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Analysis of fracture and cracks of single crystal blades in aero-engine

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ABSTRACT

An aero-engine failed during testing. It was found that a gas-cooled single crystal turbine blade had fractured and several other blades had cracked. In order to find out the failure mode and cause, fracture surface observation, metallurgical structure examination and surface trace observation were carried out, and the stress state of the blades during service was analyzed by finite element method (FEM). The results show that the failure mode of the blades is fatigue fracture caused by excessive stress. friction traces can be found at the end of the blades, and the microstructures of the blades are normal. The failure of the blades was mainly caused by two factors. On one hand, cracks initiated at the stress concentration zone, where greater working stress existed. On the other hand, there existed friction between the blade tips and the outer shell, which added an alternate stress to the stress concentration zone. Based on the analysis above, the transient round angle at the stress concentration zone should be increased, and the gap between the blade tips and the outer shell should be adjusted to avoid friction, so that the reliability of the blades can be improved.

1. Introduction

Turbine rotor blades are important components with complicated structure and under the effect of high temperature and high load, whose performance and reliability are directly related to the performance, durability, reliability and life of engines [1–3]. In the past several decades, in order to enhance the high-temperature performance of turbine rotor blades, two primary measures have been taken. On one hand, directly solidified superalloys have been widely used to substitute for deforming equiaxial superalloys, and now single crystal superalloys by direct solidification and with optimal performance are widely used [4–6]. On the other hand, hollow air-cooled blades have been gradually used to substrate for solid blades so that the heat dissipating efficiency can be enhanced. However, the more complicated structure of the hollow air-cooling blades results in more complicated stress state, which may bring some disadvantages to the fatigue life of the blades [7,8].

An aero-engine failed after testing for 35 min. It was found that a Grade I turbine blade fractured, and other nine bladed were found to have cracks. The distribution of the fractured and cracked blades was shown in Fig. 1.

In order to find out the failure mode and cause, fracture surface observation, metallurgical structure examination and surface trace observation were carried out, and the stress state of the blades during service was analyzed by finite element method (FEM).

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