Sahira Hasan Ibrahim, The Effect of Longitudinal Riblet on Flow and Heat Transfer Characteristics in a Rectangular Duct, University of Technology, Mechanical Engineering Department, PH.D, *Supervisors*: Dr. Ikhlase M. Fayed Dr. Moayed R. Hasan , 2013, 171P

Abstract

The present work has investigated numerically and experimentally the effectiveness of a streamwise riblet on the flow and heat transfer characteristics a for fully developed turbulent flow in a rectangular duct heated with constant heat flux for Reynolds number based hydraulic diameter range of $(1.5 \times 10^4 - 6 \times 10^4)$.

Numerical simulations have been done by solving the governing equations (Continuity, Reynolds Averaging Navier-stokes and Energy) equations in turbulent regime with appropriate turbulence model Shear-Stress Transport (k-ω) in three dimensions by using the FLUENT version (12.1.2). It presented the effect of different design parameters of riblet, such as: geometry shape with same dimensions of height (h) and spacing (s) [knife blade ,U-shape and V-shape], geometry size of V-shape, decreasing the riblet height from (0.5 mm to 0.25 mm) and duplicating the dimension (h and S) at four (h /s) different ratios (1,0.86,0.75,0.5) and variation of peak to peak height of riblet in streamwise and spanwise direction on the flow structure and heat transfer characteristics.The velocity contours, vorticity contours, secondary flow contours, temperature contours ,the distribution of local wall shear stress and heat transfer coefficient in spanwise direction at ribs are presented as results.Also the effects of ribs on the flow and heat transfer characteristic at duct are presented, as the heat transfer efficiency and the percentage of average skin friction and Stanton number relative to a smooth surface .

In the experimental part of this work, experiments were conducted for rectangular duct of aspect ratio =10, with the manufacturing of one model of riblet Mo. (13) [(height of small riblet / height of larger riblet =0.5] which extended in numerical simulation.The numerical results indicated that there is a clear analogy between the heat and the momentum transfer over the ribelt. Maximum reduction in average skin friction coefficient and Stanton number are about (5.9 %) and (23.4%), respectively that occurred for ribs with U -shape at Reynolds number (1.5×10^4) , and (5.8 %) and (22.3%), respectively for the V-shape at Reynolds number (6×10^4). The reduction in the heat transfer is always more than the reduction in the viscous drag for the ribbed surface at the whole range of Reynolds number , which makes the heat transfer efficiency less than unity for all riblets models. The decreasing of peak to peak height ratio of V-shape between two adjacent riblets in the spanwise or streamwise direction will increase the skin friction and heat transfer coefficient more than that for the same riblet height model. The effect of ribs in drag and heat transfer reduction at rectangular duct hardly depended on Reynolds Number, since the structure of near wall layer and streamwise streaks dimensions change with Reynolds number. Experimental results for V-shape riblet indicated an increase in the thickness of hydraulic and thermal sub-layer which and shifted up the velocity profile, reducing the skin friction coefficient and Stanton number by about (6 %) and (23%).The experimental results gave a good agreement with the numerical simulation and previous works.

Keywords: drag reduction, longitudinal Ribs, heat transfer, turbulent flow

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