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# ANALYSIS OF VARIOUS FLOW ENTITIES ON THE FLOW PAST A SEMI INFINITE MOVING VERTICAL PLATE WITH VISCOUS DISSIPATION

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**ABSTRACT:**

*A detailed analysis of various flow entities on the flow past a semi infinite inclined porous plate with viscous dissipation under the influence of gravitational force has been exhaustively examined in this paper. It is observed that, as the Schmidt number increases the fluid velocity decreases initially and thereafter it increases. Further, it is seen that far away from the boundary, a significant contribution by Schmidt number has been noticed. Further, at times, for significant values of the porosity of the bounding surface a backward flow is noticed. When the porosity of the bounding surface is held constant and as the Solutal Grashof number increases, a backward flow is noticed in the boundary layer region and as we move far away from the boundary, the velocity field in general increases. It is noticed that, as the porosity of the fluid bed increases backward flow is noticed. However, as we move far away from the boundary, the pore size of the fluid bed does not contribute much to the velocity profiles. Further, it is seen that the velocity of the fluid is absolutely zero and is found to be independent of pore size of the fluid bed. The increase in the angle of inclination and far away from the bounding surface not much of appreciable change in the velocity field is noticed. Significant contribution within the boundary layer region is seen with increase in the angle of inclination. Further, the skin friction is found to be independent of Schmidt number. It is seen that as the porosity decreases the skin friction is found to be decreasing considerably.*

***Key words:*** *Heat transfer, viscous dissipation, radiation, concentration and porosity.*

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**NOMENCLATURE:**

$u'$ : Velocity component in $x'$ – direction
$v'$ : Velocity component in $y'$ – direction
$\nu$ : kinematic viscosity
$c_p$ : Specific heat at constant Pressure
g: Acceleration due to gravity
G: Non dimensional acceleration due to gravity
$\beta$ : Volumetric coefficient of thermal Expansion
$\beta^*$: Volumetric coefficient of concentration Expansion
$T$ : Dimensional temperature
$C$ : Dimensional concentration
$\alpha$ : Fluid thermal diffusivity
$\mu$ : Coefficient of viscosity
$D$ : Mass diffusivity
$k_r'$: Chemical reaction parameter
$U_0$: Scale of free stream velocity
$C_w$ : Wall dimensional concentration
$T_w$ : Wall dimensional temperature
$C_\infty$ : Free stream dimensional concentration
$T_\infty$ : Free stream dimensional temperature
$n'$ : The constant
$\sigma_s$ : Stefan – Boltzmann constant
$K_e$ : Mean absorption coefficient
$A$ : Real positive constant
$\varepsilon A$ : A real positive constant <<1
$V_0$ : Non – zero positive constant
$G_c$ : Solutal Grashof number
$P_r$ : Prandtl number
$R$ : Radiation parameter
$E_c$ : Eckert number
$S_c$ : Schmidt number
$k_r$: Chemical reaction parameter

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**INTRODUCTION:**

At very high temperatures, the radiation effects are found to be highly prominent and are found to be extremely significant in the problems of technological importance. The problem assumes greater significance in several engineering applications and in nature viz; important applications in soil physics, geothermal energy extraction, chemical engineering, glass production, and furnace design, space technology, flight aerodynamics and plasma physics which operates at very high temperature. In all above situations, understanding the concept of boundary layer development growth and heat transfer characteristics are of primary requirement to investigate the problem more intensively and exhaustively. The energy conservation equation gets highly complicated with the inclusion of radiation component and leads to a partial differential equation which is of non-linear in nature.

The free convective heat transfer characteristics for a vertical plate in porous medium was analysed by Cheng and Minkowyiz [1] who obtained analytical expressions for boundary layer thickness. Later, Cheng [2] had examined the mixed convection on inclined surface using boundary layer approximations. Ananda Rao, *et al.* [3] studied the effects of transverse magnetic field on the heat transfer characteristics in a porous medium and brought out and the effects of porous parameter on temperature and Nusselt number while the radiative free convection flow of an optically thin grey - gas past a semi infinite vertical plate was examined by Soundalgekar and Takhar [4]. Subsequently, Hussain and Thakar [5] investigated the radiation effects on mixed convection along an isothermal vertical plate. The effects of thermal radiation on free convective flow past a moving vertical plane was examined by Raptis and Perdikis [6].

Later, Sobha and Ramakrishna [7] presented the effects of magnetic field on heat transfer characteristics in porous medium under natural convection while, The numerical solution for the existence and uniqueness of a vertical flowing fluid past a vertical surface in porous medium by considering variable wall temperature under mixed convection conditions was investigated by Ally *et al* [8]. The effects of radiation on free convective flow past a semi infinite vertical plate with mass transfer was examined by Chamka *et al* [9], while Muthucumaraswamy and Ganesan[10] had studied the radiation effects on flow past an impulsively started infinite vertical plate with variable temperature. Subsequently, Prakash and Ogulu [11] had investigated an unsteady two-dimensional flow of a radiating and chemically reacting fluid with time dependent suction. The effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction was studied by Das *et al.* [12].

Of late, Ramana Murthy *et al* [13] in the situation of flow of a second order fluid over an inclined porous plate under the influence of applied transverse magnetic field, it is observed that the influence of porosity, magnetic field and the angle of inclination is found to be more predominant only at the later part of the plate length.

The objective of the present analysis is to examine the nature of flow field of an unsteady two dimensional laminar convective boundary layer flow of a laminar, viscous incompressible, chemically reacting fluid along a semi infinite vertical porous moving plate under the influence of gravitational pull with suction taken into consideration on the bounding surface. The characteristic behavior of various parameters that effects the flow entities have been examined analytically and discussed qualitatively in detail.

**MATHEMATICAL FORMULATION OF THE PROBLEM:**

An unsteady two dimensional laminar boundary layer flow of a viscous, incompressible, radiating fluid along a semiinfinite vertical porous plate under the influence of gravitational pull has been examined in detail in this paper. In the course of analysis, the effects of viscous dissipation, thermal radiation and concentration buoyancy are taken into account. The $x'$-axis is taken along the vertical infinite plate in the upward direction and the $y'$-axis normal to the plate. The flow geometry for the case of vertical plate has been illustrated in Fig – 1. In the analysis throughout, the level of concentration of foreign mass is assumed to be very low, so that the Sorest and Duffer effects are negligible. Under the usual Boussinesq's approximation, the flow field is governed by the following equations

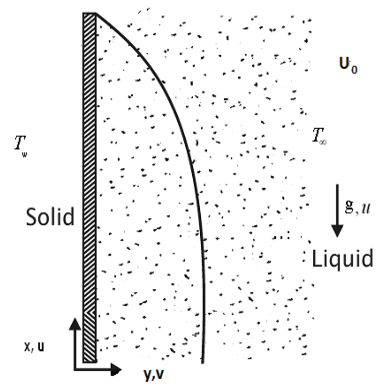


**Figure – 1: Geometry of the problem When the plate is held vertical**

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

$$\left.\begin{aligned}&\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = \nu\frac{\partial^2 u'}{\partial y'^2} + \\ &g\beta(T - T_\infty) \;+\; g\beta^*(C - C_\infty)\end{aligned}\right\} \tag{2}$$

$$\left.\begin{aligned}&\frac{\partial T}{\partial t'} + v'\frac{\partial T}{\partial y'} = \alpha\frac{\partial^2 T}{\partial y'^2} - \frac{1}{\rho c_p}\frac{\partial qr}{\partial y'} \\ &\qquad + \frac{\mu}{\rho c_p}\left(\frac{\partial u'}{\partial y'}\right)^2\end{aligned}\right\} \tag{3}$$

$$\left.\begin{aligned}&\frac{\partial C}{\partial t'} + u'\frac{\partial C}{\partial y'} = D\frac{\partial^2 C}{\partial y'^2} \\ &\qquad - k_r'^2(C - C_\infty)\end{aligned}\right\} \tag{4}$$

The boundary conditions for the velocity, temperature, and concentration fields are

$$\left.\begin{aligned}&u' = U_0,\; T = T_w + \varepsilon(T_w - T_\infty)e^{n't'}, \\ &C = C_w + \varepsilon(C_w - C_\infty)e^{n't'} \;\text{ at }\; y' = 0 \\ &u' \to 0,\; T \to T_\infty,\; C \to C_\infty \;\text{ as }\; y' \to \infty\end{aligned}\right\} \tag{5}$$

The radiative heat flux under the Roseland approximation (Brewster [9]), is given by

$$q_r = \frac{-4\sigma_s \partial T^4}{3K_e \partial y'} \tag{6}$$

Under the approximations of Roseland, the present analysis is limited to optically thick fluids. If temperature differences within the flow are sufficiently small, then eqn (6) can be linearised by expanding $T^4$ in the Taylor series about $T_\infty$, which after neglecting higher order terms is given by:

$$T^4 \approx 4T_\infty^3 T - 3T_\infty^4 \tag{7}$$

In view of Eqn (6) and (7), Eqn (3) can be re drafted as:

$$\left.\begin{aligned} \frac{\partial T}{\partial t'} + v'\frac{\partial T}{\partial y'} = \frac{k}{\rho\, c_p}\frac{\partial^2 T}{\partial y'^2} + \frac{16\sigma_s}{3\rho\, c_p\, K_e} \\ -T_\infty^3 \frac{\partial^2 T}{\partial y'^2} + \frac{\mu}{\rho\, c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \end{aligned}\right\} \tag{8}$$

From the continuity Eqn (1), it is clear that the suction velocity normal to the plate is either a constant or a function of time. To be more general and to be specific, it is assumed in the form:

$$v' = -V_0(1 + \varepsilon A e^{n't'}) \tag{9}$$

where the negative sign indicates that the suction is towards the plate. Introducing the following non dimensional scheme:

$$\left.\begin{aligned} & u = \frac{u'}{U_0},\ y = \frac{V_0 y'}{\nu},\ t = \frac{t' V_0^2}{\nu}\ S_c = \frac{\nu}{D}, \\ & p_r = \frac{\rho\, c_p \nu}{k} = \frac{\nu}{\alpha},\ n = \frac{n'\nu}{V_0^2},\ R = \frac{16\sigma_s T_\infty^3}{3K_e k} \\ & \phi = \frac{C - C_\infty}{C_w - C_\infty}\ G_c = \frac{g\beta^* \nu (C_w - C_\infty)}{U_0 V_0^2} \end{aligned}\right\} \tag{10}$$

,

In view of the Eqn (9) and (10),Eqn(2), Eqn (8) and Eqn (4) reduced to the following Dimensionless form

$$\left.\begin{aligned} \frac{\partial u}{\partial t} - \left(1 + \varepsilon A e^{nt}\right)\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + G_c \phi \\ -\frac{u}{k} + G\sin\alpha_1 \end{aligned}\right\} \tag{11}$$

$$0 = E_c\left(\frac{\partial u}{\partial y}\right)^2 \tag{12}$$

$$\frac{\partial \phi}{\partial t} - \left(1 + \varepsilon A e^{nt}\right)\frac{\partial \phi}{\partial y} = \frac{1}{S_c}\frac{\partial^2 \phi}{\partial y^2} - k_r^2 \phi \tag{13}$$

Where $G_c$, $P_r$, $R$, $E_c$, $S_c$ and $k_r$ are as mentioned in the nomenclature.

The corresponding non-dimensional boundary conditions are

$$\left.\begin{aligned} & u = 1,\ \phi = 1 + \varepsilon e^{nt} \text{ at } y = 0 \\ & u \to 0,\ \phi \to 0 \text{ as } \ y \to \infty \end{aligned}\right\} \tag{14}$$

**SOLUTION OF THE PROBLEM:**

Eqns (11) - (13) are coupled, non-linear partial differential equations for which a solution in the closed form is not available. However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. This can be done by representing the velocity, and concentration of the fluid in the neighborhood of the plate as

$$u(y,t) = u_0(y) + \varepsilon e^{nt} u_1(y) + O(\varepsilon)^2 \tag{15}$$

$$\phi(y,t) = \phi_0(y) + \varepsilon e^{nt} \phi_1(y) + O(\varepsilon)^2 \tag{16}$$

Using Eqns (15) and (16) in Eqns (11) - (12) and equating the harmonic and non- harmonic terms, and neglecting the higher order terms of $O(\varepsilon)^2$, we obtain

$$\phi_0'' + S_c\phi_0' - k_r^2 S_c \phi_0 = 0 \tag{17}$$

$$\phi_1'' + S_c\phi_1' - \left(k_r^2 + n\right)S_c\phi_1 = -AS_c\phi_0' \tag{18}$$

$$u_0'' + u_0' - \frac{1}{k}u_0 = -Gc\phi_0 - G\sin\alpha_1 \tag{19}$$

$$u_1'' + u_1' - \left(n + \frac{1}{k}\right)u_1 = -Au_0' - Gc\phi_1 \tag{20}$$

Where prime denotes ordinary differentiation with respect to y, the corresponding boundary conditions can be written as

$$\left.\begin{aligned} & u_0 = 1,\ u_1 = 0,\ \phi_1 = 1 \text{ at } y = 0 \\ & u_0 \to 0,\ u_1 \to 0,\ \phi_0 \to 0, \phi_1 \to 0 \text{ as} \\ & y \to \infty \end{aligned}\right\} \tag{21}$$

The solutions of Eqns (19) - (20) in explicit form is given by

$$\left.\begin{aligned} u_0 = & \left[1 - kG\sin\alpha_1 + \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}}\right] e^{-\left(\frac{m_1+1}{2}\right)y} \\ & + \left(kG\sin\alpha_1\right)e^{-m_1 y} - \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}} e^{-\gamma y} \end{aligned}\right\} \tag{22}$$

Where

$k$ = Porosity of the plate

$\alpha_1$ = Angle of inclination of the plate

$\gamma = \frac{S_c + \alpha'}{2}$, $\alpha' = \sqrt{S_c^{\,2} + 4k_r^{\,2} S_c}$,

$m_1 = \sqrt{1 + \frac{4}{k}}$

$$u_1 = \left\{ \frac{4AG_c S_c \gamma}{\alpha'^2 - S_c^2 - 4\beta'^2 S_c} \frac{1}{\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)} - \frac{4AG_c S_c \gamma}{\alpha'^2 - S_c^2 - 4\beta'^2 S_c} \frac{1}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)} \right.$$

$$+ \frac{G_c}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)} - \frac{kAm_1 G \sin\alpha_1}{m_1^{\,2} - m_1 - \left(n + \frac{1}{k}\right)} e^{-m_1 y}$$

$$- \frac{A(m_1+1)}{2} \left( \frac{1 - kG\sin\alpha_1 + \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}}}{\left(\frac{(m_1+1)}{2}\right)^2 - \left(\frac{(m_1+1)}{2}\right) - \left(n + \frac{1}{k}\right)} \right)$$

$$+ \left. \frac{A\gamma G_c}{\left(\gamma^2 - \gamma - \frac{1}{k}\right)\left(\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)\right)} \right\} e^{-\left(\frac{m_2+1}{2}\right)y}$$

$$- \frac{4AG_c S_c \gamma}{\alpha'^2 - S_c^2 - 4\beta'^2 S_c} \frac{e^{-\gamma y}}{\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)}$$

$$+ \frac{4AG_c S_c \gamma}{\alpha'^2 - S_c^2 - 4\beta'^2 S_c} \frac{e^{-\delta y}}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)}$$

$$+ \frac{KAm_1 G \sin\alpha_1}{m_1^{\,2} - m_1 - \left(n + \frac{1}{k}\right)} e^{-m_1 y}$$

$$- \frac{A\gamma G_c}{\left(\gamma^2 - \gamma - \frac{1}{k}\right)\left(\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)\right)} e^{-\gamma y}$$

$$+ \frac{A(m_1+1)\left(1 - kG\sin\alpha_1 + \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}}\right) e^{-\frac{(m_1+1)y}{2}}}{2\left(\left(\frac{(m_1+1)}{2}\right)^2 - \left(\frac{(m_1+1)}{2}\right) - \left(n + \frac{1}{k}\right)\right)}$$

$$- \frac{G_c e^{-\delta y}}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)} \qquad (23)$$

Where $\beta' = \sqrt{k_r^{\,2} + n}$,

$\delta = \frac{S_c + \sqrt{S_c^{\,2} + 4\beta'^2 S_c}}{2}$,

$m_2 = \sqrt{1 + 4\left(n + \frac{1}{k}\right)}$

In view of eqn (15), the final expression for the velocity field is given by:

$$u = \left[1 - kG\sin\alpha_1 + \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}}\right] e^{-\left(\frac{m_1+1}{2}\right)y}$$

$$+ (kG\sin\alpha_1)e^{-m_1 y} - \frac{G_c}{\gamma^2 - \gamma - \frac{1}{k}} e^{-\gamma y}$$

$$+ \left[ \frac{4AG_c S_c \gamma \varepsilon e^{nt}}{\alpha'^2 - S_c^2 - 4\beta'^2 S_c} \left\{ \frac{1}{\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)} - \frac{1}{\gamma^2 - \gamma - \left(n + \frac{1}{k}\right)} \right\} - \frac{1}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)} \right.$$

$$+ \frac{G_c \varepsilon e^{nt}}{\delta^2 - \delta - \left(n + \frac{1}{k}\right)}$$

$$
-\varepsilon e^{nt}\frac{A(m_1+1)}{2}\left(\frac{1-kG\sin\alpha_1+\dfrac{G_c}{\gamma^2-\gamma-\frac{1}{k}}}{\left(\frac{(m_1+1)}{2}\right)^2-\left(\frac{(m_1+1)}{2}\right)-\left(n+\frac{1}{k}\right)}-\frac{kAm_1G\sin\alpha_1\varepsilon e^{nt}}{m_1^{\,2}-m_1-\left(n+\frac{1}{k}\right)}+\frac{A\gamma G_c\varepsilon e^{nt}}{\left(\gamma^2-\gamma-\frac{1}{k}\right)\left(\gamma^2-\gamma-\left(n+\frac{1}{k}\right)\right)}\right)e^{-\left(\frac{m_2+1}{2}\right)y}
$$

$$
+\varepsilon e^{nt}\left\{-\frac{4AG_cS_c\gamma}{\alpha'^2-S_c^2-4\beta'^2S_c}\left\{\frac{e^{-\gamma y}}{\gamma^2-\gamma-\left(n+\frac{1}{k}\right)}-\frac{e^{-\delta y}}{\delta^2-\delta-\left(n+\frac{1}{k}\right)}\right\}-\frac{G_ce^{-\delta y}}{\delta^2-\delta-\left(n+\frac{1}{k}\right)}\right.
$$

$$
+\frac{kAm_1G\sin\alpha_1}{m_1^{\,2}-m_1-\left(n+\frac{1}{k}\right)}e^{-m_1y}
-\frac{A\gamma G_c}{\left(\gamma^2-\gamma-\frac{1}{k}\right)\left(\gamma^2-\gamma-\left(n+\frac{1}{k}\right)\right)}e^{-\gamma y}
$$

$$
\left.+\frac{\dfrac{A(m_1+1)\left(1-kG\sin\alpha_1+\dfrac{G_c}{\gamma^2-\gamma-\frac{1}{k}}\right)e^{-\frac{(m_1+1)y}{2}}}{2}}{\left(\frac{(m_1+1)}{2}\right)^2-\left(\frac{(m_1+1)}{2}\right)-\left(n+\frac{1}{k}\right)}\right\} \qquad (24)
$$

The skin friction on the boundary is

Given by $\left.\dfrac{\partial u}{\partial y}\right|_{y=0}$ =

$$
-\frac{(m_1+1)}{2}\left[1-kG\sin\alpha_1+\frac{G_c}{\gamma^2-\gamma-\frac{1}{k}}\right]
-m_1\left(kG\sin\alpha_1\right)+\frac{\gamma G_c}{\gamma^2-\gamma-\frac{1}{k}}
$$

$$
-\frac{4AG_cS_c\gamma\varepsilon e^{nt}}{\alpha'^2-S_c^2-4\beta'^2S_c}\frac{\frac{(m_2+1)}{2}}{\gamma^2-\gamma-\left(n+\frac{1}{k}\right)}
+\frac{4AG_cS_c\gamma\varepsilon e^{nt}}{\alpha'^2-S_c^2-4\beta'^2S_c}\frac{\frac{(m_2+1)}{2}}{\delta^2-\delta-\left(n+\frac{1}{k}\right)}
$$

$$
-\frac{\varepsilon e^{nt}G_c\frac{(m_2+1)}{2}}{\delta^2-\delta-\left(n+\frac{1}{k}\right)}
+\frac{\varepsilon e^{nt}kAm_1G\sin\alpha_1\frac{(m_2+1)}{2}}{m_1^{\,2}-m_1-\left(n+\frac{1}{k}\right)}
$$

$$
+\frac{\varepsilon e^{nt}\frac{A(m_1+1)}{2}\frac{(m_2+1)}{2}\left(1-kG\sin\alpha_1+\dfrac{G_c}{\gamma^2-\gamma-\frac{1}{k}}\right)}{\left(\frac{m_1+1}{2}\right)^2-\left(\frac{m_1+1}{2}\right)-\left(n+\frac{1}{k}\right)}
-\frac{\varepsilon e^{nt}\frac{(m_2+1)}{2}A\gamma G_c}{\left(\gamma^2-\gamma-\frac{1}{k}\right)\left(\gamma^2-\gamma-\left(n+\frac{1}{k}\right)\right)}
$$

$$
-\frac{\varepsilon e^{nt}4AG_cS_c\gamma^2}{\left(\alpha'^2-S_c^{\,2}-4\beta'^2S_c\right)\left(\gamma^2-\gamma-\left(n+\frac{1}{k}\right)\right)}
+\frac{\varepsilon e^{nt}4AG_cS_c\gamma\delta}{\left(\alpha'^2-S_c^{\,2}-4\beta'^2S_c\right)\left(\delta^2-\delta-\left(n+\frac{1}{k}\right)\right)}
$$

$$-\frac{\varepsilon e^{nt}\delta G_c}{\delta^2-\delta-\left(n+\frac{1}{k}\right)}+\frac{\varepsilon e^{nt}kAm_1^2G\sin\alpha_1}{m_1^2-m_1-\left(n+\frac{1}{k}\right)}-\frac{\varepsilon e^{nt}A\gamma^2G_c}{\left(\gamma^2-\gamma-\frac{1}{k}\right)\left(\gamma^2-\gamma-\left(n+\frac{1}{k}\right)\right)}+\frac{\varepsilon e^{nt}A(m_1+1)^2\left(1-kG\sin\alpha_1+\frac{G_c}{\gamma^2-\gamma-\frac{1}{k}}\right)}{m_1{}^2-1-\left(n+\frac{1}{k}\right)} \tag{25}$$

**CONCLUSIONS:**

(1) Fig 2, 3, 4, 5 and 6 illustrates the effect of Schmidt number on the velocity profiles for the porosity factors of 5.00, 4.00, 3.00, 2.00 and 1.00 respectively. In all these illustrations it is observed that as the Schmidt number increases the fluid velocity decreases initially thereafter increases. Further, it is seen that far away from the boundary contribution by Schmidt number is noticed to be significant. At times, for significant values of the porosity of the bounding surface a backward flow is noticed. Such a backward flow can be attributed to the fact that the driving force on the fluid is not that significant as it should have been for the flow to be move in the forward direction. As a result of this the fluid draining over the boundary percolates through the pore, hence the backward flow.

(2) The influence of solutal Grashof number on the velocity field is illustrated in fig – 7 for a fixed porosity on the bounding surfaces and as the solutal Grashof number increases, a backward flow is noticed in the boundary layer region and as we move far away from the plate the velocity field in general increases. Far away from the plate not much of significant change in the velocity field is noticed. The backward flow observed is due to the porosity of the bounding surface. The driving force that is required in such a region is not that sufficient to push the fluid in the forward direction. Further the pores that exists on the driving force as a result of which the fluid percolates through the pores and is trapped resulting in the backward flow.

(3) Fig – 8 shows the effect of porosity of the boundary surface on the velocity profiles. It is clearly illustrated that as the porosity of the fluid bed increases backward flow is noticed. This is due to the fact that larger the pore size the fluid is trapped in the pores which also results into the seepage. However as we move far away from the boundary the pore size of the fluid bed does not contribute much to the velocity profiles. Further it is seen that the velocity of the fluid is absolutely zero and is found to be independent of pore size of the fluid bed Such a phenomena clearly indicates that the forward motion of the fluid is just balanced by the retarded forces and therefore the consolidated effect remains at zero level.

(4) The influence of angle of inclination on the velocity profiles is illustrated in fig – 9. As the angle of inclination increases and as we move far away from the bounding surface, not much of appreciable change in the velocity field is noticed. From the illustration it appears that the fluid strictly adheres to the boundary surface. However, the angle of inclination appears to show significant contribution within the boundary layer region. It is observed that increase in the angle of inclination contributes to more of backward flow within the boundary layer region.

(5) The effect of angle of inclination with respect to Schmidt number over skin friction for different porosity values are illustrated in fig 10 and fig11. As the angle inclination increases the skin friction on plate decreases. Further the skin friction is found to be independent of Schmidt number. However the porosity of the fluid bed is found to have a significant role on skin friction. It is seen that as the porosity decreases the skin friction is found to decrease considerably.

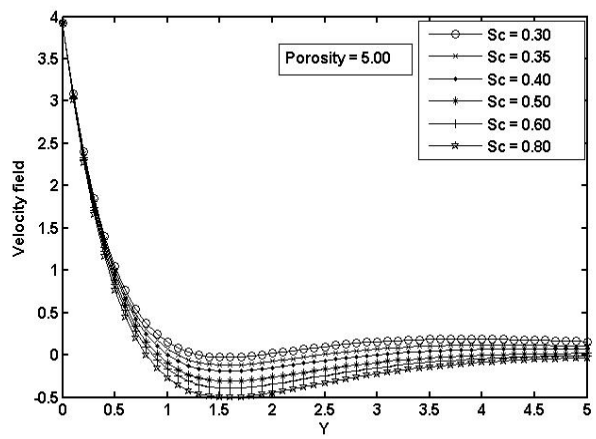


**Fig - 2: Effect of Schmidt number On Velocity field**

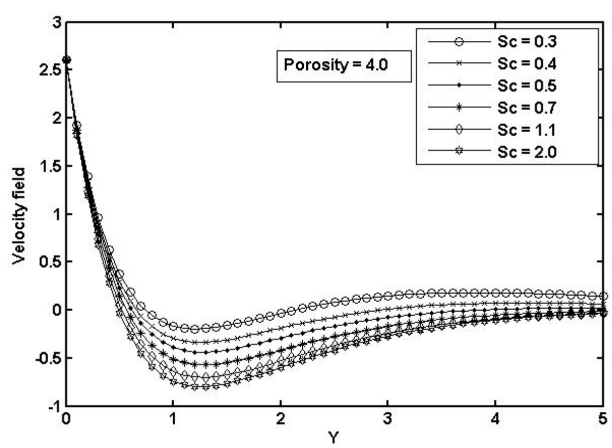


**Fig -3: Influence of Schmidt number On velocity field**

 

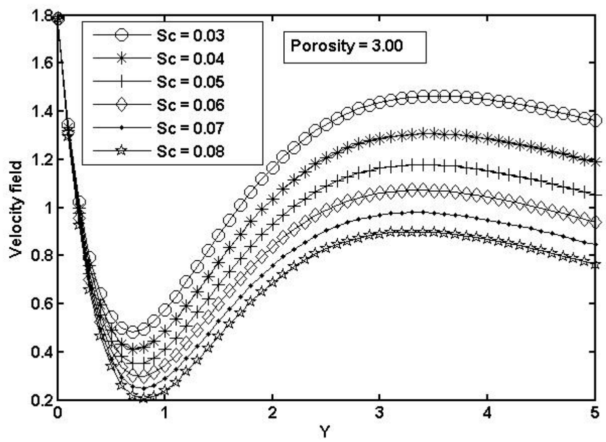


**Fig – 4: Variation of velocity profiles With reference to Schmidt number**

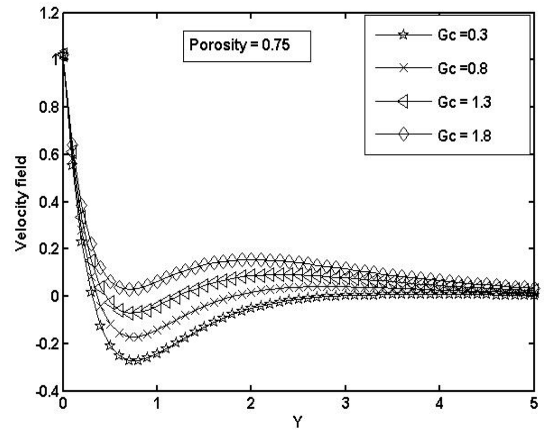


**Fig –7: Effect of Solutal Grash of Number on Velocity field**

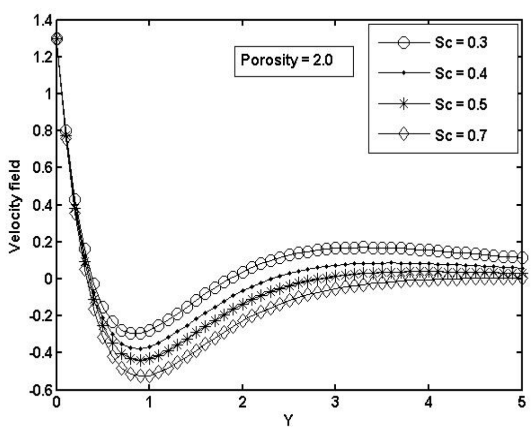


**Fig –5: Effect of Schmidt number on velocity field**

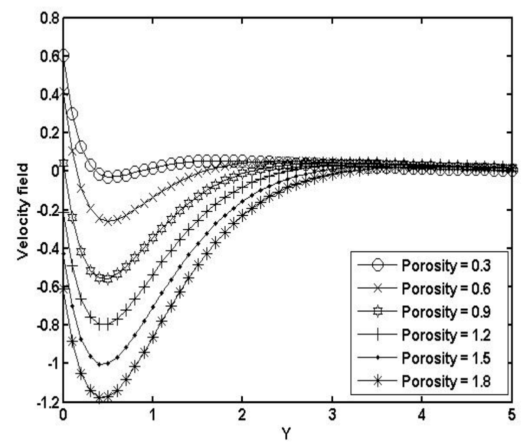


**Fig – 8: Contribution of porosity of Boundary on velocity field**

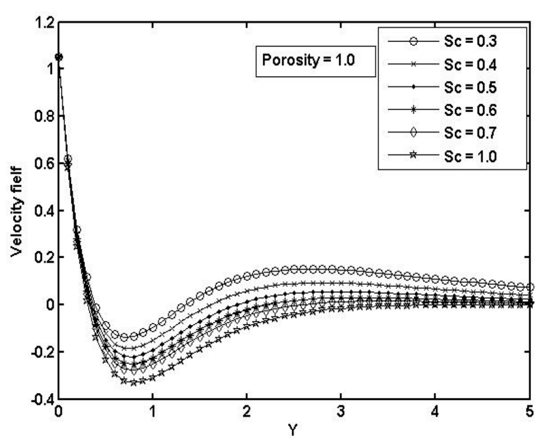


**Fig – 6: Contribution of Schmidt Number on velocity field**

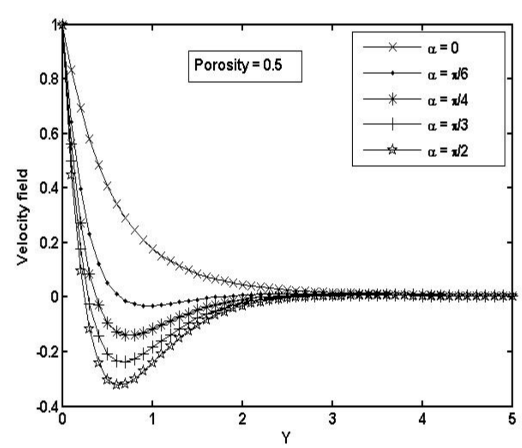


**Fig –9: Influence of angle of Inclination on velocity field**

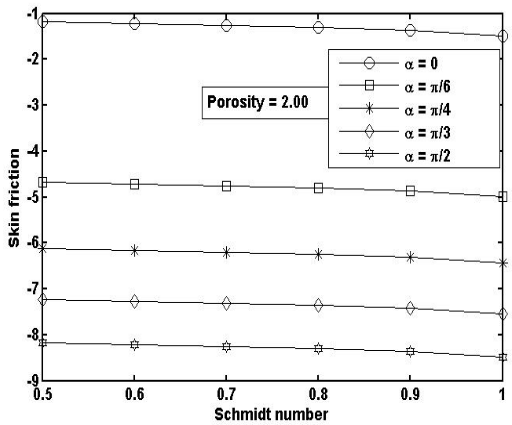


**Fig – 10: Influence of angle of Inclination on Skin friction**

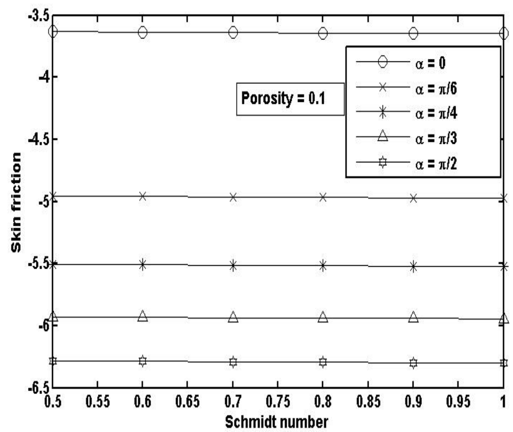


**Fig11: Influence of angle of Inclination on skin friction**

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