A FFT-based method for analyzing dissipation and fatigue behavior under low-amplitude cyclic loading in polycrystalline aggregates

André Calazans Menescal De Souza*†[1], Sylvain Moyne[2], Cédric Doudard[1], Luc Saint-Sulpice , and Sylvain Calloch

[1]École Nationale Supérieure de Techniques Avancées Bretagne – ENSTA Bretagne, CNRS UMR 6027, IRDL, 2 rue François Verny, 29806 Brest Cedex 9, France – France

[2]Institut de Recherche Dupuy de Lôme – École Nationale Supérieure de Techniques Avancées Bretagne – France

Abstract

The analysis of dissipation under cyclic loading, commonly referred to as self-heating measurements, is increasingly popular as a method for estimating the fatigue properties of materials in high-cycle conditions. To fully leverage this experimental technique, it is essential to develop models that link self-heating data to material fatigue behavior. This study proposes a method using the fast Fourier transform (FFT) applied to a representative volume element (RVE) of a polycrystalline aggregate to examine the evolution of dissipation during low-amplitude cyclic loading and to construct predictive models.

The approach emphasizes obtaining both qualitative and quantitative self-heating curves by analyzing how steady-state cyclic dissipation evolves under varying loading amplitudes. Both uniaxial and multiaxial cyclic loading conditions are investigated. The research particularly focuses on the heterogeneous distribution of micro-plasticity within the polycrystalline aggregate, where dissipation is driven by localized plasticity in a small number of grains. This study also establishes connections with models using Poisson point processes to describe the gradual and localized emergence of these dissipation phenomena.

Additionally, the investigation examines how several factors-such as grain orientation distribution, grain number, boundary conditions, stochastic critical resolved shear stresses, and loading multi-axiality-affect the onset of dissipative phenomena within the polycrystal. Finally, a fatigue criterion based on intrinsic dissipation is proposed to predict fatigue crack initiation. The initial results are in good agreement with experimental data reported in prior studies.

*Speaker

†Corresponding author: andre.calazans@ensta-bretagne.org