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Abstract

The crack extension behavior of long cracks in the near-threshold regime is analyzed at R = 0.1 using flat dog-bone specimens of a commercial aluminum alloy in two heat treatment conditions. Once a pre-crack had been introduced by cyclic compression, experiments were performed at an approximately constant ΔK-value close to the threshold initially determined by continuous load increase. Analyses of the fractured specimens in SEM and μ-CT show that the cracks propagated in an intermittent way caused by pinning of the crack front by primary precipitates and pronounced shear-dominated crack extension on low-index crystallographic planes excepting the {111} plane. Interaction with primary precipitates and grain boundaries deflected the shear-controlled cracks but did not change the crack extension mode.

1. Introduction

The crack initiation phase is typically regarded as the life-determining phase in the very high cycle fatigue (VHCF) regime. However, cracks initiated from pre-existing flaws may cause a significant shortening of the crack initiation phase with a notable amount of lifetime spent in the crack propagation phase. Long lifetimes can still be achieved in the case of very small cyclic loads, which keep the crack in the near-threshold regime but may lead to unexpected crack extension behavior. This phenomenon is related to the fact that the crack tip field interacting with the microstructure is short-ranged [1-3], and microstructural features can consequently block or deviate this field completely. It is hence important to take the crack extension phase in the near threshold regime into account in addition to the traditional VHCF scenario focused on crack initiation.

It was found in [4] that typical small crack effects can be found in this case, e.g. arrest of the crack front at microstructural barriers (e.g. [5-9]) and even shear-dominated crack extension analogous to stage-I crack growth as classified by Forsyth [10]. The last effect was the most surprising one as the cracks studied in [4] were definitely long cracks extending over several grains. However, the tests in [4] were performed at a stress ratio of R=-1 and hence not in a typical fracture mechanics testing scenario which may have contributed to enhance shear-dominated effects. Also some minor crack closure effects may have developed in the compression phase of the loading cycle when the crack faces were in contact. Therefore, the unexpected crack extension behavior found in [4] has to be verified under tension-tension loading. To this end, fatigue crack growth experiments at a stress ratio