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Hydromagnetic effect on mixed convection in a lid-driven cavity with sinusoidal corrugated bottom surface ☆

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ABSTRACT

The present numerical simulation is conducted to analyze the mixed convection flow and heat transfer in a lid-driven cavity with sinusoidal wavy bottom surface in presence of transverse magnetic field. The enclosure is saturated with electrically conducting fluid. The cavity vertical walls are insulated while the wavy bottom surface is maintained at a uniform temperature higher than the top lid. In addition, the transport equations are solved by using the finite element formulation based on the Galerkin method of weighted residuals. The implications of Reynolds number (Re), Hartmann number (Ha) and number of undulations (λ) on the flow structure and heat transfer characteristics are investigated in detail while, Prandtl number (Pr) and Rayleigh number (Ra) are considered fixed. The trend of the local heat transfer is found to follow a wavy pattern. The results of this investigation illustrate that the average Nusselt number (Nu) at the heated surface increases with an increase of the number of waves as well as the Reynolds number, while decreases with increasing Hartmann number.

1. Introduction

Mixed convection flow and heat transfer in lid-driven cavities have been receiving a considerable attention in the literature. This attention stems from its importance in vast technological, engineering and natural applications. Such applications include cooling of electronic devices, lubrication technologies, drying technologies, food processing, float glass production, flow and heat transfer in solar ponds, thermal-hydraulics of nuclear reactors and dynamics of lakes. The influence of the magnetic field on the convective heat transfer and the mixed convection flow of the fluid are of paramount importance in engineering. A combined free and forced convection flow of an electrically conducting fluid in a cavity in the presence of magnetic field is of special technical significance because of its frequent occurrence in many industrial applications such as geothermal reservoirs, cooling of nuclear reactors, thermal insulations and petroleum reservoirs. These types of problems also arise in electronic packages, microelectronic devices during their operations.

Das and Mahmud [1] conducted a numerical investigation of natural convection in an enclosure consisting of two isothermal horizontal wavy walls and two adiabatic vertical straight walls. Adjlout et al. [2] studied laminar natural convection in an inclined cavity with a heated undulated wall that is smooth wave-like pattern. Their results concluded that the hot wall undulation affected the flow and heat transfer rate in the enclosure in which the local Nusselt number distribution resulted in a decrease of heat transfer rate as compared with the square enclosure. Moreover, Kumar [3] conducted a study of flow and thermal field inside a vertical wavy enclosure filled with a porous media. The author illustrated that the surface temperature was very sensitive to the drifts in the surface undulations, phase of the wavy surface and the number of considered waves. It should be pointed out that viscous flow in wavy channels was first analyzed analytically by Bums and Parkes [4], while Goldstein and Sparrow [5] used the naphthalene technique to measure local and average heat transfer coefficients in a corrugated wall channel. Furthermore, Wang and Chen [6] analyzed forced convection in a wavy-wall channel and demonstrated the effects of wavy geometry, Reynolds number and Prandtl number on the skin friction and Nusselt number. Their results have illustrated that the amplitudes of skin friction coefficient and Nusselt number had increased with an increase in the amplitude to wavelength ratio. Al-Amiri et al. [7] investigated mixed convection heat transfer in lid-driven cavity with a sinusoidal wavy bottom surface. Their findings were that the corrugated lid-driven cavity could be considered as an effective heat transfer mechanism at larger wavy surface amplitudes and low Richardson numbers. Garandet et al. [8] studied natural convection heat transfer in a rectangular enclosure with a transverse magnetic field. Rudraiah et al. [9] investigated the effect of surface tension on buoyancy driven flow of an electrically conducting fluid in a rectangular cavity in the presence of a vertical transverse magnetic field to see how this force damps hydrodynamic movements. The problem of unsteady laminar combined forced and free convection flow and heat transfer of an electrically conducting

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