Isothermal Radiation and MHD Effect on Moving with Vertical Plate

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Abstract: Thermal radiation effect on unsteady free convective flow over a moving isothermal vertical plate with mass transfer in the presence of magnetic field is obtained. The fluid considered here is a gray, absorbing and emitting radiation but a non-scattering medium. The plate temperature is raised to T and the concentration level near the plate is also raised to C. The dimensionless governing equations are solved using the Laplace transform technique. The velocity, temperature and concentration are studied for different parameters like the magnetic field parameter, radiation parameter, thermal Grashof number, mass Grashof number and time.

Keywords: Vertical plate, Magnetic field, Diffusion, Radiation.

INTRODUCTION: It is of importance in connection with many engineering problems, such as sustained plasma confinement for controlled thermonuclear fusion and electromagnetic casting of metals. MHD finds applications in electromagnetic pumps, controlled fusion research, crystal growing, MHD couples and bearings, plasma jets, and chemical synthesis. The effects of transversely applied magnetic field, on the flow of an electrically conducting fluid past an impulsively started infinite isothermal vertical plate was studied by Soundalgekar et al (1). The dimensionless governing equations were solved using Laplace transform technique. Kumari and Nath (2) studied the development of the asymmetric flow of a viscous electrically conducting fluid in the forward stagnation point region of a two-dimensional body and over a stretching surface with an applied magnetic field, when the external stream or the stretching surface was set into impulsive motion from the rest.

MATHEMATICAL ANALYSIS:

Thermal radiation effects on unsteady flow of a viscous incompressible fluid past an impulsively started infinite vertical isothermal plate with mass diffusion, in the presence of transverse applied magnetic field is studied. Then by usual Boussineq's approximation, the unsteady flow is governed by the following equations :

$$\frac{\partial u'}{\partial t'} = g\beta\left(T - T_\infty\right) + g\beta^*\left(C' - C_\infty\right) + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^2}{\rho}u' \quad (1)$$

$$\rho C_p \frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y'^2} - \frac{\partial q_r}{\partial y'} \quad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} \quad (3)$$

$$t' \le 0 : u' = 0, T = T_\infty, C' = C_\infty' \quad \text{for all } y'$$

$$t' > 0 : u' = u_0, T = T_w, C' = C_w' \quad \text{at } y' = 0 \quad (4)$$

$$u' = 0, T \to T_\infty, C' \to C_\infty' \quad \text{as } y' \to \infty$$

Where $A = \frac{u_0^2}{\nu}$

$$\frac{\partial q_r}{\partial y'} = -4a \cdot \sigma \left(T_\infty^4 - T^4 \right) \tag{5}$$

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \tag{6}$$

By using equations (5) and (6), equation (2) reduces to

$$\rho C_p \frac{\partial T}{\partial t'} = k \frac{\partial^2 T}{\partial y'^2} + 16a * \sigma T_\infty^3 \left(T_\infty - T \right) \tag{7}$$

On introducing the following dimensionless quantities:

$$u = \frac{u'}{u_0}, t \frac{t' u_0^2}{v}, y = \frac{y' u_0}{v}, \theta = \frac{T - T_\infty}{T_w - T_\infty},$$

$$Gr = \frac{g \beta v \left(T_w - T_\infty \right)}{u_0^3}, C = \frac{C' - C_\infty'}{C'_w - C'_\infty}, Gc = \frac{g \beta v \left(C_w' - C'_\infty \right)}{u_0^3} \tag{8}$$

$$Pr = \frac{\mu C_p}{k}, Sc = \frac{v}{D}, M = \frac{\sigma B_0^2 v}{\rho u_0^3}, R = \frac{16a * v^2 \sigma T_\infty^3}{k u_0^2}$$

In equations (1) to (4), we get

$$\frac{\partial u}{\partial t} = G\gamma\theta + GcC + \frac{\partial^2 u}{\partial y^2} - Mu \tag{9}$$

$$\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\Pr \partial y^2} - \frac{R}{\Pr} \theta \tag{10}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial y^2} \tag{11}$$

The initial and boundary conditions are

$$\begin{aligned} &u = 0, \quad \theta = 0, \quad C = 0, && \text{for all } y, t \le 0 \\ t > 0 : \; &u = 1, \quad \theta = 1, \quad C = 1 && \text{at } y = 0 \\ &u = 0, \quad \theta \to 0, \; C \to 0 && \text{as } y \to \infty \end{aligned} \tag{12}$$

Using Boundary conditions (12) , The equations (9) to (11) becomes by using Laplace-transform technique

$$\theta = \frac{1}{2} \left[\exp\left(2\eta\sqrt{Rt} \right) erfc\left(\eta\sqrt{\Pr} + \sqrt{at} \right) + \exp\left(-2\eta\sqrt{Rt} \right) erfc\left(\eta\sqrt{\Pr} - \sqrt{at} \right) \right] \tag{13}$$

$$C = erfc\left(\eta\sqrt{Sc} \right) \tag{14}$$

$$
\begin{aligned}
u = {} & \frac{1}{2}\left(1+\frac{Gr}{b(1-\Pr)}+\frac{Gc}{c(1-Sc)}\right)\left[\begin{array}{l}\exp\left(2\eta\sqrt{Mt}\right)erfc\left(\eta+\sqrt{Mt}\right)\\ +\exp\left(-2\eta\sqrt{Mt}\right)erfc\left(\eta-\sqrt{Mt}\right)\end{array}\right]\\
& -\frac{Gc}{c(1-Sc)}erfc\left(\eta\sqrt{Sc}\right)\\
& -\frac{Gr\exp(bt)}{2b((1-\Pr)}\left[\begin{array}{l}\exp\left(2\eta\left(\sqrt{M+b}\right)t\right)erfc\left(\eta+\left(\sqrt{M+b}\right)t\right)\\ +\exp\left(-2\eta(M+b)t\right)erfc\left(\eta-\left(\sqrt{M+b}\right)t\right)\end{array}\right]\\
& -\frac{Gc\exp(ct)}{2c((1-Sc)}\left[\begin{array}{l}\exp\left(2\eta\left(\sqrt{M+c}\right)t\right)erfc\left(\eta+\left(\sqrt{M+c}\right)t\right)\\ +\exp\left(-2\eta(M+c)t\right)erfc\left(\eta-\left(\sqrt{M+c}\right)t\right)\end{array}\right]\\
& -\frac{Gr}{2b((1-\Pr)}\left[\begin{array}{l}\exp\left(2\eta\sqrt{Rt}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{at}\right)\\ +\exp\left(-2\eta\sqrt{Rt}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{at}\right)\end{array}\right]\\
& -\frac{Gc\exp(ct)}{2c((1-Sc)}\left[\begin{array}{l}\exp\left(2\eta\sqrt{\Pr(a+b)t}\right)erfc\left(\eta\sqrt{\Pr}+\sqrt{(a+b)t}\right)\\ +\exp\left(-2\eta\sqrt{\Pr(a+b)t}\right)erfc\left(\eta\sqrt{\Pr}-\sqrt{(a+b)t}\right)\end{array}\right]\\
& -\frac{Gc\exp(ct)}{2c((1-Sc)}\left[\begin{array}{l}\exp\left(2\eta\sqrt{ctSc}\right)erfc\left(\eta\sqrt{Sc}+\sqrt{ct}\right)\\ -\exp\left(-2\eta\sqrt{ctSc}\right)erfc\left(\eta\sqrt{Sc}-\sqrt{ct}\right)\end{array}\right] \qquad (15)
\end{aligned}
$$

where $a=\frac{R}{\Pr}$, $b=\frac{M-R}{\Pr-1}$, $c=\frac{M}{Sc-1}$ and $\eta=\frac{y}{2\sqrt{t}}$

CONCLUSION:

The numerical values of the velocity, temperature and wall concentration are computed for different parameters like magnetic field parameter, radiation parameter, Schmidt number, thermal Grashof number and mass Grashof number, time and Pr = 0.71. The purpose of the calculations given here is to study the effects of the parameters M, R, t, Gr, Gc, and Sc upon the nature of the flow and transport. The typical velocity profiles for various values of the magnetic field parameter (M = 2, 5, 10) in the presence of thermal radiation. The trend shows that the velocity increases with decreasing magnetic field parameter. The conclusions of the study are as:

(a) The velocity decreases with increasing radiation parameter or magnetic field parameter.
(b) The temperature increases with decreasing value of thermal radiation parameter.

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