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Variable viscosity effect on free convection of a non-Newtonian power-law fluid over a vertical cone in a porous medium with variable heat flux

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Abstract. The effect of variable viscosity on the free-convection boundary layer over a permeable vertical cone in a porous medium saturated with non-Newtonian power-law fluid has been studied numerically. The governing equations describing the problem are transformed into a system of nonlinear ordinary differential equations by using a similarity transformation, which is solved numerically using the Chebyshev spectral method. The effects of the power-law index, blowing/suction parameter and the viscosity parameter on the temperature profiles and the local Nusselt number are discussed.

1 Introduction

The study of convection heat transfer in porous media has gained tremendous interest because of numerous applications in geothermal extraction, storage of nuclear waste material, ground water flows, oil recovery processes, thermal insulation engineering, cooling of electronic components, food processing, casting and welding of manufacturing processes, ceramic processing, the dispersion of chemical contaminants in various processes in the chemical industry. The steady free-convection flow over a vertical flat plate in fluid-saturated porous media has been investigated by Cheng and Minkowycz [1], Johson and Cheng [2], Merkin [3], Na and Pop [4], Kumari *et al.* [5] and Bejan and Khair [6]. The free convection about a vertical cylinder embedded in a porous medium has been analyzed by Minkowycz and Cheng [7]. Cheng *et al.* [8] investigated the free-convection heat transfer from a vertical cone pointing downwards in a fluid-saturated porous medium. Yih [9] studied the effect of a uniform lateral mass flux on free convection about a vertical cone embedded in a saturated porous medium. Cheng [10] discussed the combined heat and mass transfer by natural convection from truncated cones in saturated porous media with variable wall temperature and concentration. An excellent review of the free-convection flow in saturated porous media has been presented by Pop and Ingham [11] and Nield and Bejan [12].

In all these studies, the authors assumed that the thermophysical properties of the fluid are constant. However, it is known that these physical properties may change with temperature. Mehta and Sood [13] found that the flow characteristics change substantially as compared with the constant viscosity case. The effect of variable temperature-dependent viscosity on the mixed-convection flow from a vertical plate is investigated by many authors, *e.g.* Kafoussias and Williams [14], Hady *et al.* [15], Kafoussias *et al.* [16] and Mahmoud [17]. The free- or mixed-convection boundary layer flow from a horizontal surface in a saturated porous medium taking into account the effect of variable viscosity has been studied by Kumari [18].

The above studies have dealt with Newtonian fluids. In several applications such as a ceramic processing, enhanced oil recovery, food technology, polymer engineering and liquid-composite molding, the fluids involved may exhibit non-Newtonian behavior. Free convection of a non-Newtonian fluid over an isothermal vertical surface in a porous medium is studied numerically by Chen and Chen [19]. Mehta and Rao [20] investigated analytically and numerically the buoyancy-induced flow of non-Newtonian fluids in a porous medium over a vertical plate with uniform surface heat flux. Chen and Chen [21] presented a similarity solution for the problem of natural convection of non-Newtonian fluids about a horizontal surface embedded in a porous medium. Mehta and Rao [22] studied the buoyancy-induced flow of non-Newtonian fluids over a non-isothermal horizontal plate using a similarity solution. Kumari and Jayanathi [23] analyzed the influence of a uniform lateral mass flux on the natural-convection flow over a vertical cone embedded in

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