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Analysis of conjugated heat transfer, stress and failure in a gas turbine blade with circular cooling passages

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ABSTRACT

Prediction of heat transfer coefficients and stresses on blade surfaces keys a role in thermal design of a gas turbine blade. The present study investigates heat transfer and stress in a gas turbine blade with 10 circular internal cooling passages. 3D-numerical conjugated simulations using a FVM and FEM commercial codes, CFX and ANSYS are performed to calculate distributions of the heat transfer coefficients and the stresses, respectively. The heat transfer coefficient is the highest on the stagnation point of leading edge due to impingement of incoming gas flow. It is the lowest at the trailing edge on both pressure and suction sides due to development of thermal boundary layer. However, the maximum material temperature and the maximum thermal stress occur at the trailing edge near the mid-span. Therefore, the failure of turbine blade should be predicted by total stress resulted from the combination of thermal load and cooling.

1. Introduction

Hot components in a recent gas turbine engine have been operated over conditions of maximum material temperature for enhancing energy efficiency. Because of these environments, various cooling schemes have been used and investigated. Moreover, accurate prediction of heat transfer coefficients on external and internal blade surface is important in gas turbine cooling design and optimization [1,2]. In the last years, therefore, there have been many studies of problem including: (1) Freestream turbulence intensity [3,4]; (2) Reynolds number and Mach number [5,6]; (3) boundary layer transition [7,8]; (4) surface curvature [9]; (5) surface roughness [10,11]; (6) unsteady wake [12,13]; (7) rotational effects [14,15]; and (8) tip and platform shapes [16,17].

As well as above experimental studies many numerical studies have been carried out using CFD (computational fluid dynamics) codes [18,19], which are developed by solving Navier–Stokes equations using boundary layer modeling. Among them, TEXTAN [20] had been widely used in the industry. With developing computer technology and turbulence models, CFD has become a powerful design tool. Many researchers performed CFD prediction and compared with the test data obtained in the turbine cascade. In this paper, we have conducted an analysis to obtain the conjugated heat transfer data from analysis of thermal and mechanical characteristics using a commercial code, CFX-11 with the operating conditions in an actual gas turbine blade.

In addition, we calculated the thermal stress using a commercial code, ANSYS-11. If unsuitable cooling method is used, cracks and failures are caused by the thermal and mechanical stresses. Furthermore, the temperature gradient in hot component increases with the turbine inlet temperature increasing, and it generates thermal damage by high thermal stresses

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