td>
</tr>
<tr>
<td>Installation of risers, modules, etc. (i.e. heavy lifts)</td>
<td>Dropped objects</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Dragged anchor chain</td>
<td>Pull-over and abrasion damage</td>
</tr>
<tr>
<td>Anchor handling (Rig and lay vessel operations)</td>
<td>Dropped anchor, breakage of anchor chain, etc.</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Dragged anchor</td>
<td>Hooking (and impact) damage</td>
</tr>
<tr>
<td></td>
<td>Dragged anchor chain</td>
<td>Pull-over and abrasion damage</td>
</tr>
<tr>
<td>Lifting activities (Rig or Platform operations)</td>
<td>Drop of objects into the sea</td>
<td>Impact damage</td>
</tr>
<tr>
<td>Subsea operations (simultaneous operations)</td>
<td>ROV impact</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Manoeuvring failure during equipment installation/removal</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Manoeuvring failure during equipment installation/removal</td>
<td>Pull-over and abrasion damage</td>
</tr>
<tr>
<td>Trawling activities</td>
<td>Trawl board impact, pull-over or hooking</td>
<td>Impact and pull-over damage</td>
</tr>
<tr>
<td>Tanker, supply vessel and commercial ship traffic</td>
<td>Collision (either powered or drifting)</td>
<td>Impact damage</td>
</tr>
<tr>
<td></td>
<td>Emergency anchoring</td>
<td>Impact and/or hooking damage</td>
</tr>
<tr>
<td></td>
<td>Sunken ship (e.g. after collision with platform or other ships)</td>
<td>Impact damage</td>
</tr>
</tbody>
</table>

Table 1: DNV-RP-F107: Risk Assessment
Root Cause Analysis

PARLOC 2012 INCIDENT DATABASE

- 183 loss of containment incidents
- 23 near miss incidents
- Plus some incidents excluded from study:
  - 6 incidents in 2013
  - 39 irrelevant incidents
Develop Repair Strategy

- Identify constraints bespoke to the repair
  - Physical space
  - Geographic, geologic, environmental (i.e. Weather windows)
  - Location

- Identify constraints bespoke to the Operator
  - Industry & Operator Standards
  - Time
  - Preference based on experience, reliability and trust
    - Permanent or Temporary
    - Welded repair: On deck/subsea/hyperbaric
    - Connector repairs: Flange/Hub Adaptor or pipe-to-pipe coupling
    - Clamps repairs: Structural or non-structural
    - Leak sealing: Injected epoxy or wrapping
    - Diver installed or remotely operated
# Intervention Tooling

<table>
<thead>
<tr>
<th>Step</th>
<th>Diver Installed</th>
<th>Remote Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipeline excavation/ Lift</td>
<td>Trenching/ excavation, Buoyancy</td>
<td>Trenching/ excavation, Pipe handing frames</td>
</tr>
<tr>
<td>Remove coating</td>
<td>Water pressure lance</td>
<td>ROV Pipe coating removal tool</td>
</tr>
<tr>
<td>Pipe Cutting</td>
<td>Subsea pipe cutting tool</td>
<td>ROV pipe cutting tool</td>
</tr>
<tr>
<td>Inspect seal surface</td>
<td>Visual Inspection</td>
<td>ROV Pipe inspection tool</td>
</tr>
<tr>
<td>Aligning connector</td>
<td>Diver handling with airbag support</td>
<td>Hydraulic controlled positioning system</td>
</tr>
<tr>
<td>Installing connector</td>
<td>Diver handling with airbag support</td>
<td>Hydraulic controlled positioning system</td>
</tr>
<tr>
<td>Verifying connector position</td>
<td>Visual Inspection</td>
<td>Sensors with electronic feedback to surface</td>
</tr>
<tr>
<td>Activate connector</td>
<td>Standard Subsea Tensioners</td>
<td>Remote Operated Subsea Tensioners</td>
</tr>
<tr>
<td>Seal verification test</td>
<td>Diver handling + Hydratight tools</td>
<td>Remote operated hydraulic test system</td>
</tr>
<tr>
<td>Recover installation equipment</td>
<td>Diver handling</td>
<td>ROV operated disengagement system</td>
</tr>
</tbody>
</table>
Case Study – Riser Tower

• Hybrid riser tower connects the FPSO to the subsea flowline and control systems

• Identify Damage:
  – Two 4” gas lift risers had damage at the base of a hybrid riser tower, at 1300m water depth. Root cause identified installation error.

• Two Repair Strategy options:
  • Replacement of the entire gas lift riser
  • Repair and bypass of the damaged section of the riser

• The Repair/Bypass option was selected as it was estimated to be significantly cheaper
The repair strategy had two main focus:

- Remote Vertical Riser Repair Operation: Use MORGRIP® Repair Connector to bypass the damaged part of the riser with new flexible section.

- Restraining System to support Repair Location: Structurally support the spool sections to the hybrid riser tower to avoid transfer of dynamic loads into the connectors.
Intervention Tooling – Riser Repair

• Remove coating on Risers
  – No removal of parent material
  – No additional umbilical – ROV powered
  – Remove all FBE coating layer
  – Lightweight, <50kg submerged
  – Qualified surface for sealing and gripping

• Install Anchor Gripper Unit
  – Avoid any direct connection between vessel crane and gas lift riser during the operation
  – Increase holding force as a function of applied load
  – Swift ROV installation and removal
  – Robust to impact in any direction
  – Emergency releasable

• Install Installation Frame
  – Avoid high stress in the gas lift riser
  – Ensure no clash between crane block/subsea rigging and riser tower.

• Align, Install & Activate the Connector
  – Space and weight restrictions

• Pressure test Connector
• Release and Retrieve Installation Frame
• Retrieve Anchor Gripper Unit
Intervention Tooling – Restraint System

• Create working space around water injection riser P11 by removing buoyancy
  – Toughness of glass/epoxy composite, machinability
  – Limited relevant subsea machining experience available worldwide
  – Optimizing tool rigidity versus lightweight for ROV installation

• Remove coating on P11
  – Very Limited Operation Envelope
  – Toughness of FBE – Proprietary technology applied
  – ROV installation and powered
  – No removal of parent material
  – No additional umbilical's

• Install Structural Restraint Clamp on P11 with interface for Restraint Assembly
  – High utilization of riser
  – Novel gripping system developed
  – Low and high cycle fatigue, pipe limiting factor
  – Potential for Fretting and Crevice Corrosion
  – ROV installability

• Install Restraint Assembly
• Secure repaired risers into the Restraint Assembly
Installed MORGRIP® Connectors
Installed Restraint System