Fast Fourier Transform based homogenization of the cyclic behaviour and fatigue life prediction of polycrystalline superalloys

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ABSTRACT

The mechanical performance of polycrystalline superalloys is closely related to its microstructure. Computational homogenization is a powerful tool to link macroscopic behavior with microstructure and crystal behavior by solving a boundary value problem on a periodic Representative Volume Element (RVE) of the microstructure. The use of spectral methods based on the Fast Fourier Transform (FFT) [1] to solve the periodic boundary value problem has become an alternative to classic Finite Element based homogenization [2] due to the higher numerical performance that allow the use much finer RVE discretizations. Moreover, FFT solvers have been specifically adapted for crystal plasticity (CP) based constitutive equations to obtain monotonic response of polycrystalline alloys [3].

In this work, a FFT homogenization based model is used to predict the behavior of IN718 polycrystalline superalloy under macrocopic cyclic loading. Synthetic RVEs are obtained from experimental images of the microstructure and the crystal behavior is accounted by a novel CP model that includes all cyclic phenomena observed in In718: Bauschinger effect, mean-stress relaxation and cyclic softening. The CP model is calibrated using inverse fitting from the first cycles of strain controlled fatigue tests under different strain ranges. With this approach both the evolution of the macroscopic hystheresis curve of the alloy with the cycles and the microscopic arrangement of microfields are obtained. Finally, the fatigue life is predicted based on the microscopic fields resulting of the FFT simulation when the stable cycle is reached.

Keywords: Numerical homogenization, Fast Fourier Transform, Crystal Plasticity, Cyclic Plasticity, Fatigue, Inverse Methods

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