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Natural convection in porous triangular enclosure with a centered conducting body ☆

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ABSTRACT

A numerical work was performed to examine the heat transfer and fluid flow due to natural convection in a porous triangular enclosure with a centered conducting body. The center of the body was located onto the gravity center of the right-angle triangular cavity. The Darcy law model was used to write the governing equations and they were solved using a finite difference method. Results are presented by streamlines, isotherms, mean and local Nusselt numbers for the different parameters such as the Rayleigh number, thermal conductivity ratio, and height and width of the body. It was observed that both height and width of the body and thermal conductivity ratio play an important role on heat and fluid flow inside the cavity.

1. Introduction

Porous media filled enclosures or channels were an important subject of engineering. It had very wide application areas such as solar collection, building insulation, oil distraction, building materials and some geophysical or geological applications. Analysis of the flow field and temperature distribution was also a topic in applied mathematics. All of these were given in literature on porous media [1–4].

Natural convection in a triangular shaped enclosure was mostly studied for a pure fluid filled enclosure due to its wide application for roof-building, electronic equipment and some solar applications [5–9].

Porous media filled attic shaped building was firstly proposed by Poulikakos and Bejan [10]. They proposed that the filling of attic shaped building with porous media can be a control element for heat transfer and fluid flow. Varol et al. [11] made a numerical work on natural convection in porous media filled right-angle triangular enclosure by adding a square object at different thermal boundary conditions. In this article, they indicated that thermal conditions play an important role on heat and fluid flow. Inserting of a passive element into a cavity or pipe was an old technique to control heat transfer and fluid flow of pure fluid or fluid saturated porous media. In this context, Dong and Li [12] made a numerical work to investigate the complicated flow and heat transfer phenomena in a circle shaped body inserted thick walled enclosure. Ha et al. [13] tested the different boundary conditions for the inserted body to the enclosure. They reported that the presence of the body obstructs the flow and temperature fields. Other related articles can be found in Refs. [14–16].

The main purpose of this work was to evaluate the dimensions and thermal conductivity ratio of a body in porous media filled triangular enclosures. Based on the previously mentioned literature survey and the authors' knowledge there is no study in literature for considered geometry.

2. Analysis

The schematic of the geometry with the coordinates and boundary conditions is shown in Fig. 1(a). The problem was considered to be two dimensional. The vertical wall was insulated. The bottom wall was maintained at a constant high temperature of T_h whereas the inclined wall was in a constant low temperature of T_c. A conducting body with height wy', and width wx' was inserted to the center of the enclosure. Its coordinate was $cx'$and cy'. The conducting body was located far from the origin with the distance of 0.33 in both directions ($cx' = cy' = 0.33$). L and H represented the bottom length and the height of the vertical wall, respectively. Thus, an aspect ratio was defined as H/L which was taken as unity in this paper. The grid distribution is also shown in Fig. 1(b). A regular grid was used in the system.

The following assumptions are made to obtain the governing equations: the properties of the fluid and the porous medium are constant; the cavity walls are impermeable; the Boussinesq approximation and the Darcy law model are valid; and the viscous drag and inertia terms of the momentum equations are negligible. With these assumptions, the dimensional governing equations of continuity, momentum, and energy can be written as

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{1}$$

$$\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x} = -\frac{g\beta K}{\upsilon}\frac{\partial T_f}{\partial x} \tag{2}$$

$$u\frac{\partial T_f}{\partial x} + v\frac{\partial T_f}{\partial y} = \alpha_m\left(\frac{\partial^2 T_f}{\partial x^2} + \frac{\partial^2 T_f}{\partial y^2}\right) \tag{3}$$

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