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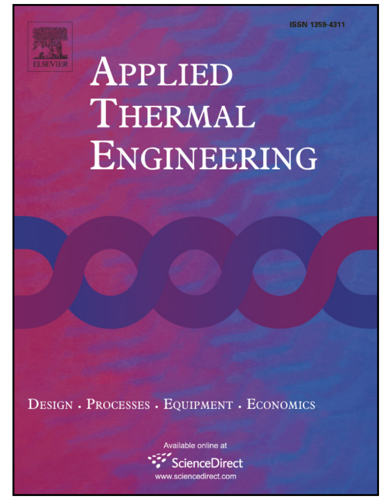

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Abstract

With the development of gas turbine, twist blades are widely used in modern gas turbine designs. Under working conditions of gas turbine, twist blades rotate in the annular cascade. Under laboratory conditions, it is often simplified by using linear cascade, or using straight blades, or using non-rotating state to study film cooling performance. The influences of the three simplifications – annular cascade versus linear cascade, twist blade versus straight blade, rotation versus non-rotation on the film cooling performance are investigated. Twist blades serve as the reference model of the paper. Three rows of cylindrical film holes are arranged at the leading edge with a pitch-to-diameter ratio P/D=8.0. One row of cylindrical film holes with a pitch-to-diameter ratio P/D=8.4 is provided on the pressure side while two rows are provided on the suction side. The steady solutions are obtained by solving Reynolds-Averaged-Navier-Stokes equations with a finite volume method. The SST turbulence model coupled with γ-θ transition model is applied for the present simulations. A film cooling experiment of a turbine vane was done and the numerical results were in agreement with experimental data. It means the numerical methodology is feasible and reliable. Besides the reference case, three cases each of which is different with the reference case either in cascade form, or in blade form, or in movement state are simulated. As for the simplification of cascade form, the main difference between the annular cascade and linear cascade appears in the area which is close to the hub, as the location of vortex core in annular cascade passage is much lower than that in linear cascade passage near the hub because of curvature effect. As for the simplification of blade form, there is a significant error of film cooling effectiveness at the leading edge regions caused by the simplification of blade form. The pressure variety at the leading edge due to geometric differences between the twist blade and straight blade coupled with rotation leads to lift off. As for the simplification of movement state, there is little effect on the area averaged film effectiveness of the whole blade, but quite a little effect on the coolant distribution. Overall, the simplification of blade form from twist to straight has the most significant effect on film cooling. The film cooling characteristics of twist blade need to be taken into consideration in the design.

Keywords: film cooling; rotating; annular; twist blade

Nomenclature

D	film hole diameter, mm
P	hole pitch, mm
s	surface length, mm
T	temperature, K
Tu	freestream turbulence intensity
η	adiabatic film-cooling effectiveness
PS	film holes on the pressure side
SS1/SS2	film holes on the suction side
SH1/SH2/SH3	film holes at the leading edge

Subscripts and Superscripts

aw	adiabatic wall
c	coolant condition
r	recovery
∞	mainstream condition
-	lateral/ pitchwise average

1. Introduction

In order to meet the increasing demand of the power output and thermal efficiency, gas turbine operates at an increasing inlet temperature. It is a challenge for the hot path components to work at a temperature which is much higher than the metal limit. Film cooling is widely used as an important protection for the components from being damaged. Cold air extracted from the compressor injects into main flow through discrete film holes on blade surface and forms a layer separating the blade from hot gas. Twist blades rotate in the annular cascade under gas turbine working