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Natural convection boundary layer flow of a micropolar fluid over a vertical permeable cone with variable wall temperature ☆

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ABSTRACT

This work studies the natural convection boundary layer flow of a micropolar fluid near a vertical permeable cone with variable wall temperature. The transformed boundary layer governing equations are solved by the cubic spline collocation method. The local Nusselt numbers are presented as functions of suction variables for different values of vortex viscosity parameter, surface temperature exponent, and Prandtl number. Results show that the heat transfer rates of the permeable cones with higher suction variables are higher than those with lower suction variables. Moreover, the heat transfer rate from a vertical permeable cone in Newtonian fluids is higher than that in micropolar fluids.

1. Introduction

The research about micropolar fluids has been of great importance because the characteristics of fluid with suspended particles cannot be successfully described by the theory of Newtonian fluids. Micropolar fluids can exhibit the microscopic effects due to the local structure and micromotions of the fluid elements. The theory about micropolar fluids and thermomicropolar fluids has been developed by Erigen [1,2], and excellent reviews about the applications of micropolar fluids have been written by Airman et al. [3,4].

Lien et al. [5] analyzed the natural convection flow of micropolar fluid about a sphere with blowing and suction. Agarwal and Dhanapal [6] studied the flow and heat transfer in a micropolar fluid past a flat plate with suction and heat sources. Lien et al. [7] examined the free convection flow of micropolar fluid about a horizontal permeable cylinder at a non-uniform thermal condition. Takhar et al. [8] studied the mixed convection flow of a micropolar fluid over a stretching sheet. Mansour et al. [9] examined the heat and mass transfer in magnetohydrodynamic flow of micropolar fluid on a circular cylinder with uniform heat and mass flux. Nazar et al. [10] studied the steady free convection boundary layer flow over an isothermal sphere in a micropolar fluid. El-Hakiem [11] studied the natural convection in a micropolar fluid with thermal dispersion and internal heat generation effects. Cheng [12] examined the free convection heat and mass transfer near elliptical cylinders in a micropolar fluid.

For the natural convection from cones, Hering and Grosh [13] studied the laminar free convection from a non-isothermal cone. Na and Chiou [14] studied the laminar natural convection over a frustum of a cone. Yih [15] examined the effect of radiation on natural convection about a truncated cone. Pop and Na [16] presented the natural convection over a vertical wavy frustum of a cone. Pop and Na [17] also examined the coupled heat and mass transfer by natural convection about a truncated cone in the presence of magnetic field and radiation effects. Hossain and Paul [18] studied the free convection from a vertical permeable circular cone with non-uniform surface temperature. Postelnicu [19] studied the free convection about a vertical frustum of a cone in a micropolar fluid with constant wall temperature.

Motivated by the works above, this paper studies the natural convection boundary layer flow along a vertical permeable cone in a micropolar fluid with variable wall temperature. The results obtained herein are compared with the solutions for a vertical permeable cone by Hossain and Paul [18] in Newtonian fluids to check the accuracy. The local Nusselt numbers are presented as functions of suction variables for different values of vortex viscosity parameter, surface temperature exponent, and Prandtl number.

2. Analysis

Let us consider the natural convection boundary layer flow of a micropolar fluid near a vertical permeable cone with variable wall temperature, as shown in Fig. 1. The origin of the coordinate system is placed at the vertex of the cone, where x is the coordinate along the surface of the cone measured from the origin and y is the coordinate normal to the surface of the cone. The surface of the permeable cone is held at a variable temperature $T_w(x)$ which is higher than the ambient fluid temperature T_∞. Under Boussinesq approximations, the

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