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# Interaction of hot corrosion fatigue and load dwell periods on a nickel-base single crystal superalloy

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**Abstract.** The effects of type II hot corrosion on the fatigue resistance of turbine blade superalloys is of growing interest as gas turbine (GT) original equipment manufacturers (OEMs) strive to optimise the operational efficiencies and versatilities of GT systems. Hot corrosion fatigue has been observed in the under platform regions of first stage GT blades, this location is subject to both relatively high principal stresses and stress gradients, combined with temperatures up to those associated with type II hot corrosion (500 °C-700 °C). The effect of the deposition flux of corrosive salt species and the tensile stress dwell period on the fatigue performance and resultant crack morphologies of single crystal (SC) superalloy CMSX-4 has been studied at 550 °C. Deposit recoat methodologies were applied to specimens that were cyclically fatigued with a load-controlled trapezoidal waveform. It was observed that introducing a longer dwell period increased the number of {100} crack initiations and reduced the fatigue life (load cycles to failure). Optical and SEM microscopy and EDX techniques were used to examine specimen fractography, and mechanisms of crack advance and propagation discussed.

**Keywords:** Hot corrosion, Fatigue Dwell Period, Single Crystal Superalloy

## 1. Introduction

Gas turbines (GTs) are used for a range of power generation applications; some of the more common being industrial power generation and aviation engines. With GTs relevance to the future of energy and aerospace industries looking to remain high [1], and demand for GTs to generate sustainable clean and efficient power being significant [2][3][1], GT original equipment manufacturers (OEMs) are constantly striving to optimise operation and efficiencies. One of the key limiting factors effecting the power density and thermal efficiencies that can be achieved by GTs is the operational gas temperatures reached in the turbine section of the engine. These gas temperatures are largely limited by the material capabilities in the following areas; high temperature oxidation/corrosion performance, and high temperature mechanical performance such as creep and fatigue [4]. Often blade cooling is used in first stage turbines in order to reduce the blade temperatures and improve the mechanical properties, however the increasing temperatures can result in the extended effect of hot corrosion. In addition to increasing temperatures the low cycle fatigue (LCF) duty cycles GTs are subjected to can also be intensified as a result of increased multi start up and shut down procedures. This can be as a result of increased renewables and peak loads on the energy grid in the case of industrial GTs, and increased short haul flights in the case of aviation engines. These combined factors provide the motivation for conducting combined hot corrosion fatigue testing.

Due to the importance of the high temperature material properties and degradation models for GT component design, there is a large amount of research available and a good understanding of them [5][6][7]. However, whilst it has been observed [8], the interactions and mechanisms generated as a result of combined hot corrosion and mechanical fatigue is not currently a heavily researched area and as such there is a limited understanding of these interactions. As a result, combined material degradation mechanisms not predicted by current design life methods have resulted from simultaneous hot corrosion and mechanical fatigue [9]. Type II hot corrosion has been reported to both assist crack initiation due to corrosion pitting, and accelerate fatigue crack propagation [10]. The work presented in this paper focuses