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MHD flow on a moving infinite vertical porous plate in the presence of thermal radiation

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Abstract
An attempt has been made in this paper to study the MHD Flow on a Moving Infinite Vertical Porous Plate In The Presence Of Thermal Radiation. The effects of various parameters on the flow entities has been examined. It is noticed that as Pr increases, the velocity in general increases. Through, there is a marginal change in the value of t, not much of significant change in the velocity profiles is observed. Further, it is observed that as Grash off number increases, the flow rate decreases. Also, as the Magnetic field increases, the flow rate decreases. This in agreement with the real life situation that the Magnetic field suppress the fluid motion.

Keywords: Impulsively started vertical plate, MHD flow, heat and mass, radiation transfer, heat flux

Introduction
Nomenclature

C_p	:	Specific heat at constant pressure
g	:	Acceleration due to gravity
k κ	:	Thermal conductivity of the fluid
P_r	:	Prandtl number
p	:	Pressure
q_r	:	Radiative heat flux in the y-direction
k	:	Thermal diffusivity
K	:	Porosity
M	:	Magnetic field
N	:	Radiation parameter
t	:	Time
T	:	Temperature of the fluid near the plate
T_W	:	Temperature of the plate
T_∞	:	Temperature of the fluid far away from the plate
u	:	Velocity of the fluid in the x-direction
u_0	:	Velocity of the fluid plate
U	:	Dimensionless velocity
y	:	Coordinate axis normal to the plate
y'	:	Dimensionless coordinate axis normal to the plate
k^*	:	Mean absorption coefficient
α	:	Thermal diffusivity
β	:	Volumetric coefficient of thermal expansion
μ	:	Coefficient of viscosity
ν	:	Kinematic viscosity
ρ	:	Density
σ	:	Stefan-Boltzmann constant
τ	:	Dimensionless skin-friction
θ	:	Dimensionless temperature

In several industrial and environmental situations, the radiative convective flow occurs flow place a very important role. Several applications are noticed in combustion and cooling chambers. The applications are more seen astrophysical flows, solar power technology and space vehicles. In the design high precision equipment, the radiative heat transfer plays a very significant role. The radiative transfer is more found in nuclear power plants, gas turbines, missiles and in air craft engines.

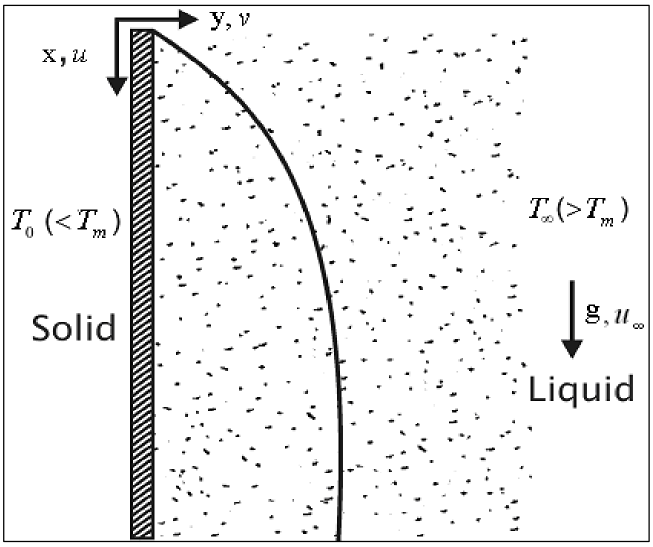
The problem of viscous incompressible fluid over an infinite horizontal plate which moves in its own plane once was studied by stokes [1]. Thereafter, the viscous force imparted by flowing fluid in a dense swarm of particles was studied by Brinkman [2]. Later on, Stewartson [3] obtained the analytical solution for viscous flow past and impulsively started semi-infinite horizontal plate. Thereafter, Berman [4], studied the case of two dimensional study state flow of an incompressible fluid with parallel rigid porus walls where the flow is influenced by uniform section and injection. Next, the flow between two vertical plates where the plates are electrically non non-conducting with the assumption that the wall temperature influences linearly in the direction of the flow was studied by Macy [5] and Mori [6].

Hall [7] studied the same problem with the help of finite differences method of a mixed explicit implicit time for the stability of the solution. Change *et al.* [8] examined the effects of radioactive heat transfer of free convection in an enclosed with specialized applications. Thereafter, Mahajan *et al.* [9] examined the influence of viscous heat dissipating effect in natural convective flows. Subsequently, Soundalgekar and Thaker [10]. Investigated radiation effects of an optionally thin gray gas bounded by a stationary vertical plate. By applying Rossland's approximation, Hossain *et al.* [11] studied the radiation effects and mixed convection along a vertical plate with uniform free surface temperature by applying Rossland's approximation, Subsequently, the effects of thermal radiation and convective flow past a moving infinite vertical plate was analyzed, discussed and presented by Raptis and Perdikis [12]. The effects of thermal radiation and flow past semi-infinite vertical isothermal plate with uniform heat flux in the presence of applied magnetic field was examined by Antony Raj *et al.* [13].

The Influence of velocity with reference to the critical parameters which appear in the equation of motion were neither commented nor examined in detail by any of the above investigators is a point of great concern academic interest. Therefore, an attempt has been made to study the effects of such parameters in this paper. Also the effect of critical parameter on the flow entities has been examined.

Mathematical Formulation

Flow of an incompressible viscous radiating fluid past an impulsively started infinite vertical plate with uniform heat flux is considered. The x-axis is taken along the plate in the vertical direction and the y-axis is taken normal to the plate. The Flow geometry is as shown below



Schematic representation of the problem

Initially, the plate and fluid are at the same temperature in a stationary condition. The plate is given an impulsive motion in the vertical direction against the gravitational field with constant velocity u_0 when $t > 0$. At the same time, the heat is supplied from the plate to the fluid at uniform rate. The fluid exhibits the properties of grey, absorbing-emitting radiation but a non-scattering medium. Then by usual Bossiness's approximation, the unsteady flow is governed by the following equations.

$$\frac{\partial u}{\partial t'} = g\beta(T - T_\infty) + \nu \frac{\partial^2 u}{\partial y^2} \tag{1}$$

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

In view of Rossland approximation q_r is given by:

$$q_r = -\frac{4\sigma}{3k^*}\frac{\partial T^4}{\partial y} \tag{3}$$

While, the initial and boundary conditions are:

$$\left.\begin{array}{l} t' \le 0 : u = 0, T = T_\infty \text{ For all } y' \\ t' > 0 : u = u_0, \dfrac{\partial T}{\partial y} = -\dfrac{q}{k} \text{ at } y' = 0 \\ u = 0, T \to T_\infty \text{ as } y' \to \infty \end{array}\right\} \tag{4}$$

Under the assumption that, the temperature differences within the flow are sufficiently small such that T^4 may be expressed as a linear function of the temperature. This is accomplished by expanding T^4 in a Taylor series about T_∞ and neglecting higher order terms, thus

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \tag{5}$$

By using equations (4) and (5), equation (2) reduces to

$$\rho C_p \frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y^2} + \frac{16\sigma T_\infty^3}{3k^*}\frac{\partial^2 T}{\partial y^2} \tag{6}$$

On introducing the following non-dimensional quantities

$$\left.\begin{array}{l} U = \dfrac{u}{u_0}, t = \dfrac{t' u_0^2}{\nu}, y = \dfrac{y' u_0}{\nu}, \theta = \dfrac{T - T_\infty}{T_w - T_\infty}, \\ Gr = \dfrac{g\beta\nu(T_w - T\infty)}{u_0^3}, \Pr = \dfrac{\mu C_p}{k}, N = \dfrac{\kappa^* k}{4\sigma T_\infty^3} \end{array}\right\} \tag{7}$$

By considering the magnetic intensity as M and the permeability of the boundary as K Eqs. (1) to (6), can be re defined as:

$$\frac{\partial U}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial U}{\partial y} = \frac{\partial^2 U}{\partial y^2} + \frac{1}{K}U \tag{8}$$

$$3N \Pr \frac{\partial \theta}{\partial t} = (3N + \Pr)\frac{\partial^2 \theta}{\partial y^2} \tag{9}$$

The initial and boundary conditions in non-dimensionless form are

$$\left.\begin{array}{l} u = 0, \theta = 0, \text{For all } y, t \le 0 \\ t > 0 : u = 1, \dfrac{\partial \theta}{\partial y} = -1 \text{ At } y = 0 \\ u = 0, \theta \to 0, \text{ As } y \to \infty \end{array}\right\} \tag{10}$$

Methodology for solution

We assume that the solutions for Eqn (8) and Eqn (9) in form of:

$$u(x,t) = u_0(y)e^{i\omega t} \tag{11}$$

$$\theta(y,t) = \theta_0(y)e^{i\omega t} \tag{12}$$

Under the modified initial and boundary conditions:

$$\left.\begin{array}{l} u_0 = 0, \theta_0 = 0, \text{ for all } y,t \le 0 \\ t > 0 : u_0 = e^{-i\omega t}, \dfrac{d\theta_0}{dy} = e^{-i\omega t} \text{ at } y = 0 \\ u_0 = 0, \theta_0 \to 0 \text{ as } y \to \infty \end{array}\right\} \tag{13}$$

Using Eqns (11), (12) and (13) in Eqns (8) and (9)

$$u(y,t) = \frac{Gr}{R1}(\exp(-m_2 y) - \exp(-m_1 y)) + \exp(-m_2 y) \tag{14}$$

$$\theta(y,t) = \frac{\exp(-m_1 y)}{m_1} \tag{15}$$

The expression for the skin friction is:

$$\left[\frac{\partial u}{\partial y}\right]_{y=0} = \frac{Gr}{R_1}[m_1 - m_2] - m_2 \tag{16}$$

Where

$$m_1 = \sqrt{\frac{3N \Pr i\omega}{3N + \Pr}}, m_2 = \sqrt{(i\omega - M - \frac{1}{K})}, R_1 = m_1(m_1^2 - (i\omega - M - \frac{1}{K}))$$

Results and Discussion

Figures 1, 2, 3 and 4 illustrates the effect of time on the velocity profiles for Pr=0.05, 0.01 0.04 and 0.03 respectively. In all these illustrations, it is observed that their relationship between Y (plate width) and velocity is always linear In some cases, their relationship is positive and while in some cases it is negative.

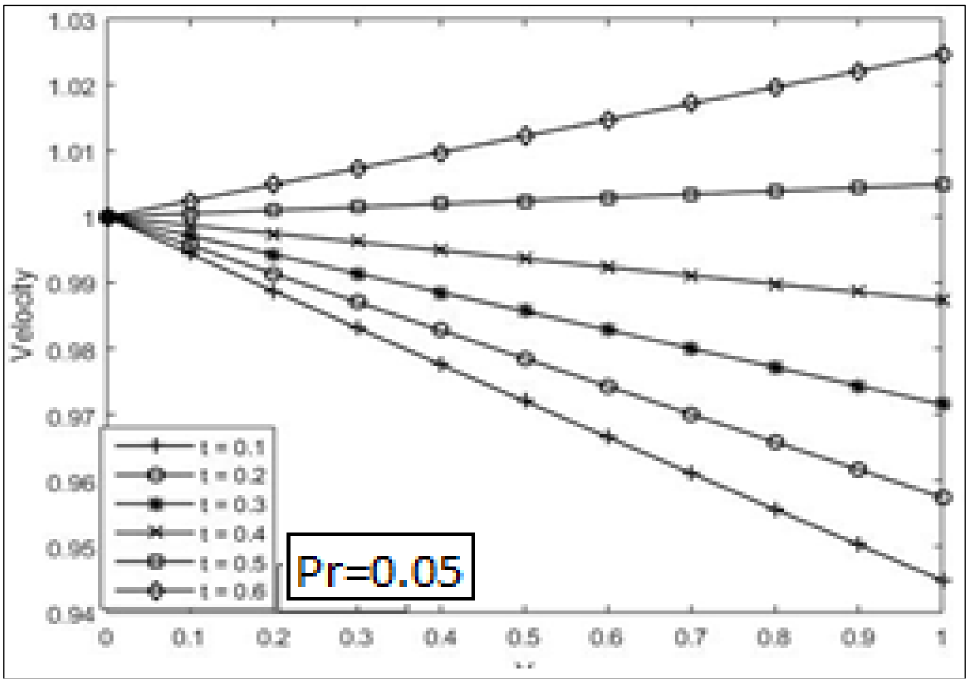


Fig 1: Effect of time on velocity for Pr = 0.05

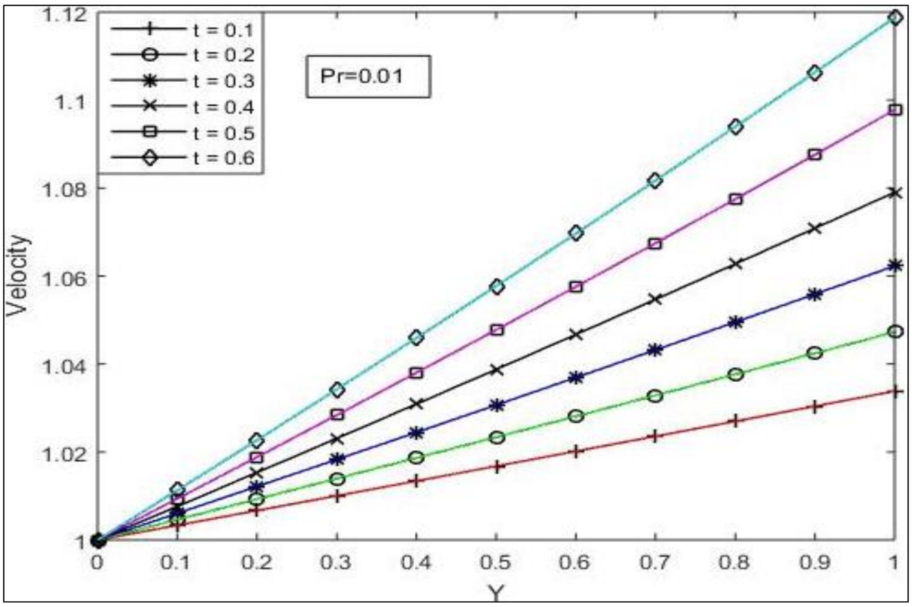


Fig 2: Effect of time on velocity for Pr =0.01

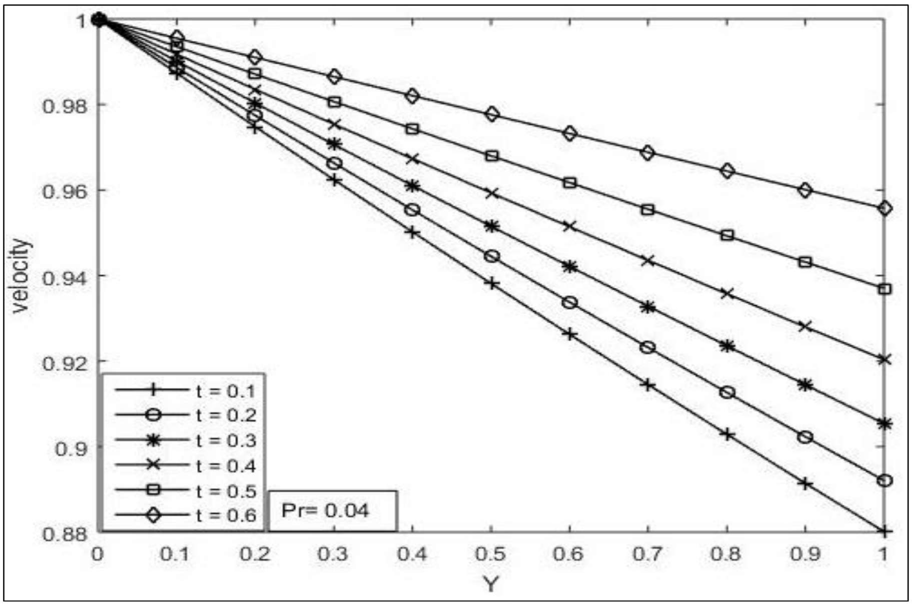


Fig 3: Influence of time on velocity for Pr=0.04

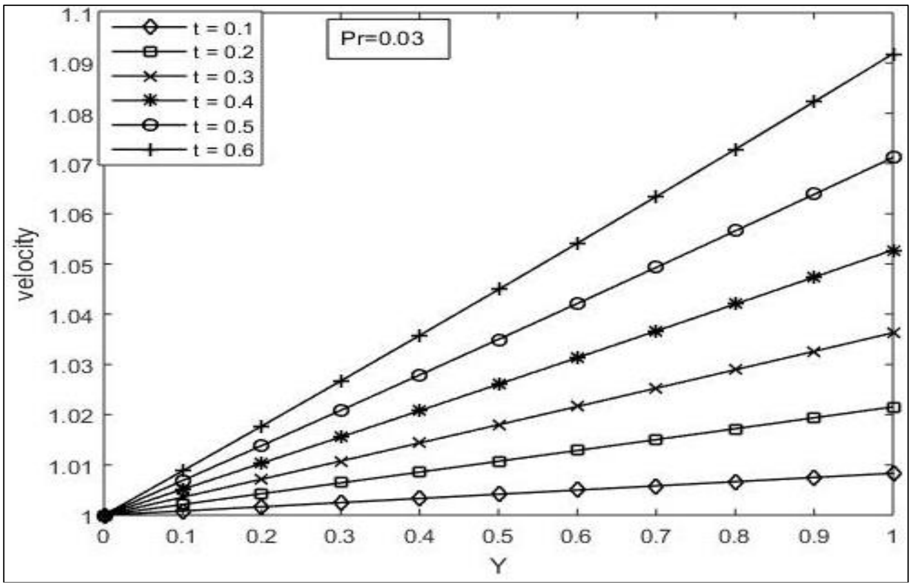


Fig 4: Influence of time on velocity for Pr=0.03

Fig – 5, Fig -6, Fig -7, Fig -8, Fig – 9 and Fig - 10 shows the nature of the velocity profiles for Prandtl numbers 0.01, 0.02,0.03,0.04 and 0.05 respectively for t = 0.6, 0.5, 0.4, 0.3, 0.2 and 0.1 respectively. In each of these figures, their relationship is found to be perfectly linear. The relationship is positive while sometimes is negative as Pr increase. Further, it is noticed that as Pr increases, the velocity in general increases. Through, there is a marginal change in the value of t, not much of significant change in the velocity profile is observed.

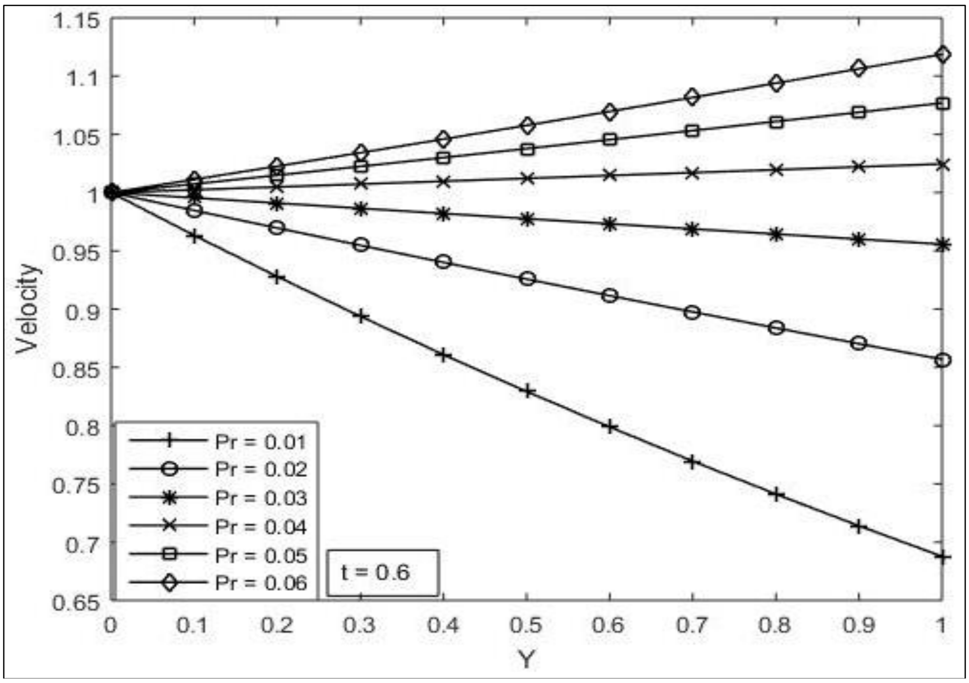


Fig 5: The nature of velocity for t=0.6

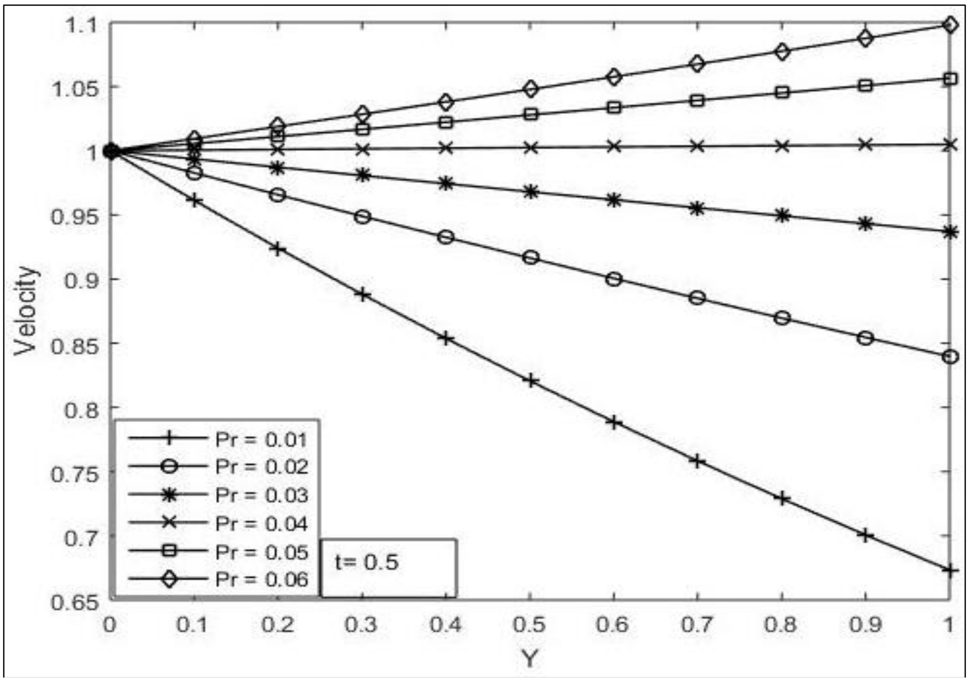


Fig 6: The nature of velocity for t=0.5

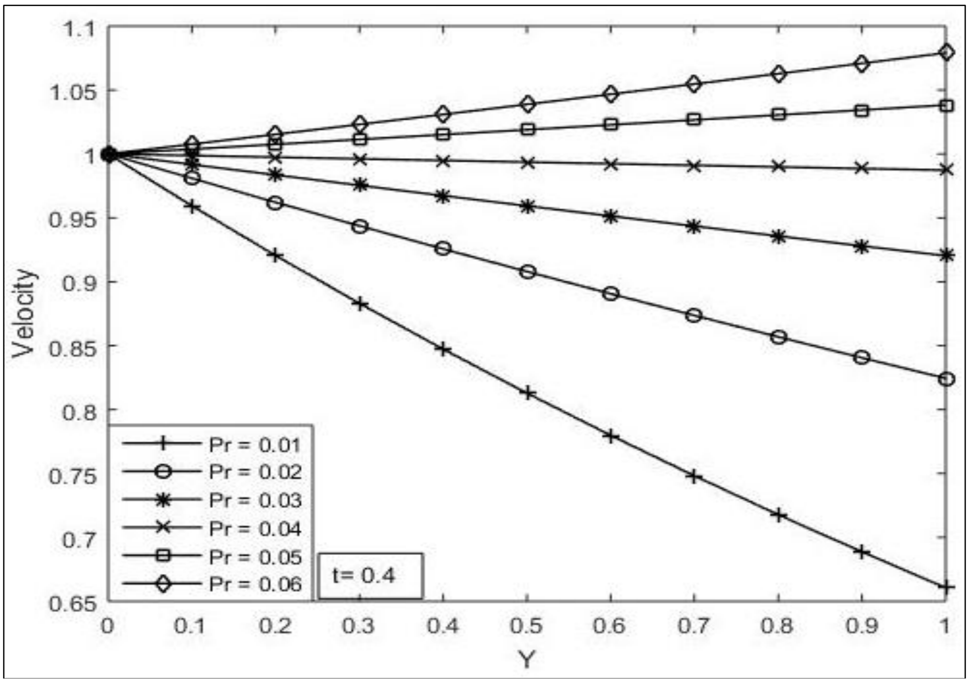


Fig 7: The nature of velocity for t=0.4

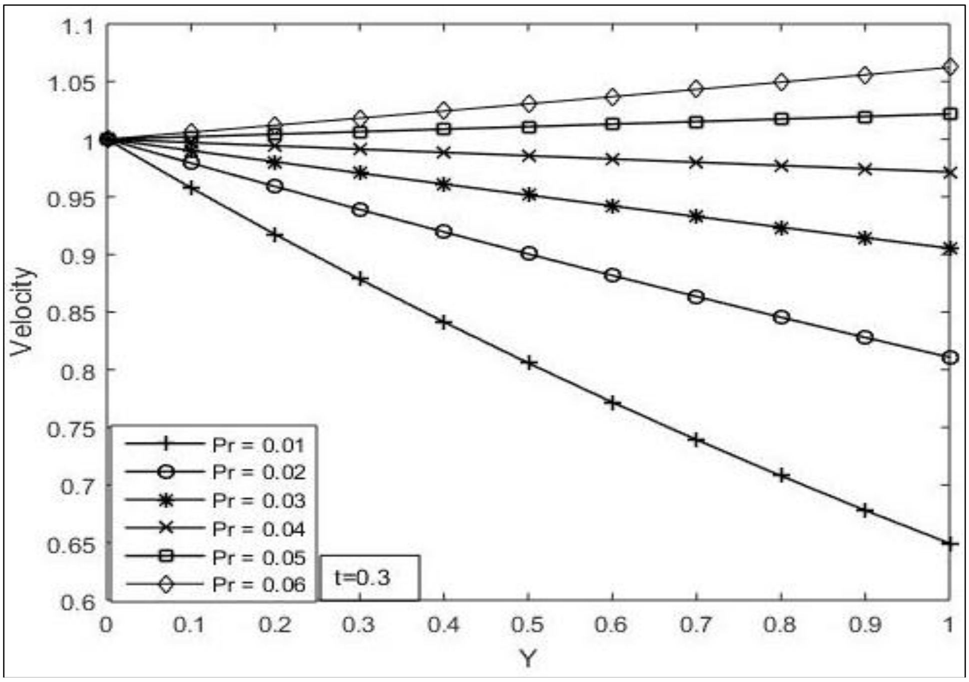


Fig 8: The nature of velocity for t=0.3

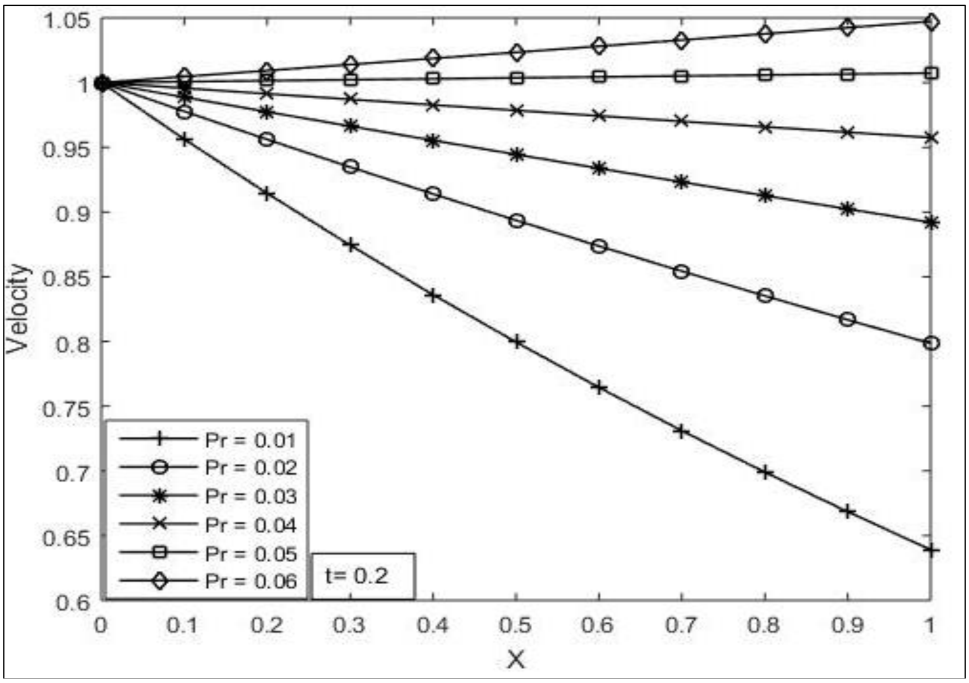


Fig 9: The nature of velocity for t=0.2

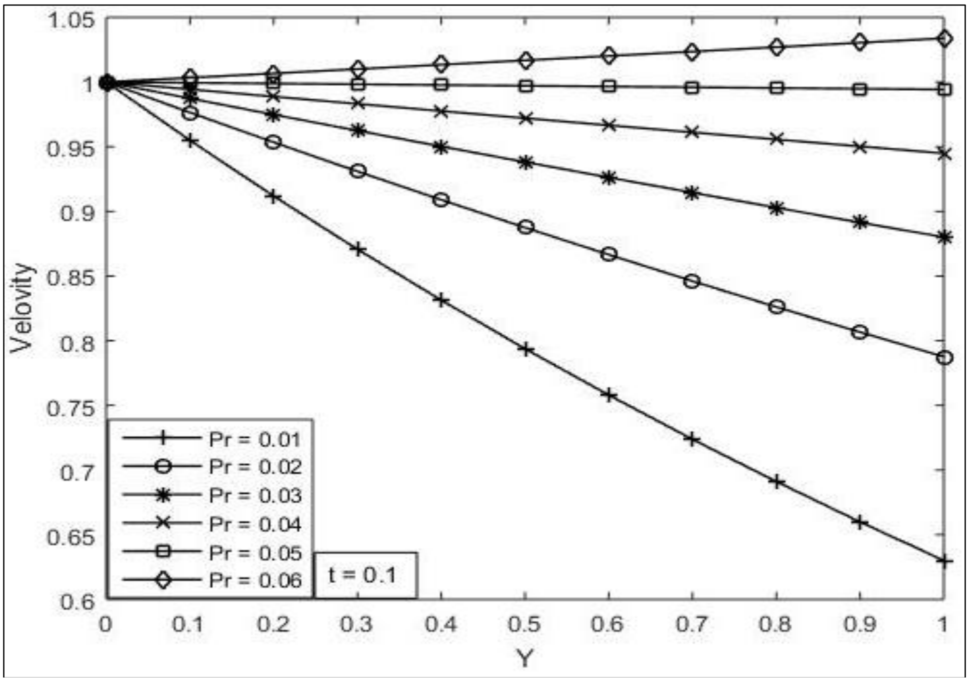


Fig 10: The nature of velocity for t=0.1

Fig - 11 and 12 illustrates the influence of Grashoff number (Gr) on flow rate for a fixed Magnetic Parameter M= 0.04 and M= 0.02 respectively. It is observed that as Grashoff number increases, the flow rate decreases in both the cases

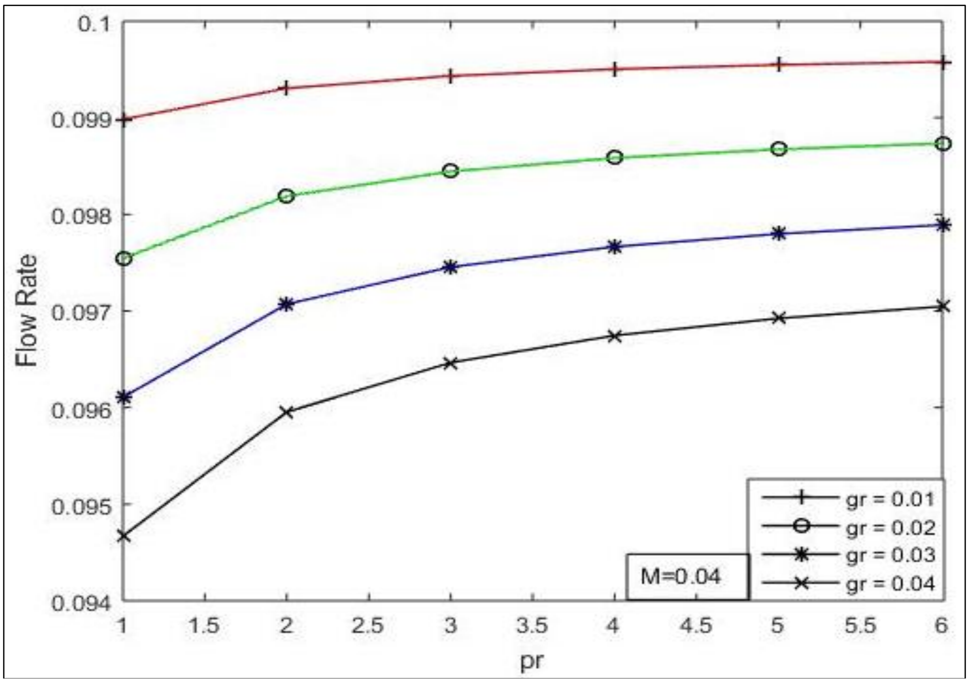


Fig 11: The nature of velocity for M=0.04

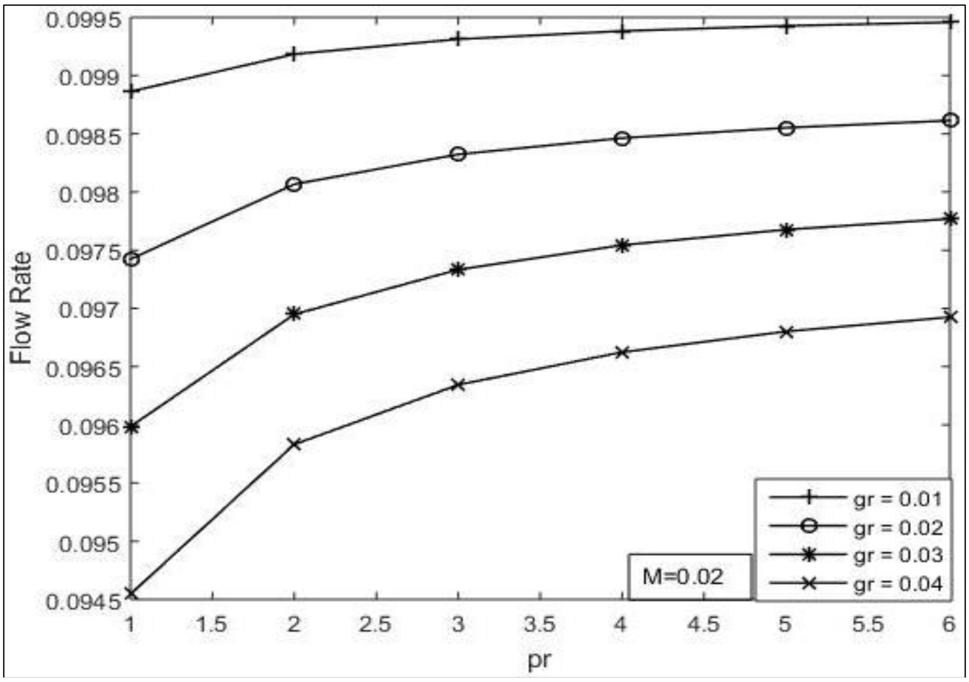


Fig 12: The nature of velocity for M=0.02

Fig-13 and 14 illustrates the effect of magnetic field on the flow rate for Gr =0.04 and Gr = 0.02 respectively. It is seen as the Magnetic field increases, the flow rate decreases. This in agreement with the real life situation that the Magnetic field suppress the fluid motion.

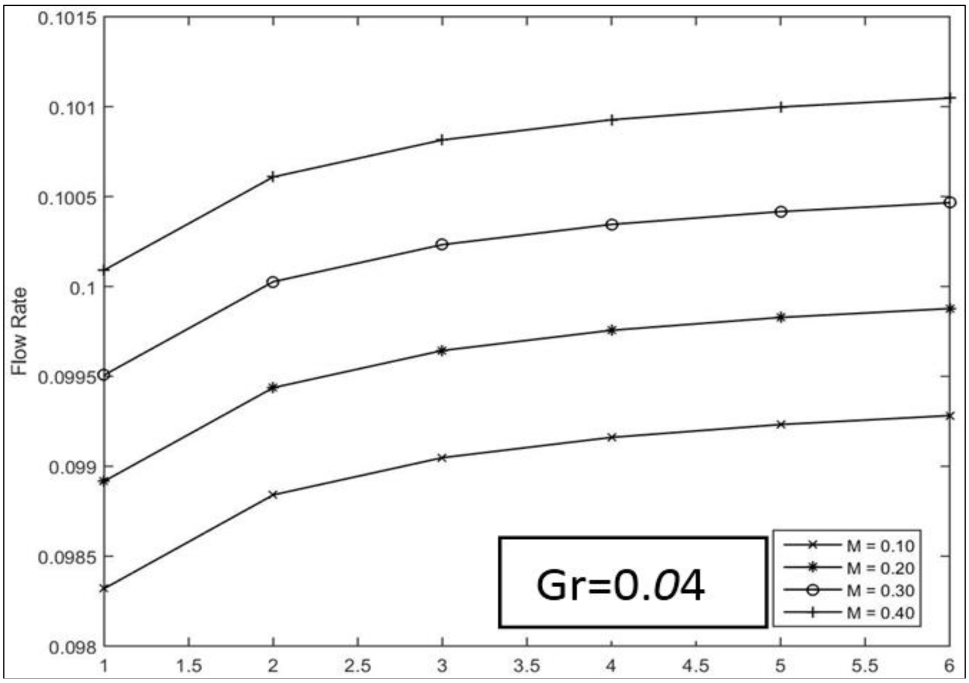


Fig 13: The effect of Magnetic intensity on Flow Rate for Gr = 0.04

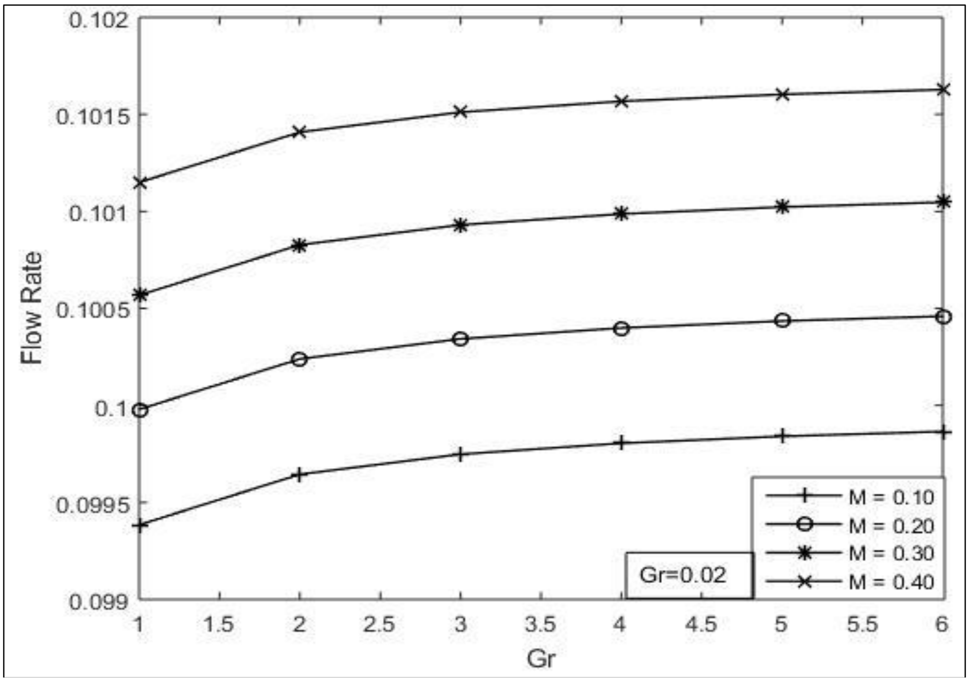


Fig 14: Influence of Magnetic field on Flow Rate for Gr = 0.02

1. References

1. Stokes GG. On the effects of Internal Friction of Fluids on the Motion of Pendulums, Camb. Phil. Trans. 1851; IX(2):8-106.
2. Brinkman HC. A calculation of viscous force extended by flowing fluid in a dense swarm of particles. Appl. sci. Res. 1947; 1:27-34.
3. Stewartson K. On the impulsive Motion of a Flat plate in a Viscous Fluid. Quarterly Jnl. of Mechanics and Applied Mathematics. 1951; IV(2):182-198.
4. Berman AS. Laminer flow in a channel with porous walls. Jnl. Appl. Phys. 1953; 24:1232-1235.
5. Mori Y. on combined free and forced convective laminar MHD flow and heat transfer in channels with transverse magnetic field, international developments in heat transfer, ASME. 1961; 124:1031-1037.
6. Macey RI, Pressure flow patterns in a cylinder with reabsorbing walls, Bull Math. Bio phys. 1963, 25(1).
7. Hall MG. The Boundary Layer over an impulsively Started Flat plate, Proc. Roy. Soc. A. 1969; 310(1502):401-414.
8. Chang IC, Yang KT, Lloyd JR. Radiation Natural Convection Interactions in Two Dimensional Complex Enclosures, ASME. Jnl. Heat Transfer. 1983; 105(1):89-95.
9. Mahajan RL, Gebhart BB. Viscous Dissipation Effects in Buoyancy-Induced Flows. Int. Jnl. of Heat Mass Transfer. 1989; 32(7):1380-1382.

10. Soundalgekar VM, Thaker HS. Radiation effects on free convection flow past a semi-infinite vertical plate. modeling measurement and control. 1993; B51:31-40.
11. Das UN, Deka RK, Soundalgekar VM. Effects of Mass Transfer on Flow Past an Impulsively Started Infinite Vertical Plate with Constant Heat Flux and Chemical Reaction, Forschang im Ingenieurwesen. 1994; 60(10):284-287.
12. Hossain MA. Takhar, Radiation effect on mixed convection along a vertical plate with uniform surface temperature, Heat and Mass Transfer. 1996; 31:243-248.
13. Raptis A, Perdikis C. Radiation and free convection flow past a moving plate, Int. J App. Mech. Engg. 1999; 4:817-821.
14. Chandrakala P, Antony Raj S. Radiation effects on MHD flow past an implusively started vertical plate with uniform heat flux, Indian Journal of Mathematics. 2008; 50(3):519-532.