

Corrosion and corrosion fatigue learnings Anders Kloven



Incident

- A 5,6" WAG riser connected to the installation experienced an incident and the dynamic section was disconnected from the platform 4th of March. The riser was used as a water injector but was not in operation at time of the incident. The riser was pressurized to 200 bar.
- The dynamic section was found on the seabed with ROV
- Other risers inspected at the installation found no signs of damage. Annulus test confirmed no outer sheath damages
- 80 meter of riser section and end fitting were recovered and sent for dissection
- Dissection show that fatigue and corrosion are active mechanisms in the degradation of tensile armor that caused the tear-off.
- The corrosive environment in the end fitting and under the bend stiffener is probably caused by the open annulus vent system used on the risers on the installation. The open annulus vent system with no back-flow protection allows atmosphere oxygen ingress in an annulus low pressure scenario
- Unfavorable design: The riser have a short bending stiffener mounted directly on the end fitting





Dissection – damaged tensile wires

- Outer tensile layer
 - 30% fatigue fractures
 - Fatigue fractures mainly in one sector
 - Fractures, ductile and fatigue, mostly aligned with gaps in the anti-wear tape
- Inner tensile layer
 - 53% fatigue fractures
 - Fatigue fractures mainly in one sector
 - Fractures, ductile and fatigue, mostly aligned with gaps in the anti-wear tape









Dissection – corrosion and corrosion products

- Corrosion in tape gaps
- Corrosion products indicates present of water, CO2 and O2
- Average corrosion rate
 - 0.013 mm/year (end-fitting area)
 - 0.004 mm/year (5 m)



Corrosion and corrosion fatigue

Continuing internal activity

Corrosion effect on fatigue:

- Hydrogen loading of material
- Reduction of cross-sectional area
- Change of surface rugosity (Mechanical effect)

(Chemical effect)

(Mechanical effect)

Focus on effect on surface:

- General/Localized corrosion
- Notches/Rugosity





Effect of surface roughness on fatigue

- Testing of corroded wire in air
- Testing of artificial notches in air (little effect)

Testing of corroded SoS wire in air:

- Reference wire (not corroded)
- CO2 corrosion, low corrosion loss (CL)
- Seawater corrosion, medium CL
- CO2 + sea water corrosion, medium/high CL
- Artificial CO2 corrosion, low CL
- What is the effect of corrosion loss on fatigue capacity?





Fatigue curves

For each S-N point:

- Cross section at failure
- Average-max cross section
- Stress recorded for minimum area
- Imposed slope







Local cross section loss

Loss factor:

- Corrosion loss at failure compared to average corrosion loss of sample
- $f_{CL} = CL frac/CL nom$

• Amplification of CL due to localized corrosion early in corrosion process?

X

x/R

CLbreak/CLnom



Localized corrosion loss factor

Nominal corrosion loss [mm]



SN-curve level at 10⁶ cycles

Notch factor at 10⁶ cycles:

• Normalized for reference SN-curve



Normalized fatigue resistance at one mill cycles

S/Sref [-]

• Largest decline at small corrosion losses due to localized attacks?



Slope of SN-curve





Nominal corrosion loss [mm]



Applied to standard corrosion rate (mean curve)

range [MPa]

Nominal Stress

- CR = 0.01 mm/year
- Mean stress correction not included
- Chemical effect not included



Number of cycles N [-]

SN-curves for nominal stresses (R=0.1) (5x15 mm wire) CR=0.010 mm/year



Testing on failed riser

- Testing on failed riser at 5 m point
- Model conservative compared to test (expected)
- Exposure time to corrosion (18 years) is a large uncertainty
 - Presence of water
 - Presence of CO₂
 - Presence of O₂



Number of cycles N [-]

Mean SN-curves for nominal stresses (R=0.1) (4x12 mm wire) CR=0.004 mm/year

Nominal Stress range [MPa]



Learning

- Ingress of moist air due to open annulus vent can cause excessive corrosion
- Corrosion a combination of unfavorable combination of C02, O2 and water
- 'Short" bending stiffener mounted directly on the end fitting ->high dynamic loading in the end-fitting area

- Stress calculation with correct cross sectional area of critical section is important
- Rugosity from corrosion important
- Recalibration of fatigue model pending
- Learning to be included in TR3051

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