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Research Article

Double Diffusion in Cavity Due to Lower Half Concentration

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Abstract: Aim of present paper is to study the heat and mass transfer in porous cavity with respect to high concentration at lower half of left vertical surface. This is an extension of work where high concentration is supplied at upper half of cavity. The right vertical surface is maintained at constant concentration Cc such that Cw>Cc. The left and right vertical surfaces of cavity are maintained at isothermal temperature Tw and Tc where Tw>Tc. Darcy model is used to describe the flow in porous medium. The governing partial differential equations are non-dimensionalised to reduce the number of variables involved. Finite element method is used to convert the governing equations into a set of algebraic equations and then solved for the square porous domain meshed with triangular elements.

Keywords: Double diffusion, finite element method, lower half concentration, porous media

INTRODUCTION

Owing to an increased interest by the eminent researchers in heat transfer and fluid flow behaviour in porous medium, recent research is significantly focused on this particular subject. The applications such as heat exchangers, drying of vegetables, transpiration through plants, percolation of pollutants through soil, design of thermal comfort spaces and many more have posed various challenges which has been addressed meticulously during the last few decades as evident by the available literature. The fundamental concept of this topic has been detailed in the books (Nield and Bejan, 2006; Ingham and Pop, 1998; Vafai, 2000; Pop and Ingham, 2001 and Bejan, 2003). The parametrical study of the heat transfer and fluid flow in different geometries embedded with porous medium is available in the open literature (Ahmed *et al*., 2009; Badruddin *et al*., 2012; Badruddin *et al*., 2006; Badruddin *et al*., 2015; Badruddin *et al*., 2006; Badruddin and Quadir, 2016; Badruddin *et al*., 2006; Salman *et al*., 2014; Ting *et al*., 2015; Ahmed *et al*., 2011; Badruddin *et al*., 2012; Quadir and Badruddin, 2016; Badruddin and Quadir, 2016; Badruddin *et al*., 2006; Badruddin *et al*., 2006; Badruddin *et al*., 2007; Badruddin *et al*., 2006; Badruddin *et al*., 2007; Badruddin and Quadir, 2016; Badruddin *et al*., 2016; Nik-Ghazali *et al*., 2014; Azeem *et al*., 2016; Badruddin *et al*., 2012 and Trevisan and Bejan, 1990). The various issues related to the heat and mass transfer were the centre point of many eminent researchers due to its various applications. Non-equilibrium turbulent heat and mass transfer in porous medium was reported by (Khan and Straatman, 2016). The fluid through porous medium in the presence of inclined magnetic field in an inclined asymmetric channel was studied to evaluate the effects of heat and mass transfer on peristaltic flow by (Ramesh, 2016). In another study, Gobin and Bennacer (1994) have investigated the double diffusion in the vertical fluid layer and observed that purely diffusive (motionless) solution prevails at moderate Grashof numbers. Similar attempt was made by (Mohammed and Bennacer, 2002) to find out the cross gradient double diffusion in an enclosure filled with saturated porous medium. In the same way the concentration gradient related double diffusive flow was investigated (Kamakura and Ozoe, 1993 and Sezai and Mohamad, 2000). The present study demonstrates the double diffusion due to vertical concentration gradient in a porous cavity.

MATHMATICAL FORMULATION

Consider a square porous cavity as shown in Fig. 1. The Lower half of left vertical wall of the cavity is maintained at higher concentration C_w and right vertical wall at C_c. This is an extension of our study where concentration is applied at upper half of left wall. The governing equations are:

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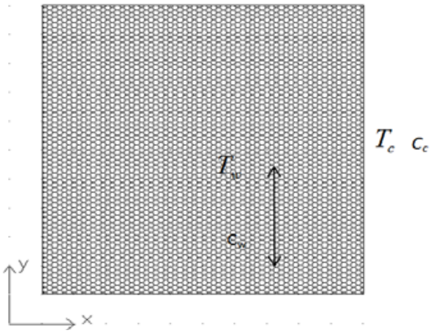


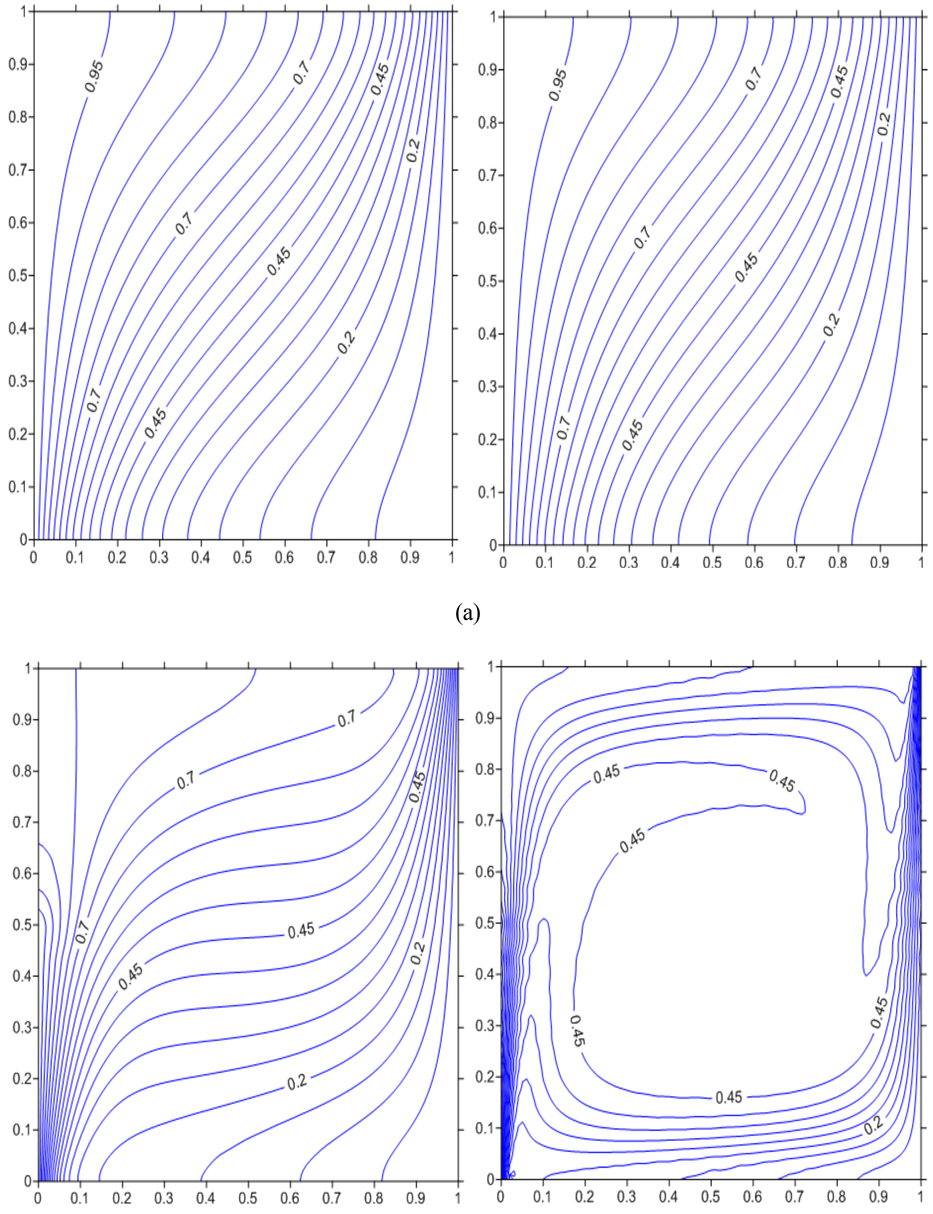
Fig. 1: A square porous cavity

$$\frac{\partial^2 \bar{\psi}}{\partial \bar{x}^2}+\frac{\partial^2 \bar{\psi}}{\partial \bar{y}^2}=-Ra\left[\frac{\partial \bar{T}}{\partial \bar{x}}+N\frac{\partial \bar{C}}{\partial \bar{x}}\right] \tag{1}$$

$$\frac{\partial \bar{\psi}}{\partial \bar{y}}\frac{\partial \bar{T}}{\partial \bar{x}}-\frac{\partial \bar{\psi}}{\partial \bar{x}}\frac{\partial \bar{T}}{\partial \bar{y}}=\left(\left(1+\frac{4R_d}{3}\right)\frac{\partial^2 \bar{T}}{\partial \bar{x}^2}+\frac{\partial^2 \bar{T}}{\partial \bar{y}^2}\right) \tag{2}$$

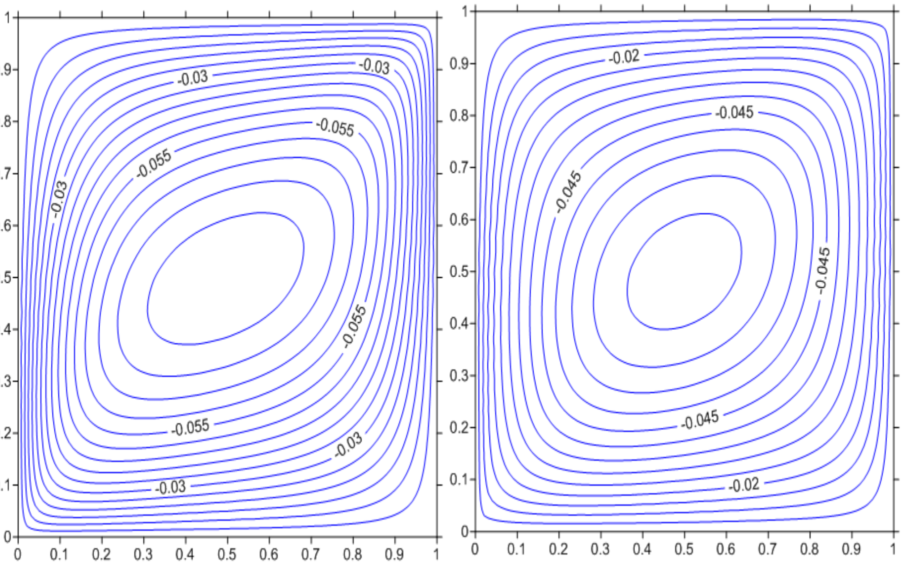
$$\frac{\partial \bar{\psi}}{\partial \bar{y}}\frac{\partial \bar{C}}{\partial \bar{x}}-\frac{\partial \bar{\psi}}{\partial \bar{x}}\frac{\partial \bar{C}}{\partial \bar{y}}=\frac{1}{Le}\left(\frac{\partial^2 \bar{C}}{\partial \bar{x}^2}+\frac{\partial^2 \bar{C}}{\partial \bar{y}^2}\right) \tag{3}$$

The corresponding boundary conditions are:



(a)

(b)



(c)

Fig. 2: (a) Isotherms; b) Isoconcentration lines; c) Streamlines at; Left *Le* = 2 Right *Le* =25

$$\text{at } \bar{x} = 0, \bar{\Psi} = 0, \bar{T} = 1, \partial\bar{C} / \partial\bar{y} = 0 \tag{4}$$

$$\text{at } \bar{x} = 0, 0 \le \bar{y} \le 1/2, \bar{C} = 1, \partial\bar{C} / \partial\bar{y} = 0 \tag{5}$$

$$\text{at } \bar{x} = 1, \bar{\Psi} = 0, \bar{T} = 1, \bar{C} / \bar{C} = 0 \tag{6}$$

$$\text{at } \bar{y} = 0, \bar{\Psi} = 0, \partial\bar{T} / \partial\bar{y} = 0, \partial\bar{C} / \partial\bar{y} = 0 \tag{7}$$

$$\text{at } \bar{y} = 0, \bar{\Psi} = 0, \partial\bar{T} / \partial\bar{y} = 0, \partial\bar{C} / \partial\bar{y} = 0 \tag{8}$$

RESULTS AND DISCUSSION

The results are discussed in this section. Figure 2 shows the temperature, concentration and streamline variation in porous cavity for two values of Lewis number i.e., *Le* = 2 *and Le* = 25. It should be noted that Lewis number represents the ratio of thermal diffusivity to mass diffusivity. This figure is obtained at *Ra* = 50, *N* = 0.5 and *Rd* = 1. By looking at isotherm corresponding to 0.95, it can be inferred that the thermal gradient increases with increase in Lewis number thus increasing the heat transfer from hot surface. It is further noticed that the iso-concentration lines are substantially affected due to change in Le from 2 to 25. The iso-concentration lines are crowded near hot surface due to increase in Lewis number indicating increased mass transfer rate. It is further observed that a large area at center of cavity is occupied by same concentration at higher Lewis number. The fluid flow becomes more organized with increase in Lewis number.

CONCLUSION

The present study investigates the effect of lower half concentration at left wall of a square porous cavity by using finite element method. It is found that the increase in Lewis number affects the mass transfer substantially. It is also found that the heat transfer increases with increase in Lewis number.

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