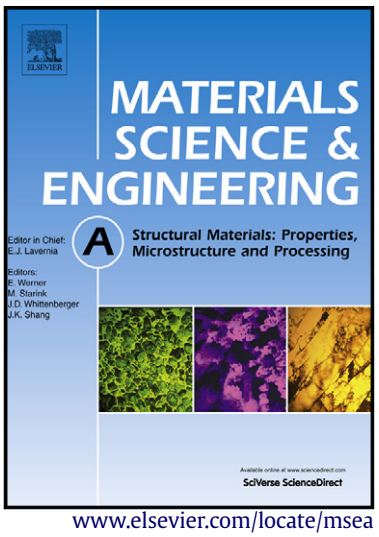

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On the role of Re in the Stress and Temperature Dependence of Creep of Ni-base Single Crystal Superalloys

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Abstract

In the present study we investigate the creep behavior of a Ni-base single crystal superalloy. We evaluate the stress and temperature dependence of the minimum creep rate, which shows a power law type of stress dependence (characterized by a stress exponent n) and an exponential type of temperature dependence (characterized by an apparent activation energy Q_{app}). Under conditions of high temperature (1323 K) and low stress (160 MPa) creep, n and Q_{app} are determined as 5.3 and 529 kJ/mol, respectively. For lower temperatures (1123 K) and higher stresses (600 MPa) the stress exponent n is higher (8.5) while the apparent activation energy of creep is lower (382 kJ/mol). We show that there is a general trend: stress exponents n increase with increasing stress and decreasing temperature, while higher apparent activation energies are observed for lower stresses and higher temperatures. We use density functional theory (DFT) to calculate the activation energy of diffusion for Re in a binary Ni-Re alloy with low Re-concentrations. The resulting energy is almost a factor 2 smaller than the apparent activation energy of creep. We explain why it is not straightforward to rationalize the temperature dependence of creep merely on the basis of the diffusion of one alloying element. We show that the evolution of the microstructure also must be considered.

Key words: Single crystal superalloys, creep, stress and temperature dependence, diffusion of Re, stress exponent, apparent activation energy.

1. Introduction

Nickel base single crystal superalloys (SXs) are widely used as blade materials in gas turbines for aero engines and for energy conversion [1-4]. They operate at high temperatures, close to their melting point, where they have to withstand mechanical loads in the creep range. The high temperature strength and superior creep resistance of SXs is governed by their microstructure, which is characterized by two heterogeneities. A large scale heterogeneity is related to the cast microstructure. One can identify dendrites and interdendritic regions, with typical primary dendrite spacings of about 400 µm [2,3]. Another small scale heterogeneity is related to the well known γ/γ' microstructure [3-5].