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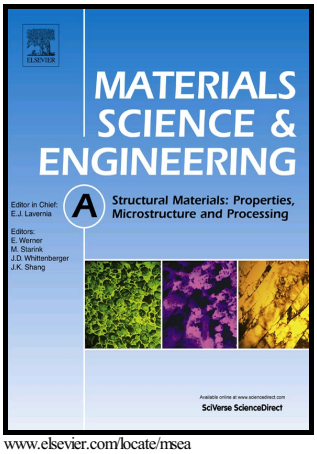

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Influences of PPB, PPB Affect Zone, Grain Boundary and Phase Boundary on Crack Propagation Path for a P/M Superalloy FGH4096

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Abstract

The fatigue crack growth (FCG) tests for hot isostatic pressed (HIPed), isothermal forged (IFed) and heat treated (HTed) FGH4096 superalloys were conducted in air at 650-750 °C with and without dwell time to investigate the effect of microstructural characteristics on FCG paths. Optical microscope (OM) and scanning electron microscope (SEM) with energy dispersive spectrometer (EDS) were used to observe and analyze the microstructures. After FCG tests, fracture surfaces and central sectioned surfaces were observed to investigate the crack propagation paths. FCG rate curves were also plotted to assist the analysis of FCG behaviors. The results indicated that prior particle boundaries (PPBs) were prevalent in HIPed specimens, but they transformed to PPB affect zones (PAZs) in IFed specimens by isothermal forging. After the standard heat treatment, PAZs were eliminated, and grain boundaries which were decorated with continuously distributed carbides became prevalent in HTed specimens. Grain boundaries in HTed specimens made the greatest contribution to FCG, and the highest FCG rate was attributed to the predominant intergranular failures. PPBs also had a pronounced influence on FCG, and the dominant failures of interparticle resulted in the high FCG rate in HIPed specimens. However, PAZs made the least contribution to FCG mainly owing to their particular microstructures. Thus, the prevalent failures of PAZs resulted in the lowest FCG rate in IFed specimens. Phase boundaries of large γ′ precipitates in PPBs or PAZs also had accelerating effect on FCG, while their contributions were relatively small.

Keywords: FGH4096 superalloy, fatigue crack growth, microstructural characteristics

1. Introduction

Aeroengine turbine discs operate at severe environment of elevated temperatures, high stress and various corrosive elements over significant period of time. These require disc materials to possess high strength, outstanding fatigue-creep performance along with good oxidation and corrosion resistance under the service condition [1]. Powder metallurgy (P/M) Ni-based superalloys have been widely used in the manufacturing of the high pressure turbine disks due to their good combination of high temperature strength and damage tolerance with segregation-less microstructures, fine grain size and uniform precipitates distribution [2-4]. For damage tolerance design, fatigue crack growth (FCG) behavior is one of the most important factors to be considered, and it is significantly influenced by microstructural characteristics of an alloy.

Hot isostatic pressing (HIP) is a common consolidation method of P/M technique which has been applied to the manufacturing of many high-performance superalloys, such as René 95 [5], LSHR [6], EP741NP [7], Astroloy [8] and Inconel 718 [9]. However, the application of the HIPed components is limited because of the introduction of previous particle boundaries (PPB). Previous