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Research Article

Mass Transfer Effects on MHD Flow through Porous Medium past an Exponentially Accelerated Inclined Plate with Variable Temperature and Thermal Radiation

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Abstract

The current paper focuses on unsteady MHD free convection flow with mass and heat transfer past an inclined plate. The inclined plate moves with exponential acceleration and is placed in a saturated porous medium having a uniform permeability but a varying concentration and temperature. The important essence of the study is to analyze the angle of inclination on the flow phenomenon with a heat source or sink alongside a destructive reaction. The governing equations are solved with the help of Galerkin Finite Element Method. A detailed discussion on the effects of pertinent material parameters, magnetic field, and permeability of the porous medium is presented. This reveals the flow reversal with an active magnetic field in porous medium. A retarding velocity is observed with angle of inclination and heat source. Applications of the present study include understanding of drag experienced at the heated/cooled inclined surfaces in a seepage flow.

Keywords: Radiation; Inclined plate; Magnetic field; Porous medium; Chemical reaction; FEM.

1. Introduction

Free convection flow is an important factor during many practical applications that include-for example, applications to astrophysics, geophysics, and many engineering problems such as cooling of nuclear reactors, boundary layer control in aerodynamics and cooling of electronic devices, and security of energy systems. Radiation effects on flow past an impulsively started infinite isothermal vertical plate with uniform surface temperature have studied by Das et al. (1996) and Hossain (1996). Researchers (Srinivasachary, 2016), (Pal, 2012) have discussed the chemical reaction and

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radiation effects on mixed convection heat and mass transfer over a vertical plate in power – law fluid saturated porous medium and Darcian porous medium with Soret and Dufour effects.
Several studies were been made by considering the importance of radioactive substance in heat and mass transfer inside an electrically conducting fluid. Mbeledogu and Ogulu (2007) deliberated the heat and mass transfer of an unsteady MHD natural convective flow of a rotating fluid past a vertical porous flat plate in the attendance of radioactive heat transfer. Raju et al. (2015) has studied the heat transfer effect on a viscous dissipative fluid flow past vertical plate in the presence of induced magnetic field. Radiation and mass transfer effects on unsteady MHD convective flow past an infinite vertical plate with Dufour and Soret effect studied by Vedavathi et al. (2015). Venateshwarlu and Padma (2015), Kumar and Varma (2011) have presented on an unsteady MHD free convective heat and mass transfer in boundary layer flow past a vertical permeable plate with thermal radiation and chemical reaction with the attendance of heat generation. Mutua et al. (2013) has studied magneto hydrodynamic free convection flow of a heat generation fluid past a semi-infinite vertical porous plate with variable suction.

Muthukumaraswamy and Ganesan (1998), observed that there is a rise in the velocity due to the presence of a mass diffusion. An increase in Schmidt number, leads to a fall in the velocity. Also, reported that the stability and the convergence of the finite difference schemes. In the study of Krupa Lakshmi et al (2016), the effect of diffusion-thermo and also thermo-diffusion resting on two-phase boundary layer flow past a stretching sheet by fluid-particle suspension in addition to chemical reaction. Now Barik (2013) analyzed a numerical steady on free convection heat and mass transfer MHD flow through a vertical channel in the presence of chemical reaction. Stanford Shateyi et al (2010) considered the effect of thermal radiation, Hall current, Soret and Dufour lying on MHD flow through mixed convection in a vertical surface for the duration of porous media.

Rout (2014) has considered the effect of radiation in addition to chemical reaction lying on natural convective MHD flow throughout a porous medium by double diffusion. Raptis et al (2004) has examined the effect of radiation lying on free convection flow of radiation past a semi infinite vertical plate into the presence of magnetic field. Unsteady free convection flow past a semi infinite vertical permeable moving plate with heat source and suction was premeditated by Ibrahim et al. (2008) by considering the effect of chemical reaction and radiation absorption. Again Mohammed Ibrahim (2014) studied an unsteady MHD free convective flow along a vertical porous plate embeds in a porous medium by heat generation, variable suction and chemical reaction effect.

Sudheer Babu and Satyanarayana (2009) investigate the effect of chemical reaction as well as radiation absorption lying on free convection flow throughout porous medium by variable suction into presence of uniform magnetic field. The study on unsteady MHD natural convection flows with exponential accelerated free-stream past a vertical plate is carried out by Seth et al. (2016) and concluded that there exists reverse flow in the secondary flow direction due to presence of thermal buoyancy force. Manglesh (2013) studied MHD free convection flow throughout porous medium into the occurrence of Hall current, radiation along with thermal diffusion. Kesavaiah et al. (2011) study the effect of chemical reaction plus radiation absorption lying on unsteady MHD convective heat and mass transfer flow past a semi infinite vertical permeable moving plate embed in porous medium by heat source also suction. Rajesh Vemula et al. (2016) investigates an unsteady MHD free convection flow nanofluid past an accelerated vertical plate with variable temperature as well as thermal radiation.

Free convective heat and mass transfer intended for MHD fluid stream over a permeable vertical stretch sheet into presence of radiation and buoyancy effect be considered by Rashidi et al. (2014) Gnaneshwar Reddy (2014) investigate the influence of thermal radiation, viscous dissipation in addition to Hall current lying on MHD convection flow above a extended vertical flat plate. Tripathy et al. (2015) explained the chemical reaction effect lying on MHD free convective surface over a moving vertical plate throughout porous medium.

Based on the above studies, the mass transfer effects on MHD flow through porous medium past an exponentially accelerated inclined plate with variable temperature and thermal radiation have been presented. The inclined plate moves with exponential acceleration and is placed in a saturated porous medium having a uniform permeability but a varying concentration and temperature.

2. Mathematical Formulation

In this problem we study an unsteady uniform MHD free convective flow of a viscous, incompressible and radiating fluid past an exponentially accelerated inclined infinite plate with variable temperature embedded in a saturated porous medium. Magnetic field of intensity B_0 is applied in the direction normal to the plate and induced magnetic field is neglected caused by the magnetic Reynolds number of the flow is very small. The x^* -axis is taken along the plate and y^* -axis is normal to the plate. The plate is inclined to vertical direction by an angle α. Initially, it is assumed that the surrounding fluid and the plate are at the same concentration C_∞ and the temperature T_∞. At time $t^* > 0$, the plate is exponentially accelerated with a velocity $u^* = u_0 e^{n^* t^*}$ in its own plane at the same time concentration and temperature level are also raised or lowered linearly with time t. The physical model is represented in figure 1. Following Bansal (1994), Schlichting and Gersten (1999) , Kumar and Varma (2011).

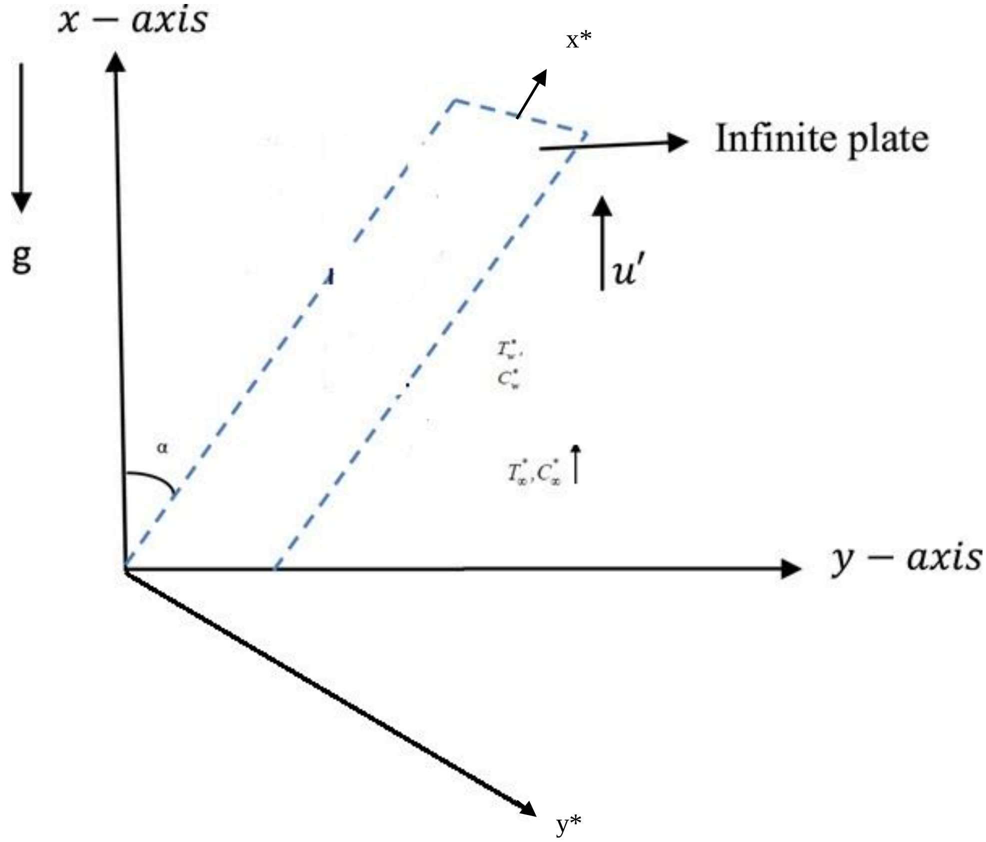

Fig .1. Geometry of the Problem

Under the above assumptions, the governing equations of flow, heat and mass transfer past an exponentially accelerated inclined plate are given by:

$$\frac{\partial u^*}{\partial t^*}=\upsilon\frac{\partial^2 u^*}{\partial t^{*2}}+g\beta\cos\alpha\left(T^*-T_\infty^*\right)+g\beta^*\cos\alpha\left(C^*-C_\infty^*\right)-\left(\frac{\sigma B_0^2}{\rho}-\frac{\upsilon}{k_p^*}\right)u^* \tag{1}$$

$$\frac{\partial T^*}{\partial t^*}=\frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}}-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*}+\frac{S^*}{\rho C_p}\left(T^*-T_\infty^*\right) \tag{2}$$

$$\frac{\partial C^*}{\partial t^*}=D\frac{\partial^2 C^*}{\partial y^{*2}}-K_c^*\left(C^*-C_\infty^*\right) \tag{3}$$

With the corresponding initial and boundary conditions:

$$\begin{aligned}
&t^*\le 0: u^*=0, T^*=T_\infty^*, C^*=C_\infty^*, \qquad for\ \ all\ y^*\\
&t^*>0: u^*=u_0 e^{n^* t^*}, T^*=T_\infty^*+\left(T_w^*-T_\infty^*\right)\frac{u_0^2 t^*}{\upsilon},\ C^*=C_\infty^*+\left(C_w^*-C_\infty^*\right)\frac{u_0^2 t^*}{\upsilon} \quad at\ \ y^*=0\\
&u^*\to 0,\ \ T^*\to T_\infty^*,\ \ C^*\to C_\infty^*, \qquad as\ y^*\to\infty
\end{aligned} \tag{4}$$

In order to write the governing equations and the boundary conditions in dimensionless form, the following non dimensional quantities are introduced.

$$y=\frac{u_0 y^*}{\upsilon}, u=\frac{u^*}{u_0}, t=\frac{t^* u_0^2}{\upsilon}, \mathrm{Pr}=\frac{\mu c_p}{k}, n=\frac{\upsilon n^*}{\upsilon_0^2}, \mathrm{k}_p=\frac{k_p^* u_0^2}{u^2},$$
$$M=\frac{\sigma B^2 \upsilon}{\rho u_0^2}, \theta=\frac{T^*-T_\infty^*}{T_w^*-T_\infty^*}, C=\frac{C^*-C_\infty^*}{C_w^*-C_\infty^*}, Gr=\frac{g\beta\nu\left(T_w^*-T_\infty^*\right)}{u_0^3}, \tag{5}$$
$$Gc=\frac{g\beta^*\upsilon\left(C_w^*-C_\infty^*\right)}{u_0^3},\ Sc=\frac{\nu}{D}, S=\frac{\upsilon S^*}{\rho C_p u_0^2}, \mathrm{R}=\frac{16 n^* \upsilon^2 \sigma T_\infty^*}{k u_0^2}, Kc=\frac{K_c^* \upsilon}{u_0^2}$$

With the non dimensional quantities, the equations (1), (2) and (3) reduces in to the following dimensionless form:

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}+\cos\alpha\left(Gr\,\theta+Gc\,C\right)-\left(M+\frac{1}{k_p}\right)u \tag{6}$$

$$\frac{\partial\theta}{\partial t}=\frac{1}{\mathrm{Pr}}\frac{\partial^2\theta}{\partial y^2}-\left(\frac{R}{\mathrm{Pr}}-S\right)\theta \tag{7}$$

$$\frac{\partial C}{\partial t}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}-KcC \tag{8}$$

With the initial and boundary conditions in dimensionless form are:

$$\begin{aligned}&u=0,\theta=0,C=0,\ for\ all\ \ y,\, t\le 0\\ &\left.\begin{aligned}&u=\mathrm{e}^{\mathrm{n}t}, \theta=t, C=t,\ at\ \ y=0,\\ &u\to 0,\theta\to 0, C\to 0\quad as\ \ y\to\infty\end{aligned}\right\} t>0\end{aligned} \tag{9}$$

3. Solution of the Problem:

Using Finite Element Method with Crank-Nikolson discretization taking $h=0.1, k=0.01$.The element equation for the typical element (e) $y_j \le y \le y_k$ for the boundary value problem can be written as:

$$\int_{y_j}^{y_k} N^{(e)^T}\left[\frac{\partial^2 u^{(e)}}{\partial y^2}-\frac{\partial u^{(e)}}{\partial t}-Nu^{(e)}+P\right]dy=0 \tag{10}$$

Where $P=G_r\cos\alpha\,\theta+G_m\cos\alpha\,C,\ N=\left(M+\dfrac{1}{k_p}\right)$

$$\left\{N^{(e)}\frac{\partial u^{(e)}}{\partial y}\right\}_{y_j}^{y_k}-\int_{y_j}^{y_k} N^{(e)}\frac{\partial u^{(e)}}{\partial y}dy-\int_{y_j}^{y_k} N^{(e)}\left[\frac{\partial u^{(e)}}{\partial t}+Nu^{(e)}-P\right]dy=0$$

omitting the first term in the above equation, we get

$$\int_{y_j}^{y_k}\left\{N^{(e)}\frac{\partial u^{(e)}}{\partial y}+N^{(e)}\left[\frac{\partial u^{(e)}}{\partial t}+Nu^{(e)}-P\right]\right\}dy=0$$

Let $u^{(e)} = N^{(e)}\phi^{(e)}$ be the finite element approximation solution ($y_j \le y \le y_k$) and we use the base functions $N^{(e)} = \left[N_j \; N_k\right], \phi^{(e)} = \left[u_j \; u_k\right]^T$, $N_j = \frac{y_k - y}{y_k - y_j}, N_k = \frac{y - y_j}{y_k - y_j}$.

$$\int_{y_j}^{y_k} \left\{ \begin{bmatrix} N_j' N_j' & N_j' N_k' \\ N_j' N_k' & N' N' \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} \right\} dy + \int_{y_j}^{y_k} \left\{ \begin{bmatrix} N_j N_j & N_j N_k \\ N_j N_k & N_k N_k \end{bmatrix} \begin{bmatrix} \dot{u}_j \\ \dot{u}_k \end{bmatrix} \right\} dy + N \int_{y_j}^{y_k} \left\{ \begin{bmatrix} N_j N_j & N_j N_k \\ N_j N_k & N_k N_k \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} \right\} dy = P \int_{y_j}^{y_k} \begin{bmatrix} N_j \\ N_k \end{bmatrix} dy$$

Where " $'$ "denotes the diff. with respect to 'y' and □ denotes the diff. with respect to 't'. Here $N_j^{'} = \frac{-1}{h}, N_k^{'} = \frac{1}{h}, h = y_k - y_j$

$$\frac{1}{l^{(e)}} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} + \frac{l^{(e)}}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} \dot{u}_j \\ \dot{u}_k \end{bmatrix} + \frac{Nl^{(e)}}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} = \frac{Pl^{(e)}}{2} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$\frac{1}{l^{(e)^2}} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} + \frac{1}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} \dot{u}_j \\ \dot{u}_k \end{bmatrix} + \frac{N}{6} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} u_j \\ u_k \end{bmatrix} = \frac{P}{2} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

We write the element equation for the elements $y_{i-1} \le y \le y_i$ and $y_i \le y \le y_{i+1}$ assemble three elements equations, we obtain

$$\frac{1}{l^{(e)^2}} \begin{bmatrix} 1 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} + \frac{1}{6} \begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix} \begin{bmatrix} \dot{u}_{i-1} \\ \dot{u}_i \\ \dot{u}_{i+1} \end{bmatrix} + \frac{N}{6} \begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix} \begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} = \frac{P}{2} \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \quad (11)$$

Now set row corresponding to the node i to zero, from the above equ.(11) the difference strategy is

$$\frac{1}{l^{(e)^2}} \left[-u_{i-1} + 2u_i - u_{i+1}\right] + \frac{1}{6} \left[\dot{u}_{i-1} + 4\dot{u}_i + \dot{u}_{i+1}\right] + \frac{N}{6} \left[u_{i-1} + 4u_i + u_{i+1}\right] = P$$

Put $l^{(e)^2} = h^2$, $r = \frac{k}{h^2}$.

$$\frac{1}{h^2} \left[-u_{i-1} + 2u_i - u_{i+1}\right] + \frac{1}{6} \left[\dot{u}_{i-1} + 4\dot{u}_i + \dot{u}_{i+1}\right] + \frac{N}{6} \left[u_{i-1} + 4u_i + u_{i+1}\right] = P$$

Employing the trapezoidal rule, the following equations are obtained using the Crank-Nicholson method :

$$A_1 u_{i-1}^{n+1} + A_2 u_i^{n+1} + A_3 u_{i+1}^{n+1} = A_4 u_{i-1}^{n} + A_5 u_i^{n} + A_6 u_{i+1}^{n} + P^* \quad (12)$$

Where

$A_1 = 2 + Nk - 6r$ $\qquad$ $A_4 = 2 - Nk + 6r$

$A_2 = 8 + 12r + 4Nk,$ $\qquad$ $A_5 = 8 - 12r - 4Nk$

$A_3 = 2 + Nk - 6r,$ $\qquad$ $A_6 = 2 - Nk + 6r$

$P^* = 12Pk = 12k(G_r \cos\alpha\, \theta_i^n + G_m \cos\alpha\, C_i^n)$

Similarly applying the applying Galerikin finite element method for equations (7) and (8) the following equations are obtained:

$$B_1\theta_{i-1}^{n+1} + B_2\theta_i^{n+1} + B_3\theta_{i+1}^{n+1} = B_4\theta_{i-1}^{n} + B_5\theta_i^{n} + B_6\theta_{i+1}^{n} + P^{**} \tag{13}$$

$$C_1C_{i-1}^{n+1} + C_2C_i^{n+1} + C_3C_{i+1}^{n+1} = C_4C_{i-1}^{n} + C_5C_i^{n} + C_6C_{i+1}^{n} \tag{14}$$

Where

$$\begin{aligned}
B_1 &= 2\Pr - 6r + 3rh\Pr + k\Pr B & B_4 &= 2\Pr - 6r - 3rh\Pr + k\Pr B\\
B_2 &= 8\Pr + 12r + 4k\Pr B & B_5 &= 8\Pr - 12r - 4k\Pr B\\
B_3 &= 2\Pr - 6r - 3rh\Pr + k\Pr B & B_6 &= 2\Pr + 6r + 3rh\Pr - k\Pr B\\
C_1 &= 2Sc + kScK_c - 6r & C_4 &= 2Sc - kScK_c + 6r\\
C_2 &= 8Sc + 4kScK_c + 12r & C_5 &= 8Sc - 4kScK_c - 12r\\
C_3 &= 2Sc + kScK_c - 6r & C_6 &= 2Sc - kScK_c + 6r\\
P^{**} &= 12Pk = (Gr\theta + GmC)\cos\alpha, & &
\end{aligned}$$

Here h,k are the mesh sizes along (y,t) directions respectively. Index i denotes to the space and n refers to the time. In equation (12), (13) and (14), taking $i = 1(1)m$ and using (9), the following systems of equations are prevailed:

$$A_iX_i = B_i \qquad i = 1(1)m \tag{15}$$

Where A_i's are the matrices of order m and X_i, B_i's column matrices having $m -$ componenets. With the help of the Thomas algorithm the solutions of the above system of equations are obtained for the velocity(u), temperature(θ), concentration(C). Also numerical solutions are obtained by running the C-program. Calculations are carried out until the steady state is reached. In order to prove the convergence of the Galerkin finite element method, the computations are carried out for small varied values of h,k by executing same C program, no significant changes was noticed in the values of velocity(u), temperature(θ), concentration(C). Hence, the Gelrkin method is stable and convergent.

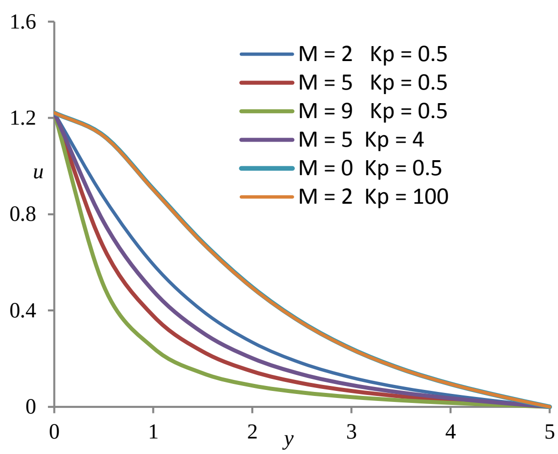

Fig .2. Velocity profile with M

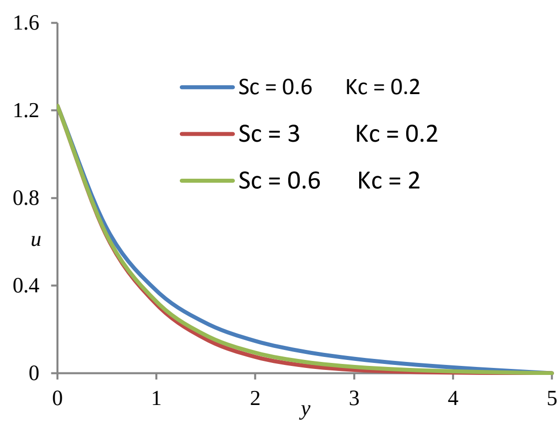

Fig. 5. Velocity profile with Sc

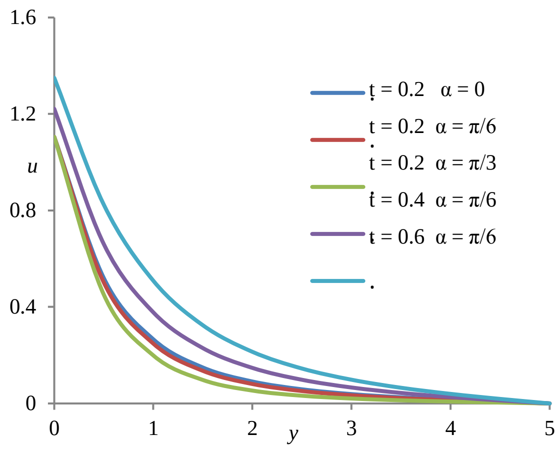

Fig. 3.Velocity profile with t

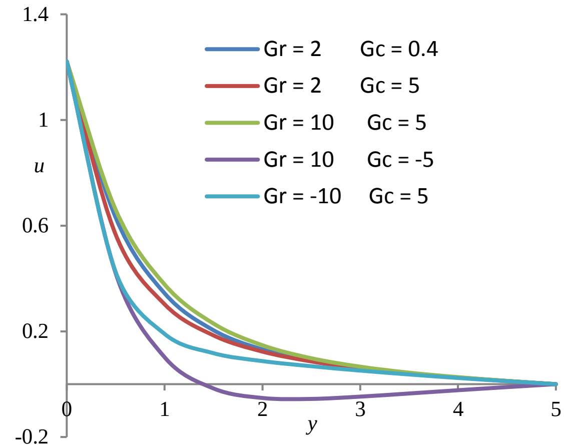

Fig. 6. Velocity profile with Gr.

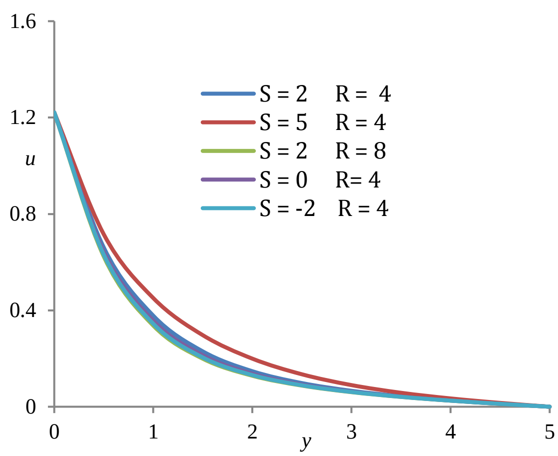

Fig. 4. Velocity profile with S

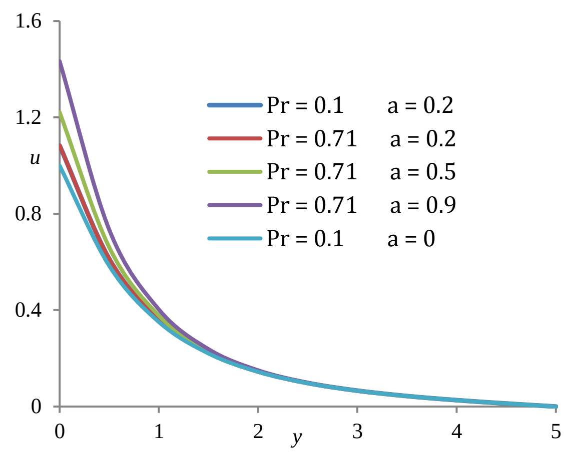

Fig. 7. Velocity profile with Pr .

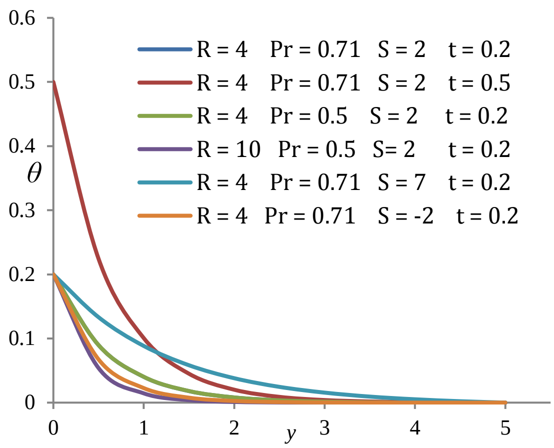

Fig. 8.:Temperature profile with R

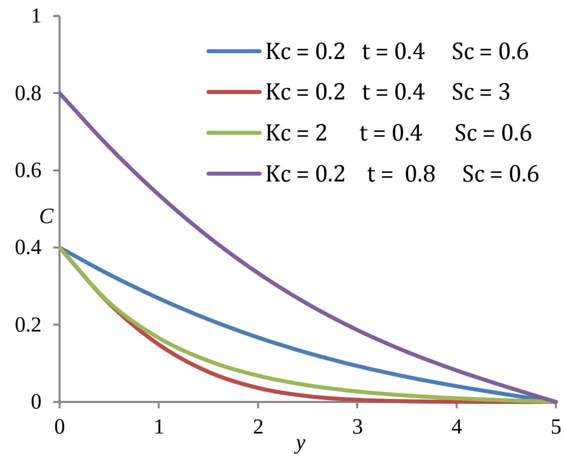

Fig. 9. Concentration profile with Kc

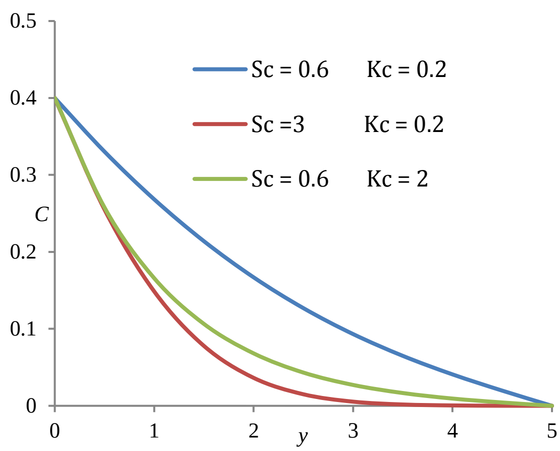

Fig. 10. Concentration profile with Sc

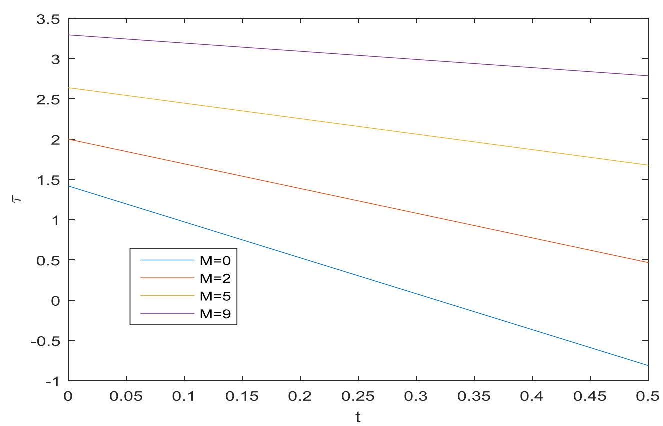

Fig. 11. : Skin friction v/s t

4. RESULTS AND DISCUSSION

Effect of various parameters that govern the flow, heat and mass transfer phenomenon along a inclined plate are discussed and illustrated graphically. Clearly, the case of vertical plate flow characteristics turns out as a special case of inclined plate flow characteristics with inclination as π/2. Velocity is found retarding for all variations along the plate. Numerically it is found to be convergent for y=5. Also, assigning to zero to the point of inclination, the instance of vertical plate can be derived as a specific case. Further, for $a = 0$ in boundary condition (9), the plate is set to a constant motion. A higher start-up is induced with an elapse of time for $a > 0$ in velocity, temperature and concentration distribution which is evident from the boundary condition. A

sudden decrease in velocity near the plate is illustrated in case of non-magnetic field and a porous medium. This is illustrated in Figure 2, the effect of magnetic field and the pore size on the flow. It is clear that the flow is being controlled by the magnetic field enhancement. The flow enhances with pore size. Hence figure 2 conclude a retarding effect on velocity distribution by an active magnetic field into porous medium. In the attendance of porous medium for ($M = 5.0$& 9.0) a uniform fall is indicated ($\mathrm{Kp} = 0.5$). Flow without a magnetic field and porous matrix is shown by curves ($\mathrm{M} = 0$ & $Kp = 0.5$) and ($M = 2$ & $M = 100$). The curves coincide with $\mathrm{y} > 1.1$ and depict a backflow.Here the velocity profiles suffer a reversal of flow indicating an active magnetic field in porous medium to prevent this. This phenomenon is due to the overriding effect of oscillations compensating the magnetic interactions with permeability of the medium.
The absence of flow inversion in the area of the plate is because of dominant effect of plate fluctuation which compensates the nonattendance of both magnetic interaction and permeability of the medium.

Angle of inclination's variations is depicted in Figure 3.Also, velocity is reduced at all points with increased angle due to the resulting force being a factor of cosine of angle. Figure 4 illustrates that an increase in heat source with constant radiation leads to increased velocity. This is shown in curves in the figure. Alternatively, with radiation parameter an opposite effect is observed. Hence velocity is increased with heat source. An observation from Figure 5 and 10 is that species with greater [Sc = 0.22(Hydrogen), Sc =0.60(Water vapour), Sc =0.78(Ammonia)], the heavier diffusion and increased chemical reaction rate leads to retarded velocity as well as concentration.
Figure 6 depicts that on cooling the plate, velocity increases with thermal buoyancy and mass buoyancy and vice-versa with heating the plate. Hence heating and cooling of the boundary has opposite effect.

From Figure 7, it will be clear that velocity decreases by an increase of Prandtl number which intern increases with acceleration parameter. The case of constant velocity of the plate is achieved in Curve when $Pr = 0.1, a = 0$ satisfying the thinner boundary layer condition. Throughout the flow domain, variation of temperature is smooth. Radiation parameter is inversely proportional with temperature. Boundary condition illustrates a direct proportion between time and plate temperature thereby indicating an increased temperature with time. From the Curve when $R = 4, Pr = 0.71, S = -2, t = 0.2$ indicated that presence of sink reduces velocity. Also, fluids with low thermal diffusivity i.e. fluids with higher values of Prandtl number illustrates a slight fall in temperature with increased strength of heat source are described in figure 8. An observation from Figure 9 is that concentration of flow is reduced by high rate of chemical reaction and increased Sc. Figure 11 illustrate skin friction increases when increasing the magnetic field

Table 1: Variation of skinfriction

M	Gr	Gc	Kp	Kc	R	t	Pr	Sc	α	S	a	τ
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	0.439772
5	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	1.940704
0	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	-0.13761
1	4	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	0.99097
1	-10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	2.283045
1	10	4	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	0.586683
1	10	-5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.5	1.952217
1	10	5	0.4	0.2	4	0.4	0.71	0.6	π/6	2	0.5	-0.68674
1	10	5	0.5	2	4	0.4	0.71	0.6	π/6	2	0.5	0.439772
1	10	5	0.5	0.2	7	0.4	0.71	0.6	π/6	2	0.5	0.598871
1	10	5	0.5	0.2	4	1	0.71	0.6	π/6	2	0.5	-1.34384
1	10	5	0.5	0.2	4	0.4	0.1	0.6	π/6	2	0.5	0.434574
1	10	5	0.5	0.2	4	0.4	0.71	3	π/6	2	0.5	0.623693
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/3	2	0.5	1.143139
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	6	0.5	-0.02484
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	0	0.5	0.524477
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	-2	0.5	0.593531
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	-5	0.5	0.665375
1	10	5	0.5	0.2	4	0.4	0.71	0.6	π/6	2	0.2	0.519722

Table 2: Variation of Nusselt number

R	t	Pr	S	Nu
4	0.2	0.71	2	0.404125
4	0.5	0.71	2	0.995934
4	0.2	0.5	2	0.401625
10	0.2	0.71	2	0.652459
4	0.2	0.71	6	0.127907
4	0.2	0.71	-2	0.537748

Table 3: Variation of Sherwood number

t	Kc	Sc	Sh
0.4	0.2	0.6	0.182215
0.4	0.2	3	0.411202
0.4	2	0.6	0.438192
0.8	0.2	0.6	0.374582

The boundary flow character is effectively provided through skin friction, Nusselt number and Sherwood number. In Table1 it illustrates the variation of skin friction with varying permeability parameter and mass and thermal buoyancy parameter. It was understood that an increase in permeability parameter and mass and also thermal buoyancy parameter lead to increase skin friction and vice-versa. Hence, skin friction is reduced by convection current in the absence of porous matrix. Instability of flow is illustrated with negative skin friction and larger time span where t=1.0. Table 2 indicates the variation of Nusselt number with an increase in values of t, Pr, R and Nusselt number is found to be increased. Also Nusselt number is found to decrease with heat source parameter(S).Hence, higher rate of heat transfer at the surface is described by fluids with low thermal diffusivity and greater radioactive property. Table 3 illustrates that an increase in Sc, Kc and it causes an increase in Sherwood number which implies that rate of solute concentrate in rise with heavier species having greater chemical reaction.

Conclusions

The discussed particular cases bring out the particular figures of Takhar [1997] as follows.

(1) Flow past a vertical plate.

(2) Plate with a constant velocity

(3) Flow in absence of magnetic field and permeability parameter.

- Backflow is prevented by offering a resistance to the fall in velocity distribution of the flow with an active traverse magnetic field in a saturated medium.
- Velocity of flow is retarding with angle of inclination, chemical reaction and presence of heavier species.
- Velocity is accelerated by the effect of heat source and convection current together. To avoid instability of flow, sink parameter has to be limited.
- Temperature decrease is caused by an increase in radiation parameter to reach an ambient state. Concentration level at all points is reduced by species with low diffusion and high chemical reaction.
- The desirable decrease in skin friction is caused due to increase in permeability and an increase in rate of chemical reaction leads to an increase in skin friction.
- The parameter reducing skin friction is free convective current without a porous medium while all others involve in increasing it. Larger time span causes instability of flow.

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