EXPERIMENTAL AND NUMERICAL STUDY OF THE EVOLUTION OF STORED ENERGY IN METALLIC MATERIALS UNDER CYCLIC LOADING

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ABSTRACT In-service loading conditions usually generate complex cyclic stress states. As such, the choice of an appropriate multiaxial fatigue criterion plays a crucial role in obtaining correct fatigue predictions. In the case of high cycle fatigue, the observation of the stabilized behavior is generally required to build either stress-based criteria or energy-based criteria. The different energy-based approaches can be classified according to the kind of energy which is assumed to drive the fatigue process. Indeed, the total strain energy is not entirely dissipated into heat since a fraction is stored in the material. While the link between fatigue damage and dissipated energy remains unclear, the interest for stored energy approaches is motivated by the correlation that exists between stored energy and fatigue damage accumulation. More specifically, energy storage and fatigue damage are both related to the behavior of dislocations. Energy storage corresponds to an increase of the free energy associated with the multiplication of defects (e.g. dislocations, vacancies) while fatigue damage often results from the evolution of the dislocation substructure. Consequently, constitutive laws must include a correct description of the energy balance to obtain robust estimations of the fatigue life under uniaxial and multiaxial loading conditions from energetic approaches. In the present work, it is proposed to study the evolution of the energy balance at both macroscopic and microscopic scales. The studied material is a medium carbon steel which is submitted to a uniaxial cyclic loading with different stress amplitudes. The evolution of stored and dissipated energies at a macroscopic scale is experimentally determined from strain and temperature measurements by using an appropriate thermomechanical framework. To gain insight into the energy balance at a microscopic scale, a polycrystalline model is proposed. The proposed model, which is based on FFT homogenization techniques, is developed within a crystal plasticity framework. An alternative definition of the internal variables associated with isotropic hardening is proposed to reproduce the diminution of the average stored energy per cycle which is experimentally observed with an increasing number of applied cycles. From the simulation results, it is observed that both the stored energy and dissipated energy fields are strongly scattered. The dispersion is mostly explained by the crystallographic orientation distribution and the internal stresses whose development is facilitated by the presence of a two-phased microstructure.