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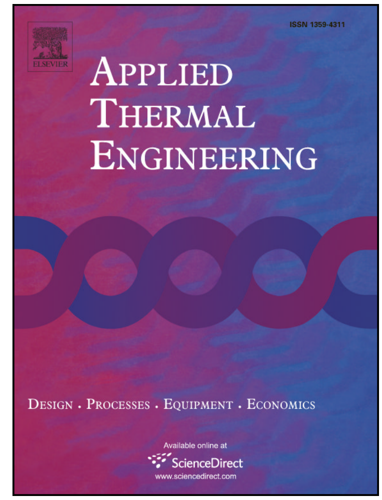

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Numerical method for the thermal analysis of a ceramic matrix composite turbine vane considering the spatial variation of the anisotropic thermal conductivity

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Abstract: A numerical method for the thermal analysis of Ceramic Matrix Composite (CMC) turbine vane was developed considering the Anisotropic Thermal Conductivity (ATC) and its spatial variation due to the vane's curved surface. A turbine vane with a cooling configuration was used as an example of the simulations; 3 different cases (Isotropic Thermal Conductivity (ITC), constant ATC, and ATC with spatial variation) were examined using the Finite Element Method (FEM). The effects of the thermal conductivity and its variation on the temperature distribution of the CMC turbine vane were also discussed. The results showed that the ATC changed the heat transfer rates in different directions inside the turbine vane, leading to a non-uniform temperature distribution. The ATC's spatial variation due to the vane's curved surface led to additional changes in the temperature distribution, especially the location of the maximum temperature and the high-temperature region. With increasing the anisotropy level, a more significant difference between the temperature fields could be observed, regardless of whether the spatial variation of the ATC was considered. The largest difference between the maximum temperatures was found to be around 107.7 K, when the ratio of the thermal conductivities in different directions was 20. The work indicates that the ATC's spatial variation should be considered in the thermal analysis of a composite hot component with a complex curved surface (such as a nozzle vane or turbine blade). The present numerical method developed for the thermal analysis, which considers the ATC's spatial variation, is of reasonable applicability and accuracy.

Keywords: heat transfer; curved surface; finite element method; 3D braided composite; temperature field.

1. Introduction

A better performance for gas turbine engines requires a higher inlet temperature [1] that is far beyond the heat resistance limits of the current turbine vane materials. In recent years, the development and implementation of highly heat-resistant materials, such as the Ceramic Matrix Composite (CMC), have attracted increasing attentions [2-5].

The CMC, a Fiber-Reinforced Composite (FRC), is of particular interests in the present study because it has anisotropic thermal conductivity, which results from different thermal properties of the fibers and the matrix, the random distributions of the fibers, and the defects introduced in the manufacturing process.

Mutnuri's experiment [6] examined the thermal conductivity of a carbon/vinyl ester composite. It was found that the Effective Thermal Conductivity (ETC) along the longitudinal direction was almost twice of that along the transverse direction. Additionally, the increase in the fiber volume fraction from

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