Abstract

A numerical study has been performed to analyse the turbulent flow behaviour along with forced convective heat transfer for a rectangular channel having double forward-facing steps with cylindrical obstacles placed near the steps. The flow equations as well as standard $k-\varepsilon$ model used for turbulence is solved by a commercial code FLUENT in ANSYS 15. Though introduction of more steps causes a high pressure drop, but can be used in beneficial manner, as rate of heat transfer is very high, for a wide range of engineering applications of cooling e.g. electronic devices, nuclear reactor, combustion chamber, gas turbine blades etc. This kind of flow behaviour is also found for flow over vehicles and buildings. With respect to simple duct flow, flow through a channel having double forward-facing steps is more complicated. In this study, a complete conceptual idea has been presented on the effect of different geometric parameters of a double forward-facing step e.g. step height ratio, obstacle diameter ratio, cross-flow position of the obstacles, step inclination angle etc., on the flow behaviour and heat transfer characteristics. The calculations have been performed for varying Reynolds number, ranging from 3×10^4 to 1×10^5. An analysis has been performed to study the effect of step height ratio and obstacle diameter ratio on the flow parameter and heat transfer performance. It is found that as the step height ratio increases the rate of heat transfer also increases with an increment in flow velocity and vorticity magnitude, turbulence characteristics in the recirculation region. Where as the effect of obstacle diameter ratio is less on the flow and the heat transfer behaviour. But an important finding has come out for obstacle diameter ratio. When obstacles getting larger in size and positioned at same centre, the heat transfer coefficient decreases for specific step height ratio and Reynolds number. But heat transfer coefficient is found to be increasing as obstacle diameter ratio increases while the bottom gap between obstacles and heated bottom wall remains constant. The cross-flow position of obstacles in vertical direction is another important parameter. To get the maximum heat transfer, the optimum cross-flow position of the first obstacle has been obtained near the middle section of the internal gap of the channel in vertical direction, where as the

optimum position of the second obstacle is its top most vertical position. Step inclination angle is also an important geometric parameter. When step inclination angle decreases, pressure drop and heat transfer coefficient also decreases. But the rate of decrease in pressure drop is relatively higher than the rate of decrease in heat transfer coefficient. So, by some agreement, the optimum step inclination angle has been found out. Lastly, a study has been conducted on the rate of entropy generation for these three main objectives. The irreversibility effect due to heat transfer and fluid friction has also be analysed for different double forward-facing step configuration with obstacles.

Keywords: turbulent forced convection, duct flow, double forward-facing step, step height ratio, obstacle diameter ratio, cross-flow position of obstacles, step inclination angle, rate of entropy generation, irreversibility.