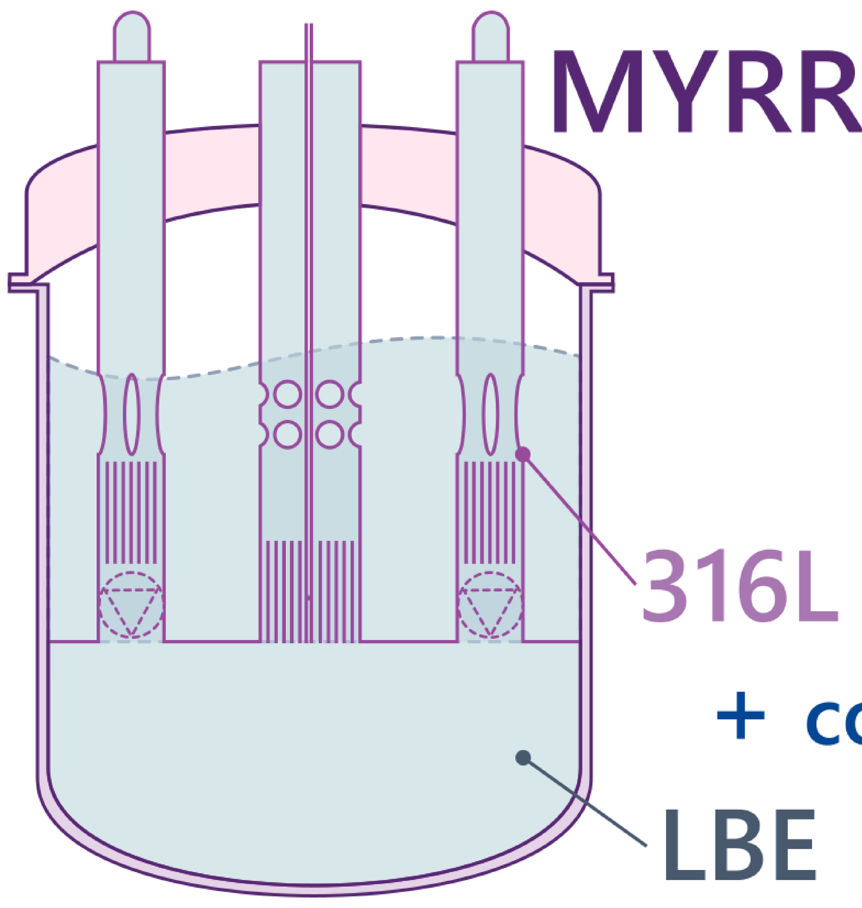
Effect of liquid metal environment on fatigue properties of 316L: assessed by the environmental factor (F_{en}) approach

sck cen — KU LEUVEN

Fuentes Solis, N.[1], Gavrilov, S.[1], Marmy, P.[1], Seefeldt, M.[2], Wevers, M.[2]
[1]Belgian Nuclear Research Centre, SCK•CEN, Mol, Belgium
[2]KU Leuven, Leuven, Belgium
E-mail: noelia.fuentes.solis@sckcen.be, Serguei.gavrilov@sckcen.be

Introduction



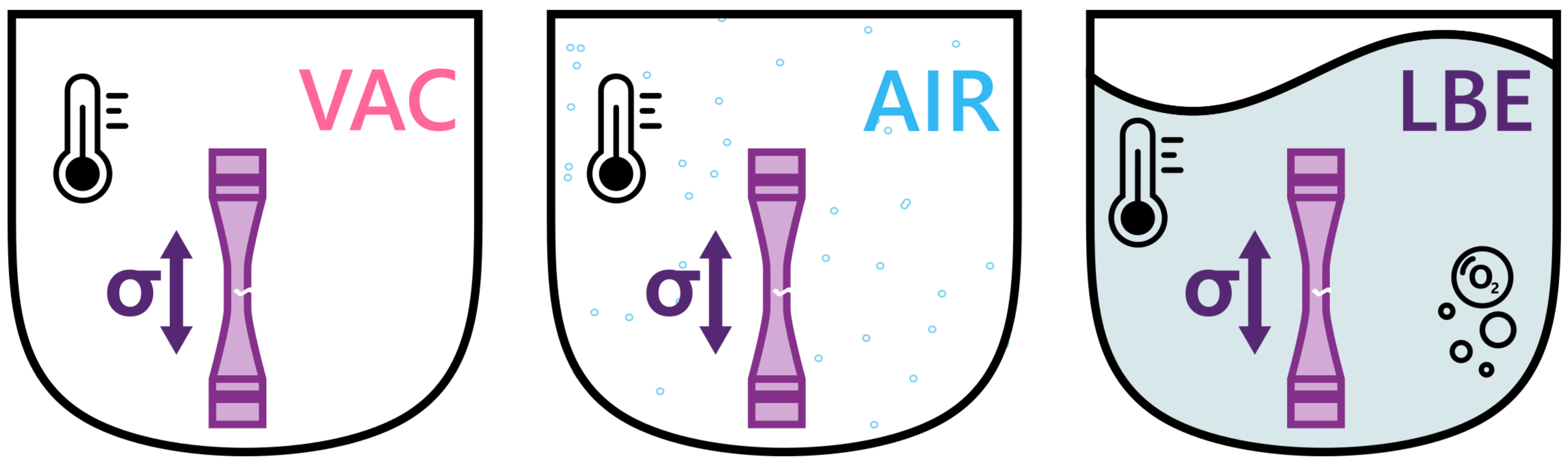
MYRRHA

Heavy liquid metal (HLM) systems require materials that are compatible with them.
The environmental effects on materials mechanical performance need to be understood and incorporated in design rules.

+ compatible?

Experimental

At SCK CEN, the effect of LBE environment on the material properties and degradation mechanisms of the candidate material, 316L austenitic stainless steel (SS) is studied through mechanical testing in LBE environments similar to the operational conditions of MYRRHA.



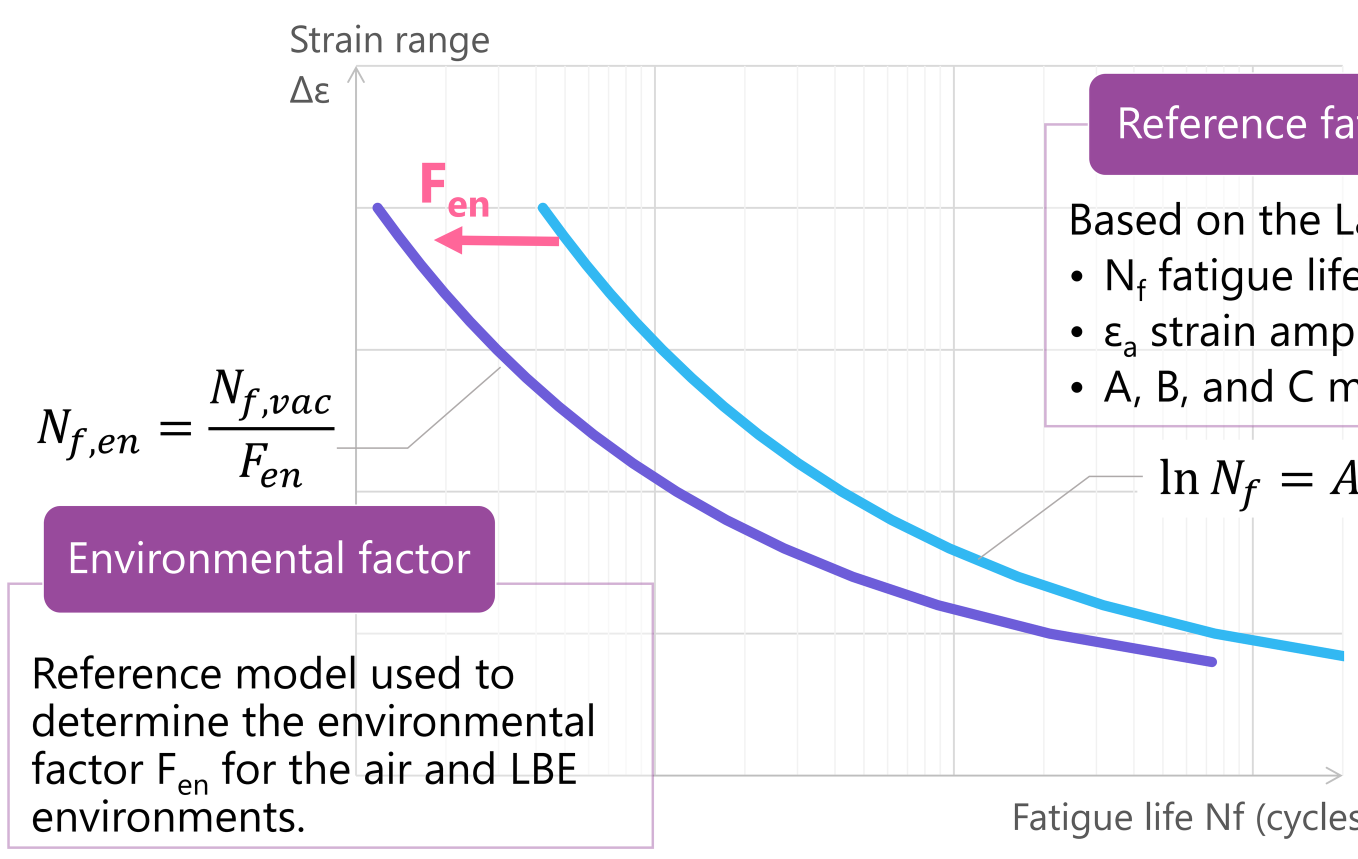
Objectives

- Influence of LBE environment on fatigue properties of 316L
- Impact of loading and environmental parameters
- Fatigue deformation mechanism in presence of LBE

Environmental Factor F_{en}

Recently, the influence of light water reactor (LWR) environments on fatigue life has been incorporated in regulatory guides: the environmental factor, F_{en}, quantifies the decrease in fatigue life due to LWR conditions. In this research, this method has been adapted to assess LBE effects, using vacuum as reference environment.

Strain–life curve



$$N_{f,en} = \frac{N_{f,vac}}{F_{en}}$$

Environmental factor

Reference model used to determine the environmental factor F_{en} for the air and LBE environments.

Reference fatigue life model

Based on the Langer equation
- N_f fatigue life
- ε_a strain amplitude
- A, B, and C material constants

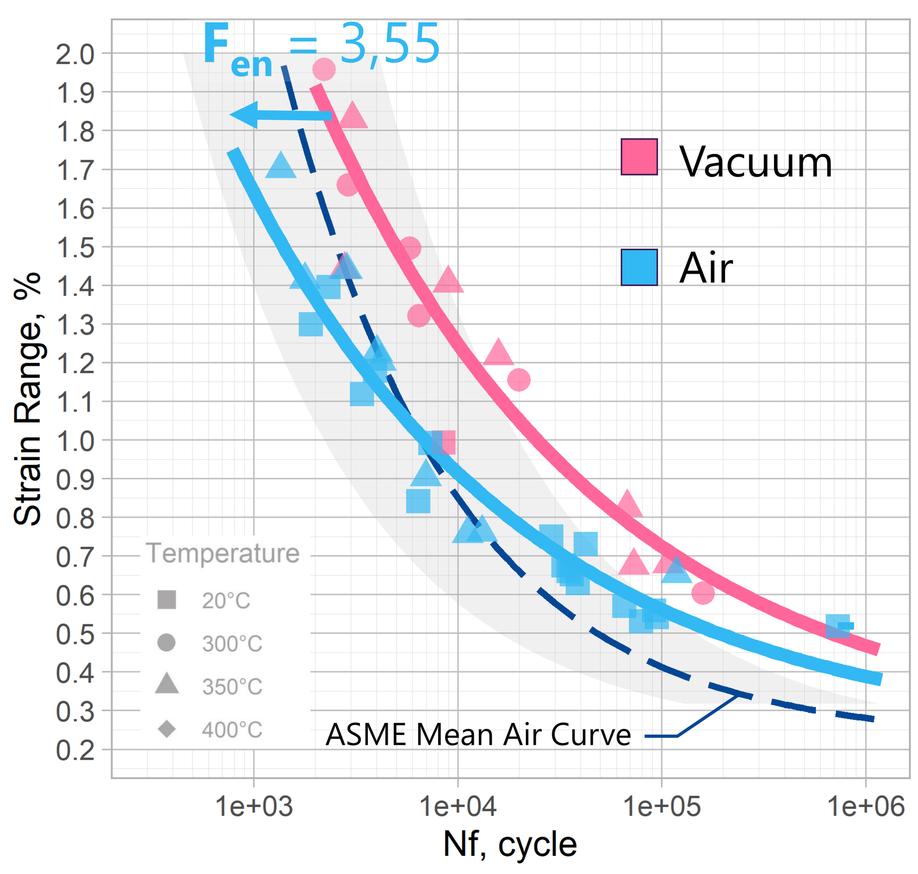
$$\ln N_f = A - B\ln(\varepsilon_a - C)$$

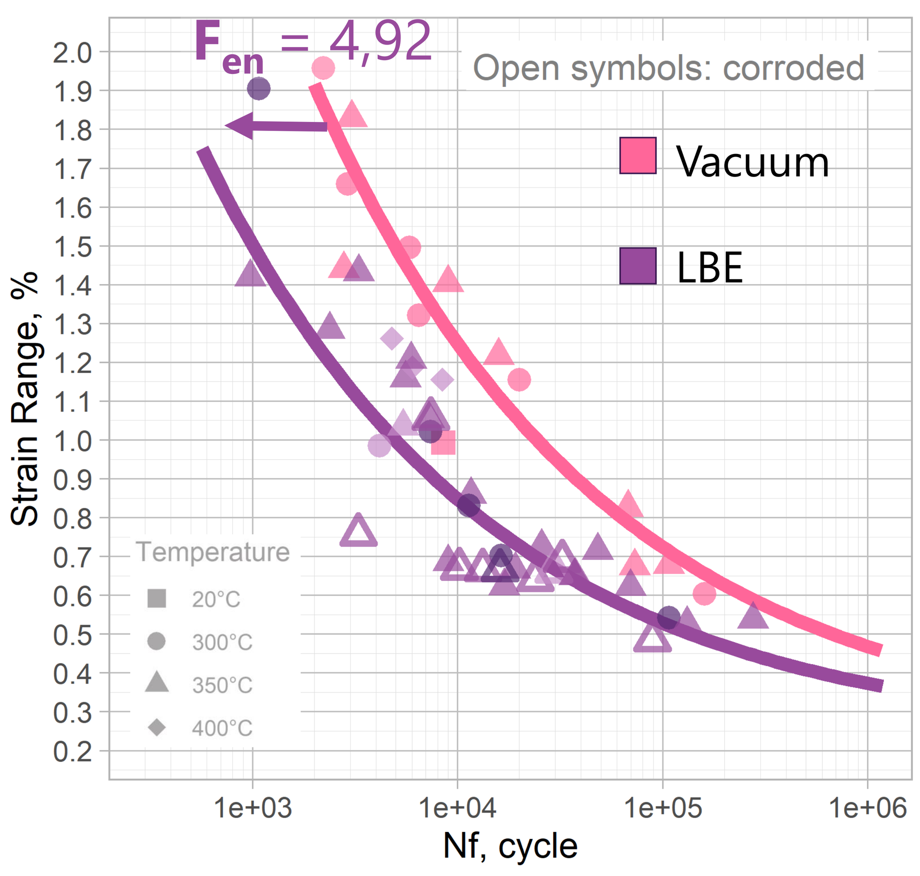
Results and Discussion

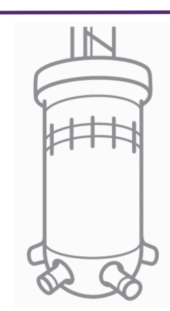
316L Strain–life: environmental factors

- Experimental data is in good agreement with ASME Mean Air Curve for austenitic SS.
- F_{en} air model suggests different slope for this heat of 316L.

ASME Mean Air Curve:
Derived from many heats of austenitic SS, predicting life within a factor of 3.



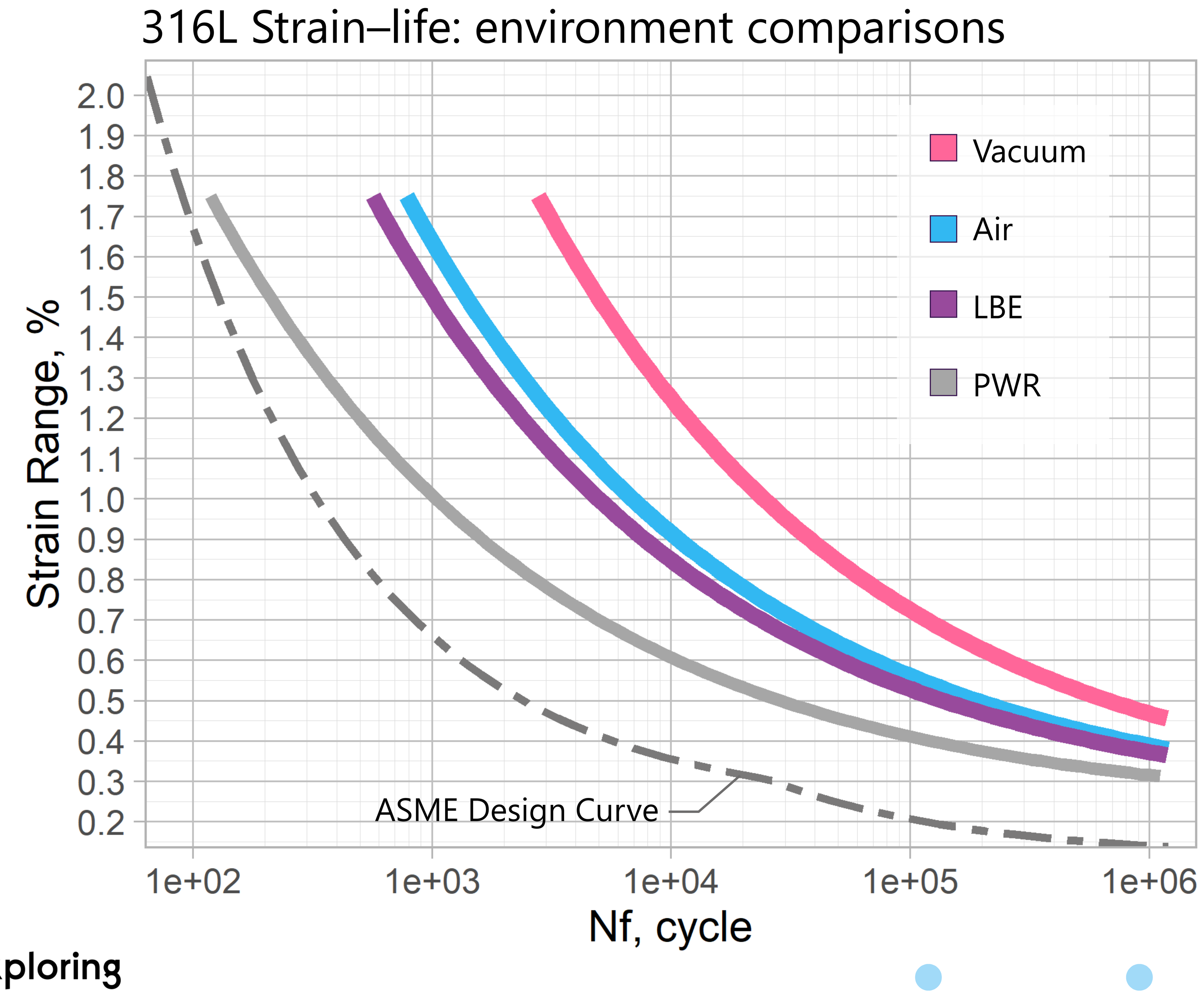




For LWR:
F_{en} between 2 and 12 using air as reference

- At higher strain ranges, the fatigue lives from tests are longer than F_{en} LBE model.
- F_{en} model is conservative.
- LBE effects appear to be less pronounced for certain strain parameters
- Next steps: determine which ones and why

316L Strain–life: environment comparisons



Some challenges:

- Fatigue properties have an inherent data scatter due to metallurgical variability in microstructure. Which differences are significant and which ones are negligible?
- Environmental factor approach relies on environmental data having the same slope as the reference. How to interpret if slopes are different?

Conclusion

There is an influence of LBE environment on fatigue life compared to the vacuum reference. However, the effect of LBE, predicted by the environmental factor approach, is comparable to that of air.

Furthermore, all experimental predictions and results, including outliers and exceptional conditions, fall above the ASME Code Section III Design Curve. This PhD research is also addressing the effect of specific parameters such as LBE oxygen concentration, temperature, surface condition, and strain rate on the deformation mechanism of this solid metal–liquid metal couple.

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