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Effect of longitudinal vortex generator on heat transfer in rectangular channels

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ABSTRACT

Average convective heat transfer on the top and bottom surfaces of a plain plate and four plates with a pair of delta winglet longitudinal vortex generator punched directly from the plates at attack angles of 15°, 30°, 45° and 60° respectively, is experimentally and numerically studied in the present paper. The plate fixed horizontally in the center of the tested channel is designed to simulate the forced heat transfer on the both surfaces of a single piece of fin in a fin-tube heat exchanger. Experimental results show that the average Nusselt number on the surfaces of plate increases with the increase of the attack angle of delta winglet pair compared with that of plain plate without delta winglet pair in the test range. The average Nusselt number of the plate with attack angle of 60° is slightly higher than that of plate with attack angle of 45°, yet may bring larger pressure drop. Strong longitudinal vortices are visualized when air flow across the leading-edges of the winglet pair. And a portion of air stream flows into the lower channel through the punched holes on the plates after rushing at the frontal face of delta winglet, and disturbs the flow field of the lower channel further. The heat transfer in the tested channel of five cases is also numerically investigated. Variance of average Nusselt number between the numerical results and experimental results for the five cases are all less than 10%, validating the present models and methods used for the simulation of fin channel flow with punched vortex generators feasible and reliable. The computed velocity and temperature fields are analyzed to understand the details of fin channel flow with longitudinal vortex generator. The experimental and numerical results reveal that the transverse flow of air stream through the punched holes disturbs the air flow in the lower channel, enhancing the heat transfer on the under surface of fin.

1. Introduction

Increasing demands are placed on the performance of air fin-tube heat exchanger used in air conditioning, power system, electronic chip cooling and aerospace, etc. for reasons of compactness, economy in manufacturing and operating costs, and energy conservation. A variety of techniques of enhancing air side heat transfer such as wavy fin, louver fin and slotted fin, etc. usually lead to a larger pressure loss penalty while enhancing heat transfer. One promising technique is to use vortex generators to produce longitudinal vortices inducing strong swirling motion that serves to bring about the enhancement of heat transfer at a modest cost of the additional pressure loss.

Longitudinal vortex generators (LVGs) passively create streamwise vortices that are carried through the inter-fin space by the main flow, causing bulk fluid to mix and the thickness of thermal boundary-layer to reduce. The relevant experimental and numerical research on the channel flow with LVGs can be found in literature [1-9].

Fiebig et al. [1] studied the performance of four different kinds of LVGs (delta wing, delta winglet pair, rectangular wing and rectangular winglet pair) in the developing laminar rectangular channel flow. The Reynolds numbers in this study were between 1000 and 2000. The drag induced by LVGs was found to be nearly proportional to the angle of attack and independent of the Reynolds number or LVG shape. Local heat transfer augmentation of several hundred percent and mean heat transfer enhancement of more than 50% over an area more than 50 times the LVG area were achieved. For per unit LVG area, the delta wing provided the best effectiveness of the heat transfer enhancement, the next was delta winglet, then rectangular winglet, and the last one was rectangular wing. For the same geometry shape and constant wing area of LVGs, the heat transfer enhancement was a function of aspect ratio (defined as the ratio of the span to the average chord, or the ratio of the square of span to the area of the wing or winglet). The optimum heat transfer enhancement was found for aspect ratios between 1.5 and 2.0 for the delta wing vortex generator in reference [1].

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