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MHD FLOW PAST AN ACCELERATED INFINITE VERTICAL POROUS PLATE

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ABSTRACT

The effect of participating parameters on MHD Flow past an accelerated Infinite Vertical Porous Plate has been extensively examined in this paper. It is noticed that as the magnetic intensity increases the velocity within the boundary layer region increases. Further, it is observed that, as the applied magnetic intensity increases, the velocity within the boundary layer also increases. A chaotic behavior of the fluid velocity is noticed when the porosity parameter is 0.7 and 0.3. Therefore, it is concluded that the velocity profiles follows a systematic pattern for low permeability parameter. Further, it is seen that as was in the earlier situations, as the magnetic intensity increases the velocity increases. The dispersion in the velocity profiles is observed to be regular as the pore size of the bounding surface decreases. It is noticed that, not much of significant change is observed in the velocity profiles when all other participating parameters remains unchanged and Gc is varied from 2 to 4. However, the trend seems to be different when Gc is varied from 4 to 16.

Key words: *MHD flow, Heat and Mass transfer and Velocity profiles.*

NOMENCLATURE

C	:	Concentration
B_0	:	Transversal Magnetic Field
C_∞	:	Concentration of the fluid far away from the plate
C_w	:	Concentration of the fluid at the wall
D	:	Molecular diffusivity
g	:	Acceleration due to gravity
Gc	:	Grashoff number for mass transfer
Gr	:	Grashoff number for heat transfer
k	:	Thermal diffusivity
K	:	Porosity
M	:	Magnetic parameter
$\Pr$	:	Prandtl number
Sc	:	Schmidt number
t	:	Dimensional time parameter
T_W	:	Wall Temperature
T	:	Temperature
T_∞	:	Temperature of the fluid far away from the plate
U_0	:	Constant velocity
u	:	Velocity along x-axis
u^*	:	Non dimensional velocity along x-axis
v	:	Velocity along y-axis
V_0	:	Constant velocity along y-axis
β	:	Volumetric coefficient of expansion for heat transfer

β^*	:	Volumetric coefficient of expansion for mass transfer
σ	:	Electrical conductivity of the fluid
ρ	:	Fluid Density
ω	:	Frequency of excitation
ν	:	Kinematic viscosity

INTRODUCTION

The characteristic features of a Newtonian fluid past a vertical plate located in saturated porous medium has brought in extensive applications in engineering processes. The applications are more found in the recovery of petroleum resources and more so in packed bed reactors in chemical engineering problems. In view of multifaceted applications in Chemistry and Chemical Technology, Physics and in situations demanding effective transfer of mass over inclined beds, the viscous drainage has been the subject of considerable interest. The technological applications are more found in porous medium such as geothermal energy extraction, dissipation of nuclear waste and fossil fuels detection etc. for further investigations - development of hydrodynamic and thermal boundary layer together with the heat transfer characteristics is observed to be the basic requirement. Free convective flow with complete heat and mass transfer occurs in many of the chemical engineering and paint technology problems. The problem assumes greater significance in designing chemical processing equipment and the safety of such an equipment.

Stokes [1] was the first to discuss and analyze such a problems of heat and mass transfer. Subsequently, the viscous force imparted by flowing fluid in dense swarm of particles was examined by Brinkman [2]. Stewartson [3] found the analytic solution for a viscous flow past an impulsively started semi infinite horizontal plate. Later, Berman [4] studied the case of two dimensional steady state flow of an incompressible fluid with a parallel rigid porous walls with the flow which is influenced by uniform suction or injection. Thereafter, high suction Reynolds number fluid flow was examined by Sellars [5]. The boundary layer growth and its development was studied by Hasimoto [6]. Mori [7] investigated the flow between two vertical plates which are electrically non-conducting under the assumption that the wall temperature varies linearly in the direction of the flow. The flow in the renal tubules as viscous flow through a circular tube having uniform cross section with permeable boundary by prescribing the radial velocity at the walls as exponentially decreasing function of axial distance was investigated by Macey8]. By using finite difference approximation of mixed and implicit method for the convergence and stability of the solution was established by Hall [9]. The effects of radioactive heat transfer on free convection with specialized applications in geophysics and geothermal reserves was examined by Yang *et al* [10]. Gebart *et al* [11] reported the influence of viscous heating and dissipation effects in a natural convective flow with varying suction. Thereafter, Thakar *et al* [12] studied in detail the influence of several participating parameters on the dispersion of thermal radiation and their effects on thin gray gas. Subsequently, Deka *et al* [13] studied the higher order numerical approximation of the above problem while Hossain *et al* [14] re examined the radiation effects on a mixed convection along a vertical plate by applying Rossland's approximation. By applying Runge - Kutta Merson quadrature method, the coupled heat transfer effects within the boundary layer region under the influence of applied was studied by Gorla *et al* [15]. Das *et al* [16] examined the situation of growth and development of MHD boundary layer flow of a non Newtonian fluid past a vertical flat plate, while Chandran *et al* [17] developed an exact solution for the above problem. The influence of constant suction at one of the boundaries was investigated by Dutta *et al* [18] while Muthukumaraswamy *et al* [19] developed the implicit finite difference method for the case of unsteady flow past an impulsively started infinite vertical plate with mass transfer. Ramana Murthy *et al* [20] studied the effect of critical parameters on flow past a semi finite moving vertical plate with viscous dissipation. Further, the effect of critical parameters of MHD flow over moving isothermal vertical plate with variable mass diffusion was reported by Ramana Murthy *et al* [21, 22].

In all the above stated investigations the influence of critical parameters over the velocity field has been analyzed analytically and illustrated graphically. Here in this paper a much more meaning full analytical solution has been obtained by using the perturbation technique.

MATHEMATICAL FORMULATION

The unsteady mixed convection mass transfer flow of a viscous incompressible electrically conducting fluid past an accelerating vertical infinite porous flat plate in the presence of transversal magnetic field B_0 as been considered. Along the plate x-axis is considered while the y-axes is assumed to be normal to the plate.

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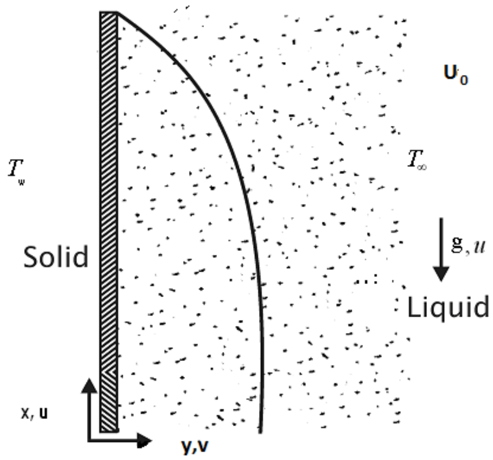

Figure-1: Schematic representation of the problem

The related magneto hydro dynamic unsteady mixed convective boundary layer flow equations under the assumptions of Bossinesq approximations is as follows:

$$\frac{\partial v}{\partial y}=0 \tag{1}$$

$$\frac{\partial u}{\partial t}+v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}+g\beta(T-T_\infty)+g\beta^*(C-C_\infty)-\frac{\sigma B_0^2}{\rho}u \tag{2}$$

$$\frac{\partial T}{\partial t}+v\frac{\partial T}{\partial y}=k\frac{\partial^2 T}{\partial y^2} \tag{3}$$

$$\frac{\partial C}{\partial t}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2} \tag{4}$$

The necessary boundary conditions are

$$u=U_0, v=-V_0, T=T_\omega, C=C_\omega \text{ on } \; y=0 \tag{5}$$

$$u=0, T\to T_\infty, C\to C_\infty \text{ as } \; y\to\infty \tag{6}$$

Introducing the following non-dimensional quantities as:

$$y^*=\frac{V_0 y}{\nu}, u^*=\frac{u}{U_0}, t^*=\frac{tV_0{}^2}{\nu}, \theta^*=\frac{T-T_\infty}{T_\omega-T_\infty}, \phi^*=\frac{C-C_\infty}{C_\omega-C_\infty} \tag{7}$$

Eqns (2) to (4) were reduced to the form and the stars (*) are ignored for readability

$$\frac{\partial u}{\partial t}-\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+Gr\theta+Gc\phi-Mu+\frac{u}{K} \tag{8}$$

$$\frac{\partial \theta}{\partial t}-\frac{\partial \theta}{\partial y}=\frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} \tag{9}$$

$$\frac{\partial \phi}{\partial t}-\frac{\partial \phi}{\partial y}=\frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} \tag{10}$$

Where

$$M=\frac{\sigma B_0^2 \nu}{\rho V_0^2}, Gr=\frac{g\beta\nu(T_\omega-T_\infty)}{U_0 V_0^2}, Gc=\frac{g\beta^*\nu(C_\omega-C_\infty)}{U_0 V_0^2}, \Pr=\frac{\nu}{k}, Sc=\frac{\nu}{D}$$

The corresponding boundary conditions now become:

$$\left.\begin{aligned} &u=1, \theta=1, \phi=1 \text{ at } \; y=0 \\ &u=0, \theta=0, \phi=0 \text{ as } \; y\to\infty \end{aligned}\right\} \tag{11}$$

Methodology for solution

We assume that the solutions in the following form:

$$u(y,t) = u_0(y) + \varepsilon e^{nt} u_1(y) + O(E^2) \tag{12}$$

$$\theta(y,t) = \theta_0(y) + \varepsilon e^{nt} \theta_1(y) + O(E^2) \tag{13}$$

$$\phi(y,t) = \phi_0(y) + \varepsilon e^{nt} \phi_1(y) + O(E^2) \tag{14}$$

Under the modified boundary conditions:

$$\left.\begin{array}{l} u_0 = 1, u_1 = 0, \theta_0 = 1, \theta_1 = 0, \phi_0 = 1, \phi_1 = 0 \text{ at } y = 0 \\ u_0 = 0, u_1 = 0, \theta_0 = 0, \theta_1 = 0, \phi_0 = 0, \phi_1 = 0 \text{ as } y \to \infty \end{array}\right\} \tag{15}$$

Using Eqns (12), (13), (14) and (15) in Eqns (8), (9) and (10)

$$u(y,t) = \left[(1 - A_{11} - A_{12})e^{-A_{10}y} + A_{11}e^{-\Pr y} + A_{12}e^{-Scy} + \varepsilon e^{nt}((1 - A_7 - A_8)e^{-A_6 y} + A_7 e^{-A_4 y} + A_8 e^{-A_2 y}\right] \tag{16}$$

Where

$$A_1 = \frac{-Sc + \sqrt{Sc^2 + 4nSc}}{2}, A_2 = \frac{-Sc - \sqrt{Sc^2 + 4nSc}}{2}, A_3 = \frac{-\Pr + \sqrt{\Pr^2 + 4n\Pr}}{2}$$

$$A_4 = \frac{-\Pr - \sqrt{\Pr^2 + 4n\Pr}}{2}, A_5 = \frac{-1 + \sqrt{1 - 4\left(M + \frac{1}{K} - n\right)}}{2}, A_6 = \frac{-1 - \sqrt{1 - 4\left(M + \frac{1}{K} - n\right)}}{2}$$

$$A_7 = \frac{-Gr}{A_4^2 - A_4 + \left(M + \frac{1}{K} - n\right)}, A_8 = \frac{-Gc}{A_2^2 - A_2 + \left(M + \frac{1}{K} - n\right)}, A_9 = \frac{-1 - \sqrt{1 - 4\left(M + \frac{1}{K}\right)}}{2}$$

$$A_{10} = \frac{-1 + \sqrt{1 - 4\left(M + \frac{1}{K}\right)}}{2}, A_{11} = \frac{-Gr}{\Pr^2 - \Pr + \left(M + \frac{1}{K}\right)}, A_{12} = \frac{-Gc}{Sc^2 - Sc + \left(M + \frac{1}{K}\right)},$$

RESULTS AND DISCUSSION

1. Figure 2, Figure 3 and Figure 4 illustrates the influence of the magnetic field with respect to the porosity on velocity profiles for Gc=2.00 and suction parameter is equal to 1.00. In each of these situations, it is noticed that, as the magnetic intensity increases the velocity within the boundary region also increases. As the porosity increases, the convergence of the velocity profiles is initially more and dispersion is subsequently wide spread.
2. Figure 5, Figure 6 and Figure 7 depicts the nature of velocity profiles at different intensities of applied magnetic field with respect to the porosity parameter when Gc = 4.00 and the suction parameter is 1.00. It is noticed that, as the applied magnetic intensity increases the velocity within the boundary layer also increases.
3. The effect of the magnetic intensity over the velocity field when Gc = 16.00 and with respect to the porosity parameter and the suction velocity is 1.00 is denoted in Figure 8, Figure 9 and Figure 10. A chaotic behaviour of the fluid velocity is noticed when the porosity parameter is 0.7 and 0.3. It is concluded that the velocity profiles follows a systematic pattern for low permeability parameter.
4. Figure 11, Figure 12 and Figure 13 illustrates the effect of magnetic parameter with reference to the porosity on velocity profiles. It is noticed that, as was in the earlier situations as the magnetic intensity increases the velocity increases. The dispersion in the velocity profiles is observed to be regular as the pore size of the bounding surface decreases.
5. The nature of magnetic influence with respect to the porosity parameter and suction velocity are illustrated in Figure 14, Figure 15 and Figure 16. The trend was noticed in earlier cases as stated above. Further, it is seen that, the suction parameter compress the velocity profiles when compared to $\varepsilon = 1$.
6. On comparing Figure 2 and Figure 7 it is observed that not much of significant change is observed in the velocity profiles when all other participating parameters remains on changed and Gc is varied from 2 to 4. However, the trend seems to be different when Gc is varied from 4 to 16. Relatively the trend seems to be not appreciable for smaller values of Gc as compared in Figure 11, Figure 14, Figure 12 and Figure 15.

LIST OF ILLUSTRATIONS

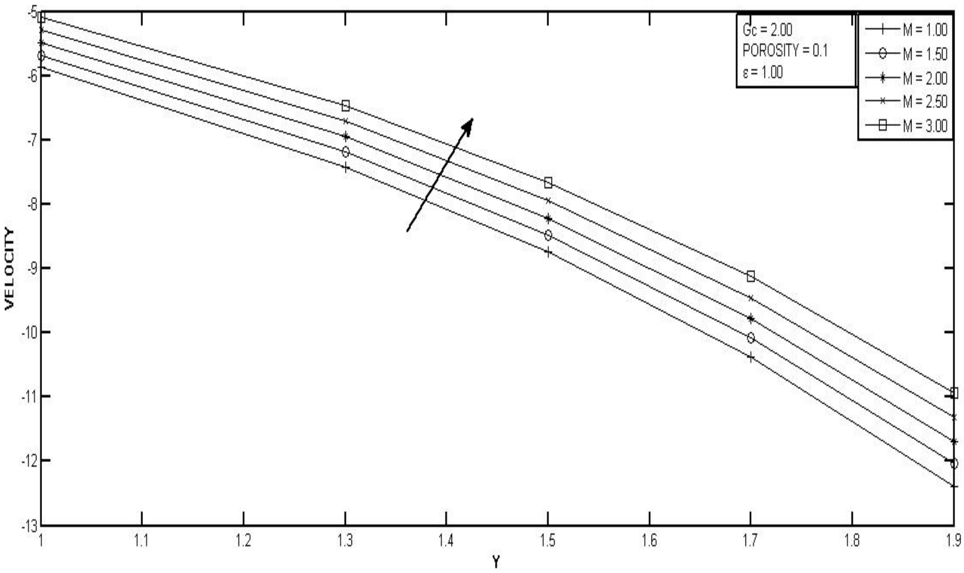

Figure-2: Influence of Magnetic field

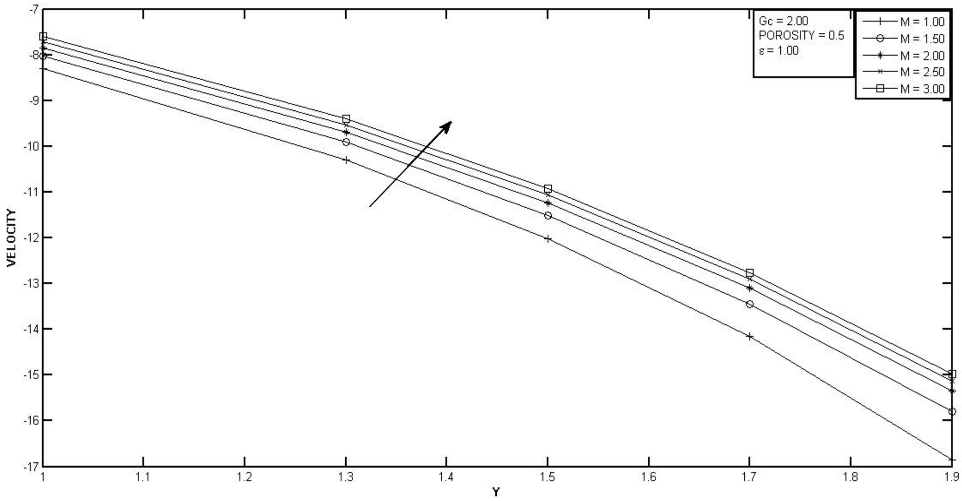

Figure-3: Effect of Magnetic intensity

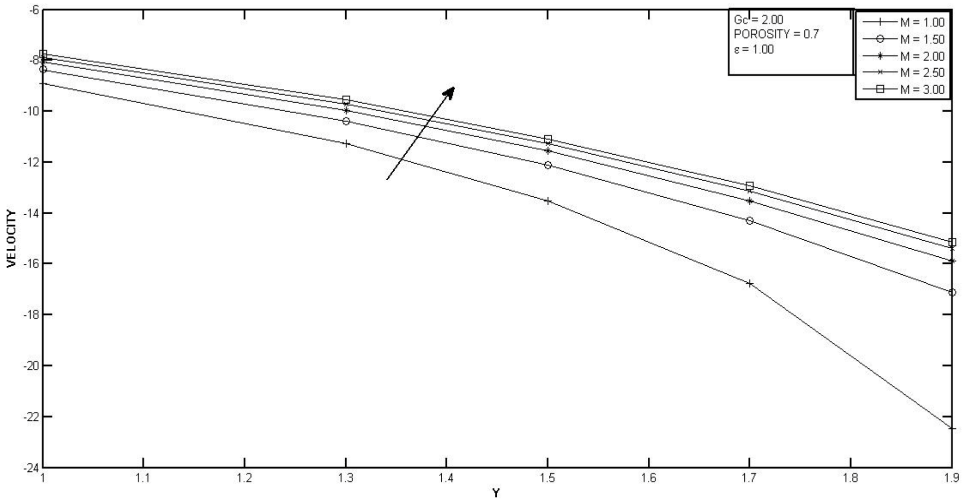

Figure-4: Consolidated effect of magnetic field and porosity on velocity profiles

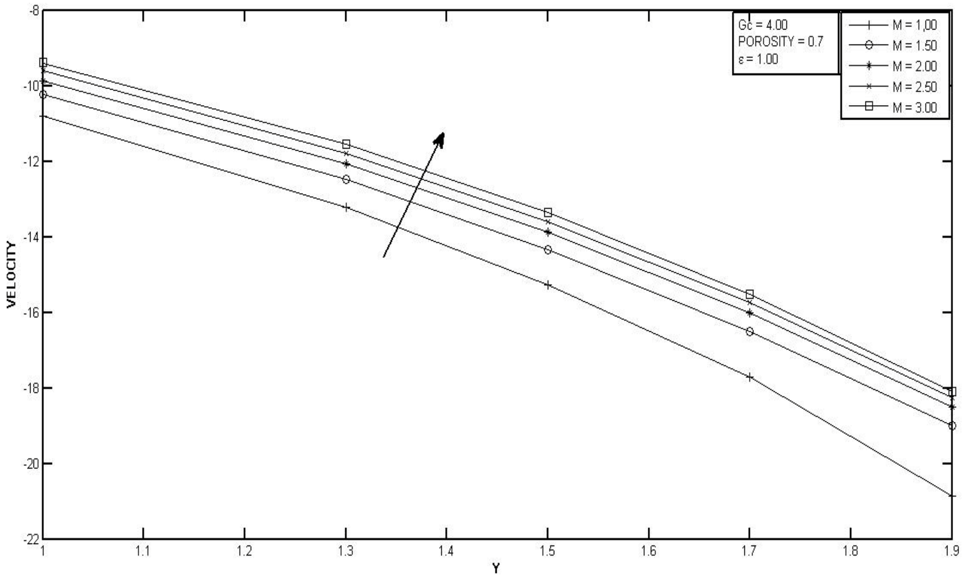

Figure-5: Influence of Magnetic field on velocity

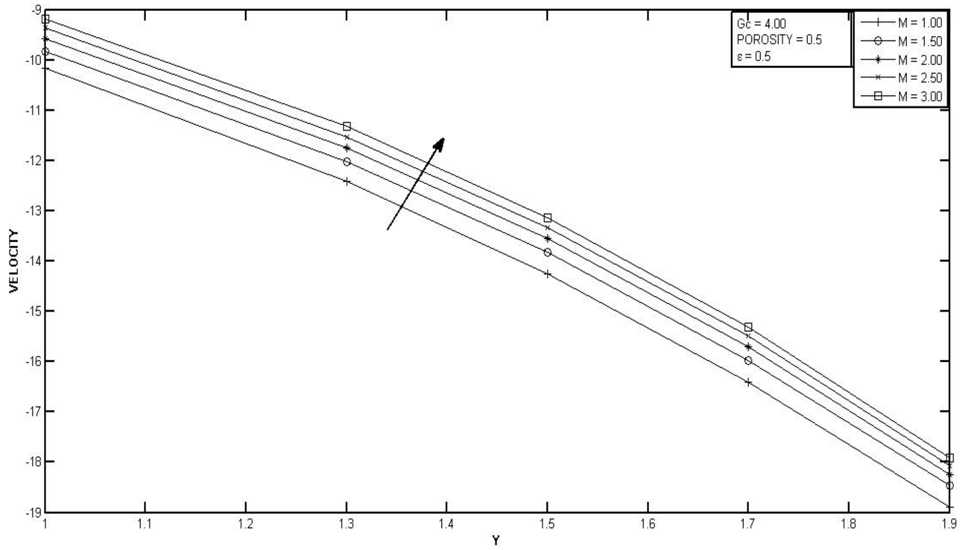

Figure-6: Effect of Grashoff number and magnetic field

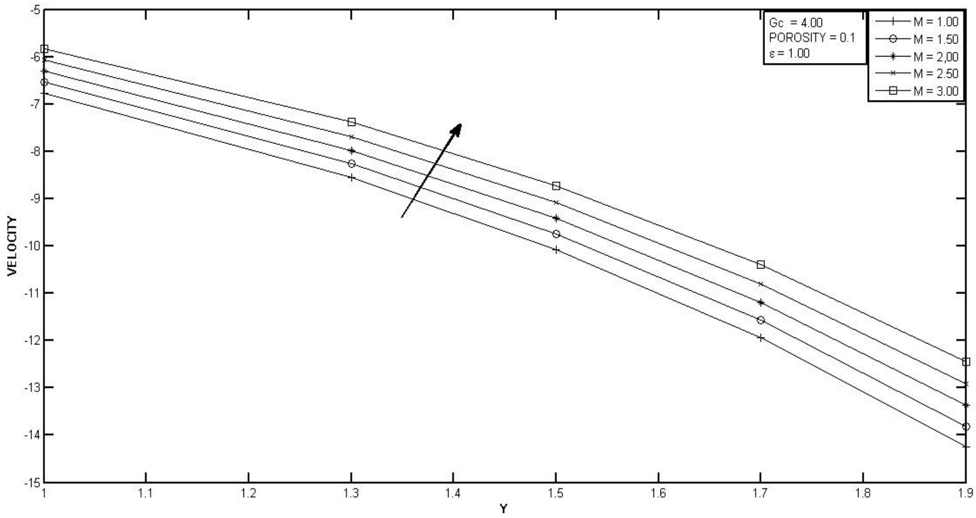

Figure-7: Combined effect of Magnetic field and porosity on velocity profiles

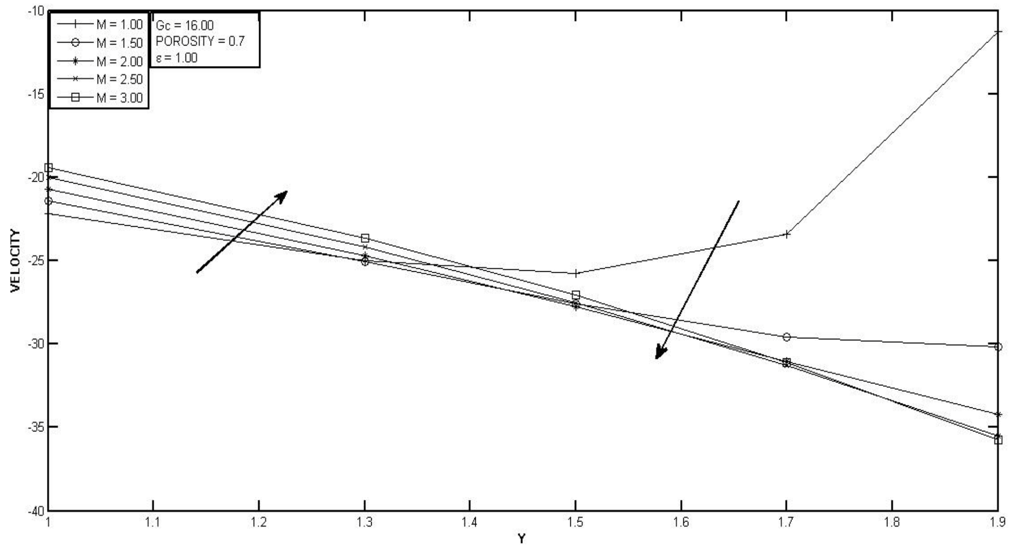

Figure-8: Influence of Porosity on velocity profiles

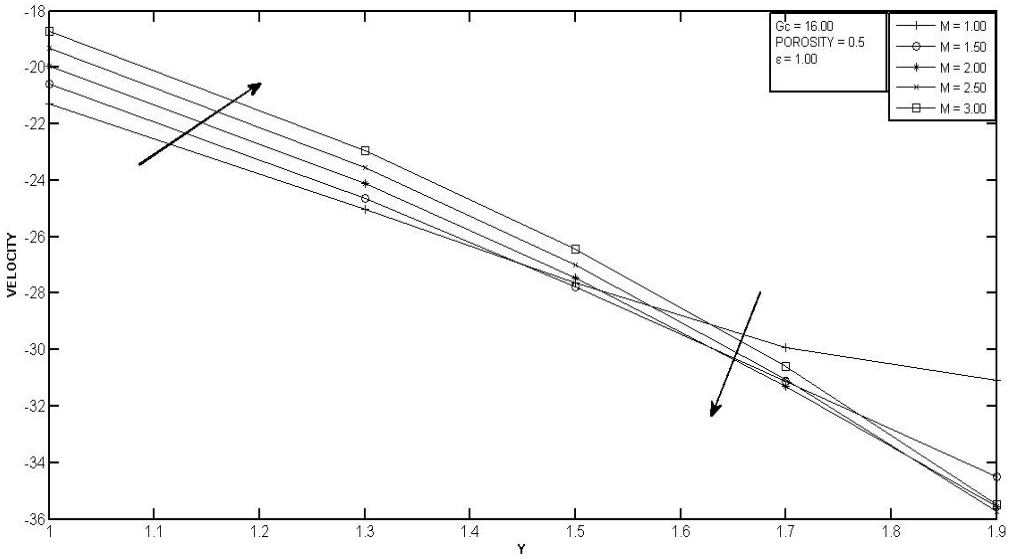

Figure-9: Effect of suction parameter and porosity on velocity profiles

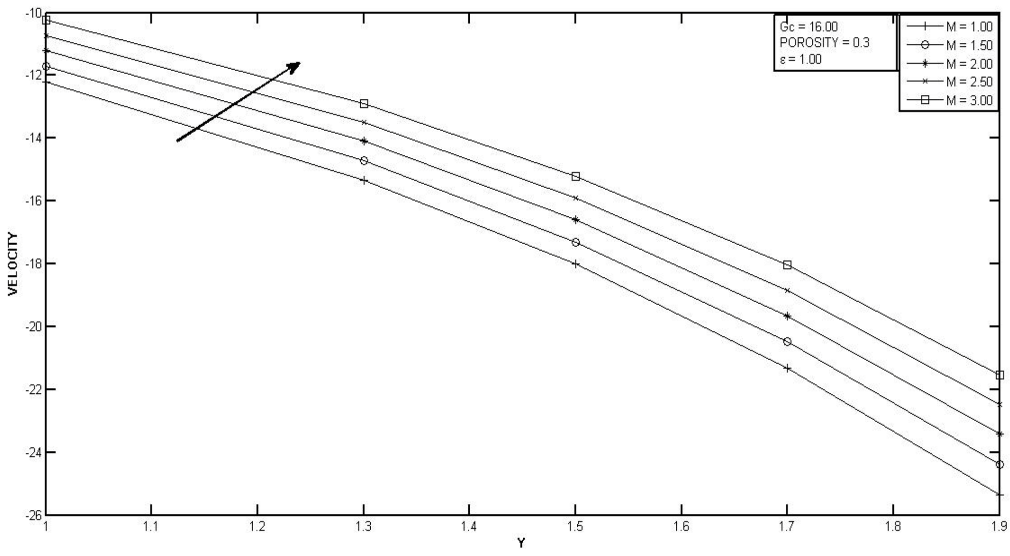

Figure-10: Consolidated effect of Grashoff number and magnetic field on velocity profiles

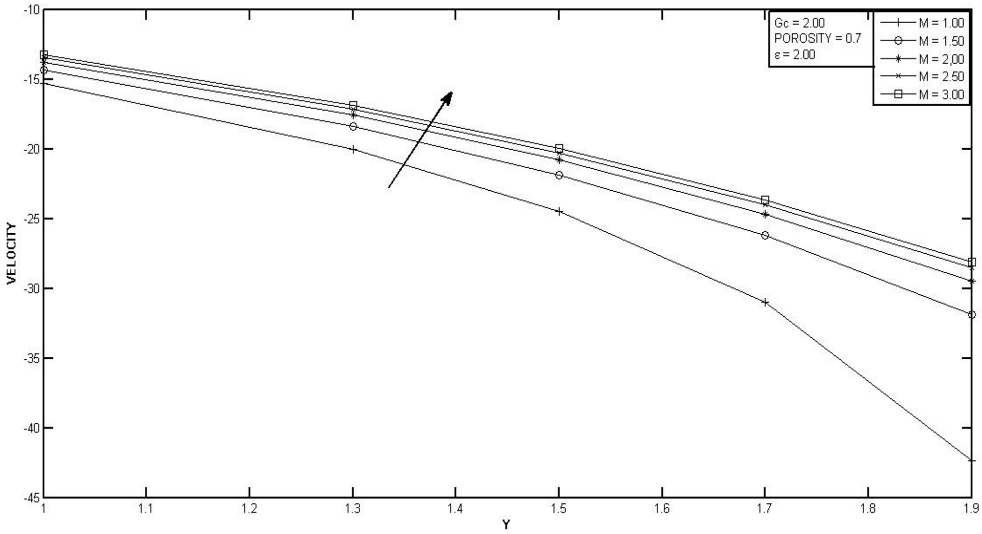

Figure-11: Influence of magnetic field on velocity profiles

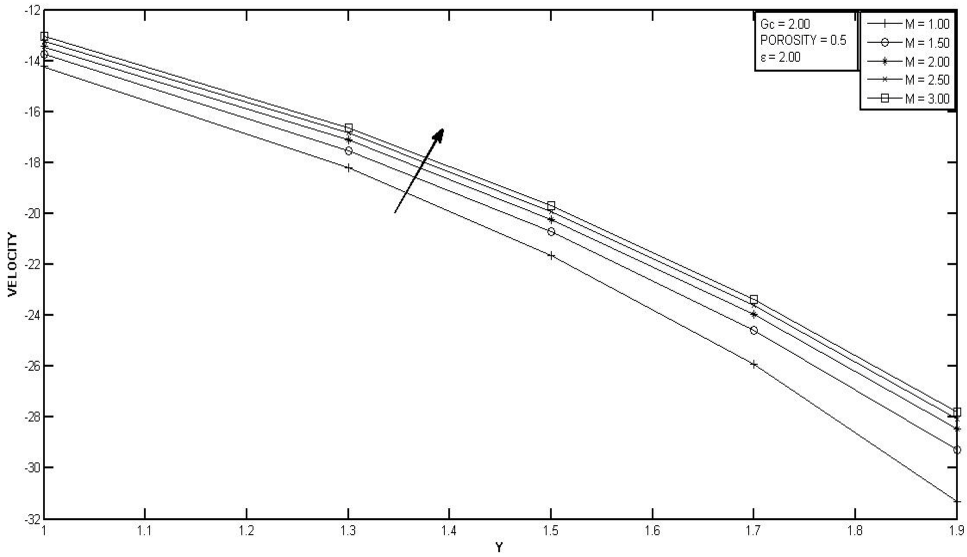

Figure-12: Effect of porosity on velocity profiles

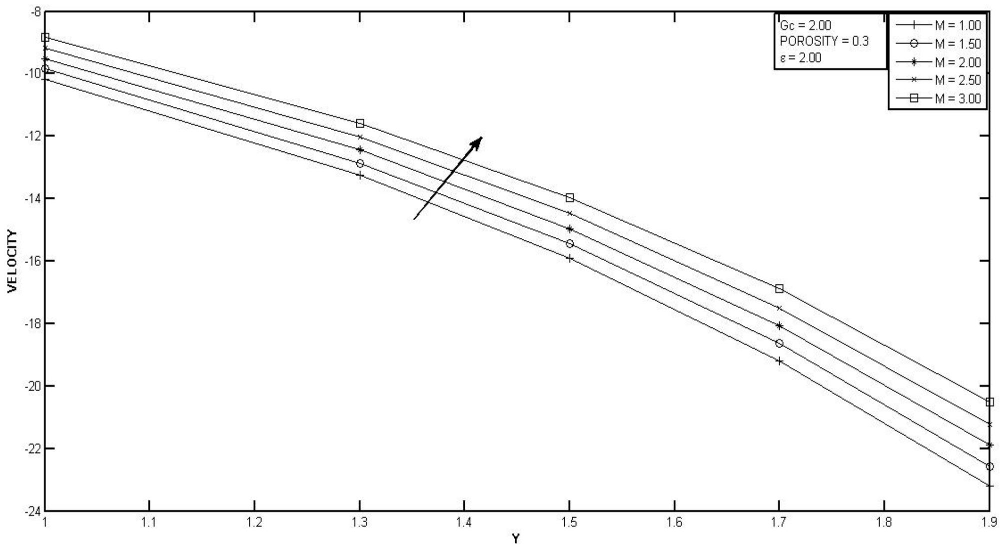

Figure-13: Influence of magnetic field on velocity profiles

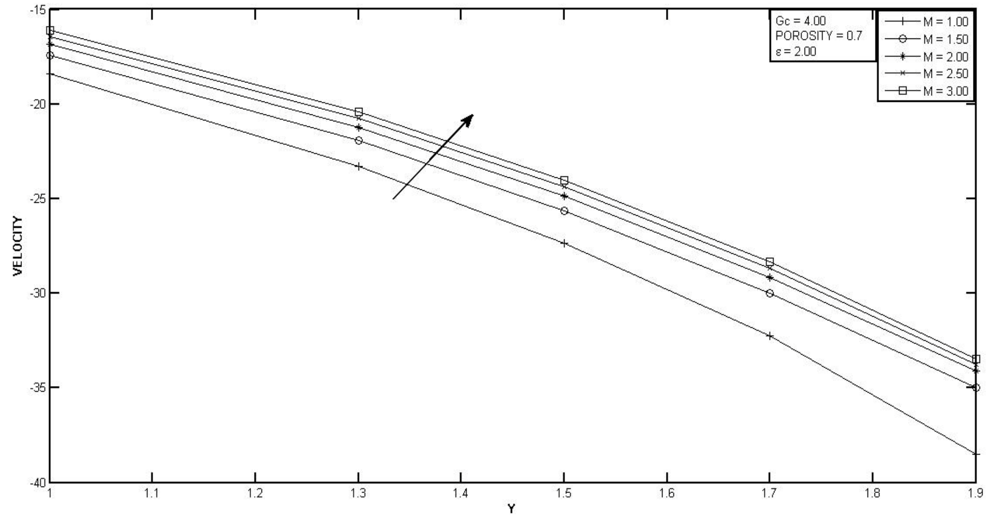

Figure-14: Effect of porosity on velocity profiles

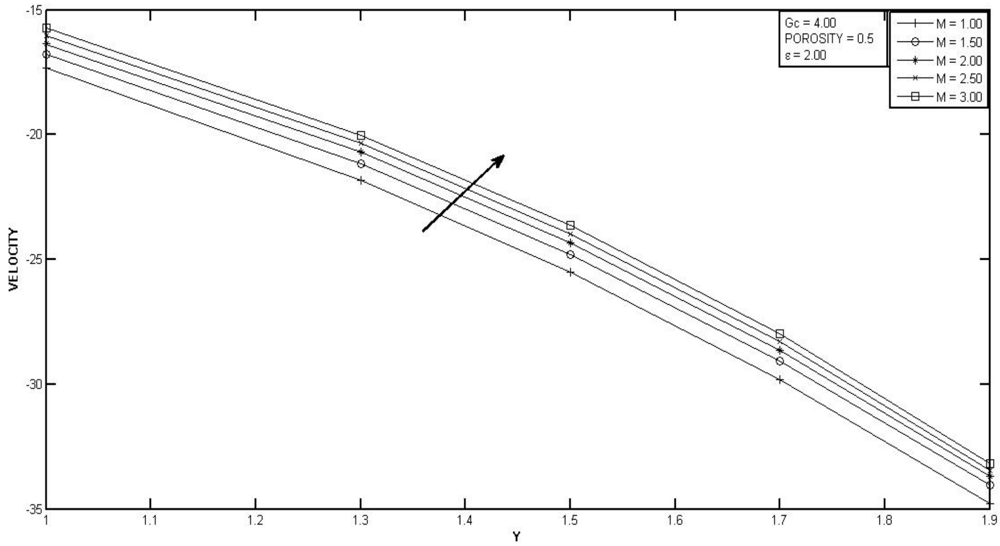

Figure-15: Combined effect of suction parameter and magnetic field on velocity profiles

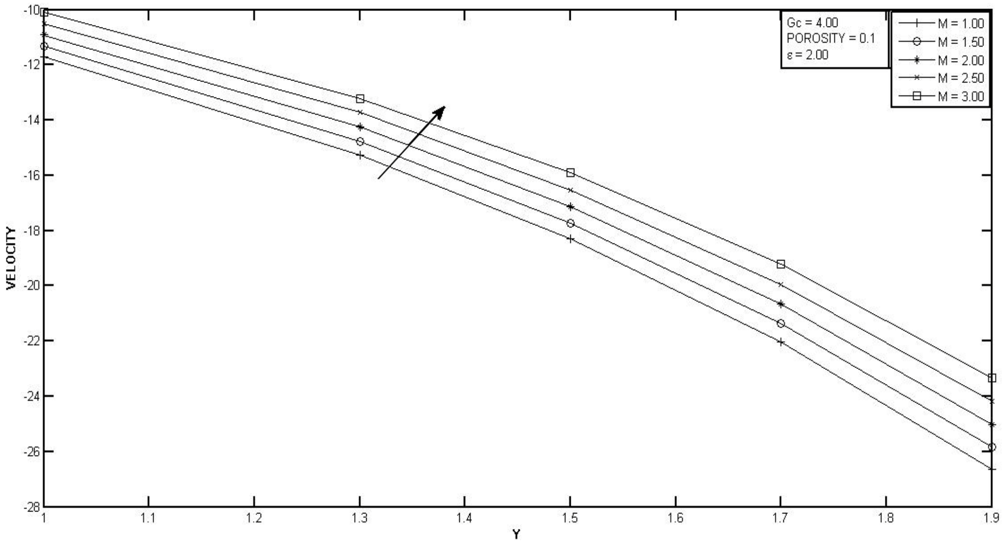

Figure-16: Influence of magnetic field on velocity profiles

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