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Soret and Dufour effects on free convection boundary layers of non-Newtonian power law fluids with yield stress in porous media over a vertical plate with variable wall heat and mass fluxes ☆

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ABSTRACT

This work studies the Soret and Dufour effects on the free convection boundary layers over a vertical plate with variable wall heat and mass fluxes in a porous medium saturated with a non-Newtonian power law fluid with yield stress. The governing equations are transformed into a dimensionless form by the similarity transformation and then solved by a cubic spline collocation method. Results are presented for the local surface temperature and concentration for various parameters of the power law fluid with yield stress in porous media. An increase in the power law exponent decreases the local surface temperature and concentration, thus increasing the local Nusselt and Sherwood numbers. An increase in the Soret parameter tends to increase the local surface concentration, thus decreasing the local Sherwood number. Moreover, increasing the Dufour number increases the surface temperature and thus decreases the local Nusselt number.

1. Introduction

The problem of the heat and mass transfer for non-Newtonian fluids in porous media is of much importance due to its practical engineering applications, such as oil recovery, food processing, and materials processing [1–9]. The characteristics of convective heat and mass transfer of non-Newtonian fluids in porous media are quite different those that of Newtonian fluids in porous media because of the non-linear nature of non-Newtonian fluids.

Chen and Chen [1] presented similarity solutions for natural convection of a non-Newtonian fluid over vertical surfaces in porous media. Chen and Chen [2] also studied the natural convection of a non-Newtonian fluid about a horizontal cylinder and sphere in porous media. Nakayama and Koyama [3] studied the natural convection of a non-Newtonian fluid over non-isothermal body of arbitrary shape in a porous medium. Yang and Wang [4] investigated the natural convection heat transfer of non-Newtonian power-law fluids with yield stress over axisymmetric and two-dimensional bodies of arbitrary shape embedded in a fluid-saturated porous medium. Rastogi and Poulikakos [5] studied the double diffusion from a plate in a porous medium saturated with a non-Newtonian power law fluid. Getachew et al. [6] examined the double-diffusive natural convection in a rectangular porous cavity saturated with a non-Newtonian power law fluid. Jumah and Mujumdar [7] studied the free convection heat and mass transfer of non-Newtonian power law fluids with yield stress over a vertical plate in saturated porous media subjected to constant wall temperature and concentration. Jumah and Mujumdar [8] also examined the natural convection heat and mass transfer of non-Newtonian power law fluids with yield stress over a vertical plate in saturated porous media subjected to variable wall temperature and concentration. Cheng [9] studied the natural convection heat and mass transfer of non-Newtonian power law fluids with yield stress in porous media from a vertical plate with variable wall heat and mass fluxes.

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 [10] 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. [11] studied the Soret and Dufour effects in a non-Darcy porous medium. Mansour et al. [12] 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 [13] examined the Soret and Dufour effects on free convection heat and mass transfer in a doubly stratified Darcy porous medium. Lakshmi Narayana and Murthy [14] examined the Soret and Dufour effects on free convection heat and mass transfer from a horizontal flat plate in a Darcy porous medium. Cheng [15] studied the Soret and Dufour effects on natural convection heat and mass transfer from a vertical cone in a porous medium with constant wall temperature and concentration. Lin et al. [16] examined the Soret effects on non-Fourier heat and non-Fickian

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