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Comportement mécanique et durée de vie du superalliage à solidification dirigée DS200.

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HIGH TEMPERATURE DAMAGE MECHANISMS IN DS200+HF ALLOY

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Ni-based directionally solidified DS200+Hf superalloy (Hafnium content of about 1.7%) is used for the manufacturing of low pressure turbine blades for aeroengines and industrial gas turbines and it consists of near <001> columnar grains oriented along the solidification direction and with random secondary orientations. The main interest of this work is to characterize the anisotropic creep and fatigue behaviors since during service operations, due to the complex geometries of blades and to the thermal gradients, both longitudinal and off-transverse loading directions have to be considered. Moreover, the casting process induces grain size differences from the root to the top of the components whose impact on the mechanical properties has to be characterized.

In this study, the main objective is to investigate the durability of this alloy and the damage mechanisms under creep and low cycle fatigue solicitations for four different cristalline structures: DS200+Hf composed of fine grains loaded longitudinally (i.e. parallel to the solidification direction), the same alloy composed of coarse grains solicited transversally to the solidification direction, the same alloy composed of fine grains (about 10 times smaller than the coarser ones) also solicited in the transversal direction and finally, the single crystal version, Mar-M200+Hf, loaded along a near <001> crystallographic orientation.

Creep tests were performed at 900°C for different initial applied stresses and interrupted creep tests and experiments performed under vacuum were specially used to investigate both the early stages of damage and the grain size effect for transverse loading. From all the results, it is observed a pronounced decrease of the strain to failure for samples loaded along the transverse direction compared to samples tested along longitudinal direction or to the monocrystalline case. Fracture surfaces observations revealed that the lower creep ductility for the fine grain specimen loaded along the transverse direction results from an intergranular failure mode. Due to this fracture mode, a higher sensitivity of the creep life to the applied stress has been observed under transverse loading compared to the longitudinal one. Fatigue tests performed at 650°C revealed that crack initiation always occurred on internal defects, like carbide clusters, and that the durability is controlled by the defect size. After presenting the results, the differences in damage modes according to the loading directions will be discussed.

A MULTI-SCALE STRATEGY FOR THE NUMERICAL MODELING OF DIRECTIONALLY SOLIDIFIED NI-BASE SUPERALLOYS

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The present work is dedicated to the mechanical behavior of the directionally solidified Ni-base superalloy DS200. This kind of material is characterized by a columnar microstructure along a macroscopic axis (x3 in the sequel). Each grain is then assumed to be a cylinder with a FCC <001> crystallographic direction collinear to x3. For the moment, purely macroscopic models are widely used for structural design by introducing a transversely isotropic symmetry [1]. However, the hypothesis of a high number of grains is not verified in some cases as in aeronautical turbine blades.

That's why, the contribution is focused on taking into account local microstructure effects by using homogenization methods adapted to polycrystalline aggregates. "Mean-field" models are constructed around a "localization" relation which transfers macroscopic variables (e.g. stress or strain) to the grain scale in order to use locally Crystal Plasticity models. At the local scale, the Méric-Cailletaud model, developed especially for Ni-base superalloys, is used [2]. This model was calibrated using experimental tensile tests of the literature at 650°C on the longitudinal direction of the columnar aggregate. For modeling transverse tests, we have to define a scale transition rule accounting for intergranular effects. An extension to local heterogeneous elasticity tensors [3]. of a class of mean-field models (the so called "β rules") is used. The evolution of plastic accommodations has to be calibrated by means of Finite Element Crystal Plasticity (FECP) simulations of a Representative Volume Element (RVE).

This kind of model is hardly applicable for components where the grain size is not "small" with respect to the component size. This is the domain of "oligogranular components", where the basic condition supporting the homogenization method (the scale separability), is violated. To address this problem, an approach coupling "mean-field" and "full field" computations is proposed. The aim of the study is to be able to derive the scatter in the real component from a "single shot" calculation with a uniform field model.

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