Accepted Manuscript

Application-oriented description of time-/temperature dependent crack growth in a conventionally cast nickel-based superalloy

Karl Michael Kraemer, Falk Mueller, Matthias Oechsner

PII: S0142-1123(16)30388-7
DOI: http://dx.doi.org/10.1016/j.ijfatigue.2016.11.025
Reference: JIJF 4140

To appear in: *International Journal of Fatigue*

Received Date: 14 July 2016
Revised Date: 14 November 2016
Accepted Date: 16 November 2016

Please cite this article as: Michael Kraemer, K., Mueller, F., Oechsner, M., Application-oriented description of time-/temperature dependent crack growth in a conventionally cast nickel-based superalloy, *International Journal of Fatigue* (2016), doi: http://dx.doi.org/10.1016/j.ijfatigue.2016.11.025

APPLICATION-ORIENTED DESCRIPTION OF TIME-/TEMPERATURE DEPENDENT CRACK GROWTH IN A CONVENTIONALLY CAST NICKEL-BASED SUPERALLOY

Karl Michael Kraemer*, Falk Mueller, Matthias Oechsner
Fachgebiet und Institut für Werkstoffkunde, Technische Universität Darmstadt
Grafenstrasse 2, 64283 Darmstadt, Germany

*Corresponding author: kraemer@mpa-ifw.tu-darmstadt.de

Abstract

The estimation of crack growth (CG) in conventionally cast nickel-based superalloys is of particular interest, since their low ductility and large grain size makes them prone to quasi-brittle fracture. Components made from this material class are often subjected to complex thermo-mechanic fatigue (TMF) loads. CG-testing under TMF loads is expensive and not yet standardized. In addition, many damage mechanisms contribute to the crack growth process under TMF conditions. Nevertheless the need for validated crack growth estimations increases with the demand for flexible load cases.
In this work, isothermal and TMF fatigue CG test data of the nickel-based cast alloy C1023 are described by a linear-accumulative CG-model. In this model, fatigue crack growth is treated as temperature-independent. Additionally, two temperature-dependent CG-contributions from creep crack growth and through oxidation damage are considered. γ'-depletion caused by surface oxidation was found to play a dominant role. By dissecting given load cycles into time steps, a revised calculation procedure was implemented to realize estimations for isothermal and thermo-mechanical crack growth, independent from the cyclic time-temperature evolution.
The procedure is validated against a variety of CG-experiments, including various TMF-tests with and without hold times. It is also possible to assess the crack evolution and the dominant driver of crack propagation.

Keywords: superalloys; crack growth rate; thermo-mechanical fatigue; linear damage summation; linear elastic fracture mechanics

1. Introduction

Nickel based cast superalloys are commonly used for gas turbine components for aero and power generation applications. The increased demand for flexibility, with more transient situations, leads to thermo-mechanical fatigue (TMF) which can be more damaging than an isothermal loading [1]. Due to their low ductility, cast nickel superalloys are prone to quasi-brittle fracture under such loads.
TMF conditions are characterized by the phase shift between the thermal and mechanical stress cycle. A situation with maximum mechanical stress at maximum temperature is called an in-phase (IP) load. An out-of-phase (OP) load arises when the minimal mechanical load occurs at maximum temperature. Even at the maximum temperatures (typically between 800 and 1000 °C) nickel-based cast alloy show low ductility and brittle cracking.