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Assessment of premature failure in a first stage gas turbine nozzle

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ABSTRACT

Premature failure of a first stage gas turbine nozzle has been the subject of a precise study and the present investigation comprehensively describes it. It was determined that failure occurred by thermal fatigue mechanism during start-up/shutdown of gas turbine. The cracks initiated from the surface of trailing edge section in which intergranular oxidation caused by high temperature hot corrosion (HTHC) was significant. In addition, the presence of continuous film of carbides at the grain boundaries was a direct result of transformation of primary carbides M_6C type to secondary carbides $M_{23}C_6$ type as a result of high temperature operation of the nozzle. Therefore, the nozzle crack initiation and propagation was facilitated by grain boundaries brittleness caused by formation of continuous film of carbides $M_{23}C_6$ at the grain boundaries. Furthermore, to experimentally confirm the degradation of the nozzle, mechanical test data was taken into consideration. It was found that the tensile properties of the alloy have decreased. In the similar test conditions, the hardness of the exposed alloy increased considerably compared to the as-cast sample, which could be attributed to the microstructural degradation, especially formation of $M_{23}C_6$ carbides in the large quantity in the matrix alloy.

1. Introduction

First stage gas turbine nozzles are mainly made of cobalt-base superalloys due to their intrinsic properties such as good stress-rupture parameters, excellent hot corrosion and oxidation resistance. The function of nozzles in the gas turbine is guiding the flow of hot gases into the bucket of turbine at the maximum favorable angle of incidence. Therefore, they are subjected to the highest-temperature gases and attain the highest metal temperatures of any component in the turbine [1,2].

Generally, first stage nozzles have severe operation conditions during service characterized by following reasons:

- Operation environment (high temperature, fuel, air contamination, etc.).
- High thermal stresses (thermal gradients).

Typically there are various factors leading to reduction of nozzle lifetime, including creep, thermal fatigue, corrosion, erosion, oxidation and foreign object damage [3]. Therefore, two distinct types of damage can be recognized by these factors: surface damage and internal degradation. Surface damage may be due to either mechanical impact or corrosion and generally is confined to the external surface of nozzle. Internal degradation is caused by microstructural changes resulting from extended exposure at high temperature under stress. The microstructural changes are responsible for the reduction in mechanical properties. Three forms of internal degradation have been verified: (1) coarsening or overaging of carbides, (2) changes in grain boundary carbides, and (3) cavitations or void formation [4–7].

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