Experimental and Numerical Visualization of Counter Rotating Vortices

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Visualization of the flow structure generated by passive vortex generators continues to be a matter of research in the fluid mechanics and heat transfer communities. In this study, self-sustaining counter-rotating vortex pairs (CVP) generated from a series of vortex generators (VG) have been characterized numerically and experimentally to understand the effects of the VG parameters on vortical flow structure formation. Four different types of VGs were considered by varying the taper angle from $0^\circ$ to $19.3^\circ$ at a fixed inclination angle of $24.5^\circ$ and a $Re_{Dh}$ of 1965 based on the hydraulic diameter of the test section. Flow fields were experimentally visualized using a smoke technique. Each VG induced a coherent CVP flow structure in the wake region despite the fact that the upstream flow was laminar. In the flow structures, CVPs initially dominate flow dynamics over a certain streamwise length; however, Kelvin-Helmholtz (KH) instability appears to affect the spatial evolution of CVP longitudinally. The CVP within the stability region were reconstructed digitally in 3D by interpolating several 2D smoke images taken at various spanwise planes. The smoke results indicate that as taper angle decreases, the onset location of KH instability decreases. Furthermore, the CVP trajectory within the stability region was observed to be predominantly controlled by a two-dimensional inviscid process, while the effects by the free stream were not significant. Based on the experimental observations and the numerically reconstructed 3D CVP flow structures, VG with smaller taper angle results in CVPs with higher circulation, which is a positive aspect for mass and heat transfer applications. Preliminary numerical simulations based on RANS have shown that heat transfer enhancement is about 50% in the region near the rectangular vortex generator.

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