Integrity management and operational experiences of flexible risers

Stavanger - November 26th 2013

Flexible risers
– Management of Integrity, learning, sharing of experiences and continuous improvement
Agenda

• Historical development
• General Observations
• Experience with flexible pipes
  – Carcass Issues
  – Failure investigations
• Integrity Management
  – Statoil RIM Portal
  – New developments
Long track record for unbonded flexibles

1986
- 5 subsea wells tied back to Gullfaks GBS (fixed platform)

1990
- 2 x 4” HP mud / cement connecting Veslefrikk A/B (jacket / semisub)

1992
- Tie back of subsea template to Snorre TLP (flowlines + risers)

1995 – 2000
- Full flexible HP/HT developments "The elephants"
Operational experience

- 20 floating production & storage/offloading units
- 250 dynamic unbonded flexible risers
- 500 km unbonded flexible flowline
- 10 loading systems with large diameter bonded flexible pipe
- 100-380 m of Water Depth
- Vital for Statoil’s oil production
Rough environmentals – every week – all winter

- 100-year condition (Aasta Hansteen)
  - 33m (108ft) max wave height
  - 17m (56ft) significant wave
  - 19s peak period (associated)
  - 1.9m/s (3.7kn) current
  - 35m/s (68kn) 1hr wind
- Storms “every” winter @ 75% of 100-year level
- Seabed temperature below freezing, all year
- Hydrate regime frequently encountered
General Qualification Status - DP

1000 PSI = 68 Barg
Outline for Design

• Operational requirements at the edge
  – High dynamics
  – High pressure
  – High temperature
  – Frequent fluctuations

• Qualifications within projects
  – New polymer & steel materials
  – New armour profiles
  – New cross section build-up
  – Pre-cooling before entry in flexibles

• Challenging operation
  – Demanding technology handover
  – Projects focus is shorter than operations
  – Experience sharing required

North Sea example
• Reservoir pressure 911 bar
• Reservoir temperature 170°C
• 100-year wave height 34m
• New guide tube layout
• New guide tube coating
• New riser external sheath

All at the same time
Observations

- Statoil only has small hydrocarbon releases from unbonded flexibles – however...
  - Progression from initial «issue» may take from seconds to years
  - Release magnitude (rate & total volume) ruled by cross section details, early detection and actions
  - Inspections, monitoring & testing vital for early discovery of anomalies
  - Feedback from damage investigations to operations needed for improvements
  - Recover pipe and establish root cause for all incidents
Carcass - exposed and vulnerable

1. **Collapse** (multi-layer pressure sheath)
   - Inter-layer gas pressure (diffusion)
   - Inter-layer gas pressure (hydrates ?)
   - De-compression

2. **Hydrate plug**
   - Axial force – startup
   - Axial force – removal

3. **Pull-out**
   - Multi-layer pressure sheath interaction

4. **Abrasion**
   - Sand production

5. **Fatigue**
   - Focused dynamic bending
     - Tight from fabrication
     - Sand / dirt blocking movements
     - Fully stretched in dynamic areas
Carcass pull-out in multi-layer PVDF risers

- Carcass is torn out/spin out
- Significant axial loads in the carcass layer
- Carcass spin out at carcass fixation
- Only relevant for multi-layer pipes
- Failure only seen on multi layer Coflon risers
- Reduced x-section radial contact
- Axial forces major components
  - Axial strain in PVDF sheaths
    - Fabrication
    - Volume loss
    - Temperature changes
    - Visco-plastic/elastic properties
    - Bulk compcating due to pressure
  - Weight of carcass + inner PVDF layer
  - Inter layer contact/friction
- Spend more than 12000 internal hours + assistance from DNV, 4Subsea and manufacturer

Paper: OMAE2013-10210
Distinct feature of multilayer structures

- Vented gap between sacrificial sheath and pressure barrier
- Mechanical fixation between carcass and sacrificial sheath
- No structural connection between carcass/SS and rest of pipe outside endfittings

End fitting body

- Cannula
- Carcass weld
- Carcass end ring
- Anti-creep sheath
- Pressure sheath
- Sacrificial sheath
- Tensile armor
- Pressure armor
- Carcass
Integrity Management of Coflon Risers

- Perform internal inspection
- Measure pitch and determine load
- Establish Operational Parameters and evaluate loads
  - Assume fully extended carcass
  - Determine weight contribution
  - Determine cool-down contribution
  - Account for plain stress condition
  - Determine carcass capacity by testing/FEM/formula
  - Determine utilization

Decide action (OK/monitoring/replacement)

\[
\sigma = 3K vol(\varepsilon) + 2G \text{ dev}(\varepsilon)
\]

\[
vol(\varepsilon) = (\varepsilon_1 + \varepsilon_2 + \varepsilon_3)/3
\]

\[
\text{dev}(\varepsilon) = \varepsilon - vol(\varepsilon)
\]
Maximize learning from risers in operation

• Replacing 30+ dynamic risers
  − Up to 25 years in operation
  − PVDF & PA11 pressure sheath
  − Intact & damaged old riser

• Detailed investigation of all risers
  − Full length internal video inspection
  − External sheath inspection
  − Annulus environment
  − Carcass & armour corrosion status
  − Polymer ageing (pressure-, anti-wear- and external-sheaths)
Systematic experience collection

• Site measurements
  − Carcass pitch distribution
  − Diameters / ovality
  − Inter-layer pressure ("frozen diffusion")
  − Radioactivity (NORM)

• Site inspections
  − Close visual external
  − Close visual internal
  − Annulus fluid samples
  − Carcass & armour corrosion
  − Strain in polymer layers

• Sharepoint database for collaboration
  − Measurements
  − Pictures / videos
  − Documents
  − Anomalies / damages
  − Statistics / trends across fields and riser types
Annulus environment

Observations

• Little accumulation of condensed water in annulus
• Oil in annulus for some risers (high C’s)
• Gas pockets in high points of riser configuration
• Annulus totally full of liquid only for risers filled with corrosion inhibitor from top
• Real life annulus environment significantly different from models & current best understanding

Possible actions

• More investigations needed
• Improved and independent diffusion / condensation models
• Improve end fitting sealing
• Improve vent systems
External sheath damages

Observations

• Insignificant reduction of tensile wire strength for wires exposed to seawater & CO₂
• “Wet tensile wires” long way from damage have no reduction in fatigue life
• Significant armour strength reduction only in areas with ample oxygen access
• Large corrosion rates sometimes seen in these areas (1 mm/year)
• Different behavior for very similar temperatures

Possible actions

• Larger external sheath damages may need clamps / repair within short period of time
• Early discovery and repair of breaches (>1x1”) in splash zone very important
• Outer sheath aging models needs improvement
• Temperature monitoring for critical risers
Successful integrity management

• Inspection
  - Topside general / close visual
  - Visual inside guide tubes
  - Internal video / measurements
  - Subsea ROV general / close visual
  - Marine growth
  - CP system visual / CP probe

• Testing
  - Riser pressure tests
  - Annulus free volume test
  - Annulus vent gas
  - Bore fluid / water phase pH / acids

• Monitoring
  - Annulus vent rate / pressures
  - Temperature
  - Pressure
  - Documentation of offline tests
  - Polymer coupon / ageing analysis

Polymer coupon cylinder
Advances in flexibles integrity management

In Service Inspection and Monitoring

• Long distance (>1000m) internal video inspection
• Detailed carcass pitch & diameter measurements in risers installed offshore
• Ultrasonic carcass movement detector (top end)
• Acoustic carcass failure detector (top end)
• Riser motion monitor lowered into temporary closed risers

After Service Inspection

• Full length internal video inspection of risers on reels
Long term Integrity Management

- Continue to reduce failure probability for flexibles by feeding experiences into design
- Platforms and FPSOs often designed for 20-25 years
  - Continuous Maintenance & Modification
- Demand for life extensions to 40 years+
  - Updated design basis
  - Improved inspection technology
- Time is key factor in most degradation processes
- Reliable systems for data acquisition and condition monitoring
- Better systems for data feed back loop
- Efficient collaboration and experience transfer between all parties are vital to safety
- Network meetings internal/external
Continued development flexible pipe

- Future safety and regularity will require strong cooperation, knowledge sharing and successful technology development (PSA)
- Improvements needed within
  - Carcass design/strength
  - Hydrate detection technology
  - External sheath robustness
  - Polymer ageing prediction models
  - Condition monitoring of static pipes
Experience with operation of flexible pipe in harsh environment

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