Link between the microstructure and the durability of polycrystalline materials: a fatigue damage model in an aluminium alloy

M. Lenglet*[a], A. Ask[a], S. Forest[b], P. Kanouté[a], S. Kruch[a]

[a] Office National d'Etudes et de Recherches Aérospatiales (ONERA)
29 Avenue de la Division Leclerc, 92320 Châtillon, France
[b] Centre des Matériaux de MINES ParisTech
63-65 Rue Henri Auguste Desbruères, 91100 Corbeil-Essonnes, France

ABSTRACT

In polycrystalline alloys, fatigue damage is strongly influenced by the microstructure. Nowadays crystal plasticity models are used in order to take into account the crystallography and microstructural mechanisms but there is no consensus on crack initiation sites and their most significant mechanisms. The present work combines experimental tests and numerical simulations in order to understand and predict the physical mechanisms that lead to crack formation in high cycle fatigue in high-strength aluminium alloys for aerospace applications.

The numerical simulations include a two parameters kinematic hardening. Experiments highlight the importance of two phenomena in fatigue crack initiation in connection with the microstructure. The first aspect is the surface roughness [1]; and our simulations succeed in putting forward the intrusion/extrusion phenomenon. The interest of large deformations in simulations is also discussed because of their effect on grain re-orientation and thus in surface roughness. The second phenomenon is progressive deformations; and the model achieves to account for it through local ratchetting and its effect on the crack initiation. We also intend to model stress relaxation, as its role is yet to be determined. In order to be able to extrapolate the mechanical behaviour over a large number of cycles, it is important to find the stabilized cycle [2]. Parallel simulations allow this to be done for representative crystalline aggregates.

Finally, different macroscopic and mostly microscopic fatigue initiation parameters [3] are compared such as the Fatemi-Socie parameter, the stored energy or the commonly used cumulative plastic strain. It leads us to multiple fatigue site initiations, which we can compare with experimental results. The aim is to more accurately predict the site of fatigue crack initiation and the predominant mechanisms in fatigue crack initiation.

REFERENCES

[1] Guilhem, Y., et al (2018). *Numerical analysis of the effect of surface roughness on mechanical fields in polycrystalline aggregates*. Modelling Simul. Mater. Sci. Eng. 26 045004

[2] Sinha, S., Ghosh, S. (2006). *Modeling cyclic ratcheting based fatigue life of HSLA steels using crystal plasticity FEM simulations and experiments*. International Journal of Fatigue, 28, 1690-1704.

[3] Efthymiadis, P., Pinna, C., & Yates, J.R. (2019). *Fatigue crack initiation in AA2024: A coupled micromechanical testing and crystal plasticity study*. Fatigue & Fracture of Engineering Materials & Structures, 42, 321-338.