

Heat and Mass Transfer in an L Shaped Porous Medium

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Abstract. This article is an extension to the heat transfer in L-shaped porous medium by including the mass diffusion. The heat and mass transfer in the porous domain is represented by three coupled partial differential equations representing the fluid movement, energy transport and mass transport. The equations are converted into algebraic form of equations by the application of finite element method that can be conveniently solved by matrix method. An iterative approach is adopted to solve the coupled equations by setting suitable convergence criterion. The results are discussed in terms of heat transfer characteristics influenced by physical parameters such as buoyancy ratio, Lewis number, Rayleigh number etc. It is found that these physical parameters have significant effect on heat and mass transfer behavior of L-shaped porous medium.

Index terms. L-Shaped porous medium, Heat and Mass Transfer, FEM

1. Introduction

Heat and mass transfer in porous media with respect to various geometries has been reported in literature but still there is scope for further research in uncommon geometrical shapes such as L shape. The heat transfer and its effect on various phenomenon can be found in the dedicated articles [1-40] that describe the various phenomenon coupled with different geometries. To the best of author's knowledge, heat and mass transfer in L shaped porous region has not been reported thus motivating us to carry on this investigation.

2. Page layout (headers, footers, page numbers and margins)

A "L" shaped porous medium is considered as shown in Figure 1. The heat and mass transfer in such system can be described with the help of momentum equation, energy transport equation and mass diffusion equation as given below.



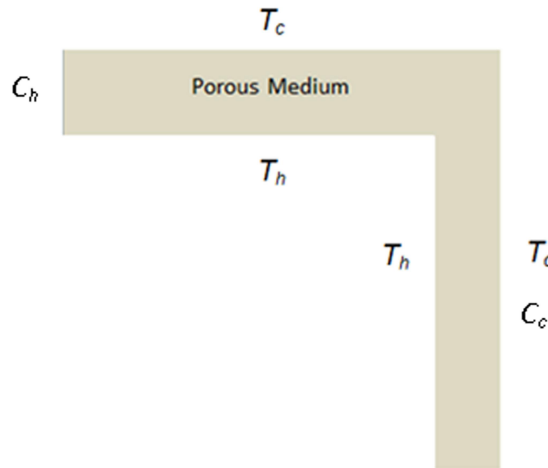


Figure 1. L Shaped porous medium

The governing equations for heat transfer in porous medium can be given in non-dimensional form as

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

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

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

The above equations should be solved with suitable method to find the values of solution variables such as temperature, stream function and concentration distribution inside the porous medium. Finite element method has been utilized in this study to solve equations 1-3 with the boundary conditions as shown in Figure 1. It should be noted that the solution of equations 1-3 is obtainable in iterative manner due to multiple solution variables which are coupled together in equation 1-3.

3. Results and Discussion

The iterative solution of governing equations yielded the value of each of solution variable at every node in the domain. These values are further processed to understand the heat and mass transfer characteristics inside the porous medium by plotting the contours of temperature, stream function and concentration. Figure 2 shows the effect of buoyancy ratio on heat and mass transfer. This figure is obtained at $Ra=100$, $Le=2$. It is found that the isotherms have not much affected due to change in buoyancy ratio. However, the concentration line distribution reaches far deep into porous region. It is noted that that mass diffusion is restricted to only horizontal leg of L shape. This could due to the nature of applied boundary condition. The fluid circulates in to cells at higher buoyancy ratio ($N=1$) but has only one circulation pattern at $N=0$. Figure 3 illustrates the change of Lewis number and its influence on heat and mass transfer. The concentration lines get affected considerably due to change in Lewis number but there was not much of its effect on isotherms. The fluid is found to have two cells at lower Lewis number as compared to its higher value.

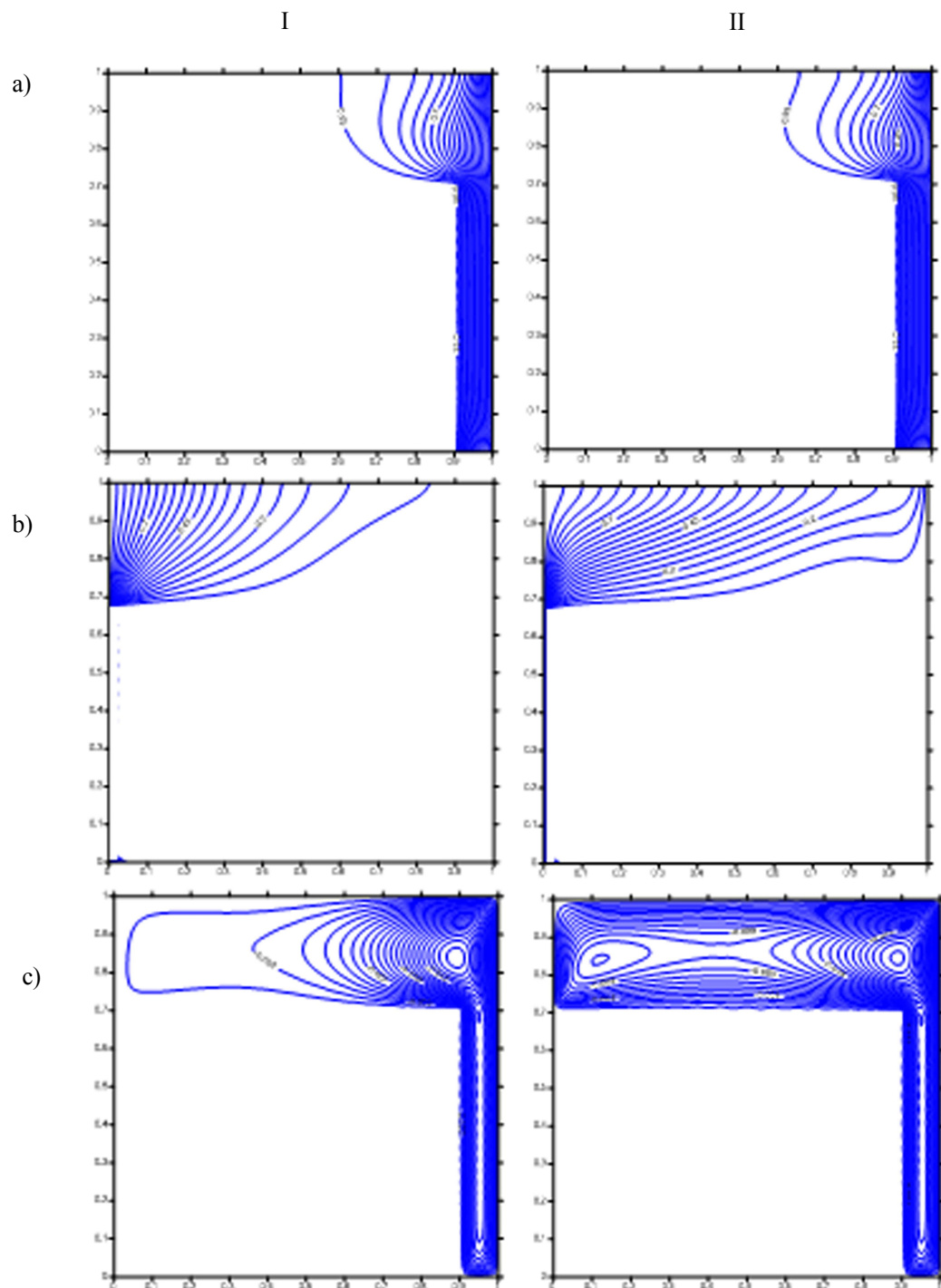


Figure 2. Contours for variation of N I) $N=0.1$ II) $N=1$ a) Isotherms b) Iso-Concentration c) Streamlines

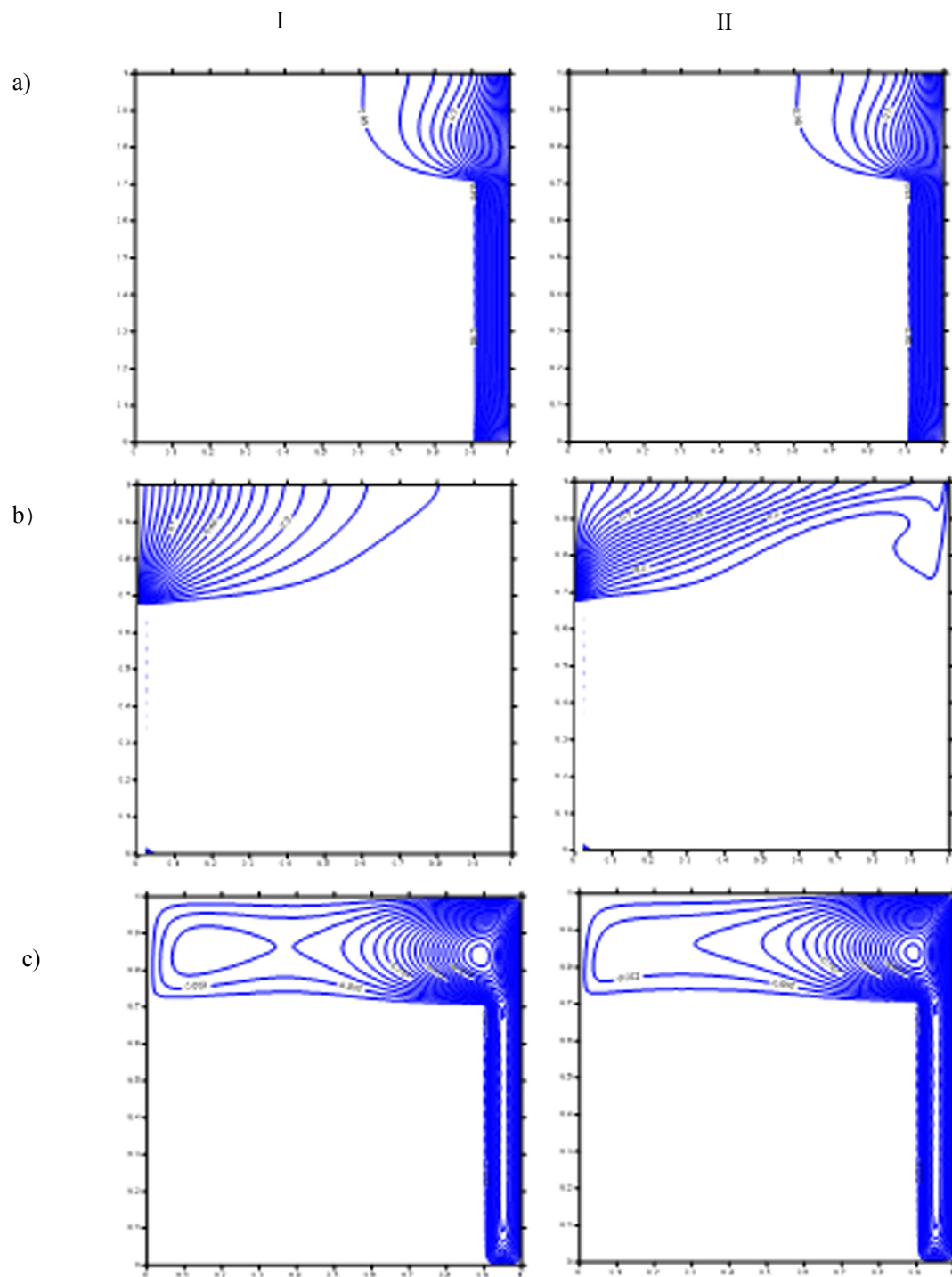


Figure 3. Contours for variation of Le I) $Le=1$ II) $Le=10$ a) Isotherms b) Iso-Concentration c) Streamlines

4. Conclusion

Heat and mass transfer in L shaped porous medium is analyzed. The following conclusion can be given based on the study carried out for present work.

- The heat and mass transfer in L shape is found to follow similar trend as in other geometrical shapes of porous medium.
- The mass diffusion is restricted to only horizontal leg of L shape porous region with no concentration lines in the vertical leg.

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