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Double diffusion from a horizontal cylinder of elliptic cross section with uniform wall heat and mass fluxes in a porous medium☆

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ABSTRACT

This work studies the double diffusion near a horizontal cylinder of elliptic cross section with uniform wall heat and mass fluxes in a fluid-saturated porous medium. A coordinate transformation is used to obtain the non-similar governing boundary layer equations. The transformed equations are solved numerically by an efficient cubic spline collocation method. Results for the local surface temperature and the local surface concentration are presented as functions of the Lewis number, the buoyancy ratio, and the aspect ratio when the major axis of the elliptical cylinder is vertical (slender orientation) and horizontal (blunt orientation). As the Lewis number is increased, the local surface concentration decreases while the local surface temperature increases. Moreover, an increase in the buoyancy ratio tends to decrease both the local surface temperature and the local surface concentration.

1. Introduction

Coupled heat and mass transfer driven by combined thermal and solutal buoyancy forces in a fluid-saturated porous medium is of great importance in geophysical, geothermal and industrial applications, such as the extraction of geothermal energy and the migration of moisture through air contained in fibrous insulations.

Merkin [1] presented the similarity solutions for natural convection heat transfer on a horizontal cylinder in a saturated porous medium. Merkin and Pop [2] studied the natural convection about two-dimensional bodies with uniform surface heat flux in a porous medium Yücel [3] studied the heat and mass transfer about a vertical cylinder with constant wall temperature and concentration in a porous medium. Yih [4] examined the heat and mass transfer characteristics in natural convection flow about a permeable horizontal cylinder in a saturated porous medium subjected to constant wall temperature and concentration. Pop et al. [5] examined the problem of natural convection heat transfer about cylinders of elliptic cross section in a porous medium. Cheng [6] studied the natural convection heat and mass transfer from a horizontal cylinder of elliptic cross section with constant wall temperature and concentration in saturated porous media. Cheng [7] studied the heat transfer by free convection from permeable horizontal cylinders of elliptic cross section in porous media using a thermal non-equilibrium model.

There are studies on other types of diffusion. Lin et al. [8] studied the Soret effects on the heat and mass transfer in a slab with non-Fourier heat diffusion and non-Fickian mass diffusion. Zhang et al. [9] studied the effects of Brownian and thermophoretic diffusions on nonequilibrium heat conduction in a nanofluid layer with periodic heat flux on one side and specified temperature on the other side.

There are a few studies on the natural convection heat transfer from elliptical cylinders for Newtonian or micropolar fluids. Merkin [10] studied the free convection boundary layers of Newtonian fluid on cylinders of elliptic cross section. Bhattacharyya and Pop [11] examined the free convection from cylinders of elliptic cross section in micropolar fluids. Hossain et al. [12] studied the effect of thermal radiation on natural convection over cylinders of elliptic cross section. Cheng [13] examined the natural convection heat transfer of Newtonian fluid from a horizontal isothermal elliptical cylinder with internal heat generation. Cheng [14] studied the natural convection boundary layer of Newtonian fluid on a horizontal elliptical cylinder with constant heat flux and internal heat generation.

This work applies the coordinate transformation and the cubic spline collocation method to obtain steady-state solutions to the problem of natural convection heat and mass transfer from a horizontal elliptical cylinder in fluid saturated porous media with uniform wall heat and mass fluxes. The effect of the Lewis number, the buoyancy ratio and the aspect ratio on the heat and mass transfer characteristics near a horizontal elliptical cylinder in a fluid-saturated porous medium is examined in both cases when the major axis is horizontal (blunt orientation) and vertical (slender orientation).

2. Analysis

Consider the steady laminar natural convection boundary-layer flow near a horizontal cylinder of elliptic cross section embedded in a

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