Flexible Pipe Integrity Management

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Flexible Pipe Integrity Management
Overview

- Introduction to Flexible Pipe
- Life Cycle Management of Flexible Pipe
  - Design, Integrity Management, Operational Support
- Damage Degradation & Failure
- Technology Development
  - Analytical methods
  - Inspection / integrity guidance
- Case Study
Introduction to Flexible Pipe

• Early flexible pipe technology
  • Project PLUTO
    • Pipeline Under the Ocean
  • Developed from subsea cable technology
  • 3-inch ID pipe from England to France
    • Fuel supply provision late in WW2
  • First Pipelay 12\textsuperscript{th} August 1944
  • By end of WW2, 781,000m\textsuperscript{3} transferred

• Key technology enabler to dynamic floating production applications
Introduction to Flexible Pipe

Carcass (Stainless / Duplex), [rough bore]
- **External Pressure Resistance**

Carcass Profile:

Internal Sheath (Polymer)
- **Internal Fluid Containment Barrier**

Pressure Armour (Carbon Steel), [re-inforced]
- **Hoop Load Resistance**

Armour Profile:

Tensile Armour (Carbon Steel)
- **Tensile Load Resistance**

External Sheath (Polymer)
- **External Fluid Barrier**
Introduction to Flexible Pipe, Layouts

FREE HANGING

LAZY WAVE

STEEP WAVE

PLIANT WAVE®

STEEP S

LAZY S
Life Cycle Management of Flexibles

- Concept
- Definition
- Operations
- Detail Design
- Inspection & Monitoring
- Historical Data
- Degradation & Failure
- Risk Assessment & Integrity Management
- Manufacture
- Installation & Commissioning
- Project to Operations Handover
- Concept Definition
- Historical Data
- Guidance on Inspection & Monitoring
- Degradation & Failure
- Operations
Life Cycle Management of Flexibles

Project Activities
- Project Management & QC
- NEXUS Integrity Centre
- Data Management / Reporting

Operational Engineering Support | Inspection & Vacuum Test Services | Co-ordinate Inspection Activity
---|---|---
Risk Analysis | Integrity Management Strategy | Implement IM Strategy
Data Collection

Periodic Review of IM Strategy
Re-assess, Learn, and Implement Recommendations
Fitness for Service Summary

Operational Engineering Support
Inspection & Vacuum Test Services
Co-ordinate Inspection Activity

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Damage, Degradation & Failure

• Industry statistics & guidance developed through SureFlex JIP
  • “State of the Art Report on Flexible Pipe Integrity”
  • “Guidance Note on Monitoring Methods and Integrity Assurance for Unbonded Flexible Pipe”

• SureFlex originally ran in 2009-2010
  • 12 members (predominantly operators, plus HSE and 1 operator)

• In the period since SureFlex...
  • Increased operational experience gained
  • New technology deployed; smooth bore gas risers, materials (various)
  • Additional degradation / failures; sweet service 55deg pipe, corrosion
  • New inspection & monitoring technologies developed and deployed

• SureFlex2015 JIP proposal currently issued to industry
Damage, Degradation & Failure

Flexible Pipe Damage

- Operation: 262
- Installation: 48
- Loadout (pre-install): 1
- FAT: 4

See note in 6.1.1 above, on the inclusion of FAT failures.
Damage, Degradation & Failure

Flexible Pipe Failure/Damage Mechanisms

- External Sheath Damage / Flood
- Pull-Out / Internal Sheath
- Ancillary Device Failure
- Overbend
- End Fitting Leak
- Birdcaging
- Oxidation
- Vent System anomalies
- Wax Buildup
- Corrosion
- Cage / Failure
- Other

Others:
- Smooth bore collapses
- Pigging Damage
- Upheaval Buckling
- Excess Torsion
- Excess Tension
- Sheath cracking
- Armour wire failure
Damage, Degradation & Failure

- Failure modes, layer by layer basis
  - Focus is structural layers i.e. Not fabric / polymer tape layers
  - Real examples / case studies given where available

- Flexible pipe layers reviewed
  - Carcass
  - Internal Pressure Sheath
  - Pressure Armour (including backup layers)
  - Tensile Armours
  - Outer Sheath
  - Ancillary Equipment
Damage, Degradation & Failure

- Carcass
  - Rapid Gas Decompression / Collapse
    - Older (pre 2001) multilayer PVDF designs
    - Permeation through sheath in normal ops.
    - Gas build-up between PVDF layers, polymer saturated with permeated gas

Carcass Profile

Carcass Manufacture

To annulus vent system

Permeation into annulus during normal operations

Flexible Pipe Bore

Outer Sheath

Tensile Armours

Pressure Armour

Multilayer PVDF Pressure Sheath

Carcass
Damage, Degradation & Failure

- Carcass (continued) RGD
  - With excessive decompression rates, carcass collapse is possible due to expanding gas
Damage, Degradation & Failure

• Internal Pressure Sheath

Internal Sheath crack

Failure initiation region of PVDF

Sacrificial Sheath failure
Damage, Degradation & Failure

- Internal Pressure Sheath (crack initiation next to carcass ridges)
Damage, Degradation & Failure

- Pressure Armour (unlock)
Damage, Degradation & Failure

- Tensile Armour Defects
Damage, Degradation & Failure

• Outer Sheath, armouring annulus historically designed for dry conditions
  • Outer sheath integrity often compromised during installation e.g. shortly after damage

• Significant uptake in vacuum testing has identified further cases, a large proportion relating to inadequate annulus vent systems
Damage, Degradation & Failure

• Outer Sheath Damage Implications
  1. Corrosion Fatigue
    • Normally critical at bend stiffener interface
    • Internal pressure armour often critical with high op. pressure
    • Assessments normally based on deoxygenated environment, breach assumed distanced from fatigue critical area and repaired
2. General Corrosion

- May be prevalent if sheath breach located in oxygenated environment, proven cases of severe degradation or failure relating to this mechanism, and further cases which are currently being managed / investigated

- Particularly onerous for breaches within I-tubes / beneath ancillary equipment where CP shielding may be an issue

- Example, ref OMAE2007-29382
Damage, Degradation & Failure

- Ancillary Equipment
Damage, Degradation & Failure

- Ancillary Equipment (riser hold-down failure)

- Tethers
  - Tophat / Swivel
  - Riser

- Seabed
  - Approximately 10 metres
  - Approximately 1 metre
Damage, Degradation & Failure

- Ancillary Equipment (riser hold-down failure)
  - Connection failure, riser displaced 75 metres vertically upwards
Flexible Pipe Technology Development
Case Study, In-Service Riser Repair

• Galley Field, Northern Producer FPF
  • Approx 120 miles NE of Aberdeen
  • Installed September 1997
  • 10yr design life

• Flexible Riser System
  • Lazy-S Configuration
  • 3xProd., Oil Exp., Gas Exp., Water Inj., Umbilical
Case Study, In-Service Riser Repair

- Riser tie in platform
- 8-inch Gas Export
- Inverted Bellmouth I-tube
- Damage Bellmouth Pontoong
Case Study, In-Service Riser Repair
Case Study, In-Service Riser Repair

- Bubbles identified from inverted bellmouth
  - Routine GVI
  - Checks indicate permeated gas levels of leakage
    - Annulus flooded, confirmed by vacuum test
  - Assumed breach within lower bellmouth
  - Borescope inspection inconclusive
Case Study, In-Service Riser Repair

- Potential restriction at bellmouth
  - Confirm riser not “jammed” at lower bellmouth
  - Confirm tension not supported at pontoon

- Riser Pull Test – Lateral Displacement
  - Lateral mid-span displacement associated with vertical lift at bellmouth
  - Riser de-pressurised & isolated before test

- Conclusions
  - Test results a good overall comparison with analysis
  - Riser tension not supported at pontoon
  - Riser can be lifted for inspection
Case Study, In-Service Riser Repair

- Riser Pull Test
Case Study, In-Service Riser Repair

0.00 Te

0.75 Te

1.50 Te
Case Study, In-Service Riser Repair

Vertical Deflection at Base vs Horizontal Deflection at Pull Point

- Pull Test Results
- Analysis, Free Base, Test Point Pull
Case Study, In-Service Riser Repair

- Riser Lift & Inspection
  - At transit draft
  - Inspection basket deployed Prior to lift
Case Study, In-Service Riser Repair

- Small damage area with debris embedment
Case Study, In-Service Riser Repair

- Larger section of outer sheath removed to assess armours
Case Study, In-Service Riser Repair

- Gas Export Operations Halted
  - Severity of damage & failure consequences
  - Loss of Gas Export revenue
  - Reduced Production
  - Consent to flare
- Temporary Mitigation
  - Gas Export swapped with Water Injection Service
    - Early restart of Gas Export operations
  - Technical integrity assessment
    - Supported riser service swap
    - Justification for in-service use of damage riser
      - Economic consequences of Water Injection failure
      - Water Injection repair before full winter season
Case Study, In-Service Riser Repair

• Permanent Repair
  • Cut out damaged section and re-terminate
  • Riser lift to hang-off deck to effect repair
  • Weather window assessed for each stage
  • Critical maximum lifts to +30m and +40m
  • Vessel actively winched towards MWA
  • Analysis predicted weather windows
    • Hsig = 5m to 9m (+40m lift)
    • Hsig = 12m (+30m lift)
Case Study, In-Service Riser Repair

Initial Crane Lift on End Fitting

40 metre Lifts: Dual Clamps & Strand Jacks
Case Study, In-Service Riser Repair
Case Study, In-Service Riser Repair

- Riser repair completed successfully
- Riser brought back into WI service

Conclusions / Key Lessons

- Damage worse than expected from minor sheath breach
  - Subsequent similar cases on other assets have lead to full bore failures
- Vacuum testing and integrity management allowed timely repair
- Successful riser repair
- Inverted bellmouths and similar devices require debris protection
Questions?