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Viscous Dissipation Effect on Steady free Convection Flow past a Semi-Infinite Flat Plate in the presence of Magnetic Field

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Abstract:

The viscous dissipation effect in the presence of a magnetic field is thoroughly studied in the two-dimensional free convectional flow past a continuously moving semi-infinite flat plate. The velocity and temperature profiles are plotted for various parameters such as Gehart number (Gb), Prantl Number (Pr) and the magnetic field (M). The equations are solved using Runge- Kutta method with shooting technique. It is observed that the normal behavior of Viscous Dissipation effect changes in the presence of a magnetic field.

Keywords: Heattransfer, Moving surface, Prandtl number, Gebhart number,(Gb) Viscous dissipation.

I.INTRODUCTION

A moving boundary involving fluid flow and its effects of viscous dissipation has found many industrial applications such as agriculture, petroleum industries, stellar and planetary magnetospheres, aeronautics, chemical engineering and electronics. Sakisdas(1961) investigated the flow of a fluid in the boundary layer and revealed that the growth of the boundary layer is in the direction of motion of the solid surface. But it is different from Blasius flow past a flate. In 1962 Gabhart proposed that the act of gravitational force in the natural convection of fluid flow generates appreciable temperature, reveals the rate of change of mechanical energy which is converted into the heat per unit volume in a viscous fluid.Many research scholars have some constraints on velocity and temperature distribution on the surface. In 1967 Tsouetal investigated some theoretical and practical studies of flow and temperature fields in the boundary layer on a moving surface for various values of the prandtl number.

In 1969, Gebhart and Mollendorf study the viscous dissipation effects on the free convection of fluids with the effect of exponential variation wall temperature.The effects of transversely applied magnetic field, on the flow of an electrically conduction fluid past an impulsively started infinite isothermal vertical plate was studied by Soundalgekar et.al (1979) .In 1995,M.Massoudi investigated the effects of variable viscosity and viscous dissipation on the flow of a third grad fluid in a pipe.In 1997 PVSN Murthy and P.Singhareinitiated the effect of viscous dissipation on non-darcy natural convection flow along an isothermal verctical wall in a porous medium.In 1999 Anjali and Kandasamyanalysied the viscous dissipation effects on heat transfer while a fluid flow over a continuous moving semi-infinite flat plate. Electrically conducting fluid over a sphere in the presence of Magnetic field with the effect of viscous dissipation has been studied by Alam et.al (2007)Cortell (2007) investigated on viscous flow with effect of heat transfer over a non linear stretching sheet.Moreover, the problem extended to study the effect of viscous dissipation and radiation on the thermal boundary layer over a non linear stretching sheet by cortell (2008). Before that in (2006) Raptis and perdikis studied viscous flow near a non-linear stretching sheet in the presence of chemical reaction and magnetic field. In2000, Nield studied the Resolution of Paradox involving Involving Viscous dissipation and nonlinear drag in a porous medium.The study of MHD natural convective flow of an incompressible viscous fluid over a infinite vertical oscillating plate by kishan et.al (2006) In 2009 Arabauy studied the effects of mass transfer over a stretching surface in the presence of suction/injection effects.Before this in (2007) Alao and Adegbic studied the combined effect of viscous dissipation and radiation of non Newtonian fluid over a non darcy porous medium with natural convection flow. El-Anabawy (2009) investigated the effects of chemical reaction on mass transfer over a stretching surfaceKanri et.al (2011) study the combination effect of viscous dissipation and radiation on free convection in non-darc y porous medium satured with non Newtonian fluid. In 2011 GeethaPalansamy and M.B.K. Moorthyinversigated that the Viscous dissipation effect on steady free convection flow and mass transfer flow past a semi-infinite flat plate.

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The aim of the present study is to study the effect of viscous dissipation on heat transfer in the flow past a continuously moving semi infinite flat plate in the presence of magnetic field. The analysis showed that the viscous dissipation have significant influence on the non-dimensional heat transfer coefficients

II. MATHEMATICAL FORMULATION

Here, the two dimensional fluid flow past a continuously moving semi-infinite flat plate in the presence of magnetic field has been considered. Assume that x– axis to be taken along the flat plate and y – axis to be considered normal to the plate. Let u and v the velocities components of the fluid flow along x and y directions respectively. The governing equations under the boundary layer and Boussinesq approximations may be written as:

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \quad (1)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma_0 B_0^2}{\rho_x}U_0^2 \quad (2)$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}+\frac{\nu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2 (3)$$

Along with the boundary conditions:

$u=U_0\,, v=0, T=T_w, \quad at \quad y=0$

$u=0,\ T\rightarrow T_\infty, \quad at \quad y\rightarrow\infty$

Here:

c_p= Specific heat

ν = Kinematic viscosity of the ambient fluid

$U_{0=}$ Velocity of fluid at y =0

$B_{0=}$ Magnetic field intensity

σ_0= Thermal diffusivity

The following similarity transformation is used to converted the above partial differential equations into ordinary differential equation as follows:

$$\eta=y\sqrt{\frac{U_0}{\nu x}} \quad (4)$$

$$\psi(x,y)=\sqrt{\nu x U_0}\,\mathrm{f} \quad (5)$$

$$\theta=\frac{T-T_\infty}{T_w-T_\infty} \quad (6)$$

Where:

η = The similarity variable, θ = The dimensionless stream function depends on η only

Let Ψ be the stream function defined such that $u=\frac{\partial\Psi}{\partial y}\, v=-\frac{\partial\Psi}{\partial x}$ so that, the equation of continuity automatically satisfied.

$$\frac{\partial u}{\partial x}=-\frac{U_0}{2}f''(y\sqrt{\frac{U_0}{\nu}}x^{-3/2}) \quad (7)$$

$$\frac{\partial v}{\partial y}=y\,\frac{U_0}{2x}f''\,(\sqrt{\frac{U_0}{\nu x}}) \quad (8)$$

The equation (7) and (8) automatically satisfied the equation (1)

From the equation of motion

$$u\,\frac{\partial u}{\partial x}+v\,\frac{\partial u}{\partial y}=\nu\,\frac{\partial^2 u}{\partial y^2}-\frac{\sigma_{oB_0}}{\rho x}U_0{}^2$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=f'U_0(\frac{-U_0\,y}{2x}f''\sqrt{\frac{U_0}{\nu x}})+(\frac{U_0}{2x}\,f'y-\sqrt{\frac{U_0\,\nu}{2\sqrt{x}}}f)(U_0\,f''\frac{\sqrt{U_0}}{\sqrt{\nu x}})$$

$$=(\frac{U_0}{2x}f'y-\frac{\sqrt{\nu U_0}}{2\sqrt{x}}f)(U_0 f''\frac{\sqrt{U_0}}{\nu x}) \quad (9)$$

$$\frac{\partial^2 u}{\partial y^2}=U_0{}^2\frac{f'''}{\nu x} \quad (10)$$

Using equation (9) and (10) in equation (2), we get as

$$(\frac{U_0}{2x}f'y-\frac{\sqrt{\nu U_0}}{2\sqrt{x}}f)(U_0 f''\frac{\sqrt{U_0}}{\nu x})=\nu U_0{}^2\frac{f'''}{\nu x}-\frac{\sigma_0 B_0^2}{\rho_x}u_0^2$$

$$f'''+\frac{1}{2}ff''-M=0 (11)$$

The Equation (11) is the similarity transformation of equation (2)

From the equation of energy

$$u\,\frac{\partial T}{\partial x}=-f'\theta' U_0 y\sqrt{\frac{U_0}{\nu}}\times\frac{1}{2}x^{-\frac{3}{2}}(T_{w-}T_\infty)$$

$$v\,\frac{\partial T}{\partial y}=\frac{U_0}{2x}f'y(T_w-T_\infty)\theta'\sqrt{\frac{U_0}{\nu x}}-\frac{\sqrt{\nu}U_0}{2\sqrt{x}}(T_w-T_\infty)\theta'\sqrt{\frac{U_0}{\nu x}}\,f$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=-f'\theta' U_0 y\sqrt{\frac{U_0}{\nu}}\frac{1}{2}x^{-\frac{3}{2}}(T_{w-}T_\infty)+\frac{U_0}{2x}f'y(T_w-T_\infty)\theta'\sqrt{\frac{U_0}{\nu x}}-\frac{\sqrt{\nu}U_0}{2\sqrt{x}}(T_w-T_\infty)\theta'\sqrt{\frac{U_0}{\nu x}}\,f$$

$$=-\frac{U_0}{2x}(T_w-T_\infty)\theta' f$$

$$\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}+\frac{\nu}{c_p}\left(\frac{\partial u}{\partial y}\right)^2=\frac{k}{\rho c_p}(T_w-T_\infty)\,\theta''\frac{U_0}{\nu x}+\frac{U_0}{x}(T_w-T_\infty)G_b(f'')^2$$

$$-\frac{U_0}{2x}(T_w-T_\infty)\theta' f=\frac{k}{\rho c_p}(T_w-T_\infty)\,\theta''\frac{U_0}{\nu x}+\frac{U_0}{x}(T_w-T_\infty)G_b(f'')^2$$

$$\frac{k}{\rho c_p}(T_w-T_\infty)\,\theta''\frac{U_0}{\nu x}+\frac{U_0}{x}(T_w-T_\infty)G_b(f'')^2+\frac{U_0}{2x}(T_w-T_\infty)\theta' f=0$$

$$\frac{U_0(T_w-T_\infty)}{x}\left\{\frac{\theta' f}{2}+\frac{k}{\rho c_p}\theta''\frac{1}{\nu}+G_b\left(f''\right)^2\right\}=0$$

The final similarity transformation of equation of Energy is

$$\theta''+\frac{1}{2}P_r f\theta'+G_b(f'')^2P_r=0 \qquad (12)$$

The final transformed equations with boundary conditions are :

$$f'''+\frac{1}{2}f\,f''-m=0$$

$$\theta''+\frac{1}{2}\Pr f\,\theta'+G_b\,Pr(f'')^2=0$$

With the boundary and initial conditions as:

$$f(0)=0;\ f'(0)=1;\ \theta(0)=1\ at\ \eta=0$$
$$f'(\infty)=0;\ \theta(\infty)=0\ at\ \eta\to\infty \ (13)$$

The non-dimensional numbers are defined as the Viscous dissipation parameter known as the Gebhart number, given by $G_b=\frac{U_0^2}{c_p(T_w-T_\infty)}$, and the Prandtl number given by Pr = ν/a.

III. MATERIALS AND METHODS

The set of Eq. (11) & (12) together with the boundary conditions (13) have been solved numerically by applying shooting technique along with Runge-Kutta Gill method. The ordinary differential Eq.(1) to (3)along the boundary conditions are solved by giving approximate initial guess values for the missing initial conditions of f (0), θ' (0), and these values are matched with the corresponding boundary conditions at f'(∞)θ(∞).Extensive calculations have been performed to obtain the flow and temperature fields for a wide range of parameters 0<Pr≤10, and 1≤G_b≤10.

IV. DISCUSS OF RESULTS

For physical understanding of the problem numerical computations are carried out of different physical parameters Magnetic field, Gambhert Number, Prandtl Number upon the nature of the flow. The value of Prandtl number Pr is chosen such that they represent water (Pr=7.0). The numerical values of the velocity are computed for different physical parameters like Gambhert Number. The Velocity profile for different values of Gambhert Number are shown in figure .1

Fig.2 demonstrates viscous dissipation effects on temperature profile with different values of Gambhert Number with Magnetic field and Prandtl number. It observed viscous dissipation effects goes on decrease with increase value of Gambhert Number. Samething were analyzed by giving the different values of magnetic field and prandtl number in the figure 3 & 4.

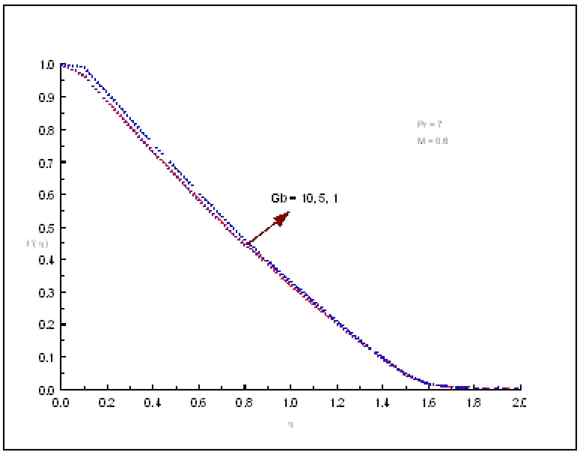

Figure.1 Effect of viscous dissipation parameter on no dimensional velocity f'

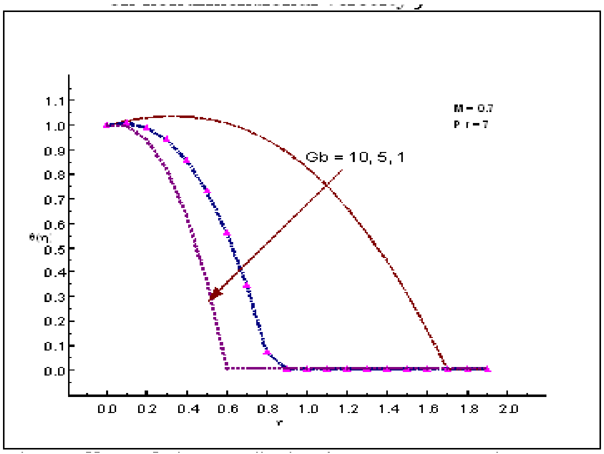

Figure.2 Effect of viscous dissipation parameter Gb on non-dimensional temperature θ

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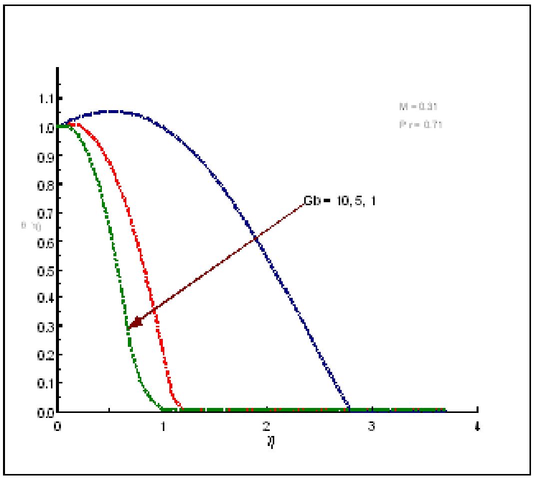

Figure.3.Effect of viscous dissipation parameter Gb on non-dimensional temperature θ

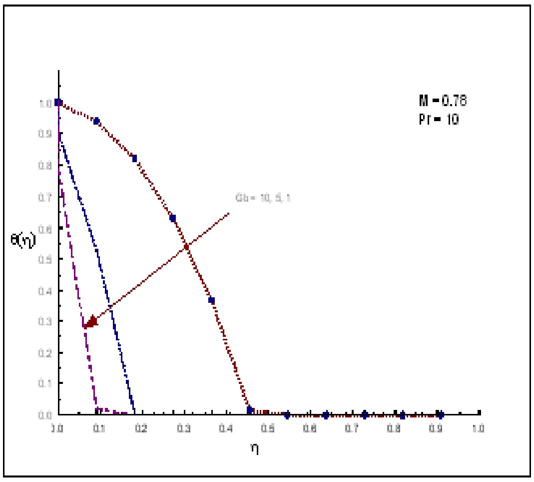

Figure-4 Effect of viscous dissipation parameter Gb on non-dimensional temperature θ

V.CONCLUSION

An exact analysis of Viscous Dissipation effect on steady free convection flow past a continuously moving semi-infinite flat plate in the presence of magnetic field has been studied. The similarlity equations are solved by using runge-kutta gill method with shooting techniques.The effect of different parameters like magnetic field parameter, Pradtl number, Gebhart number are studied graphically. The conclusions of the study are as follows:

- Viscous dissipation effect increase in the velocity profile with increase value of Gebhart number(G_b)
- Viscous Dissipation effect of fluid flow in the temperature profile is decrease with increasing value of magnetic field.
- Viscous Dissipation effect of fluid flow in the temperature profile is decrease with the increase value of Pradtl number.
- Viscous Dissipation effect more in the air than in water.

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