Effect of aspect ratio on natural convection in an inclined rectangular enclosure with sinusoidal boundary condition

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Abstract

The aim of the present numerical study is to understand the natural convection flow and heat transfer in an inclined rectangular enclosure with sinusoidal temperature profile on the left wall. The top and bottom walls of the enclosure are kept to be adiabatic. The finite difference method is used to solve the governing equations with a range of inclination angles, aspect ratios and Rayleigh numbers. The results are presented in the form of streamlines, isotherms and Nusselt numbers. The heat transfer increases first then decreases with increasing the inclination of the enclosure for all aspect ratio and Rayleigh number. Increasing the aspect ratio shows a decreasing trend of the heat transfer for all Rayleigh numbers considered. A correlation equation is also introduced for the heat transfer analysis in this study.

1. Introduction

Natural convection in enclosures has been extensively studied over the last three decades and its application has covered wide range of fields. For example, in engineering, natural convection can be used in the cooling of the nuclear reactor, electronic components and glass production. The problems arise from this topic have drawn a lot of researchers to do deeper investigation due to new improvements and inventions in science and technology. Natural convection in inclined enclosures is very important because the buoyancy force affects the flow structure in enclosures. Rasoul and Prinos [1] studied natural convection in an inclined square enclosure with constant temperature for various Rayleigh number (Ra) and Prandtl number (Pr). They found that the average Nusselt number (Nu) increases with increasing Ra for all inclination angles (φ) and it increases with increasing Pr for given Ra. Abu-Nada and Oztop [2] studied the effects of inclination angle on natural convection in a two-dimensional enclosure filled with Cu-nanofluid. Heat transfer increases almost linearly with increasing of Ra but the effect of nanoparticles concentration on Nusselt number (Nu) is more pronounced at low Ra than at high Ra. It was observed that lower heat transfer is found at φ = 90°. Mahapatra et al. [3] performed numerical study on mixed convection flow in an inclined enclosure with magnetic field, thermal radiation and heat generation. It is observed that the enclosure inclination causes formation of multiple cells in the enclosure. The effect of various orientations on convective flow in a titled isosceles triangular enclosure was investigated by Basak et al. [4]. They observed that titled cavities have higher strength of fluid flow and heat circulation.

Most of the studies are performed in square enclosures. However, natural convection is very important in other geometries in real life situations, particularly, rectangular enclosures. Wilkes and Churchill [5] performed a finite difference computation on natural convection in a long horizontal rectangular enclosure. They demonstrated that the steady state results are in good agreement with analytical solutions. The effect of aspect ratio on natural convection of water near its density maximum temperature in rectangular enclosure was studied by Tong [6]. The results revealed that Nu exhibits a strong dependence on aspect ratio (Ar), Ra and the density distribution.

Non-uniform temperature profile in enclosures is useful for some engineering applications. Dalal and Das [7] studied natural convection in an inclined two-dimensional enclosure with sinusoidal temperature profile on one wall. The results revealed that inclination of the cavity affects the flow and heat transfer. Saeid [8] investigated natural convection in a porous cavity with sinusoidal bottom wall temperature and cooled top wall. It was found that Nu increases on increasing the amplitude of hot wall temperature for all Ra = 20 to 500. It was also noticed that Nu increases on increasing heat source length for a given Ra, but the heat transfer per unit area decreases by increasing the length of heat source. Basak et al. [9,10] investigated the effect of various thermal boundary conditions on natural convection flow in a square cavity with uniformly and non-uniformly heated bottom wall and adiabatic top wall while maintaining constant temperature of cold vertical walls. They revealed that Nu follows a power law variation with Ra for convection dominant regimes. Basak et al. [11] also studied the effects of non-uniformly heated walls in a square cavity filled with porous medium. The left and bottom walls are uniformly and non-uniformly heated, while the right