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Heat transfer enhancement of mixed convection in a square cavity with inlet and outlet ports due to oscillation of incoming flow ☆

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ABSTRACT

A numerical study of unsteady laminar mixed convection flow in a square cavity with ventilation ports due to an oscillating velocity at the inlet port is performed. It is found that after certain time duration, a periodic variation in the fluid flow and temperature field in the cavity are created. It is observed that the heat transfer is enhanced for all the Strouhal numbers investigated in comparison to its steady state case. To realize the optimizing Strouhal number to reach the best performance of the system, the total Nusselt number and the coefficient of pressure drop in a cycle of the oscillation is evaluated with respect to the Strouhal number. It is found that for a region of the Strouhal number between 0.5 and 1, the performance of the system will be desirable with considering both the maximum heat transfer rate and minimum pressure drop in the cavity.

1. Introduction

Mixed convection heat transfer is one of the most important matters in many industrial applications such as electronic device cooling, heat exchangers, nuclear reactors and so on. Hence many researchers have investigated the properties of mixed convection in a wide range of situations [1–6]. Aydin [7] performed a numerical simulation to investigate laminar combined convection in a shear and buoyancy-driven cavity. He considered two set of thermal boundary condition in order to study the interaction of the forced convection induced by the moving wall with natural convection induced by the buoyancy force, in two situations of the aiding and opposing buoyancy mechanisms. Leong et al. [8] analyzed mixed convection in an open cavity in a horizontal channel with various aspect ratios of the cavity. They found that the Reynolds number and Grashof number have significant role in control of the flow field in the cavity.

There are some procedures to augment the heat transfer rate to achieve better performance. For example, with adding nanoparticles which have high thermal conductivity to the pure fluid, the thermal conductivity of the remaining fluid will be augmented and cased to better heat exchange [9–11]. One of the interesting ways to increasing the heat transfer is by creating an oscillating motion in the flow field. Saeidi and Khodadadi [12] performed a numerical study of unsteady laminar forced convection in a square cavity with ventilation ports due to an oscillating velocity at the inlet port. They considered various frequency of the velocity oscillation and reached a periodic variation state in the fluid flow and thermal field in the cavity at each frequency. They observed that the best heat transfer rate is comprehended when the dimensionless frequency (Strouhal number) is close to unity and also heat transfer is enhanced in comparison to the steady state case. The effects of the oscillation on the heat transfer and fluid flow have been investigated by the other researchers [13–18]. Khanafer et al. [19] investigated numerically, unsteady laminar mixed convection heat transfer in an oscillating lid-driven cavity to study the effects of Reynolds number, Grashof number and oscillating frequency on heat transfer. Noor et al. [20] presented a numerical simulation of flow and heat transfer inside a square cavity with double-sided oscillating lids. The oscillating angular frequency of lid motion and Reynolds number are two important parameters in this study. They showed that the flow patterns are formed in four arrangements and depends on the lid frequency of oscillation for high Reynolds number. Heat transfer has been determined by average Nusselt number. They deduced that as the dimensionless lid frequency increases, the average Nusselt number decreased.

The aim of this study is to simulate numerically the unsteady laminar mixed convection heat transfer and fluid flow in a cavity with inlet and outlet ports due to an oscillating velocity at the inlet port. Various Richardson number and the Strouhal number have been used in order to study the influence of them on heat transfer. It is seen that at some Strouhal numbers, the heat transfer is enhanced in

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