FAILURE ANALYSIS IN THE OIL & GAS INDUSTRY: THE IMPORTANCE OF EXPERIMENTAL TESTING IN FATIGUE DIAGNOSIS.

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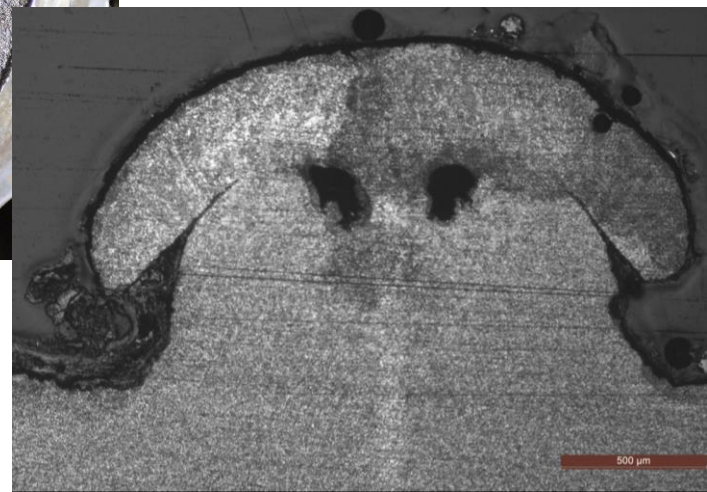
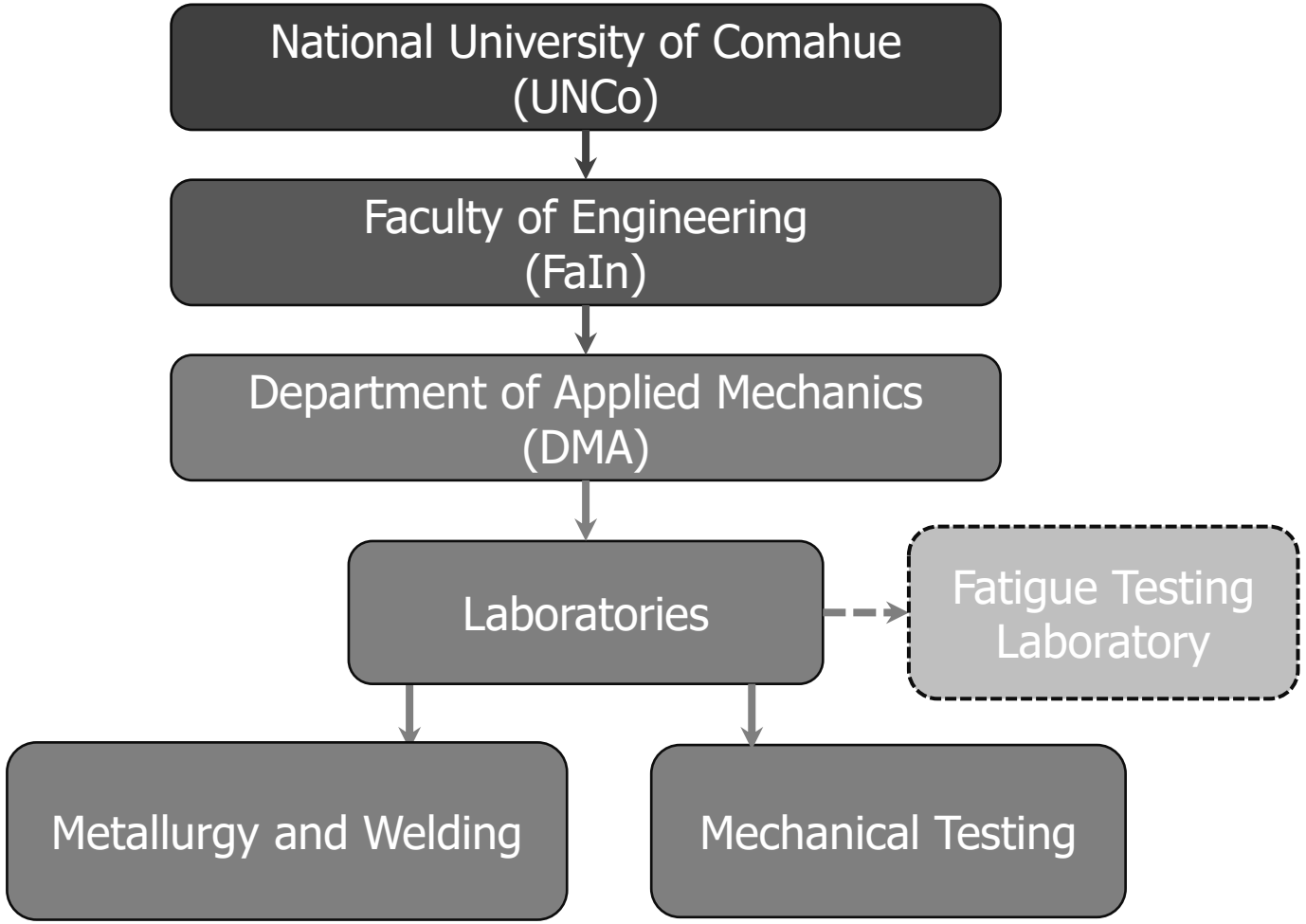
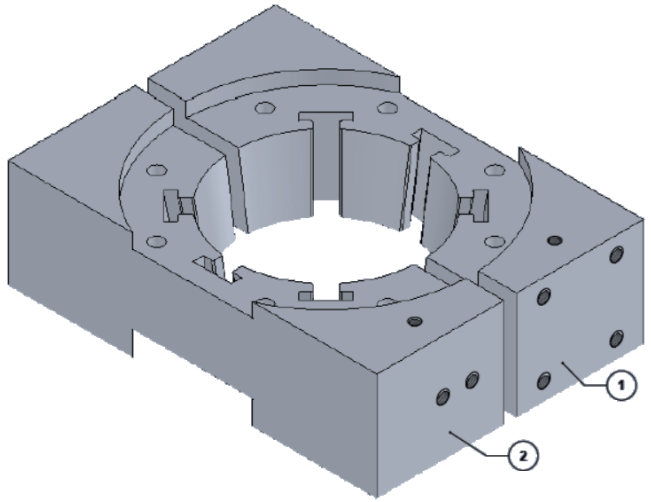
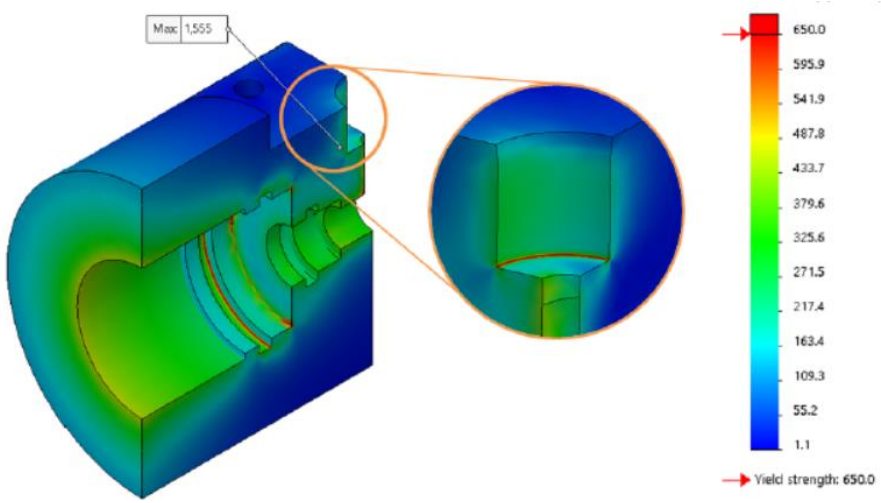


Who we are?

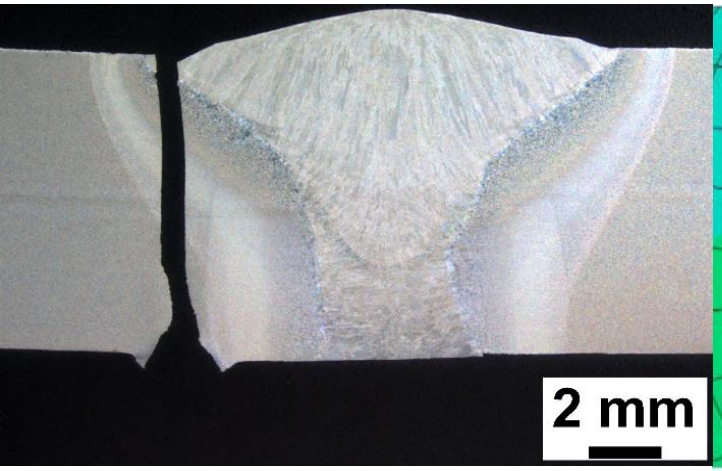

National University of Comahue (UNCo)
Faculty of Engineering (FaIn)
Department of Applied Mechanics (DMA)
Laboratories
Fatigue Testing Laboratory
Metallurgy and Welding
Mechanical Testing

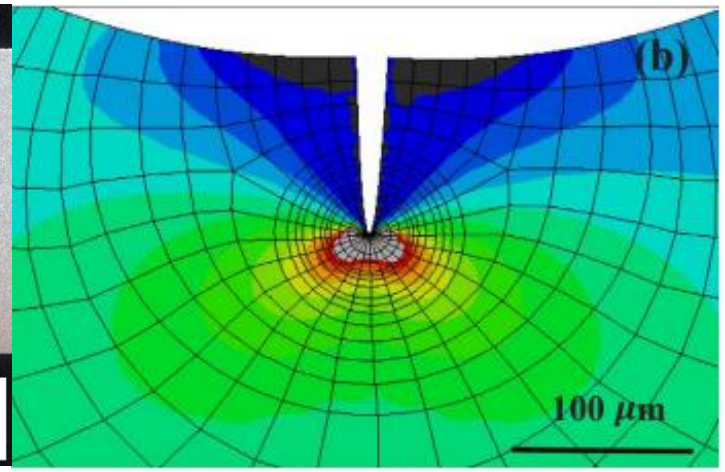
What do we do?


1
2

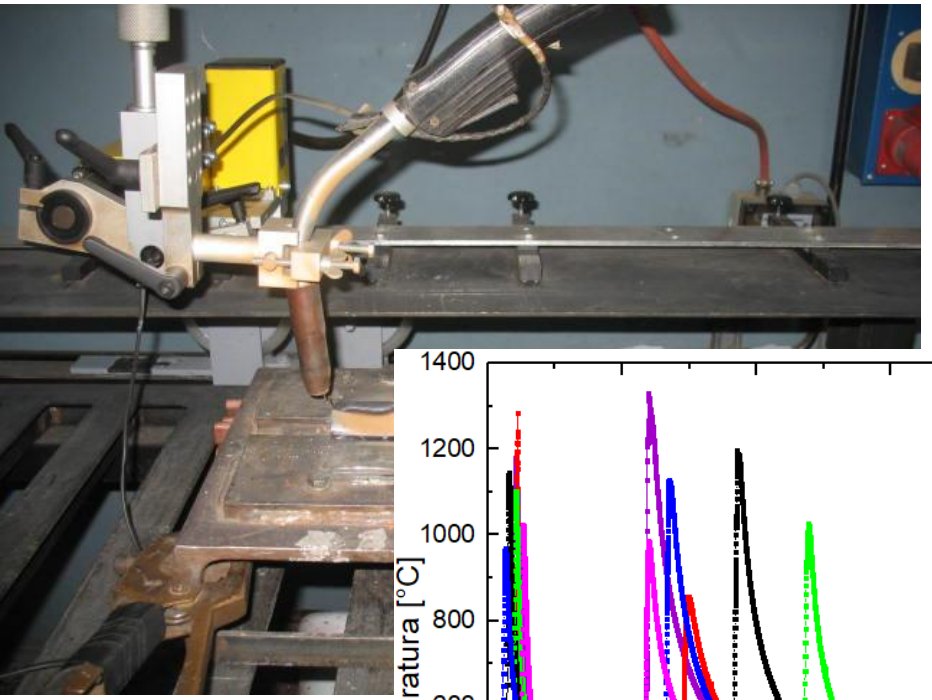

Max: 1,555

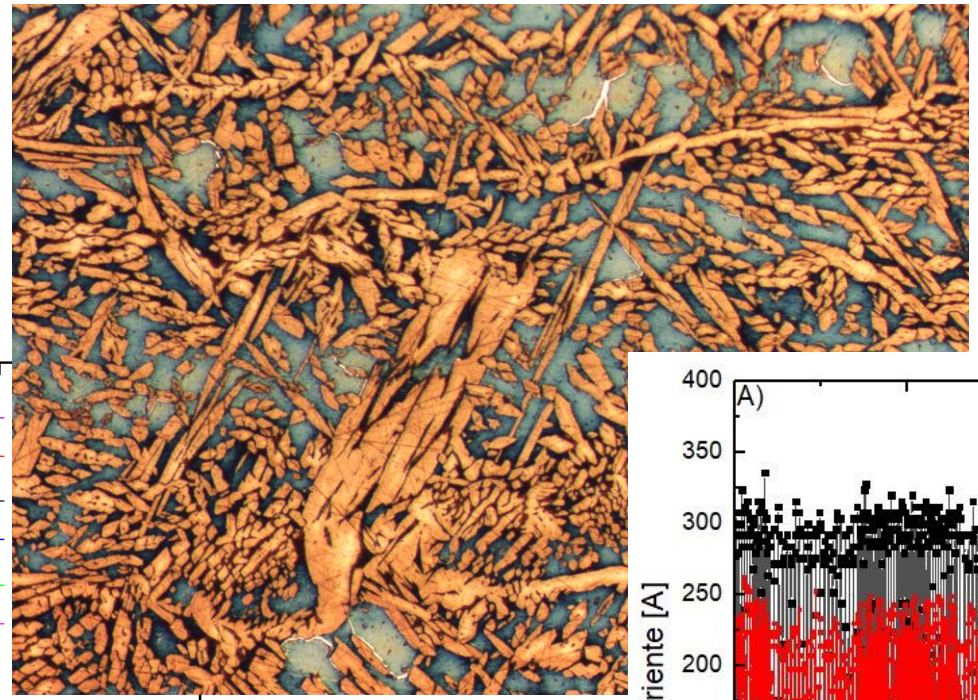
650.0
595.9
541.9
487.8
433.7
379.6
325.6
271.5
217.4
163.4
109.3
55.2
1.1
Yield strength: 650.0

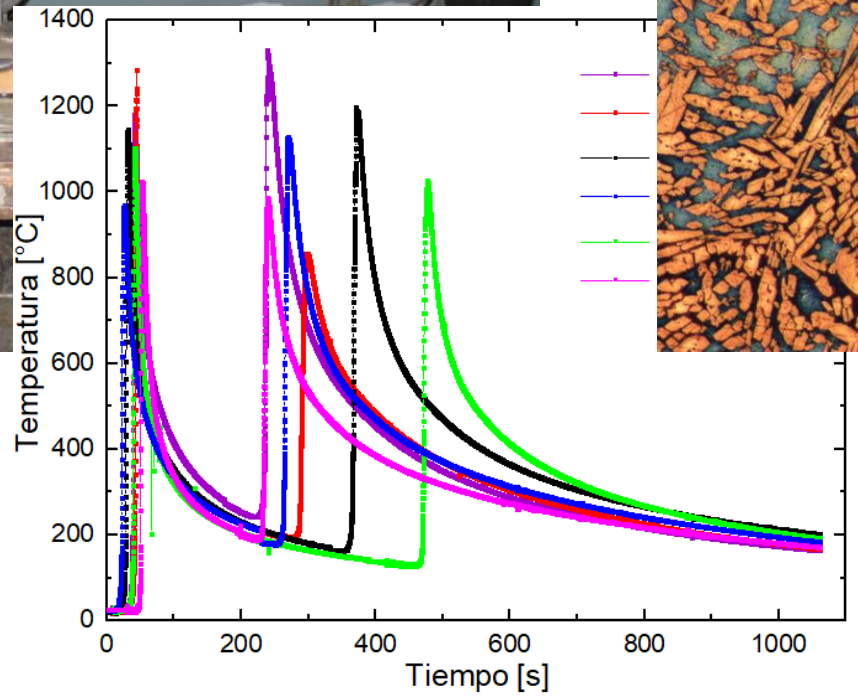

2 mm

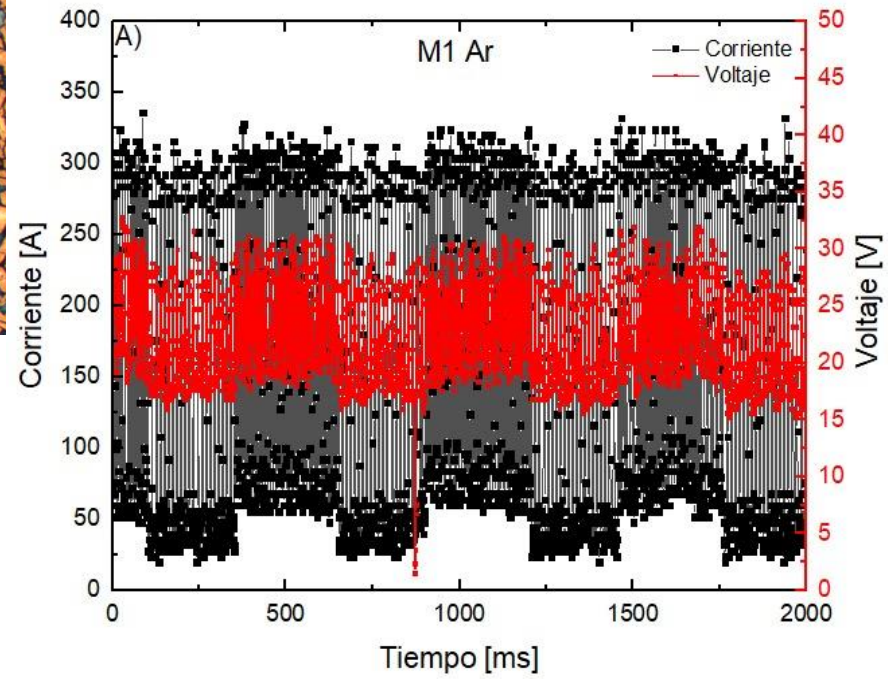

(b)
100 μm

Laboratory of Metallurgy and Welding







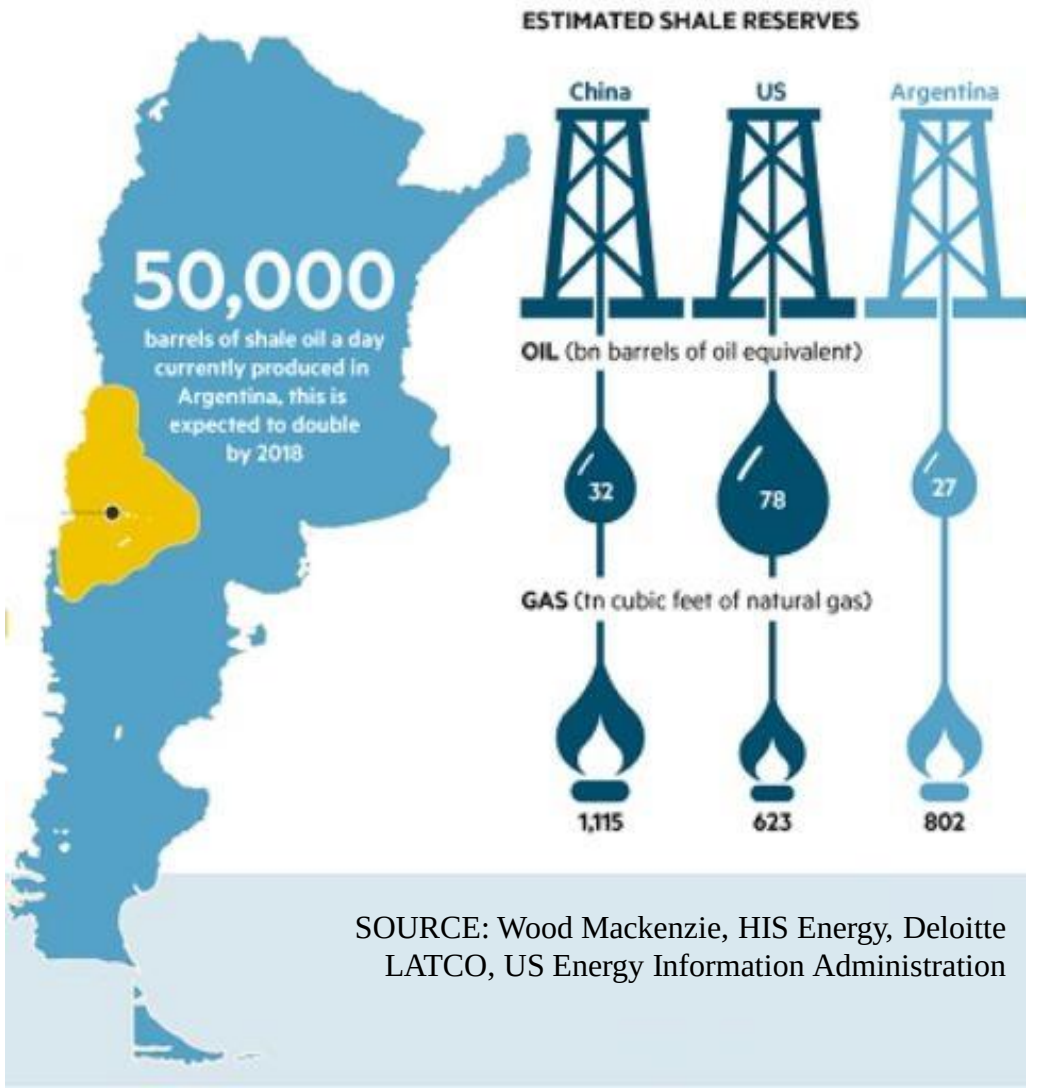


Laboratory of Metallurgy and Welding

Laboratory of Mechanical Testing

Fatigue Testing Laboratory

The O&G Industry

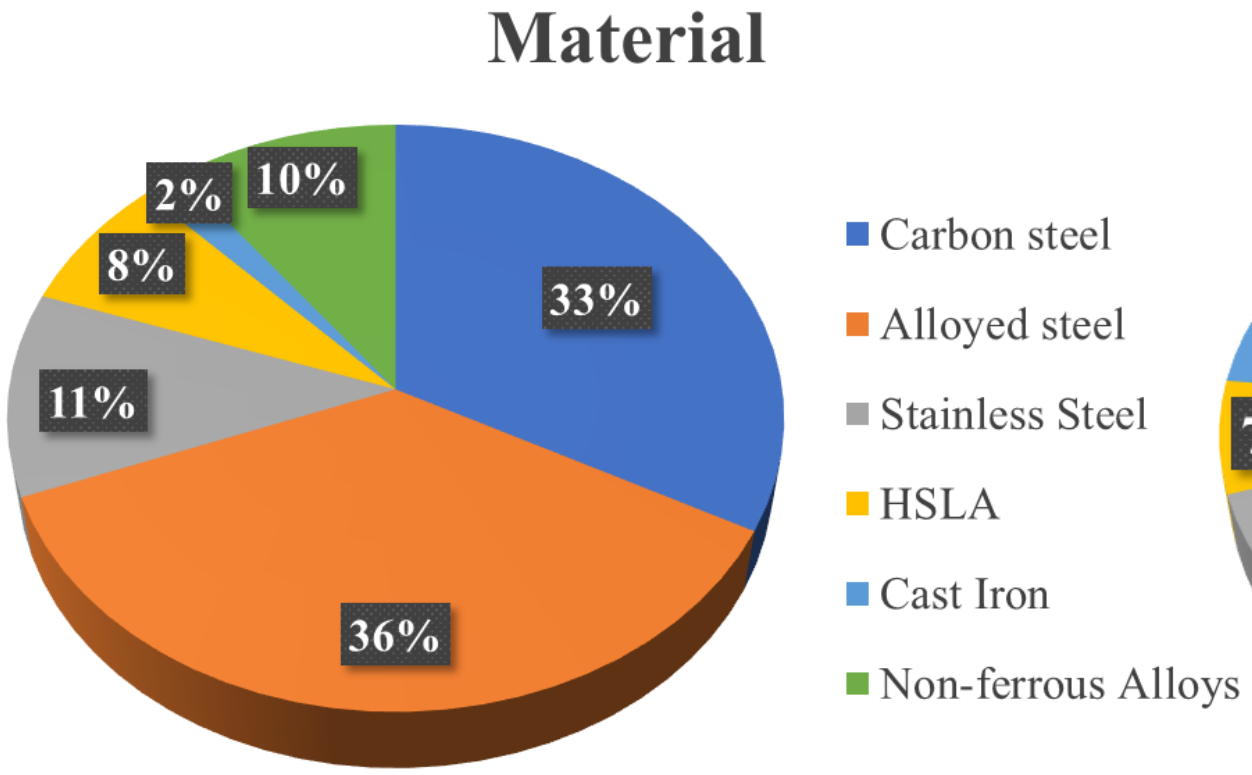


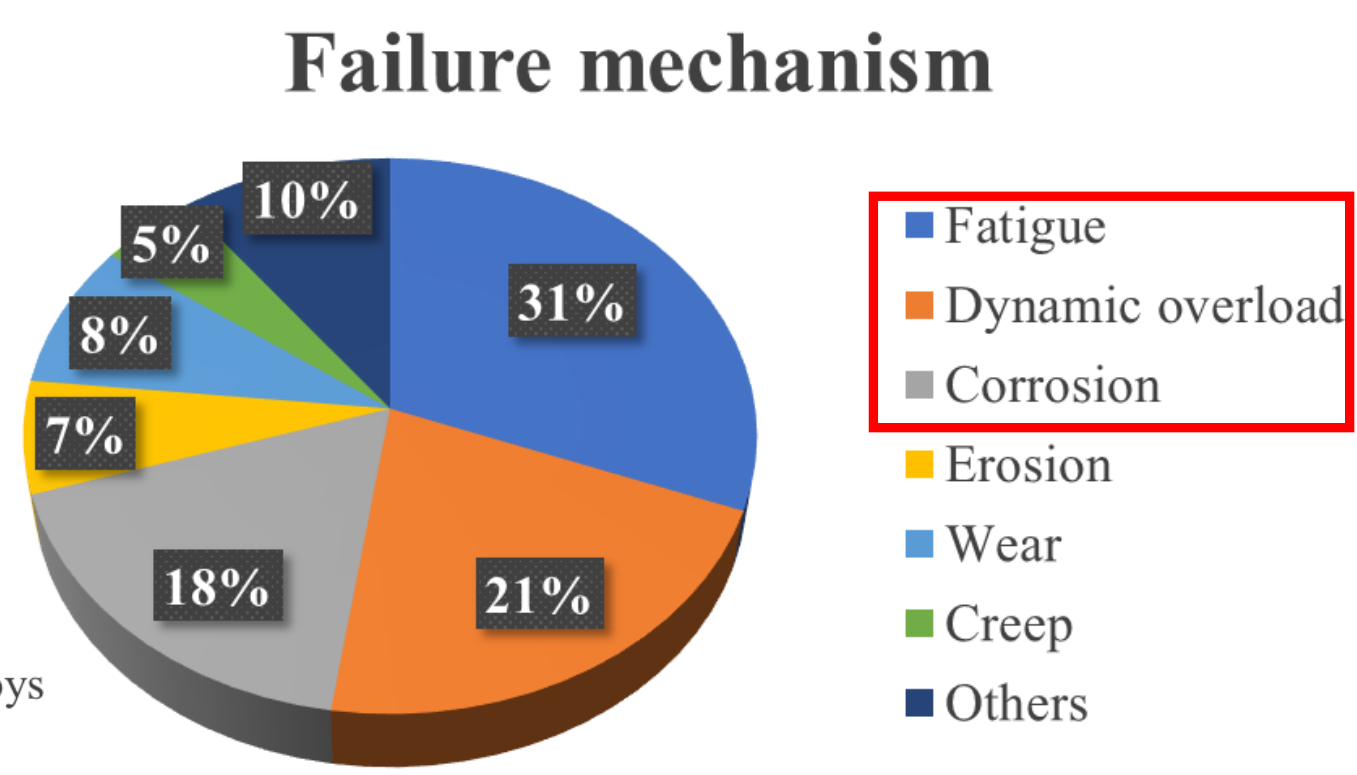
SOURCE: Wood Mackenzie, HIS Energy, Deloitte LATCO, US Energy Information Administration

The O&G Industry

The O&G Industry

Failure analysis





Fatigue failures: low cycle fatigue

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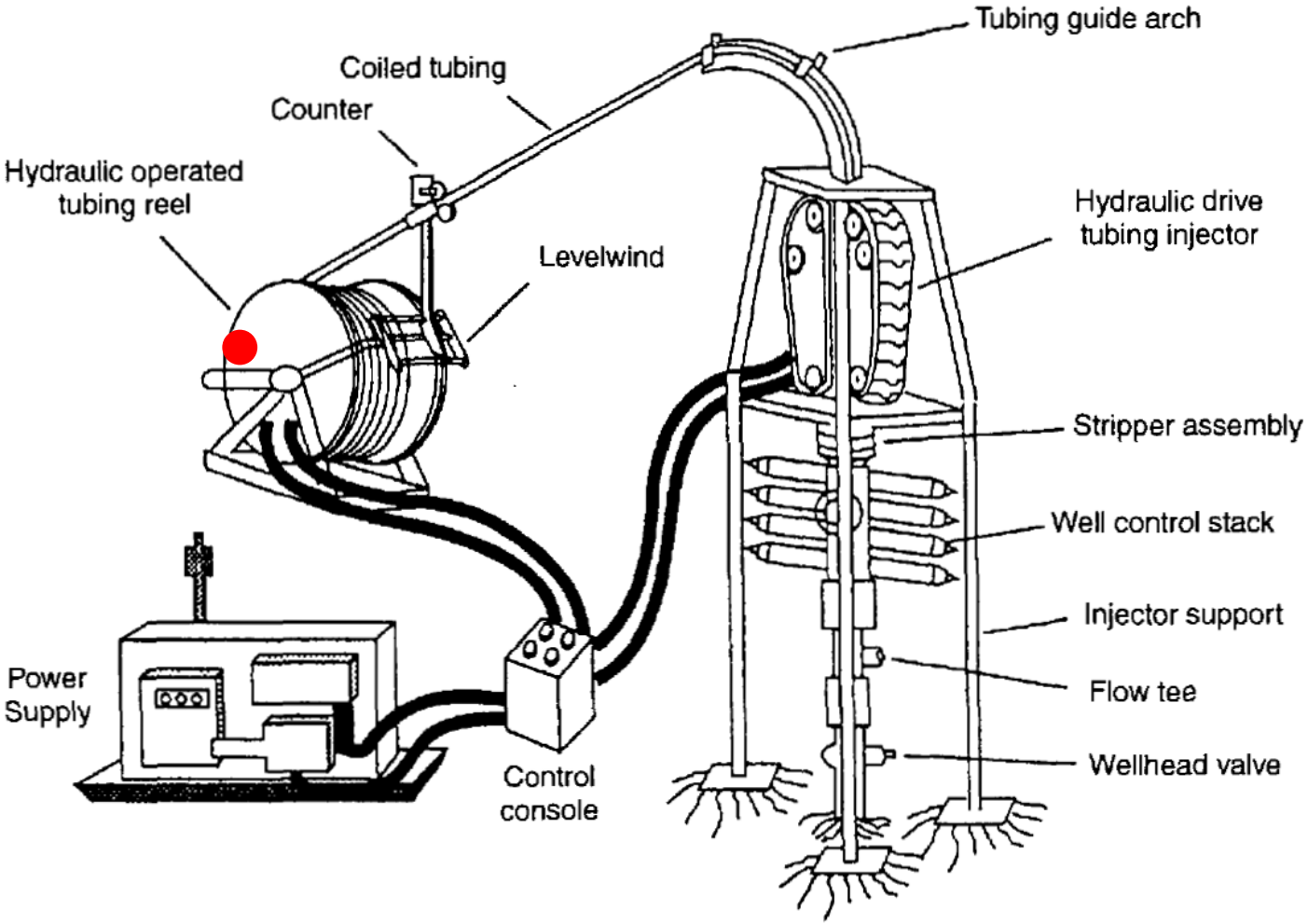
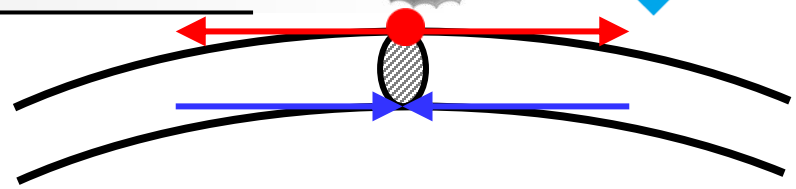
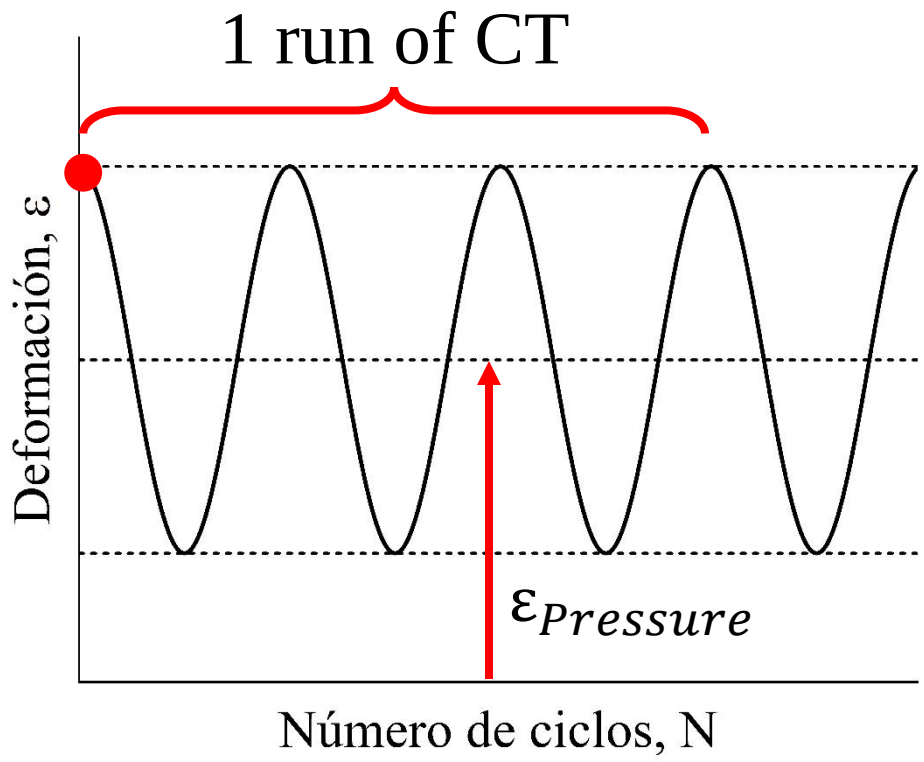


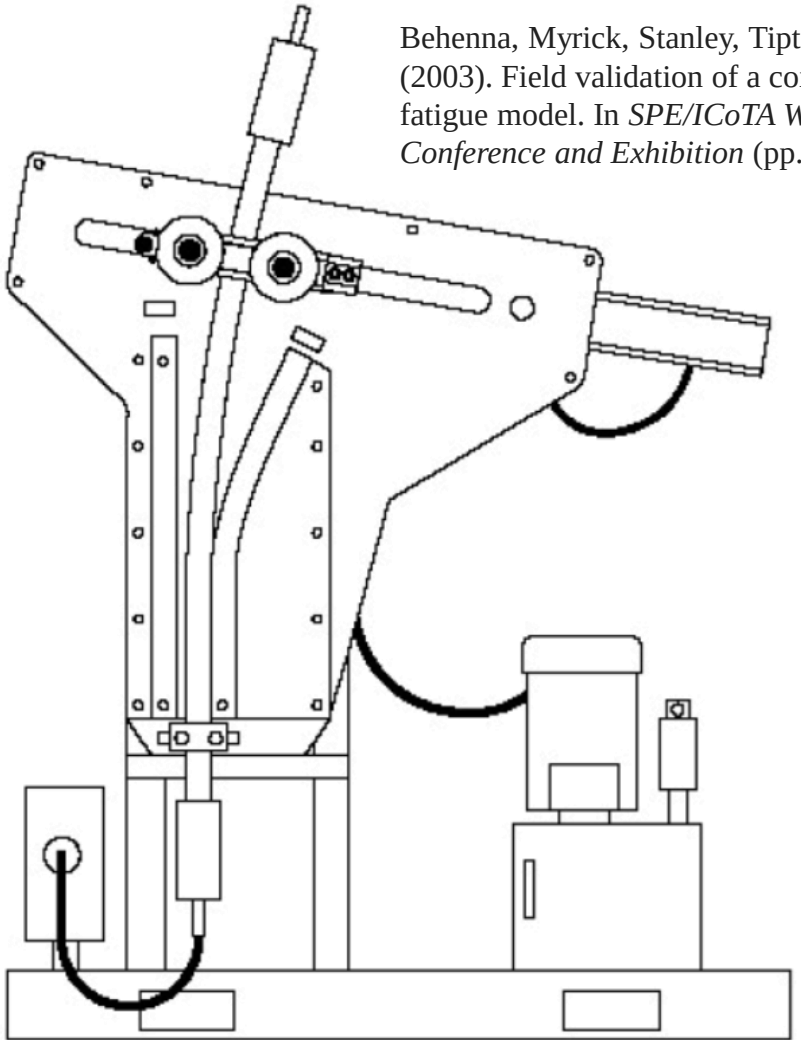


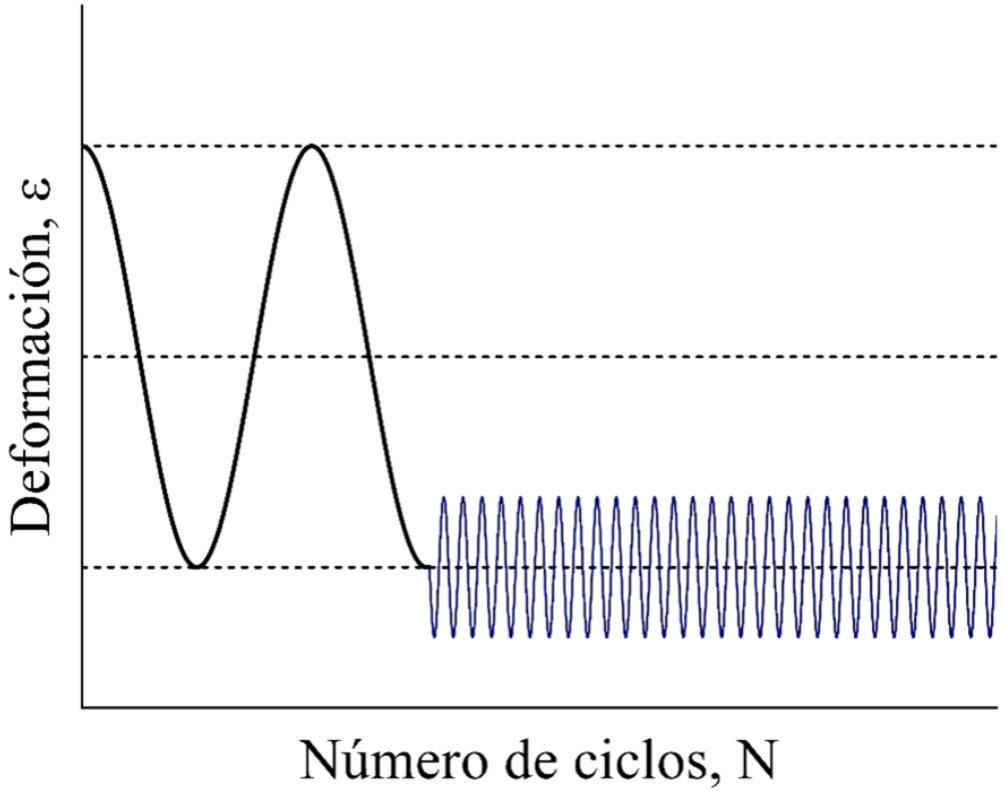
$$N_1 = 2\left(\frac{\sigma_r}{\sigma_m}\right)^2 + 2\left(\frac{\sigma_g}{\sigma_m}\right)^2$$



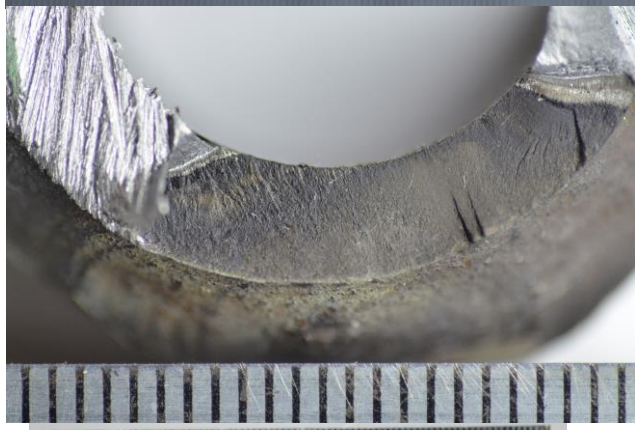
Experimental testing

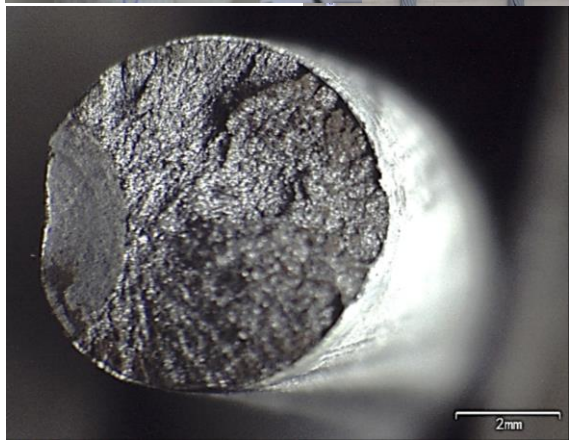
Behenna, Myrick, Stanley, Tipton, Hammond, (2003). Field validation of a coiled tubing fatigue model. In *SPE/ICoTA Well Intervention Conference and Exhibition* (pp. SPE-81726).



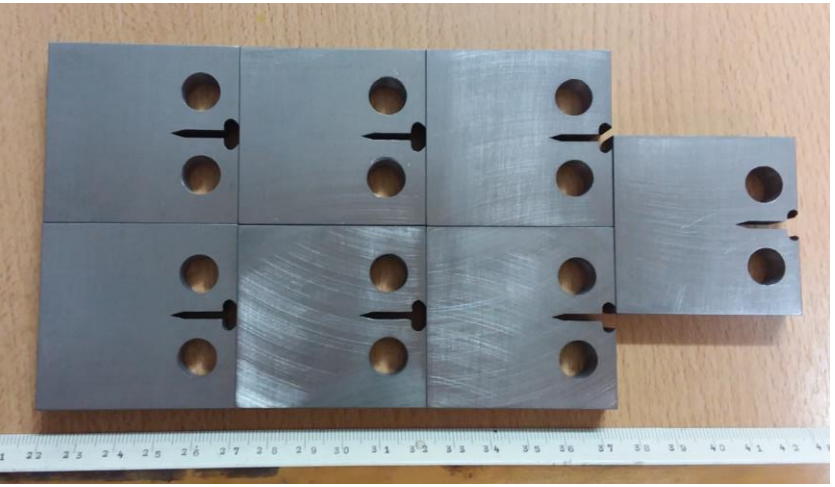


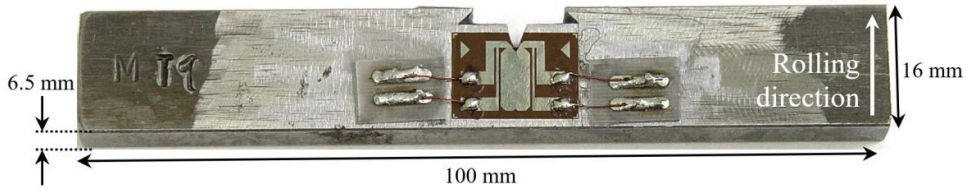
Fatigue failures: high cycle fatigue

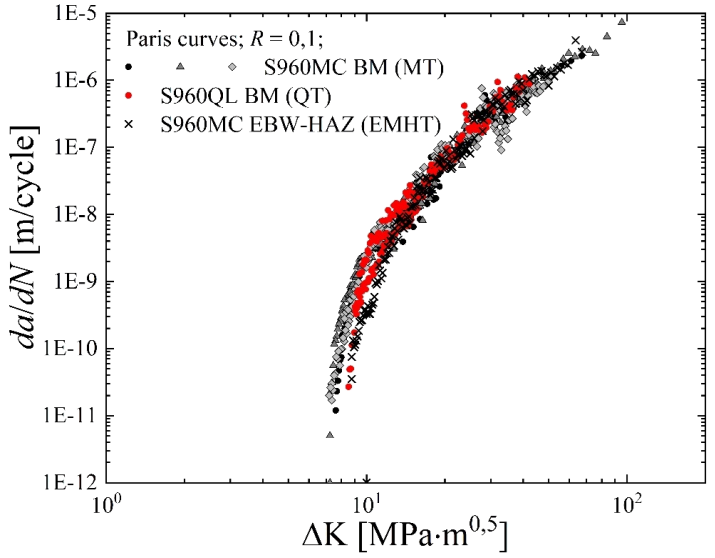


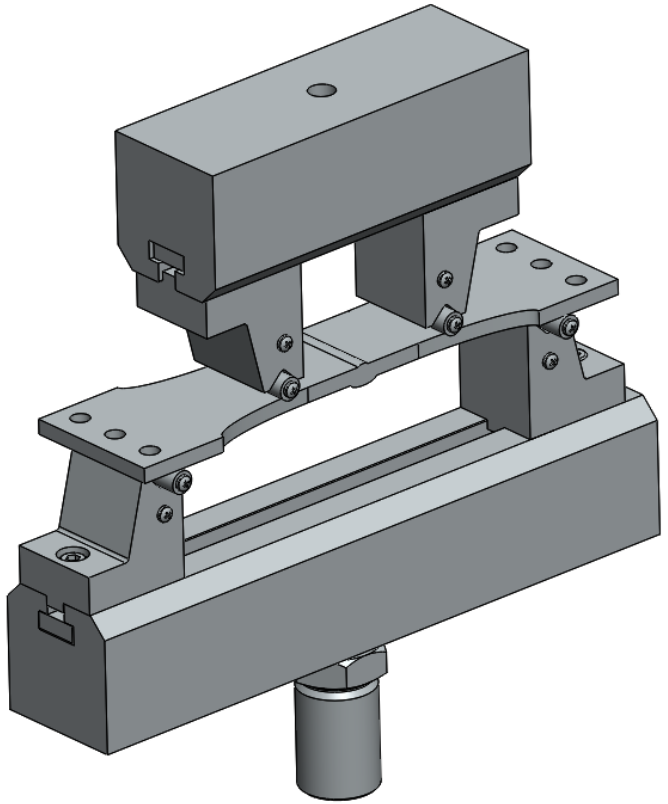


Experimental testing







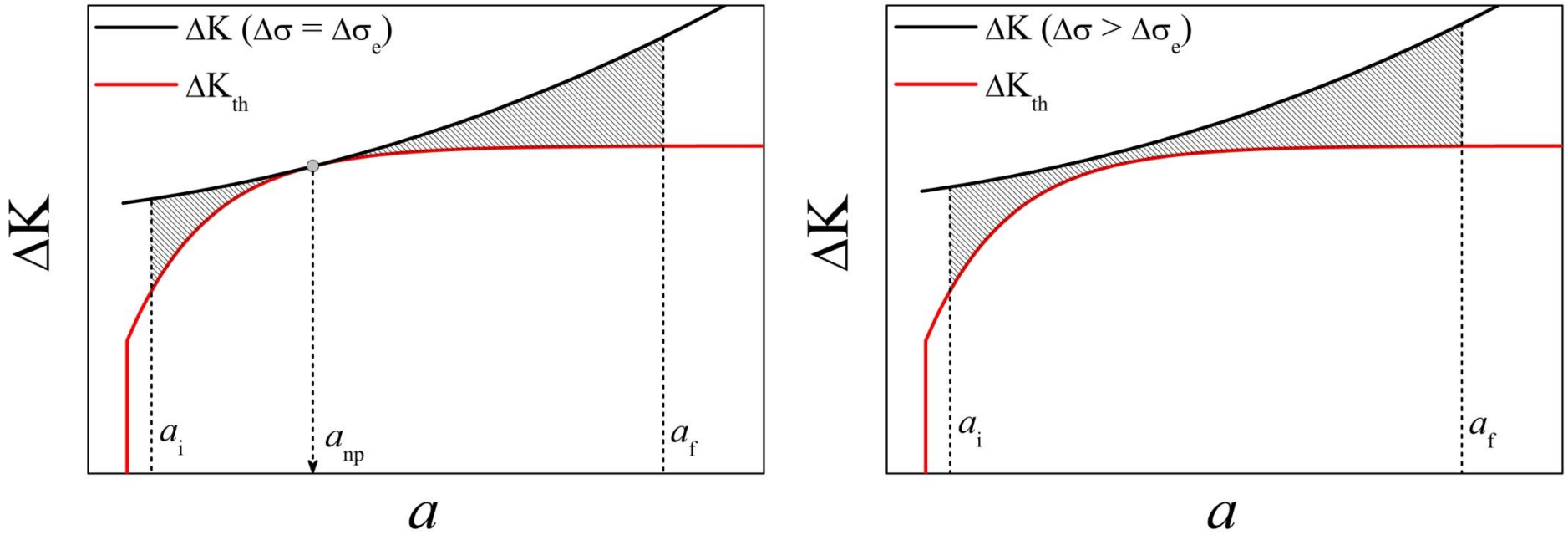


Fracture mechanics assessment

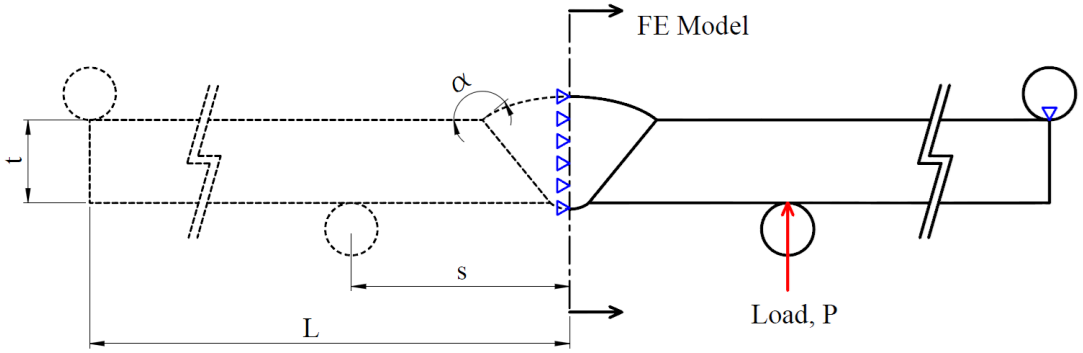
$$\frac{da}{dN} = C(\Delta K - \Delta K_{th})^m$$

$$\Delta K = \Delta K_{th}$$

$$N_f = \int_{a_i}^{a_f} \frac{da}{C(\Delta K - \Delta K_{th})^m}$$



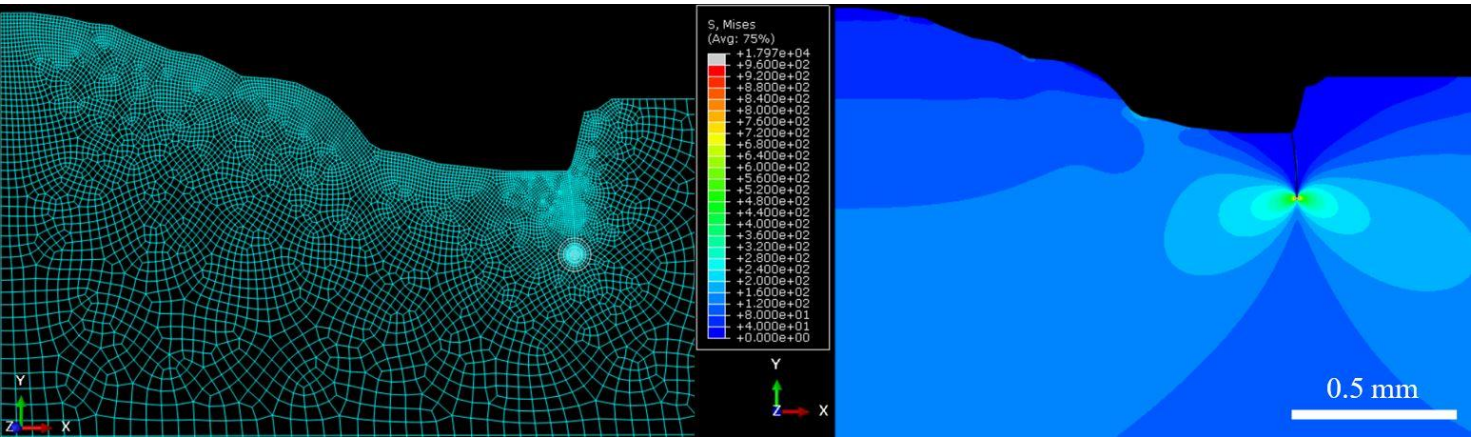
ΔK calculation

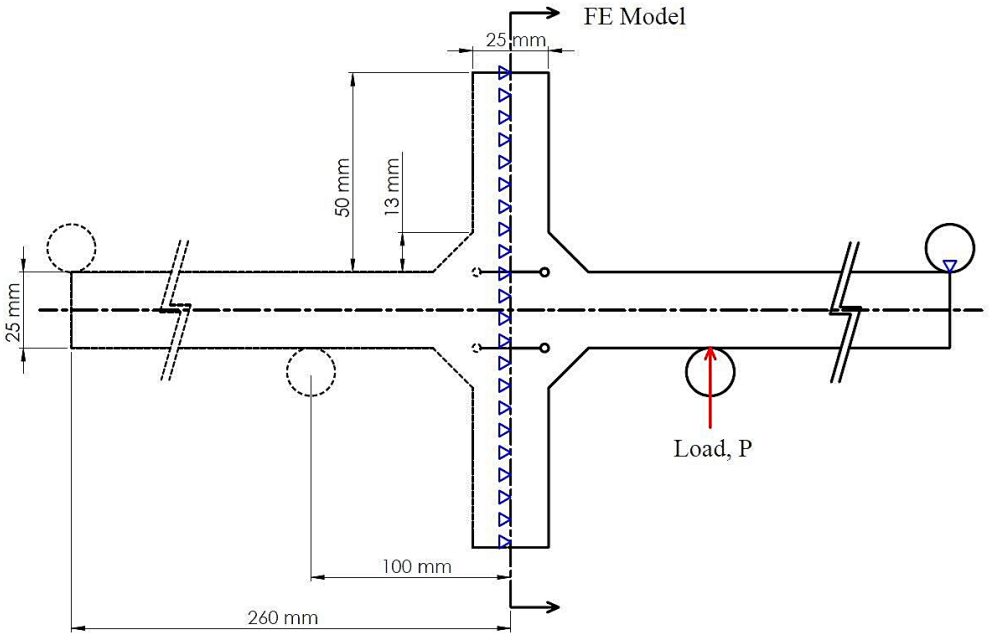


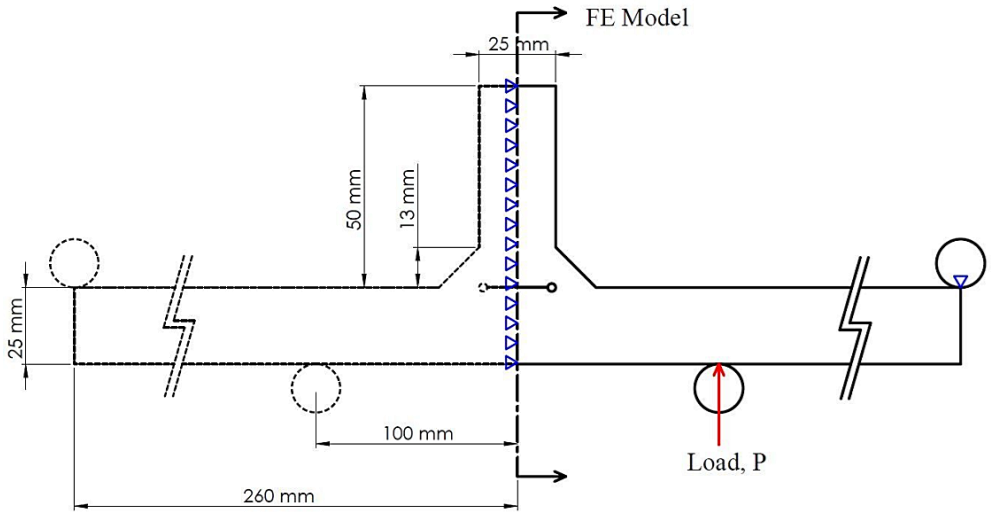
FEA

↓

ΔK vs *a*







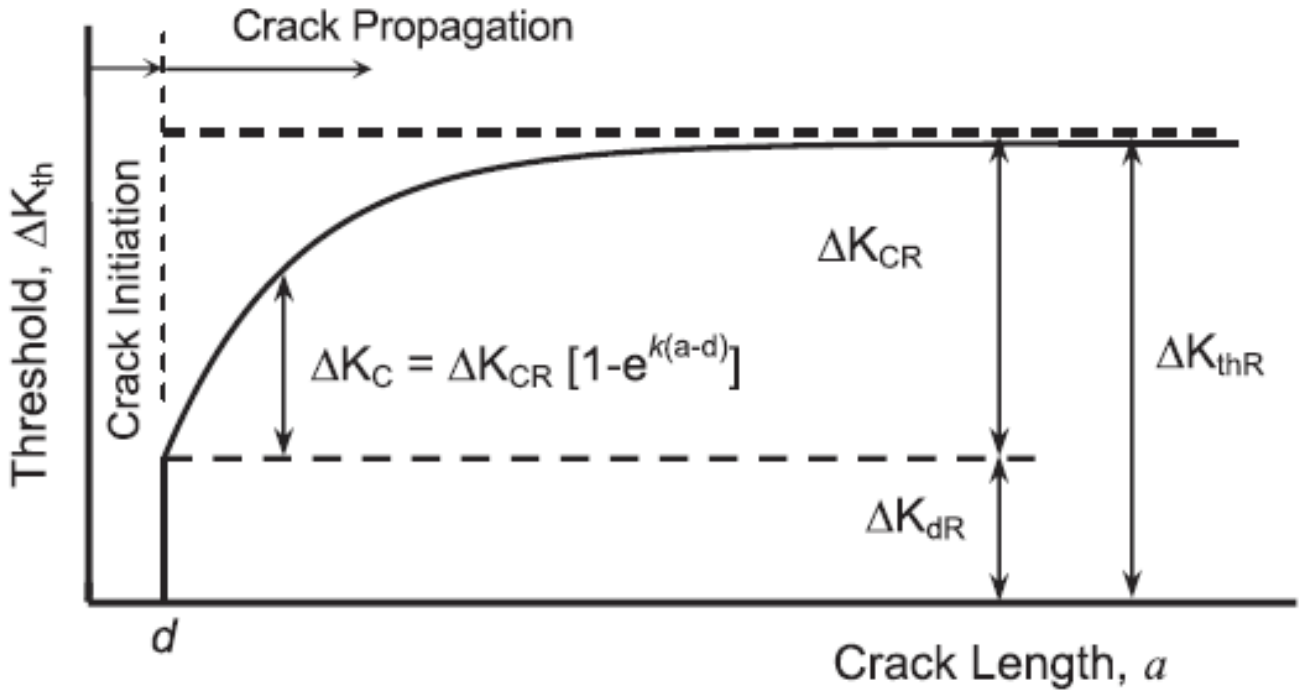
Propagation threshold, ΔK_{th}

- Chapetti M. D. *Int J Fatigue*, 2003; 25 (12): 1319–26.

$$\Delta K_{th} = \Delta K_{dR} + (\Delta K_{thR} - \Delta K_{dR})[1 - e^{-k(a-d)}]$$
$$= Y\Delta\sigma_{th}\sqrt{\pi\, a} \qquad a \geqslant d$$

$$\Delta K_{dR} = Y\Delta\sigma_{eR}\sqrt{\pi\, d}$$

$$k = \frac{1}{4d}\frac{\Delta K_{dR}}{(\Delta K_{thR} - \Delta K_{dR})}$$

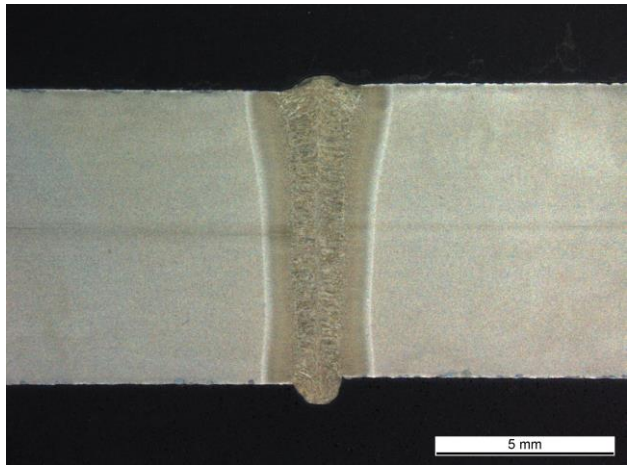


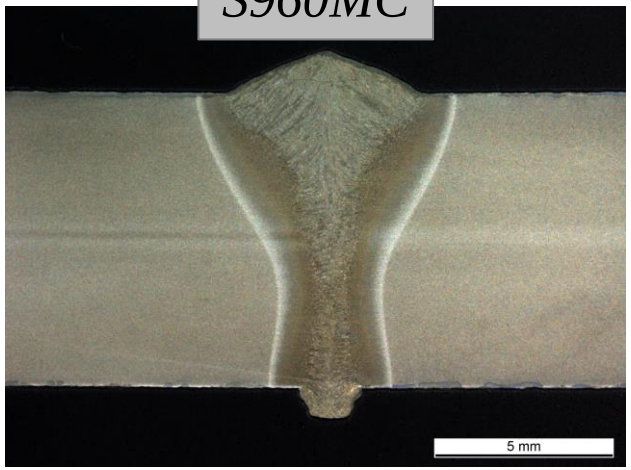
- ΔK_{thR}: Long crack propagation threshold
- $\Delta\sigma_{eR}$: Plain fatigue limit
- *d*: Microstructural barrier (grain size, martensite lath, etc)

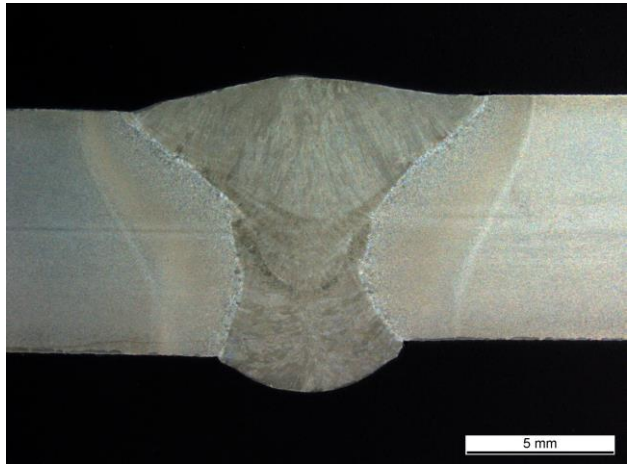
$R = 0.1$

Application in HSS

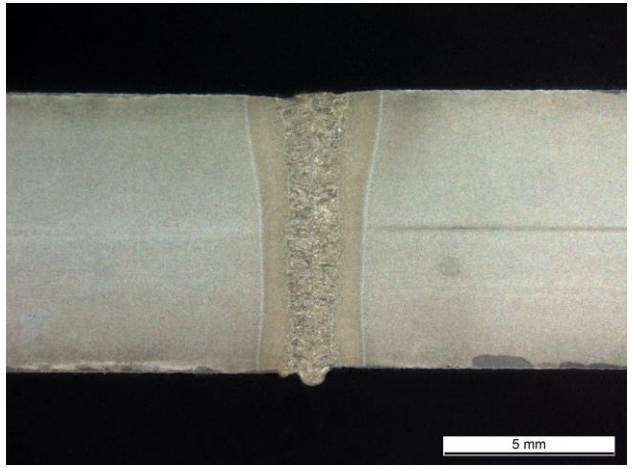
S960MC

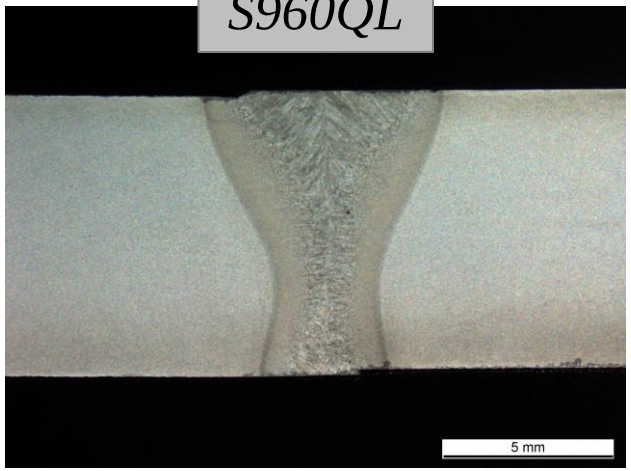


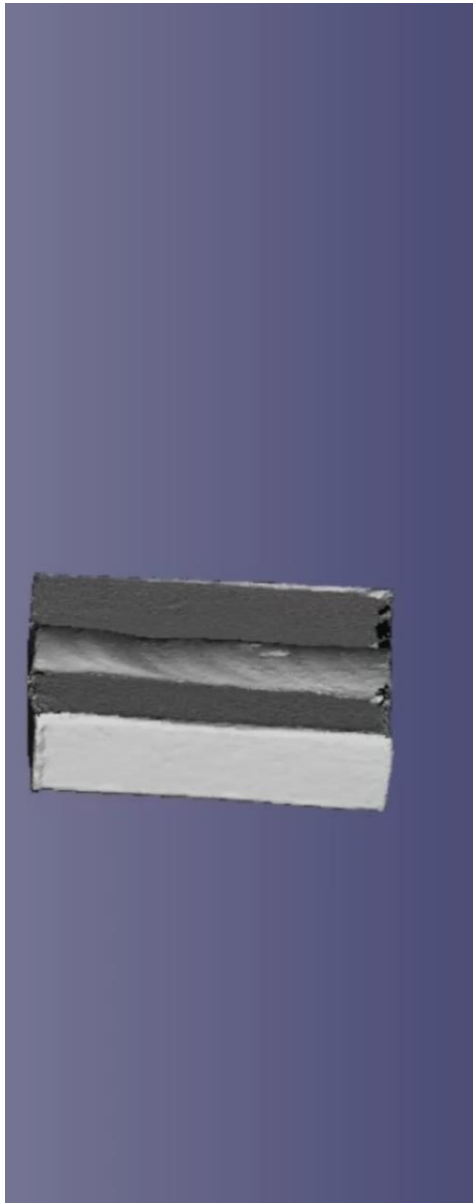




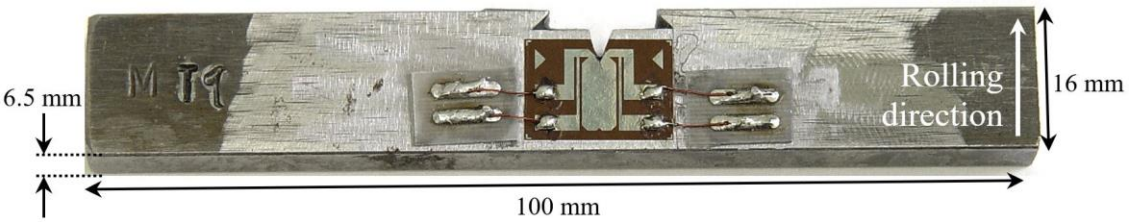
S960QL

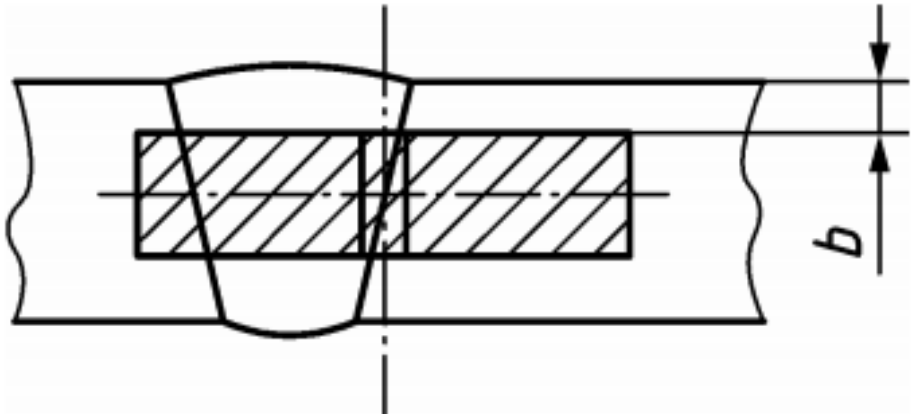


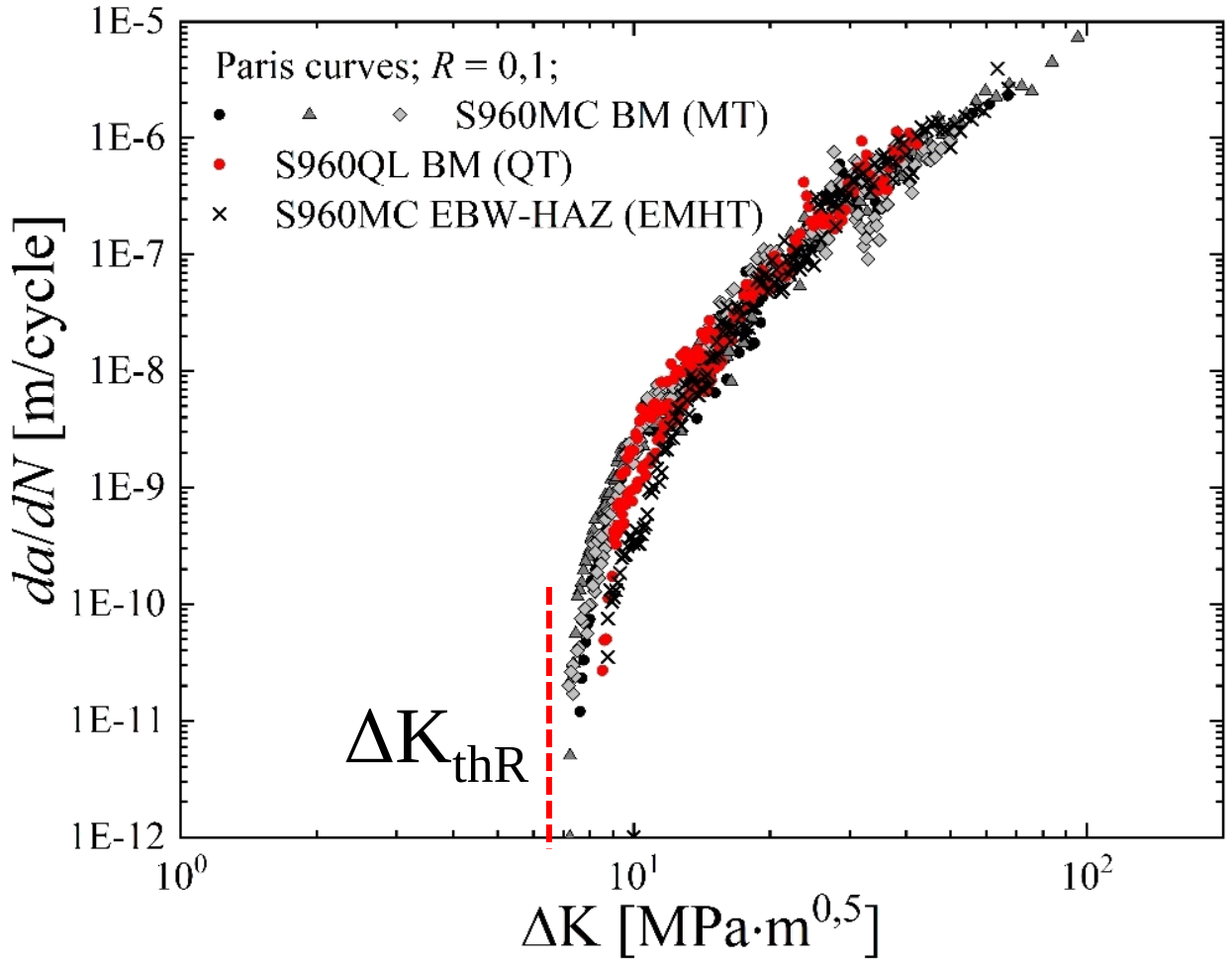




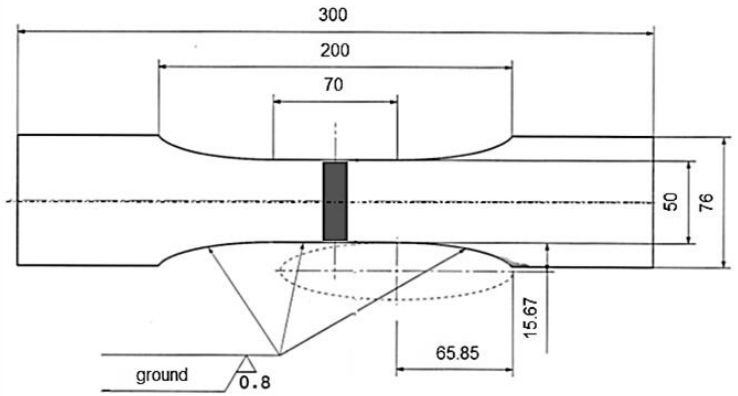
Application in HSS

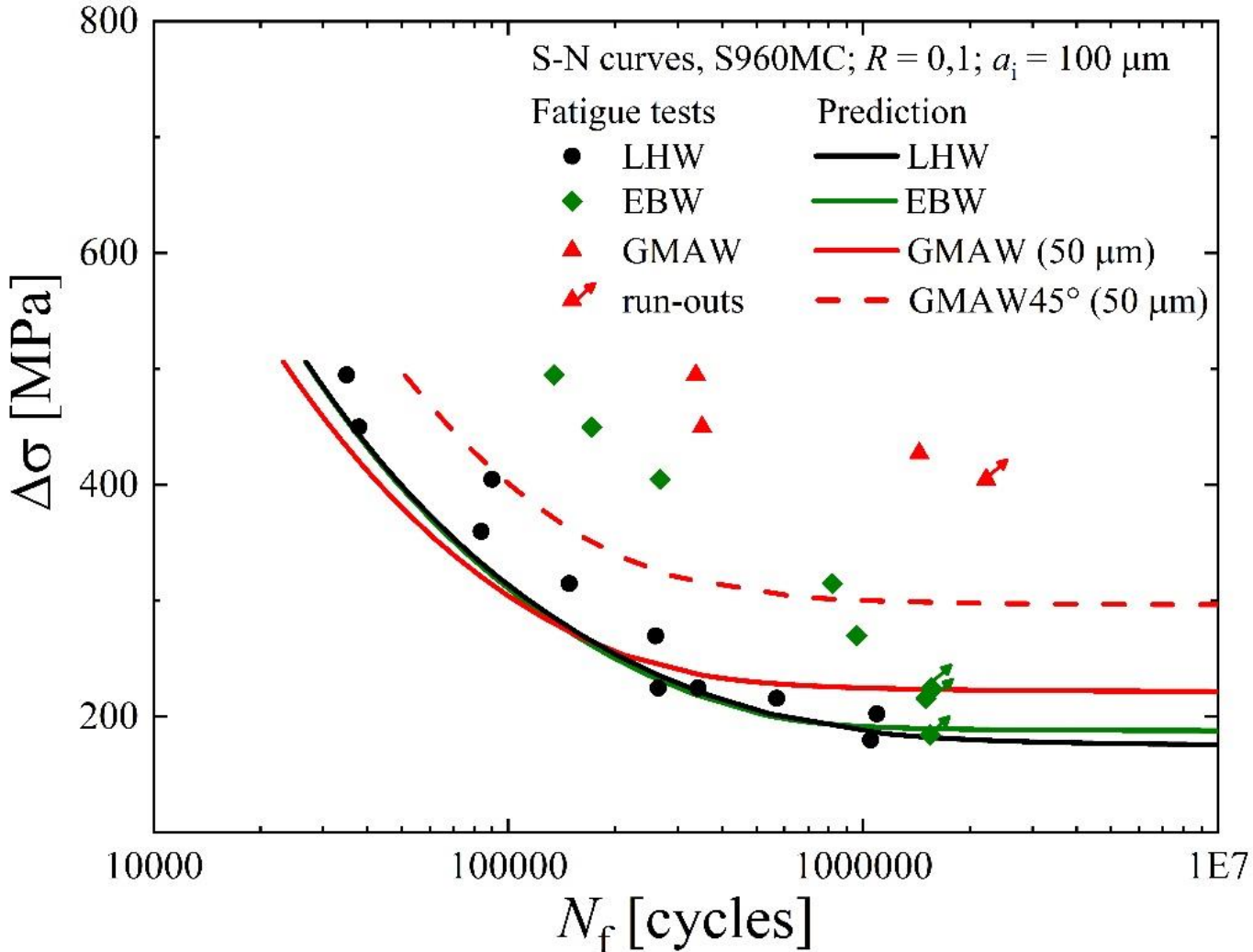






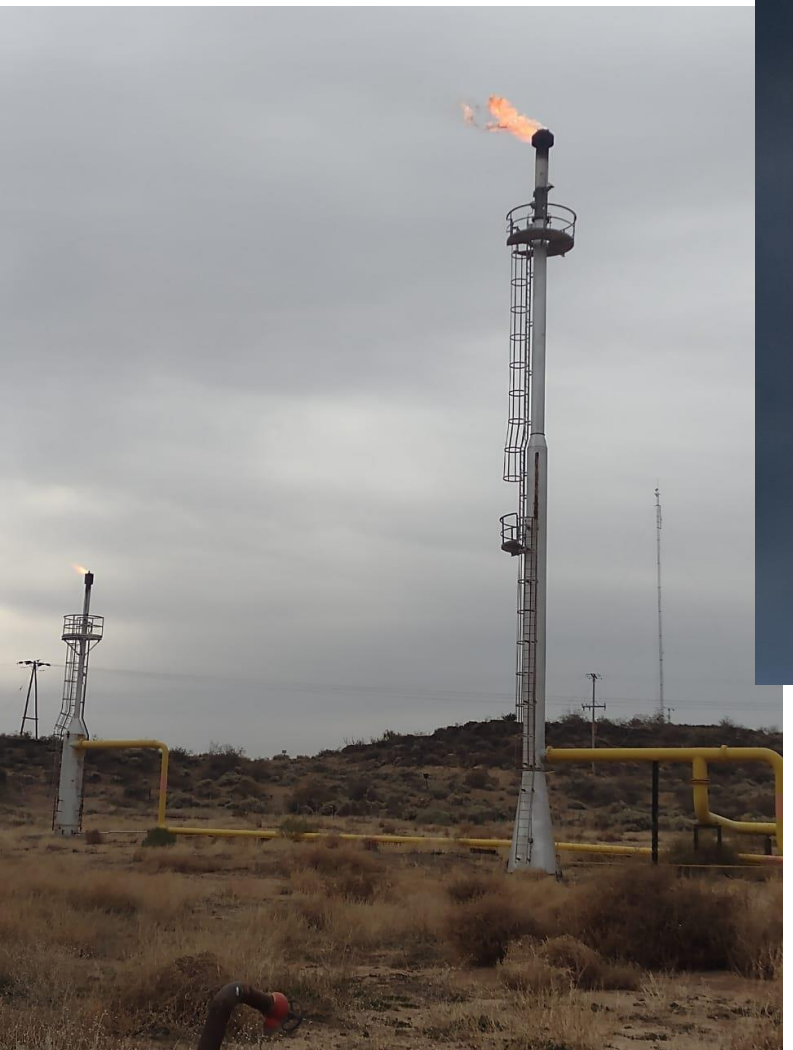
Fatigue test





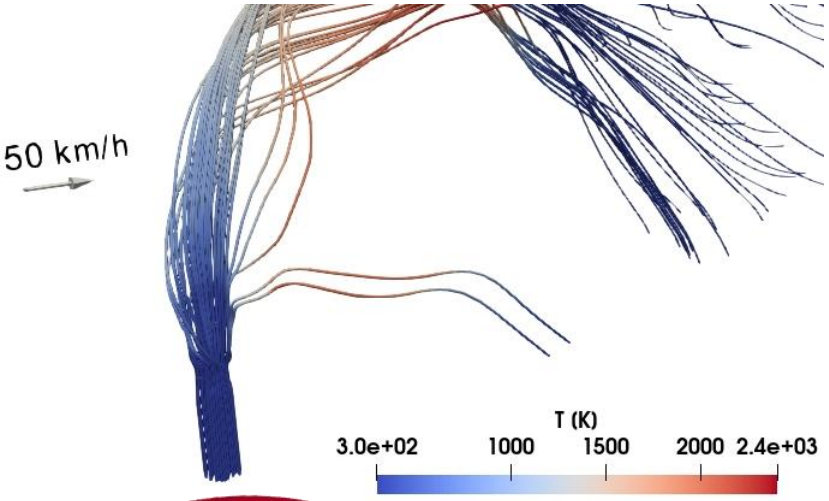
Projects: Fire tubes

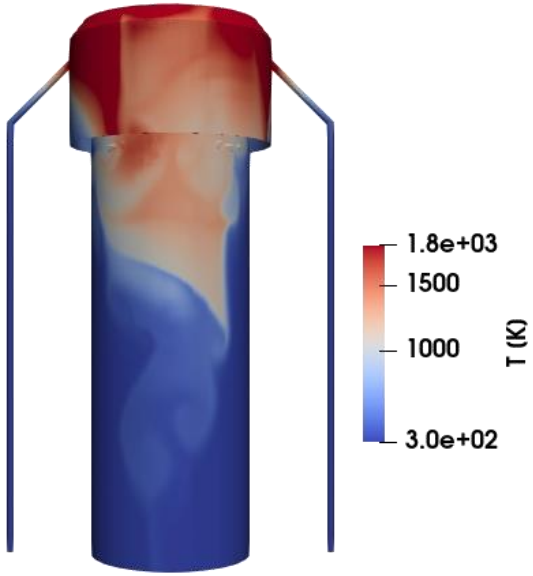
Projects: Flares

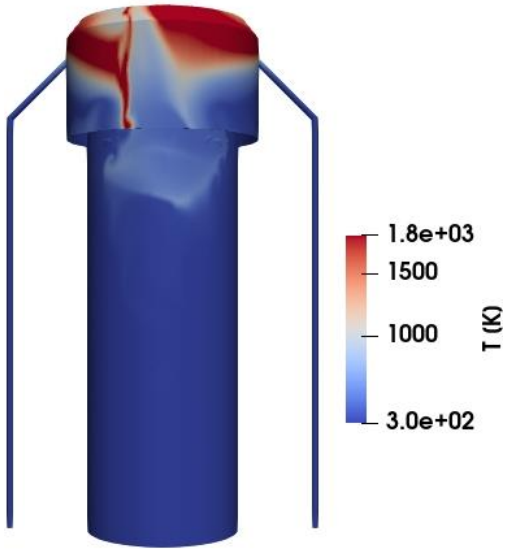


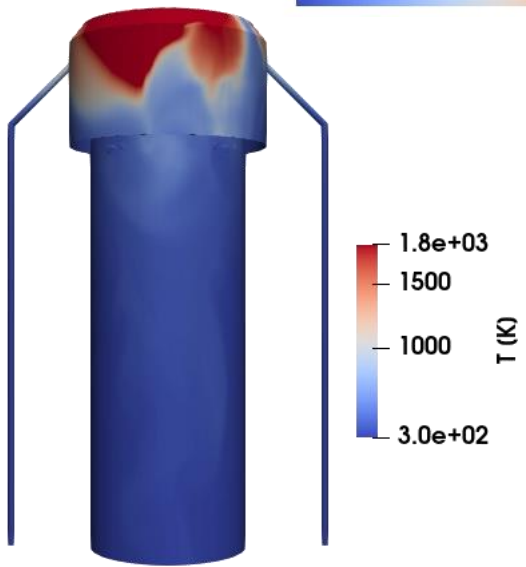
https://www.canadianenergycentre.ca/international-comparisons-of-gas-flaring-2022-edition/

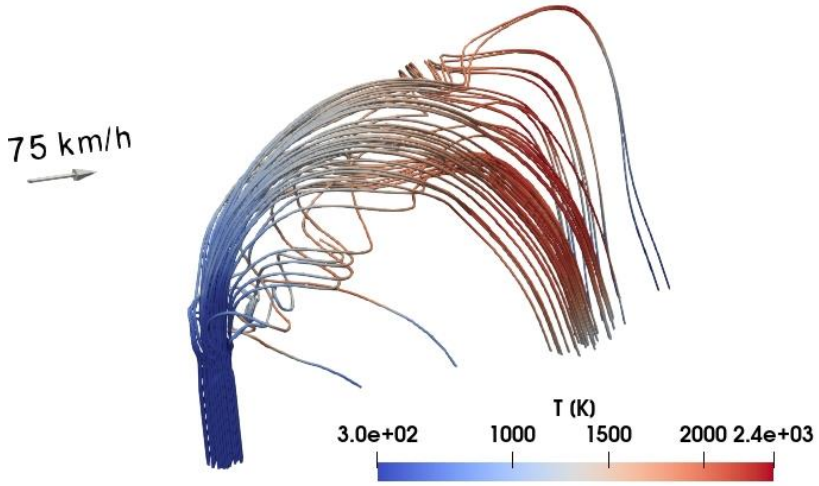
Projects

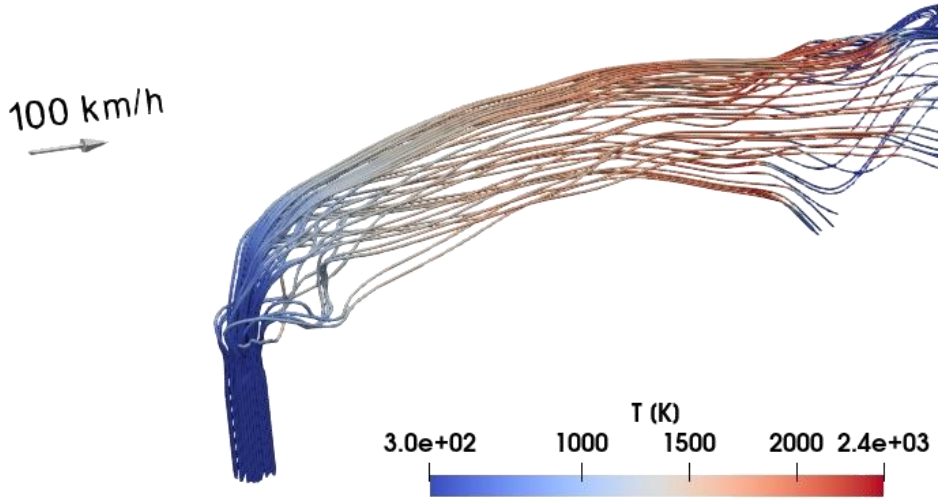

50 km/h
T (K)
3.0e+02
1000
1500
2000
2.4e+03


1.8e+03
1500
1000
T (K)
3.0e+02

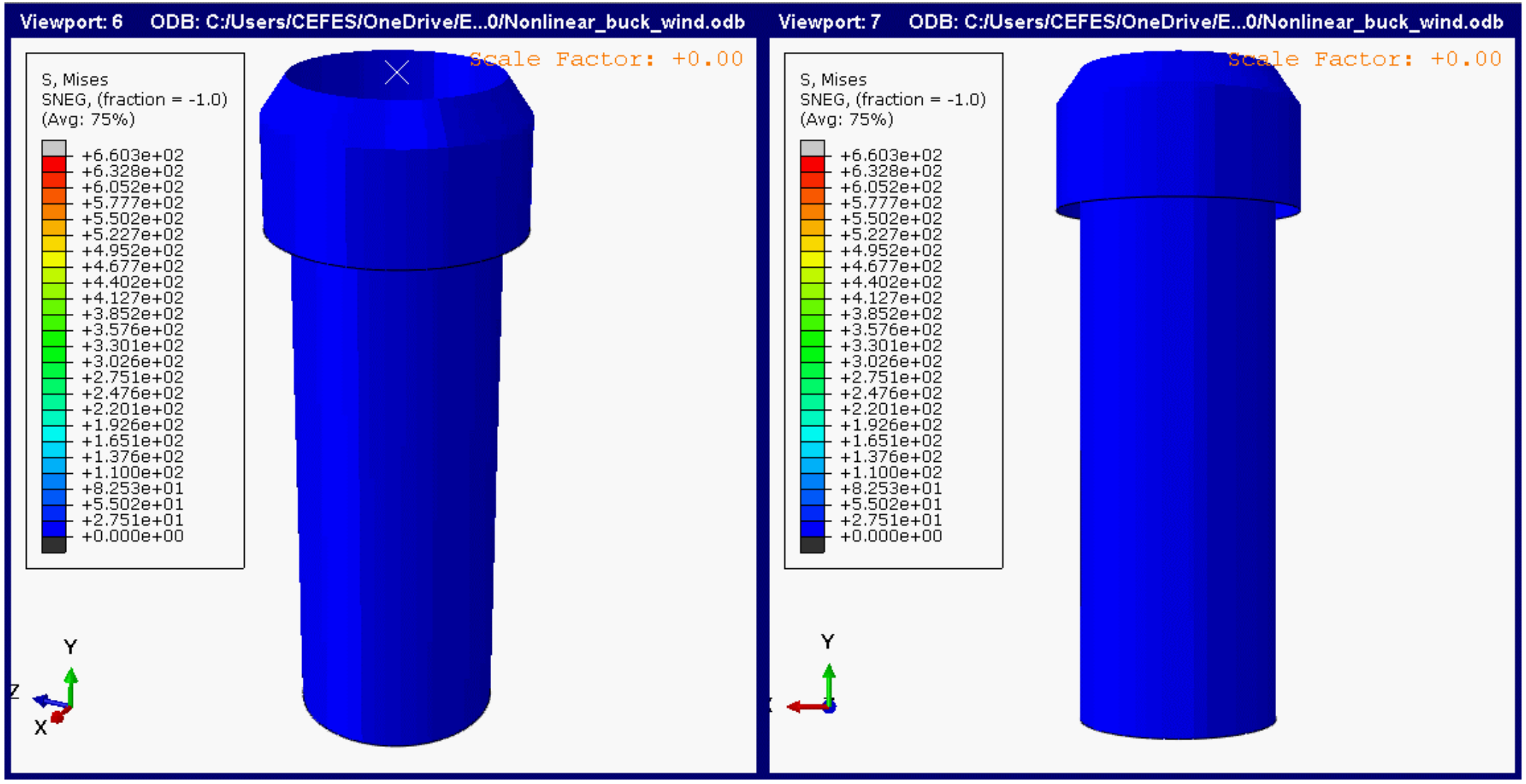

1.8e+03
1500
1000
T (K)
3.0e+02


1.8e+03
1500
1000
T (K)
3.0e+02


75 km/h
T (K)
3.0e+02
1000
1500
2000
2.4e+03


100 km/h
T (K)
3.0e+02
1000
1500
2000
2.4e+03

Projects


Viewport: 6 ODB: C:/Users/CEFES/OneDrive/E...0/Nonlinear_buck_wind.odb
Scale Factor: +0.00
S, Mises
SNEG, (fraction = -1.0)
(Avg: 75%)
+6.603e+02
+6.328e+02
+6.052e+02
+5.777e+02
+5.502e+02
+5.227e+02
+4.952e+02
+4.677e+02
+4.402e+02
+4.127e+02
+3.852e+02
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+2.201e+02
+1.926e+02
+1.651e+02
+1.376e+02
+1.100e+02
+8.253e+01
+5.502e+01
+2.751e+01
+0.000e+00
Y
Z
X
Viewport: 7 ODB: C:/Users/CEFES/OneDrive/E...0/Nonlinear_buck_wind.odb
Scale Factor: +0.00
S, Mises
SNEG, (fraction = -1.0)
(Avg: 75%)
+6.603e+02
+6.328e+02
+6.052e+02
+5.777e+02
+5.502e+02
+5.227e+02
+4.952e+02
+4.677e+02
+4.402e+02
+4.127e+02
+3.852e+02
+3.576e+02
+3.301e+02
+3.026e+02
+2.751e+02
+2.476e+02
+2.201e+02
+1.926e+02
+1.651e+02
+1.376e+02
+1.100e+02
+8.253e+01
+5.502e+01
+2.751e+01
+0.000e+00
Y

Conclusions

- Experimental testing is an important part of failure analysis.
- There is a huge demand for experimental tests designed *ad-hoc*.
- Fatigue is one of the most common damaging mechanism in the O&G industry
- Fracture mechanics tests can help to estimate fatigue lives of different components, by applying the Resistance curve method.
- There is a need to reduce time of the tests, and this can be achieved with resonant testing.
- Statistical nature of input variables is very important for fatigue analysis

Thank you very much for your attention
Some cracks are not dangerous…

问题

¿Preguntas?

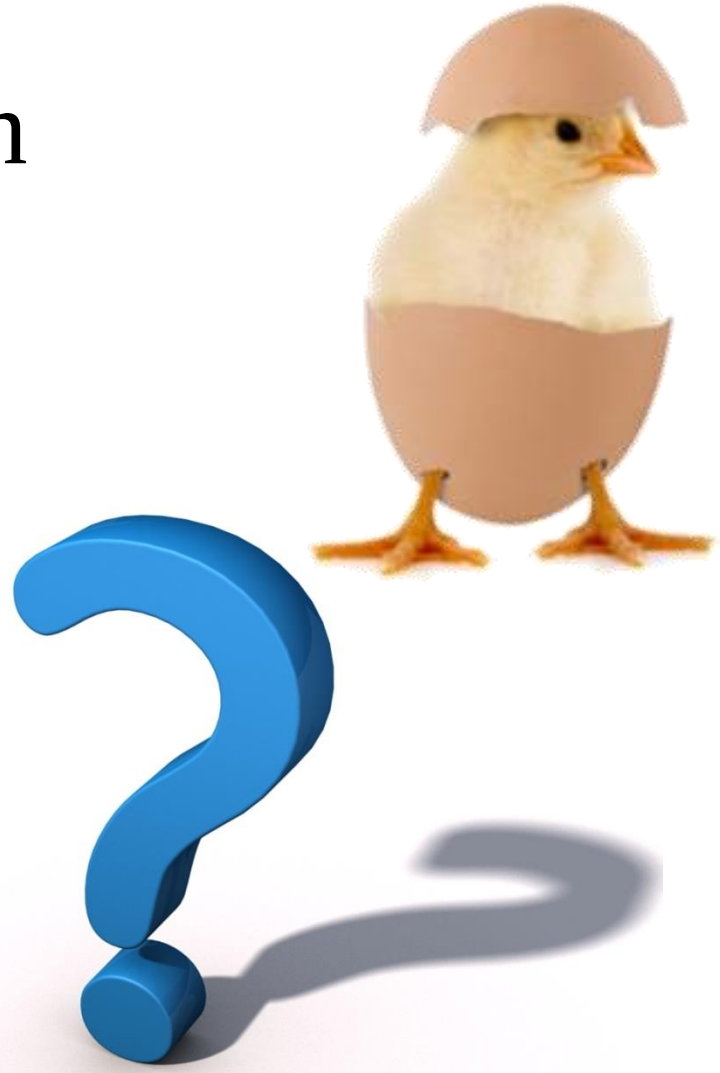
Fragen?

Domande?

Questions?

вопросы?

質問



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