Innovative inspection, monitoring, and analysis techniques to provide integrity assurance

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Ian MacLeod  Wood  Engineering Manager
Toby Rider  CNRI  Technical Integrity Team Leader
Overview

- Background – Example Riser Configuration
- Riser Assurance Activities
- Advanced FE analysis
  - Confirm ongoing risk management
- Monitoring / inspection program
  - Various techniques
- Pipe inspection / dissection
Background – Example Riser Configuration

Riser Structure (Ref. API RP 17B)

- Outer Sheath
- Outer Tensile Armour
- Inner Tensile Armour
- Backup Pressure Armour (non-interlocked)
- Pressure Armour (interlocked)
- Internal Pressure Sheath
- Carcass
- Anti-wear Layers

Combined Bend Stiffener & Anchor

- Bend Stiffener Anchor (steel)
- Riser Bend Stiffener (PU)
Riser Assurance Activities

Objective: validate armour wire integrity on all risers

Pressure testing tends to be considered:
- Flexible pipe structure redundancy in armour wires
  - ~150 tensile armour wires with code utilisation 0.67
- Early breaks / initiation may not be identified using this method

BHGE MAPS® inspection
- Can identify any unloaded (broken) wire within scan range
Assurance Methods - Inspection

MAPS inspection

• Seeks to identify % armour wire breakage on a flexible riser

Where issues exist, options are:

• Repeat MAPS inspection to verify data

• Consider access restrictions

• Physical inspection
  – Look for physical displacement
  – Hang-off deck, rope access, drone deployment

• Monitoring System

• Verify potential failure mechanisms / risks
Drone / UAV inspection

Easy to Perform on **Opportunistic Basis**

- Best quality / resolution versus previous approaches

Previous Approaches Used:

- Rope Access Inspection
  - Circumstances may mean additional risk (and restrictive mitigations)
  - Personnel / time / cost implications

- Inspection from deck above
  - Poor quality survey due to sub-optimal view
Detection of potential wire break events
  – Acoustic and accelerometer based system (Pulse)
Need to consider baselining any new monitoring system
  – Establishing of thresholds and known/baseline
If monitoring system identifies wire break event
  – Verification by MAPS inspection and enact response
No confirmed breaks to date
Advanced FE Analysis Methods

1. Global Analysis
   - Curvature/Tension at Stiffener Base

2. Cyclic Bending Stress Analysis
   - Stress (MPa)
   - Pipe Curvature (1/m)

3. Bend Stiffener FE Model
   - Contact Loads

4. Cross Section FE Model

5. Combine Stresses
   - Tensile Wire Stress Due to Cyclic Bending
   - Wire Stress Due to Contact

6. Fatigue Life

Contact Analysis
Local Stress Analysis
Advanced FE Analysis – Fatigue Assessment

Example of Potential Failure Hotspot

Stiffener Anchor Middle (Contact Point 1)

PU-steel Interface (Contact Point 2a)

Hang-Off Angle > Built-in Angle

Local inward bending due to contact

Deformation exaggerated by 5x
Advanced FE analysis – Individual Wire Breaks

Environmental Conditions
- Internal Fluid
- Vessel Offset

Global Analysis

Effective Tension at Hang-off

Internal Pressure

Wire Stress for Various Riser Operating Scenarios

True-Wall Tension

Postprocessing

Number of Broken Wires

Local Analysis

Number of Wires Broken
Advanced FE Analysis Output Example

- True-wall tension e.g. 1-yr env. and bore contents
- Riser Pressure 115 bar
- Utilisation 0.64 (Design Code Limit 0.67)
- 4 broken wires

- 2: Environment
- 3: Utilisation
- 4: Number of Broken Wires
Finite Element Analysis Summary

• When contact stresses are excluded from model:
  – Fatigue life effectively infinite
  – Aligned with original design approach / results
• When local interface contact stresses included
  – Calculated life can be reduced by orders of magnitude
• In a non-operating production riser application
  – For example stabilised crude versus gas lifted production
    • Hang-off loads will increase
  – Further reduction in calculated life by factor of ~4
• With limited wire breaks, risk may be managed
Pipe inspection / dissection

• Sample flexible riser section obtained

• Further development activities:
  – Blind testing
    • Various inspection techniques applied by vendor with zero knowledge of wire condition in sample
  – Dissection, further validate;
    • mechanism / in-service inspection / blind testing
Conclusions

• Consider operating conditions in fatigue design
• Ensure all local interfaces are assessed in design
• Ensure assurance measures mitigate specific threats
  – i.e. not generic / “off the shelf”
• Where risks justify, investigate and deploy inspection / monitoring techniques
  – early identification of degradation prior to a failure
  – consider alternative / novel inspection
  – limited previous drone inspection of flexible risers
Thank you.

Questions?