Corrosion and corrosion fatigue learnings

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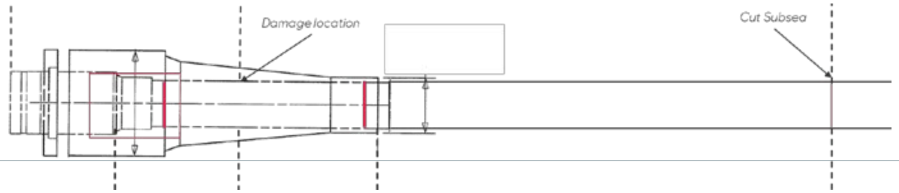
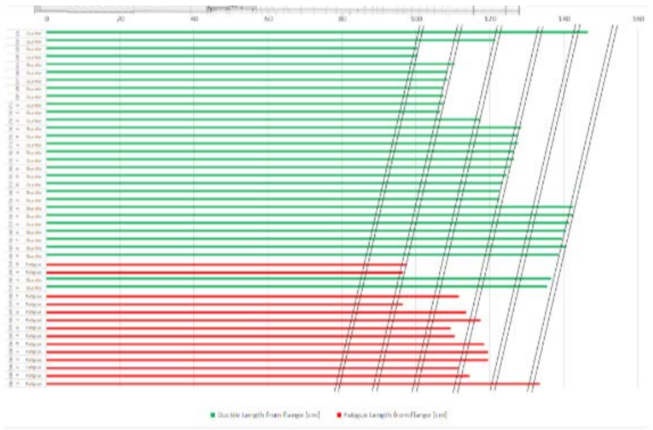
Incident

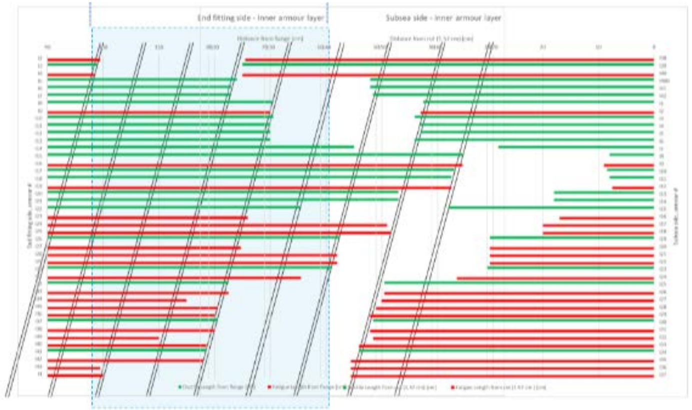
- A 5,6" WAG riser connected to the installation experienced an incident and the dynamic section was disconnected from the platform 4th of March. The riser was used as a water injector but was not in operation at time of the incident. The riser was pressurized to 200 bar.
- The dynamic section was found 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, CO_2 and O_2
- Average corrosion rate
  - 0.013 mm/year (end-fitting area)
  - 0.004 mm/year (5 m)

Corrosion and corrosion fatigue

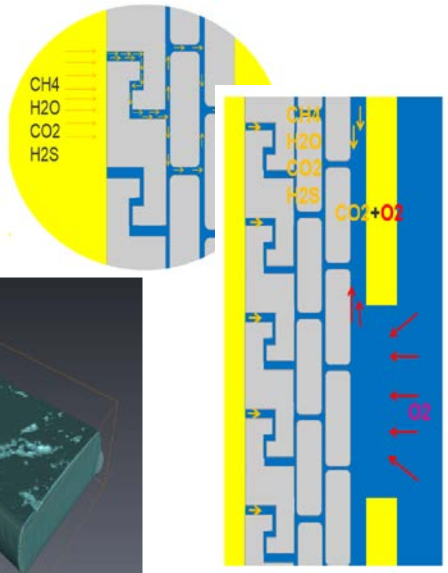
Continuing internal activity

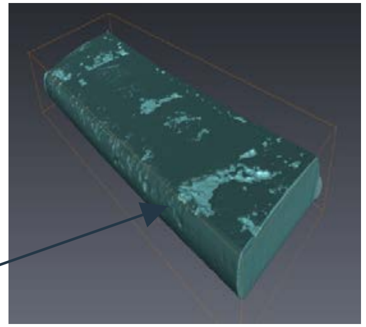
Corrosion effect on fatigue:

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

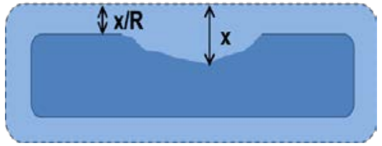
Focus on effect on surface:

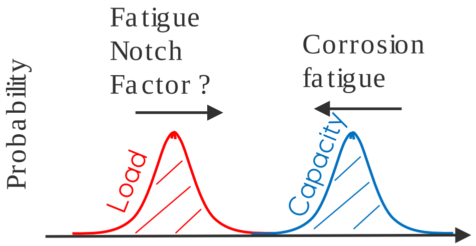
- General/Localized corrosion
- Notches/Rugosity





Localized corrosion





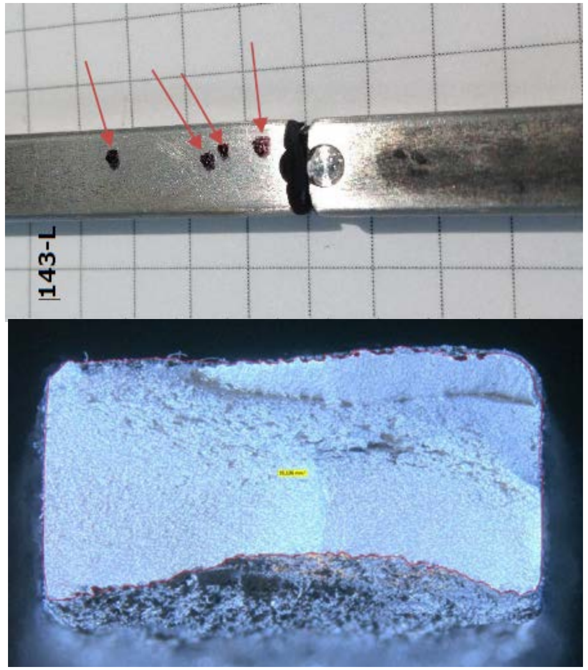
Effect of surface roughness on fatigue

- 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)
- CO_2 corrosion, low corrosion loss (CL)
- Seawater corrosion, medium CL
- CO_2 + seawater corrosion, medium/high CL
- Artificial CO_2 corrosion, low CL

- What is the effect of corrosion loss on fatigue capacity?



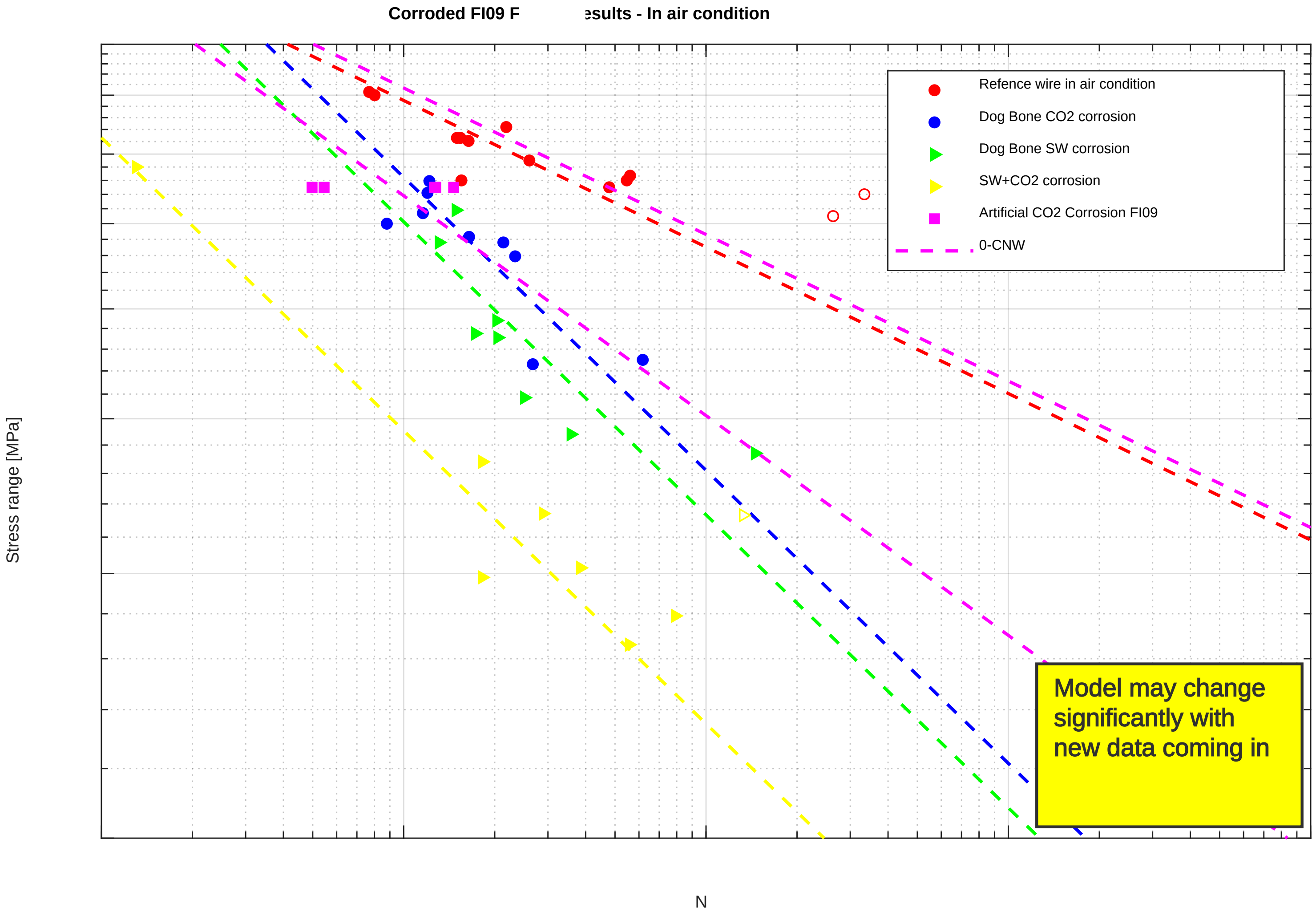
Open

Fatigue curves

For each S-N point:

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

- Imposed slope

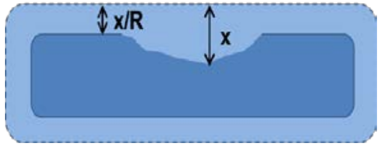


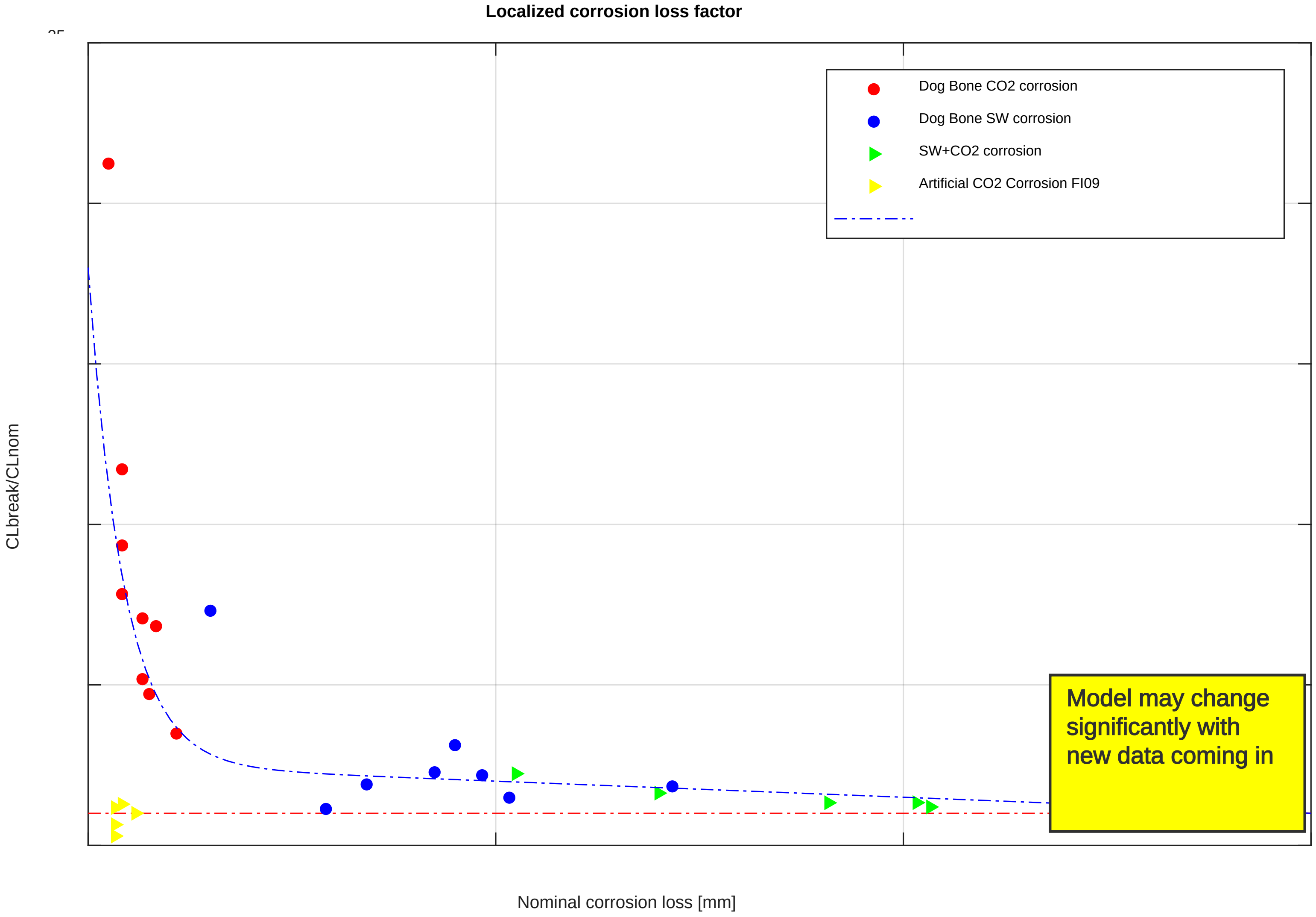
Local cross section loss

Loss factor:

- Corrosion loss at failure compared to average corrosion loss of sample
- f_{CL} = CLfrac/CLnom

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



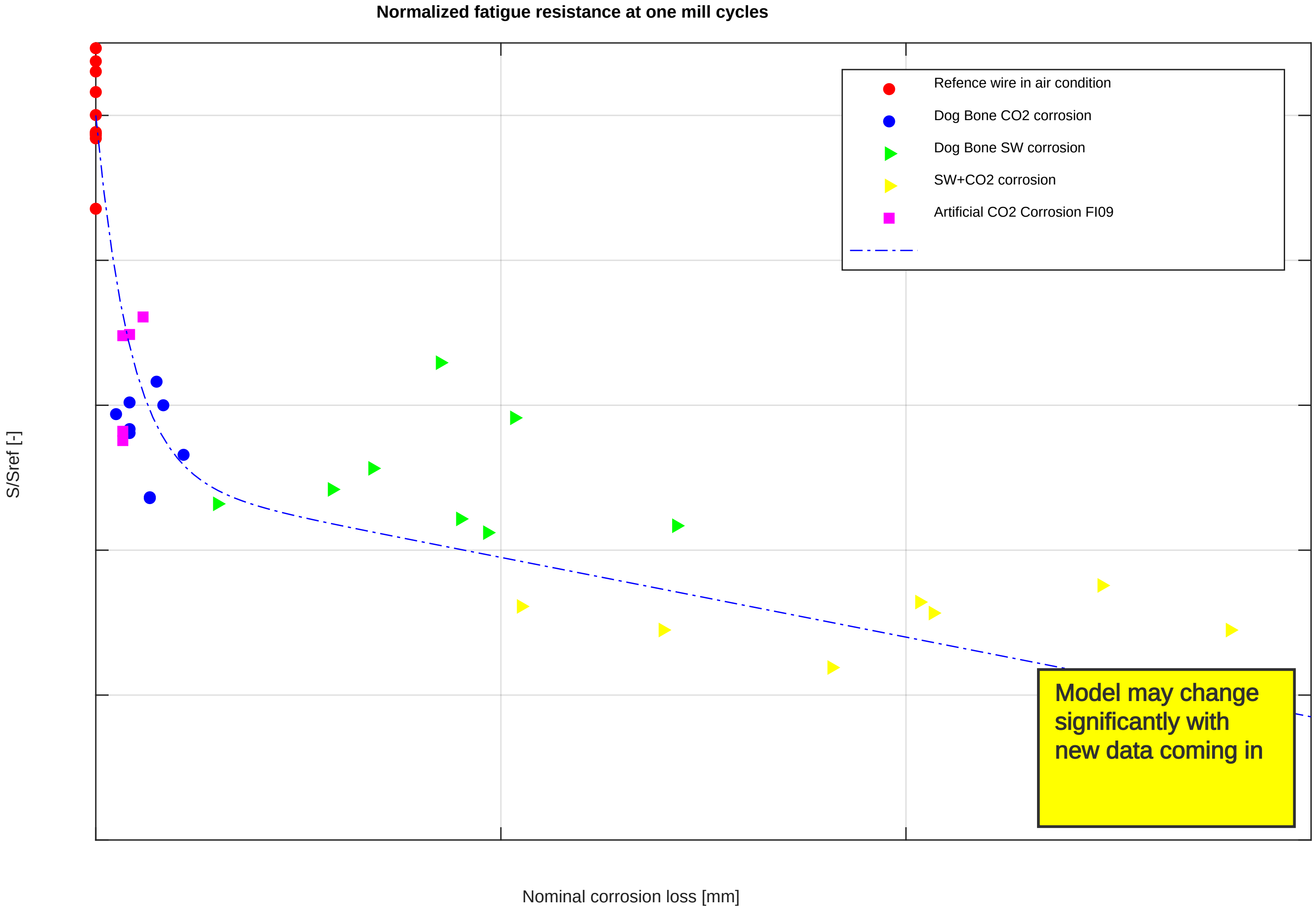


Open

SN-curve level at 10^6 cycles

Notch factor at 10^6 cycles:

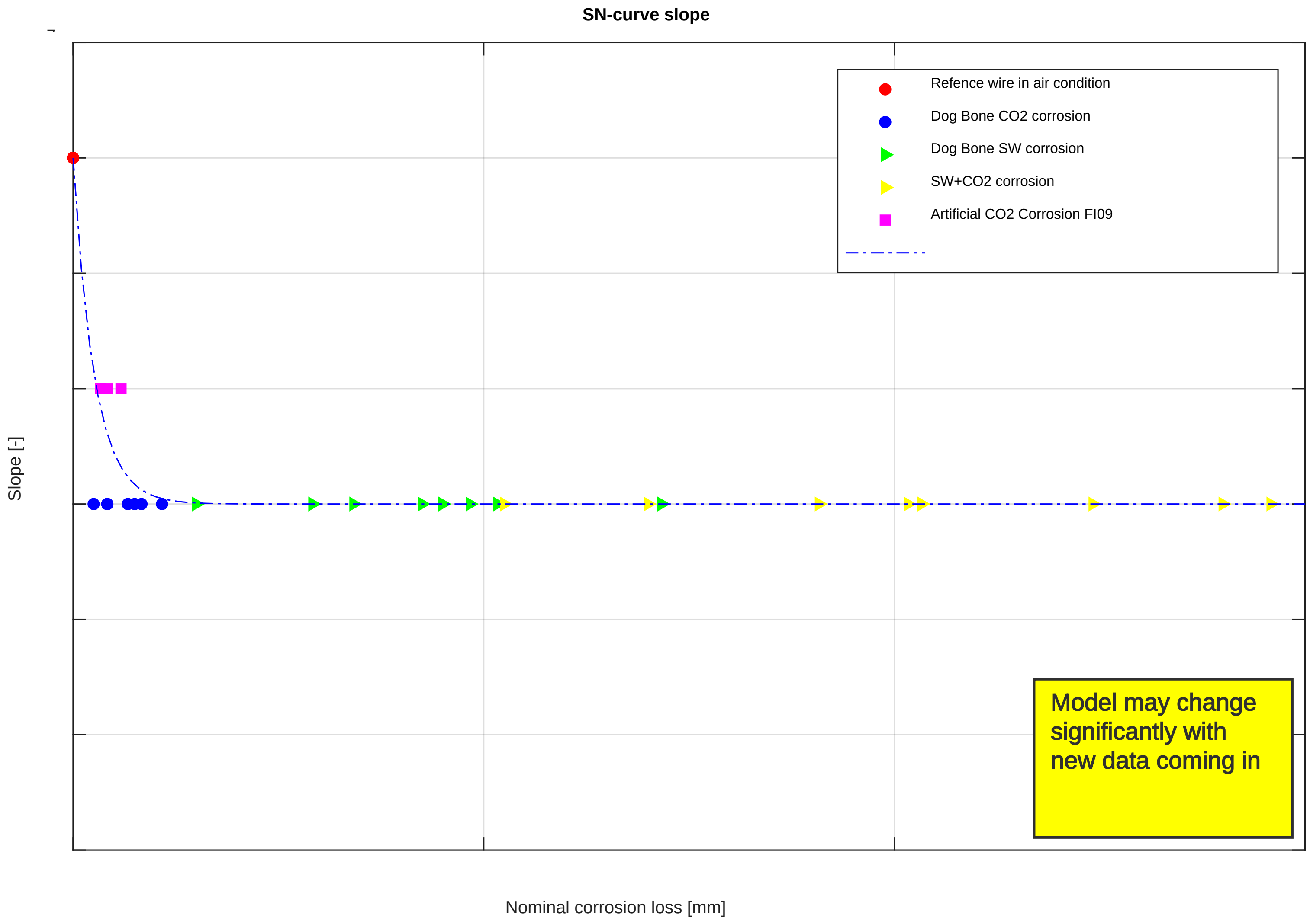
- Normalized for reference SN-curve



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

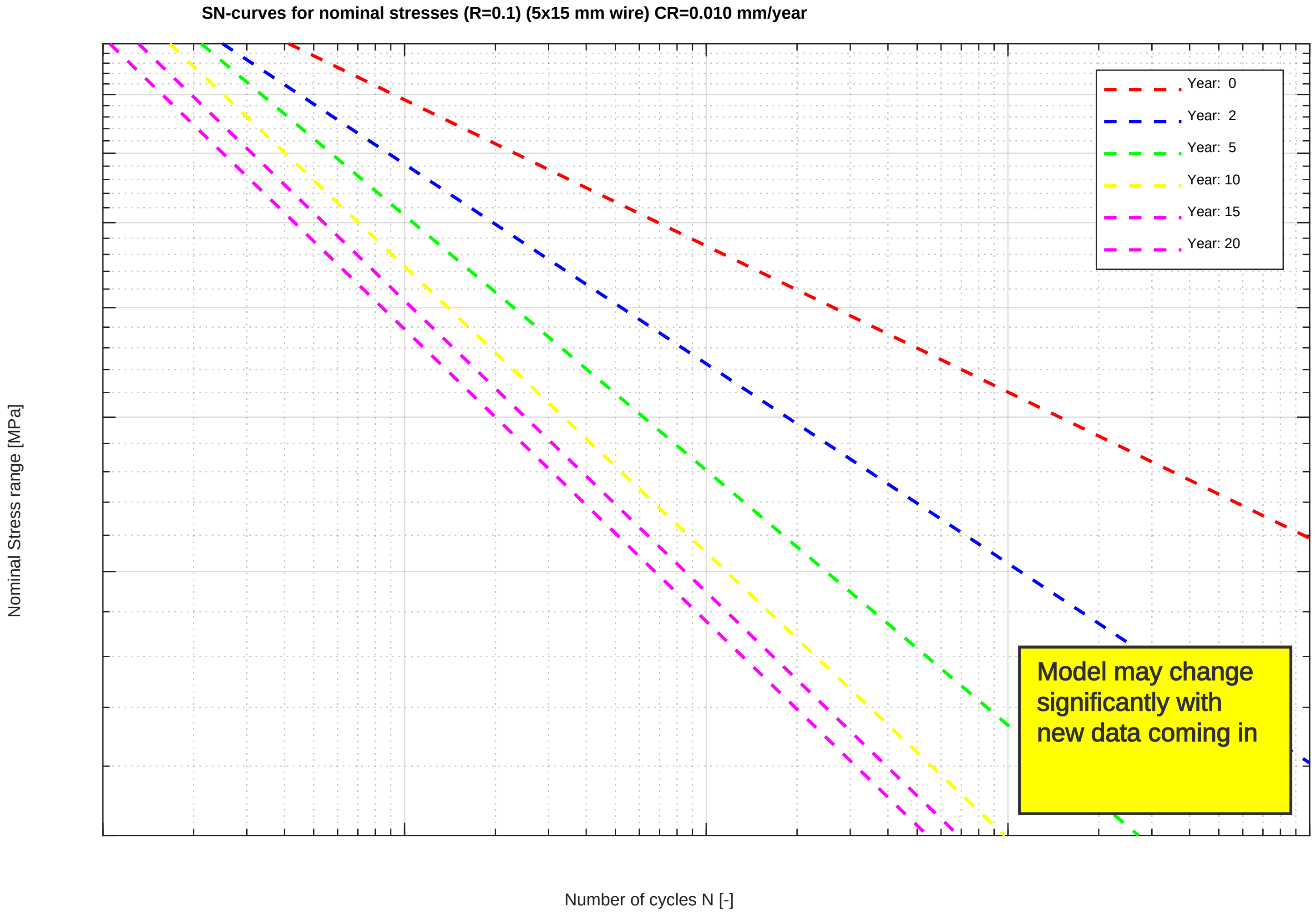
Slope of SN-curve

- Corroded wire seems to follow a slope of 3



Applied to standard corrosion rate (mean curve)

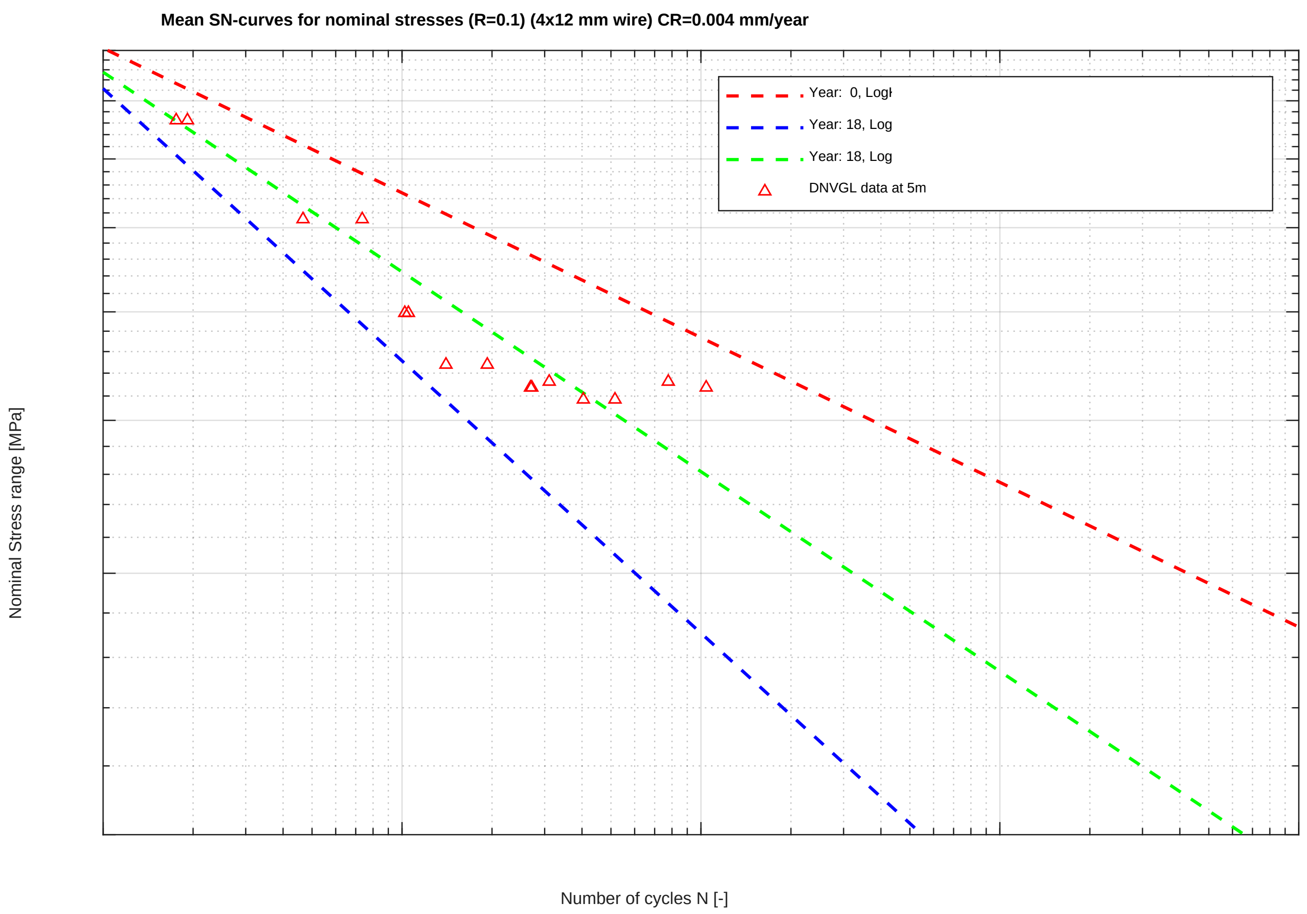
- CR=0.01mm/year
- Mean stress correction not included
- Chemical effect not included



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 CO_2
    - Presence of O_2



Open

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

Corrosion and corrosion fatigue learnings

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