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Vortices and Heat Transfer

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SCHOOL OF MECHANICAL, INDUSTRIAL & AERONAUTICAL ENGINEERING

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Abstract

The use of vortex methods for heat transfer has picked up considerable attention since the 1970's. Vortices have the ability to enhance heat transfer through bulk fluid mixing. Most of the research on this topic focuses on the heat transfer enhancements the vortices facilitate on heated surfaces. What was not known was the direct influences of fluid properties, of the vortices, on the heat transfer. This research project aims to understand the fluid mechanisms that aid heat transfer in a rectangular flow channel consisting of a single delta winglet vortex generator and a heated bottom surface. The research was done using numerical methods to attain results for vorticity, circulation, shear stress, helicity, and heat transfer. The computational results were validated with past experimental research and was found to be in good agreement. The results showed the formation of two counter-rotating vortices. The main vortex was generated by the vortex generator, while the induced vortex formed because of the motion of the main vortex. Velocity contour plots showed how the boundary layer was augmented by the vortices, and it was found that the downwash of the main vortex contributes most of the heat transfer, while the upwash from the induced vortex lowers heat transfer. Further inspection of Stanton number plots confirmed this. Regions of high shear stress was found under the main vortex, while lower shear stress emanated from the induced vortex. This confirmed that the vortices applied a shear stress on the boundary layer causing energy transfer to the heated surface. It was found that the circulation has an influence on the heat transfer by observing the trends of the plots for circulation and heat transfer. The results for helicity showed that there was energy transfer from the downwash of the main vortex to the heated surface. The +/- sign of the helicity indicated the direction that the main vortex tube was directed in the freestream direction while the induced vortex tube was direct in the opposite. This caused the induced vortex the lower the shear stress on the wall as it was resistant to the freestream flow. Overall, it was concluded that; (a) the circulation of the vortex has the most influence on heat transfer, (b) shear stress is the mechanism for which energy is transferred, (c) helicity gives a good indication of the vortex boundary layer mixing and hence convective heat transfer.