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Abstract

This study aims to examine the effects of both material microstructure and voids on the high-cycle fatigue behavior of metals. To deal with this matter, finite element analyses of polycrystalline aggregates are carried out, for different configurations of crystalline orientations, in order to estimate the mechanical state, at the grain scale, in the vicinity of a small elliptical hole. Fatigue criteria are then applied to estimate the average fatigue limit in fully reversed tension, for different defect sizes and ellipse aspect ratios. The constitutive models and the fatigue criteria are calibrated using experimental data obtained from specimens made of 316L austenitic steel. The estimations are then compared with the experimental trends.

Keywords: High-cycle fatigue, Elliptical notch, Crystal plasticity, Micromechanics, Fatigue criteria.

1. Introduction

The high-cycle fatigue strength of metallic materials is strongly influenced by the microstructure and may be significantly affected by the presence of defects, and it is thus important to be able to quantify their detrimental effect. A large number of approaches attempting to predict the influence of a defect on the fatigue limit can be found in the litterature. For instance, Kitagawa and Takahashi have proposed a criterion based on a linear elastic fracture mechanic threshold [1]. Shyam et al. have extended this approach by considering an elastic plastic fracture mechanic threshold [2]. Empirical fatigue criteria have been proposed by Frost [3] and Murakami and Endo [4]. Endo and McEvily have developped a criterion relying on the fatigue crack propagation [5]. The gradient of a fatigue equivalent stress, inspired by classical multiaxial fatigue criteria such as the Crossland criterion [6], has been used by Nadot and his coworkers [7, 8, 9].

Among these approaches, the one proposed by Murakami and Endo is based on the defect size $\sqrt{area}$, expressed by the square root of the area of the defect projected in the direction of the maximum principal stress, which is a crucial parameter to determine the fatigue strength [4]. Billaudeau et al. have shown, from push-pull fatigue tests carried out on specimens made of low carbon steel (SAE1035) and containing an artificial notch, that the fatigue limit is affected not only by the size of the defect $\sqrt{area}$ but also by its

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