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ELASTICO-VISCOUS MHD FREE CONVECTIVE FLOW PAST AN INFINITE VERTICAL POROUS PLATE WITH VARIABLE SUCTION AND SORET EFFECT

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Research Aim

An attempt has been made to study the unsteady MHD free convective elastic-viscous fluid past an infinite vertical porous plate with variable suction, where the plate temperature oscillates with the same frequency as that of variable suction velocity with the Soret effects. The elastico-viscous fluid flow is characterized by Walters liquid (Model B'). The governing equations of the fluid motion are solved analytically by adopting regular perturbation technique. The approximate solutions have been derived for the velocity profile, temperature field, concentration field and skin friction. It is noticed that the flow field is considerably affected by the elastico-viscous parameter. The velocity profile and the approximate skin friction coefficient have been presented graphically to observe the elastico-viscous effects for various values of the flow parameters involved in the solution.

Literature survey

The study of visco-elastic fluid flows has attracted the attention of many researchers because of its wide applications in various branches of science and technology. The complex stress-strain relationship of visco-elastic fluid flow mechanism is used in geophysics, chemical engineering, petroleum engineering, hydrology, soil-physics, bio-physics, paper and pulp technology. A theoretical model for visco-elastic fluids has been proposed by Walters [1].

Convective heat transfer in a porous media is a topic of rapidly growing interest due to its application to geophysics, geothermal reservoirs, thermal insulation engineering, exploration of petroleum and gas fields etc. The convective heat transfer mechanism through porous media has been studied by Nield and Bejan [2]. MHD convective flow of a micro-polar fluid past a continuously moving vertical porous plate in the presence of heat generation/absorption has been investigated by Rahman and Sattar [3]. As presence of suction being more important and appropriate from the technological point of view, Nanda and Sarma [4], Schetz and Eichhorn [5], Soundalgekar [6] and kafousias [7] have studied unsteady free convective flow vertical plate with suction.

Investigation of MHD flow for an electrically conducting fluid past a heated surface has of its applications in many engineering problems such as plasma studies, petroleum industries, MHD power generator, cooling of nuclear reactors, the boundary layer control in aerodynamics, etc. RamanaKumari and Bhaskar Reddy [8] have studied a two-dimensional unsteady MHD free convective flow of a viscous incompressible electrically conduction fluid past an infinite vertical porous plate with variable suction. Model studies on MHD free and forced convection with heat and mas transfer problems have been carried out by Singh and Singh [9], E Elbashbeshy [10] and Ahmed [11].

Soret effect which is also known as thermal-diffusion effect concerns with the methods of separating heavier gas molecules from lighter ones by maintaining temperature gradient over a volume of a gas containing particles of different masses. Hayat et al. [12] have analyzed a mathematical model in order to study the heat and mass transfer characteristics in mixed convection boundary layer flow about a linearly stretching vertical surface in a porous medium filled with a visco-elastic fluid, by taking into account the diffusion thermo (Dufour) and thermal diffusion (Soret) effects. Jha and Singh [13] have presented an analytical study for free convection and mass transfer flow past an infinite vertical plate moving impulsively in its own plane taking Soret effects into account

The main objective of the present investigation is to study the elastico-viscous effects on unsteady MHD free convective flow past an infinite vertical porous plate with variable suction and Soret effect, where the plate temperature oscillates with the same frequency as that of variable suction velocity. The effects of the visco-elastic fluid on velocity component and skin friction coefficient have been shown graphically with the combination of other flow parameters involved in the solution.

Mathematical Formulation

The unsteady oscillatory MHD free convective elastic-viscous fluid past an infinite vertical porous plate with variable suction under the influence of a uniform transverse magnetic field is considered. Let the components of velocity along with x' and y' axes be $\bar{u}$ and $\bar{v}$and which are chosen along the plate and normal to the plate respectively. The polarization effects are assumed to be negligible and hence the electric fields are also negligible. All the physical variables are functions of $\bar{y}$ and $\bar{t}$only as the plate is infinite. It is also assumed that the variation of expansion coefficient is negligibly small and the pressure and influence of the pressure on the density are negligible. In a convective fluid the flow mass is caused by a temperature difference, the thermal diffusion (Soret effect) cannot be neglected. Within the framework of above assumptions and Boussinesq approximation the dimensionless forms of governing equations are as follows:

$$\frac{1}{4}\frac{\partial \mathrm{u}}{\partial \mathrm{t}} - \left(1 + \mathrm{A}\varepsilon \mathrm{e}^{\mathrm{i}\omega \mathrm{t}}\right)\frac{\partial \mathrm{u}}{\partial \mathrm{y}} = \frac{\partial^2 \mathrm{u}}{\partial \mathrm{y}^2} - \mathrm{k}_1\left[\frac{1}{4}\frac{\partial^3 \mathrm{u}}{\partial \mathrm{t}\,\partial \mathrm{y}^2} - \left(1 + \mathrm{A}\varepsilon \mathrm{e}^{\mathrm{i}\omega \mathrm{t}}\right)\frac{\partial^3 \mathrm{u}}{\partial \mathrm{y}^3}\right] + G_r\mathrm{T} + G_c\mathrm{C} - \left(M + \frac{1}{K}\right)\mathrm{u} \qquad (3.1)$$

$$\frac{1}{4}\frac{\partial \mathrm{T}}{\partial \mathrm{t}} - \left(1 + \mathrm{A}\varepsilon \mathrm{e}^{\mathrm{i}\omega \mathrm{t}}\right)\frac{\partial \mathrm{T}}{\partial \mathrm{y}} = \frac{1}{P_r}\frac{\partial^2 \mathrm{T}}{\partial \mathrm{y}^2} \qquad (3.2)$$

$$\frac{1}{4}\frac{\partial \mathrm{C}}{\partial \mathrm{t}} - \left(1 + \mathrm{A}\varepsilon \mathrm{e}^{\mathrm{i}\omega \mathrm{t}}\right)\frac{\partial \mathrm{C}}{\partial \mathrm{y}} = \frac{1}{S_c}\frac{\partial^2 \mathrm{C}}{\partial \mathrm{y}^2} + S_0\frac{\partial^2 \mathrm{T}}{\partial \mathrm{y}^2} \qquad (3.3)$$

The corresponding boundary conditions are

$$\mathrm{u} = 0, \mathrm{T} = 1 + \varepsilon \mathrm{e}^{\mathrm{i}\omega \mathrm{t}}, \mathrm{C} = 1 \quad \text{at } \mathrm{y} = 0$$

$$u \to 0, T \to 0, C \to 0 \text{ as } y \to \infty \quad (3.4)$$

Solution Methodology

In order to reduce the above system of coupled non-linear partial differential equations to a system of ordinary differential equations, the velocity, temperature and concentration in the neighbourhood of the porous plate are taken as

$$u(y,t) = u_0(y) + \varepsilon u_1(y)e^{i\omega t} + 0(\varepsilon^2) + \cdots$$

$$T(y,t) = T_0(y) + \varepsilon T_1(y)e^{i\omega t} + 0(\varepsilon^2) + \cdots$$

$$C(y,t) = C_0(y) + \varepsilon C_1(y)e^{i\omega t} + 0(\varepsilon^2) + \cdots \quad (4.1)$$

Substituting (3.1) in equations (2.7) to (2.9) and equating the harmonic and non-harmonic terms, and neglecting the higher terms of $0(\varepsilon^2)$, we obtain

$$u_0'' + u_0' - \left(M + \frac{1}{K}\right)u_0 = k_1 u_0''' - G_r T_0 - G_c C_0 \quad (4.2)$$

$$u_1'' + u_1' - \left(M + \frac{1}{K} + \frac{i\omega}{4}\right)u_1 = -G_r T_1 - G_c C_1 \quad (4.3)$$

$$T_0'' + P_r T_0' = 0 \quad (4.4)$$

$$T_1'' + P_r T_1' - \left(\frac{i\omega}{4} P_r\right) T_1 = 0 \quad (4.5)$$

$$C_0'' + S_c C_0' + S_c S_0 T_0'' = 0 \quad (4.6)$$

$$C_1'' + S_c C_1' - \left(\frac{i\omega}{4} P_r\right) S_c S_0 T_0'' = 0 \quad (4.7)$$

The corresponding boundary conditions are

$$u_0 = 0, u_1 = 0, T_0 = 0, T_1 = 0, C_0 = 1, C_1 = 0 \quad \text{at } y = 0$$

$$u_0 \to 0, u_1 \to 0, T_0 \to 0, T_1 \to 0, C_0 \to 0, C_1 \to 0 \text{ as } y \to \infty \quad (4.8)$$

Again to solve equation (4.2), consider very small values of k_1, so that the velocity can be expressed as

$$u_0 = u_{01}(y) + k_1 u_{02}(y) \quad (4.8)$$

Using (4.8) into equation (4.2), we get the following set of ordinary differential equations:

$$u_{01}'' + u_{01}' - \left(M + \frac{1}{K}\right)u_{01} = -G_r T_0 - G_c C_0 \quad (4.9)$$

$$u''_{02} + u'_{02} - \left(M + \frac{1}{K}\right) u_{02} = u'''_{01} \tag{4.10}$$

The corresponding boundary conditions are

$$u_{01} = 0, u_{02} = 0 \text{ at } y = 0$$

$$u_{01} \to 0, u_{02} \to 0 \text{ as } y \to \infty \tag{4.11}$$

Significant conclusions:

- Increasing values of elastic-viscous parameter lead to reduce the velocity profiles of non-Newtonian fluid in comparison with the Newtonian fluid.
- The velocity profiles decreases with the growth of Magnetic parameter, Prandtl number and Grashof number.
- The effect of Schmidt number enhances the velocity profile.
- Skin friction enhances with the increasing values of elastic-viscous parameter in comparison with their values to that of Newtonian fluid.
- Skin friction at the plate reduces with the increasing values of Prandtl number and Schmidt number but it enhances with the growth of Grashof number.