The Effect of Embedded Vortices on Film Cooling with Compound Angle Orientations

Hyo Kyung Chung and Joon Sik Lee
School of Mechanical & Aerospace Engineering
Seoul National University, Seoul 151-744, Korea

Abstract

Experimental results are presented, which describe the effect of embedded vortices on film cooling downstream of film-cooling holes with compound angle orientations. Results are obtained from a row of eleven holes which are spaced 3 hole diameters apart in the spanwise direction. The inclination angle of the hole is fixed at 35°, and two orientation angles of 0° and 60° are investigated. The blowing ratios considered are 0.5, 1.0, and 2.0. Vortex circulation magnitude is 0.22 m^2/s in the middle of film-cooling holes at a mainstream velocity of 10 m/s. Four relative positions of vortices with respect to film cooling holes are investigated. In the case of compound angle injection, the effect of rotational directions of vortices are also observed: one with the same rotational direction with the vortex generated by injectant and mainstream interaction, and the other with the opposite rotational direction. Detailed distributions of adiabatic film cooling effectiveness and heat transfer coefficient are measured using thermochromic liquid crystal.

Results show that distrubutions of local adiabatic effectiveness and heat transfer coefficient varies remarkably according to the relative position of the vortex. At the low blowing ratio, film cooling performance is mainly affected by adiabatic film cooling effectiveness. When the vortex center is located right above the film cooling hole, the adiabatic film cooling effectiveness mostly decreases compared to those of other vortex locations. Consequently a large triangular thermal spot appears. In general, the compound angle injection provides the higher film cooling effectiveness and more uniform distribution compared to the simple angle injection even in the presence of the embedded vortices.

The heat transfer coefficient is severely affected by the secondary flow in the injectant. At the low blowing ratio, the heat transfer coefficient increases in the downwash region of vortices and slightly decreases in the upwash region. As the blowing ratio increases, the heat transfer coefficient varies remarkably according to the relative position of the vortex due to the effect of the secondary flow, and is greatly affected by both the rotational direction and the relative position of the vortex.

Keywords : film cooling, embedded vortex, compound angle, film cooling effectiveness, heat transfer coefficient, thermal spot

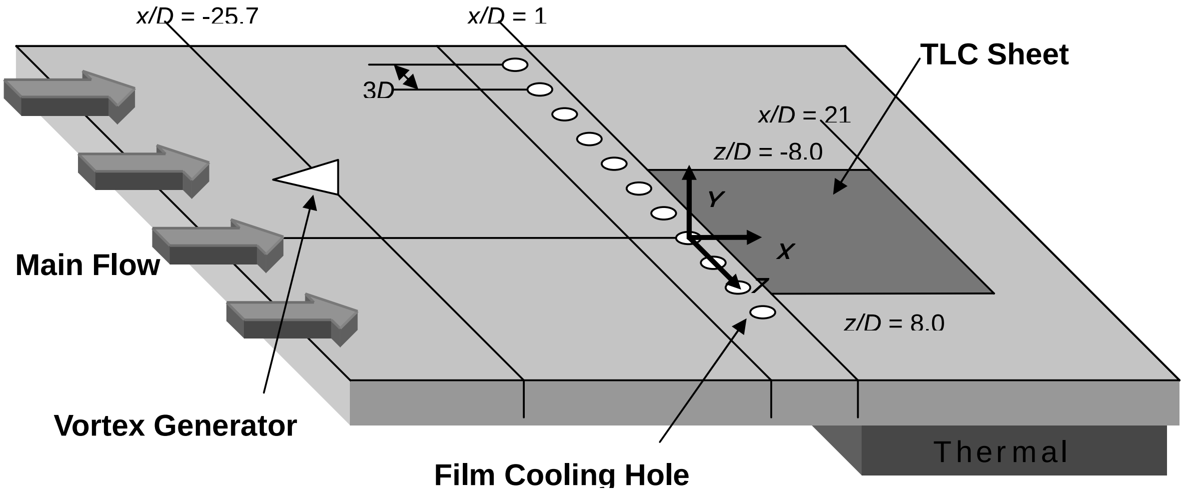


Figure 1 Schematic diagram of test section and coordinate system

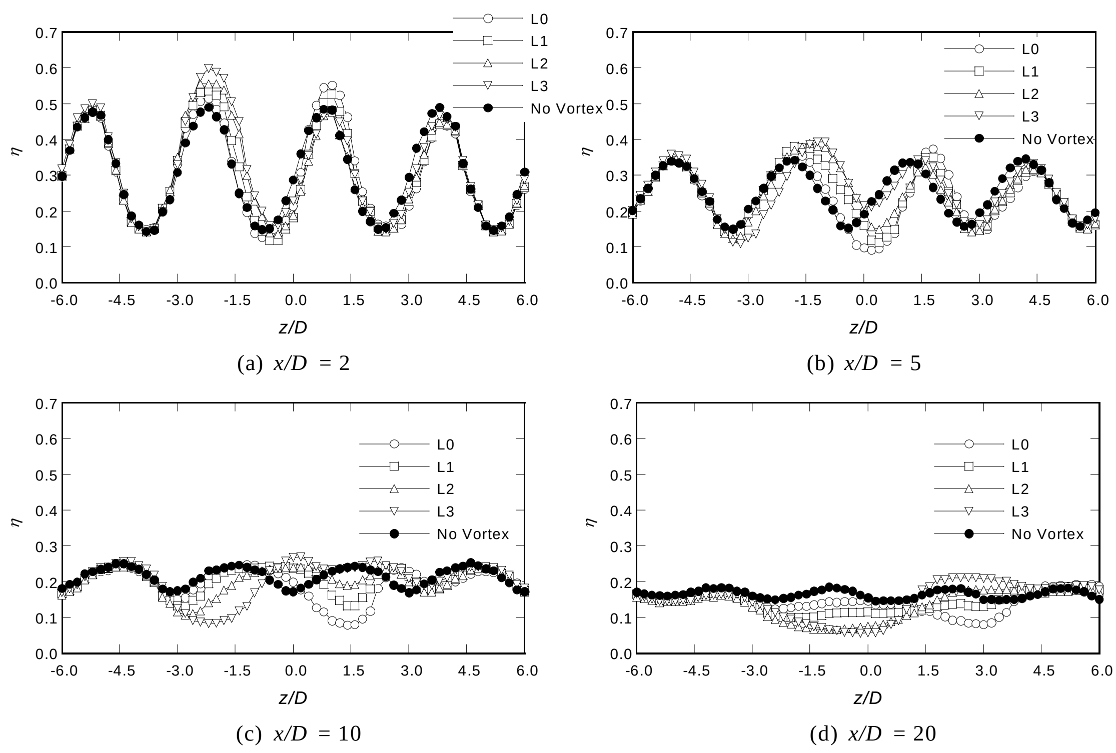
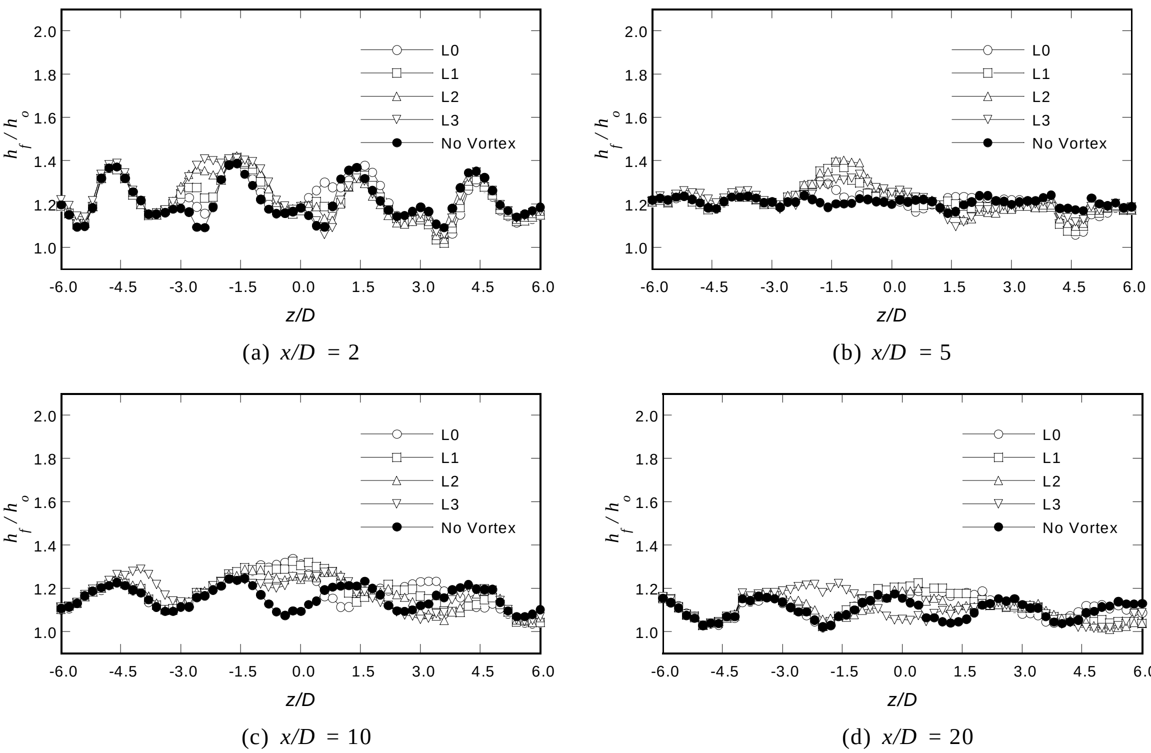


Figure 2 Local adiabatic effectiveness when $\beta = 60^{\circ}$ and $M = 0.5$
where β: compound angle, M: blowing ratio



(a) x/D = 2 (b) x/D = 5

(c) x/D = 10 (d) x/D = 20

Figure 3 Local heat transfer coefficient ratio when $\beta = 60^{\circ}$ and $M = 1.0$