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Soret and Dufour effects on natural convection boundary layer flow over a vertical cone in a porous medium with constant wall heat and mass fluxes ☆

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ABSTRACT

This work studies the Soret and Dufour effects on the boundary layer flow due to natural convection heat and mass transfer over a vertical cone in a fluid-saturated porous medium with constant wall heat and mass fluxes. A similarity analysis is performed, and the obtained similar equations are solved by the cubic spline collocation method. The effects of the Dufour parameter, Soret parameter, Lewis number, and buoyancy ratio on the heat and mass transfer characteristics have been studied. The local surface temperature tends to increase as the Dufour parameter is increased. The effect of the Dufour parameter on the local surface temperature becomes more significant as the Lewis number is increased. Moreover, an increase in the Soret parameter leads to an increase in the local surface concentration and a decrease in the local surface temperature.

1. Introduction

Heat and mass transfer problems on natural convection flow in fluid-saturated porous media have received considerable attention during the last several decades because of numerous applications in engineering problems, such as the design of building components for energy consideration, control of pollutant spread in groundwater, compact heat exchangers, solar power collectors and food industries.

Bejan and Khair [1] examined the heat and mass transfer by natural convection in a porous medium. Lai [2] studied the heat and mass transfer by natural convection from a horizontal line source in a saturated porous medium. Nakayama and Hossain [3] examined the heat and mass transfer by natural convection in a porous medium by integral methods. Cheng [4] studied the effect of a magnetic field on heat and mass transfer by natural convection from vertical surfaces in porous media by an integral approach. Yih [5] examined the coupled heat and mass transfer by free convection over a truncated cone in porous media for variable wall temperature and concentration or variable heat and mass fluxes. Chamkha and Khaled [6] studied the hydromagnetic heat and mass transfer by mixed convection from a vertical plate embedded in a uniform porous medium. Yih [7] examined the uniform transpiration effect on coupled heat and mass transfer in mixed convection about inclined surfaces in porous media for the entire regime. Khanafer and Vafai [8] studied the double-diffusive mixed convection in a lid-driven enclosure filled with a fluid-saturated porous medium. Rathish Kumar et al. [9] studied the effect of thermal stratification on double-diffusive natural convection in a vertical porous enclosure. Cheng [10] examined the double-diffusive natural convection along a vertical wavy truncated cone in non-Newtonian fluid-saturated porous media with thermal and mass stratification. Moreover, Cheng [11] studied the combined heat and mass transfer in natural convection flow from a vertical wavy surface in a power-law fluid-saturated porous medium with thermal and mass stratification.

The Soret effect referred to species differentiation developing in an initial homogeneous mixture submitted to a thermal gradient. The Dufour effect referred to heat flux produced by a concentration gradient. Postelnicu [12] examined the heat and mass characteristics of natural convection about a vertical surface embedded in a saturated porous medium subjected to a magnetic field by considering the Dufour and Soret effects. Partha et al. [13] studied the Soret and Dufour effects in a non-Darcy porous medium. Mansour et al. [14] examined the multiplicity of solutions induced by thermosolutal convection in a square porous cavity heated from below and submitted to horizontal concentration gradient in the presence of Soret effect. Lakshmi Narayana and Murthy [15] examined the Soret and Dufour effects on free convection heat and mass transfer in a doubly stratified Darcy porous medium. Lakshmi Narayana and Murthy [16] examined the Soret and Dufour effects on free convection heat and mass transfer from a horizontal flat plate in a Darcy porous medium. Cheng [17] studied the Soret and Dufour effects on natural convection heat and mass transfer froma vertical cone in a porous medium with constant wall temperature and concentration. Moreover, Cheng [18] examined the Soret and Dufour effects on free convection boundary layer flow over a vertical cylinder in a porous medium with constant wall temperature and concentration.

The objective of this paper is to study simultaneous heat and mass transfer by natural convection from a vertical cone in a fluid-saturated porous medium with constant wall heat and mass fluxes, including

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