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Combined convection heat transfer in a porous lid-driven enclosure due to heater with finite length ☆

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Abstract

A numerical work is performed to analyze combined convection heat transfer and fluid flow in a partially heated porous lid-driven enclosure. The top wall of enclosure moves from left to right with constant velocity and temperature. Heater with finite length is located on the fixed wall where its center of location changes along the walls. The finite volume-based finite-difference method is applied for numerical experiments. Parameters effective on flow and thermal fields are Richardson number, Darcy number, center of heater and heater length. The results are shown that the best heat transfer is formed when the heater is located on the left vertical wall.

Keywords: Combined convection; Lid-driven cavity; Porous medium

1. Introduction

Flows and heat transfer in a lid-driven cavity with buoyancy or without buoyancy effect, for steady or unsteady cases, have been an important topic because of its wide application area in engineering and science. Some of these applications include oil extraction, cooling of electronic devices and heat transfer improvement in heat exchanger devices. Shankar and Deshpande [1] reviewed and showed its applications from a scientific and engineering point of view. Thus, some researchers proposed numerical and experimental technique to solve temperature and flow field in that geometry for non-porous medium [2–9].

Lid-driven cavities with filled saturated porous medium are another important application because of its wide applications in engineering such as heat exchangers, solar power collectors, packed-bed catalytic reactors, nuclear energy systems and so on [10,11]. Al-Amiri [12] made a numerical study to perform laminar flow and heat transfer for square lid-driven cavity heated from a driving wall filled with a porous medium. They wrote the governing equation in the streamline-vorticity form and these equations were solved via the finite-volume method. Khanafer and Chamkha [13] numerically solved a similar problem of boundary conditions with Al-Amiri by taking into account volumetric heat-generating fluid for mixed convection. They concluded that both *Ri* number and internal *Ra* number are effective on heat transfer. Jue [14] made a numerical study to investigate mixed convection flow caused by a torsionally oscillatory lid with thermal stable stratification in an enclosure filled with porous medium using semi-implicit projection finite-element method. He indicated that the permeability of the porous medium deeply dominates the flow strength as

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Nomenclature

C_F	Forcheimer coefficient
Da	Darcy number
g	gravity
Gr	Grashof number
H	height of cavity
K	permeability
Nu	Nusselt number
P	pressure
Pr	Prandtl number
Re	Reynolds number
Ri	Richardson number
T	temperature
u,*v*	dimensionless velocities in *x*- and *y*-directions
U_{lid}	moving wall velocity
x,*y*	dimensionless Cartesian coordinates

Greek letters

ε	porosity
ψ	stream function
φ	any dependent variable
β	thermal expansion coefficient

the permeability is decreased. Das and Morsi [15], Kim and Hyun [16] studied the natural convection in an enclosure for heat-generating porous media. Khanafer and Vafai [17] analyzed the double-diffusive mixed convection in a lid-driven porous enclosure with horizontal walls kept at constant and different temperatures and concentrations. They indicated that the buoyancy ratio, *Da* number, *Le* number and *Ri* number have important effects on the double-diffusive phenomenon. Asbik et al. [18] solved the equations for mixed convection in a vertical saturated porous enclosure.

To the best of the author's knowledge, there is no information on the combined convection heat transfer in a partially heated lid-driven porous enclosure. Therefore, the present study is different from the others that concentrate on length and locations of the heater. It is believed that the study will contribute to academic and engineering research. The main aim of the present study is to determine the combined convection temperature and flow field due to the position of

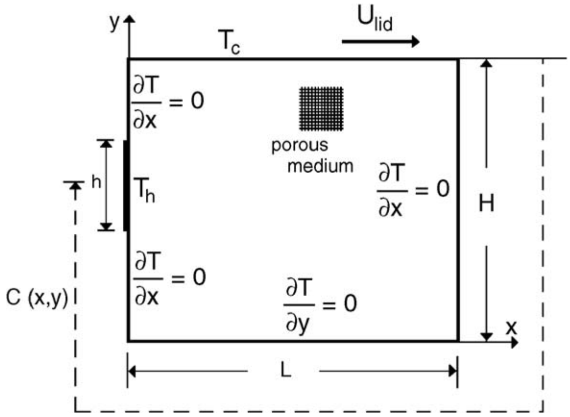

Fig. 1. Physical model of a square lid-driven cavity (geometry, coordinate system and boundary conditions).