Micro-mechanical modelling of high cycle fatigue behaviour of metals under multiaxial loads

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Mots clés :

Résumé

The high cycle fatigue (HCF) strength assessment methods are generally based on mechanical quantities calculated at macroscopic or mesoscopic scales and validated by the model's ability to accurately reproduce experimental results. Multiaxial mesoscopic fatigue strength criteria are usually based on scaling transition assumptions aiming at capturing the stress or strain state in the grain. In the case of critical plane based criteria (Dang Van, Papadopoulos, Morel), fatigue crack initiation is supposed to be controlled by a mechanical quantity linked to a particular orientation (critical plane).

Several investigations conducted by the research teams of Arts et Métiers ParisTech aim to highlight the influence of both the microstructure, the loading path and the defects on the multiaxial high cycle fatigue behaviour of different metallic materials, using finite element simulations of polycrystalline aggregates. High cycle fatigue tests have been conducted under uniaxial and multiaxial loading conditions with both smooth specimens and specimens containing artificial defects. The experimental results are compared with those of finite element crystal plasticity computations on synthetic microstructures. Statistical information regarding mesoscopic mechanical fields provides useful insight into the microstructural dependence of the driving forces for fatigue crack nucleation at the mesoscopic scale (or the scale of individual grains). The application of different crack initiation criteria at the mesoscopic (grain) scale shows a strong variability of the hydrostatic, normal and shear stresses. At the fatigue limit level, this variability is greater for anisotropic elastic behavior, while the role of crystal plasticity seems to be secondary.
The results from these FE models are used along with an original probabilistic mesomechanics approach to quantify the loading path and defect size effects. The resulting predictions, which are sensitive to the microstructure, include the probability distribution of the high cycle fatigue strength.

The results offered hence new insights into the multiaxial fatigue modeling of metals and structures taking into account the microstructure. The usual assumptions of scaling transition rules used in multiaxial fatigue models can be in particular discussed.