International Communications in Heat and Mass Transfer 38 (2011) 1269–1278

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Laminar combined magnetoconvection in a wavy enclosure with the effect of heat conducting cylinder ☆

Rehena Nasrin

Department of Mathematics, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

ARTICLE INFO

Available online 6 July 2011

Keywords:
Combined magnetoconvection
Joule heating
Corrugated wall
Lid-driven enclosure
Heat conducting cylinder
Finite element method

ABSTRACT

In the current work, a numerical study of the flow characteristics on combined magnetoconvection in a lid-driven square enclosure, differentially heated, is carried out. This problem is solved by using finite element method of the partial differential equations, which are the heat transfer and stream function in Cartesian coordinates. The tests are performed for different solid–fluid thermal conductivity ratio, cylinder location and Richardson number while the Prandtl number, Reynolds number, magnetic and Joule heating parameters are kept constant. One geometrical configuration is used namely two undulations. The outcome obtained shows that the heat conducting inner square cylinder affects the flow and the heat transfer rate in the enclosure. The trend of the local heat transfer is found to follow a wavy pattern. Results are presented in terms of streamlines, isotherms, average Nusselt number at the heated wavy wall, average temperature of the fluid in the enclosure and dimensionless temperature at the cylinder center for different combinations of the governing parameters.

1. Introduction

The influence of the magnetic field on the convective heat transfer and the combined convection flow of the fluid are of paramount importance in engineering. At an atomic level, Joule heating is the result of moving electrons colliding with atoms in a conductor, whereupon momentum is transferred to the atom, increasing its kinetic energy. The increase in the kinetic energy of the ions manifests itself as heat and a rise in the temperature of the conductor. Hence energy is transferred from electrical power supply to the conductor and any materials with which it is in thermal contact. Combined convection plays a significant roll 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. A combined free and forced convection flow of an electrically conducting fluid in a cavity in the presence of magnetic field and Joule heating effect 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, micro electronic devices during their operations. The analysis of the influence of combined convection for different boundary conditions and shapes is necessary to ensure efficient performance of heat transfer equipments. The heat transfer from a wavy surface is functional in several practical appliances for instance refrigeration system, radiator, louver, plurality of holes etc.

It should be pointed out that viscous flow in wavy channels was first studied analytically by Bums and Parkes [1], while Goldstein and Sparrow [2] used the naphthalene technique to measure local and average heat transfer coefficients in a corrugated wall channel. Garandet et al. [3] analyzed natural convection heat transfer in a rectangular enclosure with a transverse magnetic field. Furthermore, Moallemi and Jang [4] performed Prandtl number effects on laminar mixed convection heat transfer in a lid-driven cavity. Rudraiah et al. [5] 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 damped hydrodynamic movements. Kumar [6] 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. Moreover, Adjlout et al. [7] studied laminar natural convection in an inclined cavity with a heated undulated wall that is smooth wave-like pattern. Their results showed 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. Wang and Chen [8] formulated 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. They concluded that the amplitudes of skin friction coefficient and Nusselt number had increased with an increase in the amplitude to wavelength ratio. The problem of

☆ Communicated by: W.J. Minkowycz.
E-mail address: rehena@math.buet.ac.bd.

0735-1933/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2011.06.005