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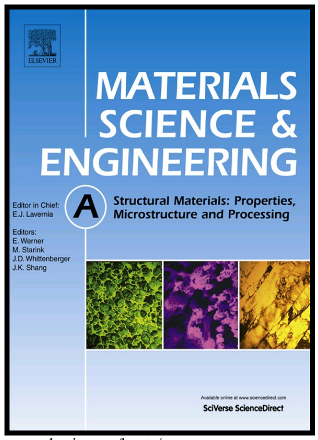

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PII: S0921-5093(18)30270-3
DOI: https://doi.org/10.1016/j.msea.2018.02.062
Reference: MSA36149

To appear in: *Materials Science & Engineering A*

Received date: 20 January 2018
Revised date: 13 February 2018
Accepted date: 14 February 2018

Cite this article as: Joshua McCarley and Sammy Tin, Utilization of hot deformation to trigger Strain Induced Boundary Migration (SIBM) in Ni-base Superalloys, *Materials Science & Engineering A*, https://doi.org/10.1016/j.msea.2018.02.062

Utilization of hot deformation to trigger Strain Induced Boundary Migration (SIBM) in Ni-base Superalloys

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Keywords: Grain Boundary Engineering, CSL, Annealing, Twin, Misorientation, Ni-base Superalloy

Abstract

The effect of strain on the resultant microstructure of an experimental low stacking fault energy Nickel based superalloy containing 24 wt. pct. Co was investigated. Billets subjected to a preliminary heat treatment at 1110ºC were compressed to strain limits of 0.15 and 0.5 at strain rates ranging from 0.1/s to 0.01/s and temperatures at 1020ºC and 1060ºC. The as-deformed microstructures were assessed and characterized using electron backscatter diffraction, as were microstructures corresponding to a super-solvus anneal heat treatment at 1160ºC for one hour. This study sought to identify a critical strain limit at which conditions indicative of Strain induced boundary migration (SIBM) could be effectively triggered for the experimental Ni-based superalloy over a set range of thermal-mechanical parameters. Microstructures corresponding to SIBM were then compared to more extensively deformed billets which contained notable fractions of dynamically recrystallized grains to quantify differences in the length fraction and density of $\sum 3$ twin boundaries of the respective microstructures. Though billet samples deformed to both 0.15 and 0.5 contained notable magnitudes of stored strain energy, microstructures deformed to 0.15 were noted as having maintained larger length fractions of $\sum 3$ twins due to a predominant absence of dynamic recrystallization. Annealed samples originally deformed to 0.15 yielded annealing twin length fractions as high as 59% when compared a sample deformed to the 0.5 strain limit under equivalent thermal-mechanical conditions that resulted in a twin length fraction of 50%. Although samples deformed to the lower strain limit exhibited higher length fractions of annealing twins, samples deformed to the higher strain limit of 0.5 were noted to yield $\sum 3$ densities as high as $0.65\mu m^{-1}$, whereas the annealed sample deformed under equivalent thermal-mechanical parameters to the 0.15 strain limit produced $\sum 3$ densities as low as $0.32\mu m^{-1}$.

1. Introduction

Nickel-based superalloys are commonly implemented in the high temperature sections of modern gas turbine engines. They are widely considered to be the materials of choice for turbine engines due to the fact that they have been shown to exhibit excellent resistance to fatigue, creep, and corrosion at elevated temperatures.[1-4] These favorable features are due to microstructures possessed by Ni-based superalloys, which consist of coherent intermetallic particles of Ni_3Al (γ') with an ordered $L1_2$ crystal structure, which is contained within an austenitic (γ) disordered face-centered cubic (FCC) nickel matrix.[5]

Grain boundary engineering (GBE) involves the manipulation of the distributions and relative fractions of high coincident lattice (CSL) boundaries with $\sum<29$, which largely correspond to “special” boundaries known as twin boundaries. Various studies focusing on Ni-