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Recrystallization and fatigue fracture of single crystal turbine blades

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ABSTRACT

Two rotor blades in an aero-engine fractured during testing. The fracture mode and cause were analyzed on the basis of fracture surface observation, chemical analysis, and metallurgical structure examination. The results show that the two blades failed in the same mode – fatigue fracture caused by recrystallization. In order to find out the cause of recrystallization, simulation tests were carried out by grit blasting and solution heat treatment. It is found that recrystallization formed during solution treatment because of the plastic deformation by grit blasting, and with the increase of the pressure and time for grit blasting, the depth of the recrystallized layer went up.

1. Introduction

Owing to the elimination of the grain boundaries perpendicular to the main stress axis, directionally solidified (DS) and single crystal (SC) superalloys have excellent mechanical properties, such as high heat resistance, fatigue strength, creep strength and vibration damping ability, and have been introduced into most of the advanced aero-engines.

An aero-engine failed with the rotational speed declining suddenly from 52,000 r/min to 51,700 r/min and vibration enlarging abnormally during testing. After checking, it was found that two rotor blades fractured. There were totally 39 same rotary blades as these two. None of the blades was found to have tip rubbing trace. Some of the blades were found to have collision trace. These blades are made of a SC superalloy, and the bodies of the blades are covered with coating. In the present work, the fracture cause and mode of the failed blades were analyzed, and some prevention measures for such failure were proposed.

2. Experimental procedure

Fracture surface and metallographic structure observation was carried out by scanning electron microscopy and optical microscopy. Metallographic specimens were prepared by metallographic polishing. The polished specimens were etched in the reagent consisting of 20 g $CuSO_4$, 100 ml HCl and 100 ml H_2O.

3. Experimental results

3.1. Macroscopic features

The failed blades are shown in Fig. 1, which are referred to as No. 14 blade and No. 21 blade according to their locations in the aero-engine. For No. 14 blade, the fracture took place at the 2/3 height of the blade body, and the whole transverse

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