Coupled Thermomechanical High Cycle Fatigue in a Single Crystal Ni-Base Superalloy

Michael R. Hirsch, Robert L. Amaro, Stephen D. Antolovich, Richard W. Neu

PII: S0142-1123(13)00132-1
DOI: http://dx.doi.org/10.1016/j.ijfatigue.2013.04.026
Reference: JIJF 3119

To appear in: *International Journal of Fatigue*

Received Date: 7 November 2012
Revised Date: 22 April 2013
Accepted Date: 26 April 2013

Please cite this article as: Hirsch, M.R., Amaro, R.L., Antolovich, S.D., Neu, R.W., Coupled Thermomechanical High Cycle Fatigue in a Single Crystal Ni-Base Superalloy, *International Journal of Fatigue* (2013), doi: http://dx.doi.org/10.1016/j.ijfatigue.2013.04.026

Coupled Thermomechanical High Cycle Fatigue in a Single Crystal Ni-Base Superalloy

Michael. R. Hirsch [a,*], Robert L. Amaro [b], Stephen D. Antolovich [a,c], Richard W. Neu [a,c]

[a] George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, 801 Ferst Drive, Atlanta, GA, 30332-0405, USA

[b] Formerly with George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, 801 Ferst Drive, Atlanta, GA, 30332-0405, USA. Currently with the National Institute of Standards and Technology, 325 Broadway, Boulder, CO, 80305, USA

[c] School of Materials Science and Engineering, Georgia Institute of Technology, 771 Ferst Drive, Atlanta, GA, 30332-0245, USA

*Corresponding author: Tel.: +1 978-660-5847
E-mail address: m.hirsch@gatech.edu

Keywords: Thermomechanical fatigue; Life modeling; Ni-base superalloy; Load interaction

Abstract

Thermomechanical fatigue (TMF) is the life-limiting damage phenomenon occurring in gas turbine components. Laboratory TMF tests are traditionally used to simulate the operating conditions inside of the turbine. However, typical LCF laboratory TMF test conditions do not account for the superposition of a HCF waveform which occurs during operation. This work studies the effects of the superposition of a HCF waveform during a high temperature hold occurring in both in-phase and out-of-phase bithermal fatigue TMF tests performed on a single crystal Ni-base superalloy. Results indicate that an atypical inelastic deformation-environmental degradation interaction is caused by the modification of the waveform due primarily to the change in the mean strain during HCF loading. The effect on life was found to be severe under certain conditions. Analysis of the deformation response and the extent of environmental degradation, in the form of γ' depletion, are presented. An existing physics-based life model (Amaro, R.L., Antolovich, S.D., and Neu, R.W., "Mechanism-based life model for out-of-phase thermomechanical fatigue in single crystal Ni-base superalloys," *Fatigue & Fracture of Engineering Materials & Structures*, 2012) [1], which explicitly accounts for inelastic-environmental interactions, is used to provide insight to the likely dominant deformation modes.

Introduction

Thermomechanical fatigue is the damage process of primary concern for turbine blades. TMF deformation results from the superposition of mechanical and thermal waveforms. The waveforms can be in-phase (IP), such that the maximum temperature occurs at the maximum applied load, or out-of-phase