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Failure analysis of a third stage gas turbine blade

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ABSTRACT

This paper investigates a third stage turbine blade failure in the 150 MW unit of a thermal power plant. This primary event caused extensive damage to the unit, i.e. rupture of all blades present in the third and subsequent stages. The blade is made of nickel-based superalloy, Inconel 738, and the blade failure occurred at approximately 22,400 operating hours (25,600 equivalent operating hours) after a major overhaul. Several examinations were carried out in order to identify the failure's root cause: visual examination, SEM fractography, chemical analysis, micro-hardness measurement, and microstructural characterization.

The fracture on the turbine blade is located at the top fir tree root and the fracture surface exhibits two characteristic zones: the first zone shows slow and stable crack growth with crystallographic faceted cracking and striation formation, and the second shows interdendritic fracture, typical of final stage failure.

From the examinations carried out, it was possible to identify the cause of the primary failure. The identified fracture mechanism was high cycle fatigue originated by fretting on the fir tree lateral surface (i.e. fretting fatigue).

1. Introduction

Gas turbine blades are critical components of a power plant. In the event of their failure, the power plant will shut down, which can lead to prolonged outages and economic loss. When this occurs, it is necessary to conduct a detailed failure analysis of the turbine blades in order to understand the problem and improve the turbine system's reliability [1,2].

During the last few decades, the operating temperatures of gas turbine engines have been continually increased to achieve increased engine power and efficiency. For this reason gas turbine blades are made of nickel-based and cobalt-based superalloys: these are the only materials able to withstand the combination of high stress and high temperature [3], while weathering the oxidative and corrosive environment.

Turbine blades are susceptible to damage and crack formation in regions of contact (serrations) exposed to both centrifugal loading and oscillatory vibrations. This phenomenon is known as fretting fatigue and often occurs in the blade and disk attachment region of gas turbines and jet engines [4]. Fretting is a phenomenon that occurs at the contact area between two materials under load and subject to slight relative movement by vibration or some other solicitations. Damage begins with local adhesion between mating surfaces and progresses when adhered particles are removed from the surface [5]. Fretting fatigue is similar to fretting contact but with the interface oscillation originating from an additional remotely applied cyclic bulk load [6].

This wear mode can cause surface micro-crack initiation within the first several thousand cycles, significantly reducing the component life. Additionally, cracks due to fretting are usually hidden by the contacting components and are not easily

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