Investigation of effectiveness of applying cross-injection film cooling technique to curved surfaces

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ABSTRACT

In this thesis, liquid crystal thermography with steady-state experimental method is used to investigate the effectiveness of cross-injection film cooling technique as applied to convex surfaces. Based on a comparison with flat plate case, the feasibility of applying this cooling technique to the curved surfaces of gas turbine blades is understood. In order to produce the secondary flow phenomena in the endwall region of a turbine blade, one leg of vortices of a delta wing is used in the experiments to realize the interaction mechanism between the vortex generated by the cross-injection coolant and the secondary vortex of the main flow. In the experiments, the cooling hole diameter, hole-to-hole distances, and an included angle (120 degrees) are fixed. The main flow velocities are 6 m/s, 8 m/s, and 10 m/s, corresponding to the Reynolds numbers of 9.2x10^4, 1.24x10^5, and 1.5x10^5, respectively, for a turbine blade/vane with a chord length of 241 mm. The blowing ratios are 0.5, 1, and 2. The delta-wing vortex generator is used to generate secondary flow with upwash vortex or downwash vortex. Experimental results show that the influence trends of Reynolds number and the blowing ratio on flat plate cases agree with the literature. When the blowing ratio increases from 0.5 to 1, the film cooling effectiveness may increase. However, when the blowing ratio further increases up to 2, flow separation may occur at the coolant hole exit, causing the effectiveness to decrease in that region. This situation is the most remarkable for the concave surface. Because the cross-injection coolant generates a counter-clockwise marching vortex (viewed from upstream toward downstream), the upwash vortex in the main flow helps enhance the cross-injection vortex, hence, increase the effectiveness. On the other hand, the downwash vortex weakens the cross-injection vortex and decreases the effectiveness. Both the convex and concave curvatures hamper the attachment of cross-injection coolant to the surface, resulting in a reduction in film cooling effectiveness. The effect is also the most influential for the concave surface.

Keywords: liquid crystal thermography, cross-injection, film cooling, curved surfaces, upwash vortex, downwash vortex, Reynolds number, blowing ratio, delta-wing vortex

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