Double Diffusion in Cavity Due to Upper Half Concentration

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Abstract

The present article discusses the effect of high concentration at upper vertical surface in a square porous 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. The governing momentum, energy and concentration equations are converted into algebraic form of equations using finite element method. The domain is meshed with triangular elements with proper care to capture the high degree of non-linearity at the boundaries of square cavity. Results are discussed with respect to Lewis number, buoyancy ratio and Rayleigh number.

Keywords — *Porous media, double diffusion, Finite element method*

I. INTRODUCTION

The significance of the flow through porous medium cannot be undermine due to its vast area of applications ranging from the industry to the science and technology. The important detail of the subject is well documented in the books [1-5]. The natural convective heat transfer is analyzed in detail describing the effects of various physical and geometrical parameters on heat transfer characteristics and fluid flow pattern [6-29]. There are plenty of occasions whereby the vertical surfaces such as cavities, cylinders, annulus are used in many industrial applications. Natural convective heat and mass transfer in MHD fluid flow past a moving vertical plate was studied by Javaherdeh et al. [30] and presented the influence of the various physical parameters on the heat transfer rate. Similar attempt was made to study the rotation and Soret effects on MHD free convection heat and mass transfer flow past an accelerated vertical plate through a porous medium [31]. Nayak et al. [32] presented their findings on the heat and mass transfer effects in a boundary layer flow through porous medium. They concluded that the presence of chemical reaction as well as porous matrix with moderate values of magnetic parameter reduces the temperature and concentration in the flow field. Similarly, a wide research pertaining to the double diffusive convection in various geometries are reported in the literature [33-36]. An attempt is made in this study to investigate the double diffusive flow in a square porous cavity.

II. MATHEMATICAL FORMULATION

A square porous cavity is assumed as shown in figure 1. The Upper half of left vertical wall of the cavity is maintained at higher concentration C_w and right vertical wall at C_c. The left wall is maintained at temperature T_w and right wall at T_c. The governing equations are

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

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

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

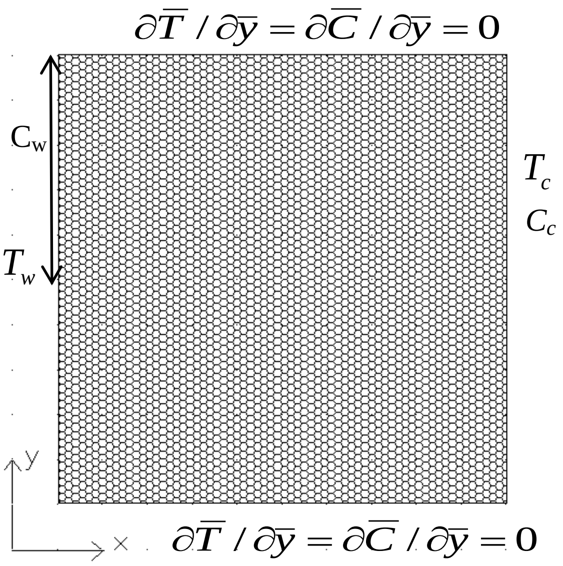

FIGURE 1: SCHEMATIC DIAGRAM OF THE SQUARE CAVITY

The corresponding boundary conditions are:

AT $\bar{x}=0,\ \bar{\psi}=0,\ \bar{T}=1, \partial\bar{C}/\partial\bar{y}=0$ (4A)

AT $\bar{x}=0, 1/2 \le \bar{y} \le 1,\ \bar{C}=1,\ \partial\bar{C}/\partial\bar{y}=0$ (4B)

AT $\bar{x}=1,\ \bar{\psi}=0,\ \bar{T}=0,\ \bar{C}=0$ (4C)

AT $\bar{y}=0,\ \bar{\psi}=0,\ \partial\bar{T}/\partial\bar{y}=0,\ \partial\bar{C}/\partial\bar{y}=0$ (4D)

AT $\bar{y}=1,\ \bar{\psi}=0,\ \partial\bar{T}/\partial\bar{y}=0,\ \partial\bar{C}/\partial\bar{y}=0$ (4E)

III.RESULTS AND DISCUSSION

The thermal energy and concentration distribution along with streamlines are elaborated in this section. Figure 2 shows influence of Lewis number when square porous cavity is subjected to higher concentration at upper half. This figure is obtained at *Ra=50, N=0.5 and Rd=1*. It is seen that the iso-concentration lines diffuse little bit into lower half of cavity at Le=2, even though the higher concentration is applied at upper half of cavity. However, this diffusion into lower part of cavity is increased due to increase in Lewis number. The concentration lines indicate that the Sherwood number increases with increase in the Lewis number. It is found that the higher magnitude streamlines are pushed towards the center of cavity due to increase in Lewis number. More area of cavity is occupied with less concentration lines in comparison to the case of lower half concentration at left wall. This shows that maintaining high concentration at lower half of cavity provides better distribution of mass as compared to higher concentration at upper of cavity.

IV.CONCLUSIONS

The present study is undertaken to analyze the mass transfer behavior due to upper half concentration at left wall. It is found that the increase in Lewis number leads to increase in Sherwood number.

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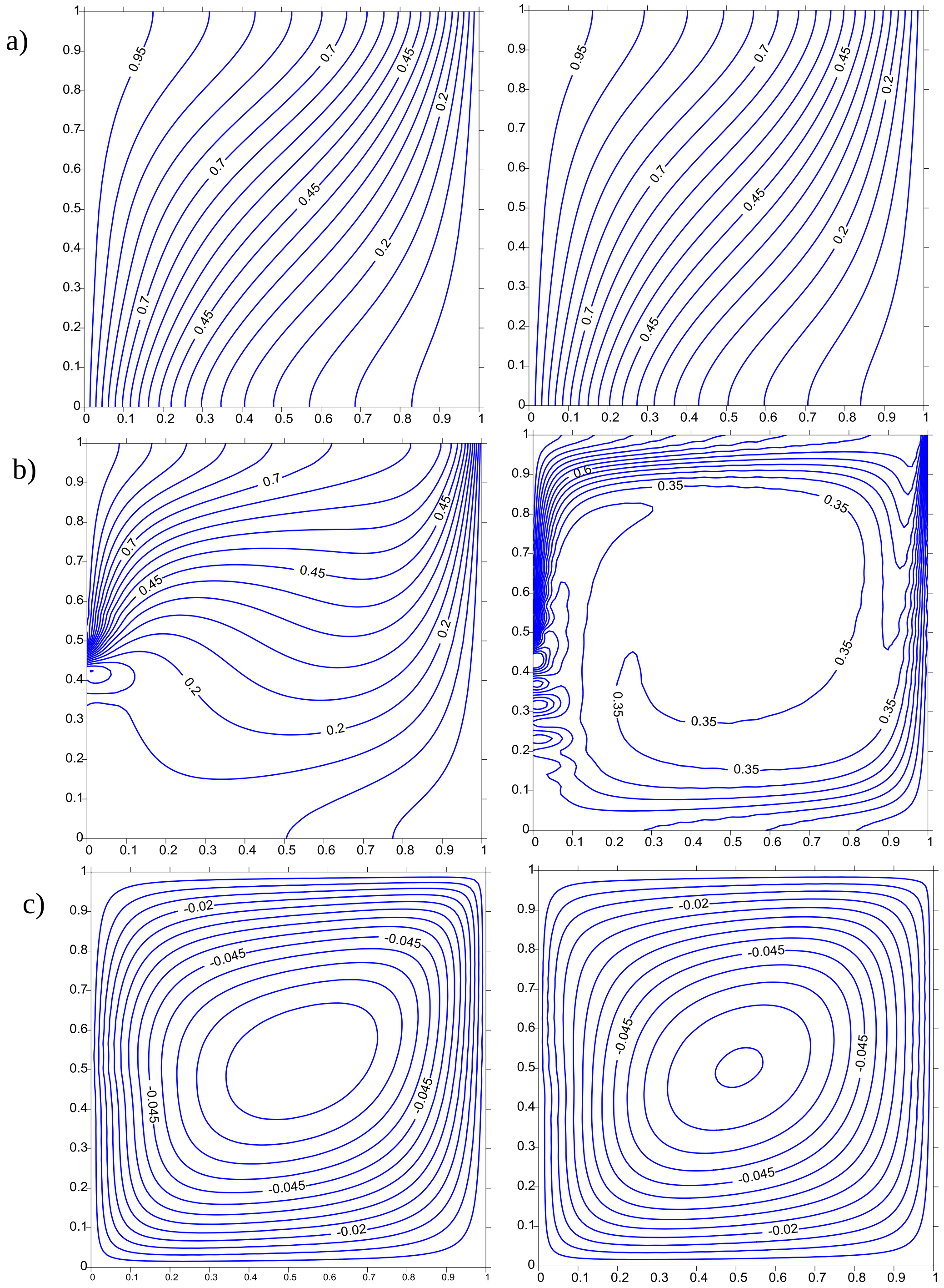

Figure 2: a) Isotherms b) Iso-concentration lines c) Streamlines at Left *Le=2*, Right Le=25