A cyclic slip irreversibility based model for fatigue crack initiation of nickel base alloys

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A cyclic slip irreversibility based model for fatigue crack initiation of nickel base alloys

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Abstract

The opportunity to define a microscopic law of fatigue crack initiation using Manson-Coffin law formulated in terms of cyclic slip irreversibility deduced from AFM measurements is discussed for a polycrystalline superalloy with different grain sizes and precipitate sizes. The results show that the modified Manson-Coffin law, relating cyclic slip irreversibility parameter to fatigue crack initiation life, is sustained through a two-parameter power law: ε_f' and c. The analysis suggests that the exponent c-value can be related to the degree of plastic strain incompatibility between grains, and the cumulative irreversible cyclic plastic strain to crack initiation is a relevant damage indicator for crack initiation. Consequently, our approach allows giving a physical base of engineering law.

Keywords: Cyclic slip plastic irreversibility; Low-cycle fatigue; Manson-Coffin fatigue crack initiation law; Ni-base superalloy; Atomic force microscopy (AFM)

1. Introduction

Fatigue damage of materials that exhibits flow localization is very often related to a surface phenomenon [1]. In these materials, the cyclic slip irreversibility, which is a phenomenon resulted from the slip displacements caused by the movement of dislocations in the forward part of the fatigue loading cycle that are not fully recovered in the reverse part of the fatigue loading cycle, is a primary source of fatigue crack initiation [2-3]. Cyclic slip irreversibility may arise from quite different physical mechanisms such as irreversible dislocation displacements resulted from cutting of precipitates and surface roughening caused by to-and-fro glide of dislocations, as recapitulated in Refs. [4-5]. Some other important factors known to promote cyclic slip irreversibility are the local microstructure (e.g. grain size, precipitate size, deformation twinning, extended stacking fault and grain boundary) and environment (e.g. oxygen and/or hydrogen interstitials) [6-10].

Cyclic slip irreversibility is difficult to be analyzed quantitatively [11]. Thereby, there exist many different forms of characterizing the cyclic slip irreversibility in which they are given numerical values, as summarized in Ref. [4]. Though, the cyclic slip irreversibility defined as the fraction of

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