International Journal of Research in Advent Technology, Vol.6, No. 10, October2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Influence of thermal diffusion effects on unsteady MHD free convection flow past an exponentially accelerated inclined plate with ramped wall temperature

R. Vijayaragavan[1] and V. Bharathi [2]

[1]*Department of Mathematics Thiruvalluvar University, Vellore, Tamilnadu, India.*

[2]*Department of Mathematics, Adhiparasakthi College of Arts and Science (Autonomous) Kalavai,Tamilnadu, India.*
Email: [1]rvijayaraagavantvu@gmail.com, [2]bharathiv42@gmail.com.

Abstract: Influence of thermal diffusion effects on the Unsteady MHD natural convection flow past an exponentially conducting, chemically reacting, incompressible, viscous and heat absorbing fluid past an accelerated inclined plate with ramped wall temperature is studied through a porous medium in the presence of thermal and mass diffusions. The solutions of velocity, temperature and concentration equations are found in closed form by using Laplace Transform technique. The expressions for Nusselt number, Sherwood number are also derived. Convection Natural flow near a ramped temperature plate is also compared with the flow near an isothermal plate with uniform surface concentration.

Keywords: Ramped wall temperature, Isothermal plate, Incline plate, Thermal diffusion.

1. INTRODUCTION

In many applications for the study of MHD with heat and mass transfer such as energy production, conversion, Refrigeration, membrane filtration, drying, ovens, air-conditioning, stoves, toaster Cooling of electronic equipment, materials processing, Manufacturing, welding, soldering, casting, laser machining Automobiles, aircraft design, weather, absorption, climate, evaporation, distillation etc and the many engineering devices using conducting fluids of electrically, namely, generators in MHD, jet engines in plasma, accelerators in MHD, flow-meters in MHD, nuclear reactors, pumps in MHD, etc.

Narahari et al. [1] discussed Ramped Temperature Effect on Unsteady MHD Natural Convection Flow an Infinite Inclined Plate in the Presence of Chemical Reaction, Radiation and Heat Source. Seth et al. [2] studied MHD natural convection flow with heat transfer past a moving plate with ramped wall temperature. Seth et al. [3] also analyzed natural convection flow with heat and mass transfer of a chemically reacting and heat absorbing fluid past an accelerated moving vertical plate with ramped surface concentration and ramped temperature using the porous medium. Chandran et al. [4] discussed natural convection near a vertical plate with ramped wall temperature. Hari et al. [5] studied effect of thermo-diffusion and MHD second grade fluid flow of a parabolic motion with ramped surface concentration and ramped wall temperature. Hussain et al. [6] have analyzed Hall effects on MHD natural convection flow with heat and mass transfer of heat absorbing and chemically reacting fluid past a vertical plate with ramped temperature and ramped surface concentration. Ahmed et al. [7] has performed Transient mass transfer flow past an infinite vertical plate with ramped plate velocity and ramped temperature. Reddy et al. [8] analyzed convective ramped wall temperature and concentration boundary layer flow of a chemically reactive heat absorbing and radiating fluid over a vertical plate in conducting field with hall current. Hazarika et al. [9] have studied chemical reaction on a transient MHD flow past an impulsively started vertical plate with ramped temperature and concentration with viscous dissipation. Seth et al. [10] have performed heat and mass transfer effects on unsteady MHD natural convection flow of a chemically reactive and radiating fluid through a porous medium past a moving vertical plate with arbitrary ramped temperature. Sinha [11] studied effect of chemical reaction on an unsteady MHD free convective flow past a porous plate with ramped temperature. Das et al. [12] discussed hall effects on unsteady MHD natural convective flow past an impulsively moving plate with ramped temperature and concentration. Shah et al. [13] studied general solution for MHD free convection flow over a vertical plate with ramped wall temperature and chemical reaction. Chemical reaction and radiation effects on the transient MHD free convection flow of dissipative fluid past an infinite vertical porous plate with ramped wall temperature have presented by Rajesh et al. [14]. free convection flow of a radiating and chemically reacting fluid past an impulsively moving plate with ramped wall temperature have developed by Kalidas et al.[15]. Chamkha et al. [16] have presented similarity solutions for hydromagnetic simultaneous heat and mass transfer by natural convection from an inclined plate with heat generation or absorption. Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption developed by Chamkha.et al. [17]. Seth et al. [18] investigated MHD natural convection flow with radiative heat transfer past an impulsively moving plate with wall ramped temperature. Reddy et al. [19] analyzed convective ramped wall temperature and concentration boundary layer flow of a chemically reactive heat absorbing and radiating fluid over a vertical plate in conducting field with hall current. Hari R. et al. [20] studied effect of thermo-diffusion and parabolic motion on MHD second grade fluid flow with ramped wall temperature and ramped surface concentration. Rout et al. [21] investigated effect of heat source and chemical reaction on MHD flow past a vertical plate with variable temperature. Reddy et al. [22] presented the viscous dissipation effects on MHD flow over a vertical plate with ramped chemical reaction and wall temperature. Veera Krishna, et al. [23] developed the unsteady MHD convective flow of a porous medium in a rotating parallel plate channel with temperature dependent source. Vijayaragavan and Bharathi [24] analyzed thermal Diffusion effects on unsteady MHD Free convection with exponentially Accelerated inclined plate. Mthucumaraswamy and Prema [25] discussed hall effects on flow past an exponentially accelerated infinite vertical plate of an mass diffusion . Rajput et al. [26] studied dufour effect on unsteady MHD flow past an inclined oscillating plate with mass diffusion and variable temperature. Hari et al. [27] Heat and mass transfer in magneto hydrodynamic(MHD) Casson fluid flow past over an oscillating vertical plate embedded in porous medium with ramped wall temperature. Ali et al. [28] investigated Natural convection in polyethylene glycol based molybdenum disulfide nanofluid with thermal radiation, chemical reaction and ramped wall temperature. Reddy et al. [29] presented unsteady MHD natural convection flow past an impulsively moving plate with ramped temperature. Garg et al. [30] analyzed effect of an exponentially accelerated ramped vertical plate on an unsteady MHD free convection flow in the presence of magnetic field. Ali et al. [31] developed general solution for MHD -free convection flow over a vertical plate with chemical reaction and ramped wall temperature.

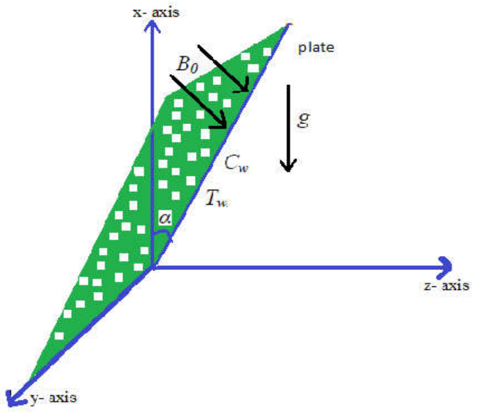
In present investigation Influence of thermal diffusion effects on the Unsteady MHD natural convection flow past an exponentially conducting, chemically reacting, incompressible, viscous and heat absorbing fluid past an accelerated inclined plate with ramped wall temperature is studied through a porous medium in the presence of thermal and mass diffusions. The solutions of velocity, temperature and concentration equations are found in closed form by using Laplace Transform technique. The expressions for Nusselt number, Sherwood number are also derived. Convection Natural flow near a ramped temperature plate is also compared with the flow near an isothermal plate with uniform surface concentration.

2. MATHEMATICAL ANALYSIS

The Unsteady MHD convection flow with heat and mass transfer of an chemically reacting, exponentially conducting, incompressible, viscous and heat absorbing fluid past an accelerated inclined plate with ramped temperature is examined through a porous medium in the presence of thermal and mass diffusions. We assume the co-ordinate system in such a process that x^* -axis is along the plate in upward direction, y^* -axis normal to the plane of the plate and z^* -axis perpendicular to $x^* y^*$ -plane. The fluid is allowed by uniform transverse magnetic field B^* applied parallel to y^* axis. Consider at time $t^* \leq 0$, both the plate and fluid are at rest and maintained at uniform temperature T_∞^* and uniform surface concentration C_∞^*. At time $t^* \geq 0$, plate starts moving in x^* -direction against the gravitational field with time dependent velocity u^*. Temperature of the plate is lowered or raised to $T_\infty + (T_w^* - T_\infty^*)\dfrac{t^*}{t_0}$ at $0 \leq t^* \leq t_0$ .Also $t_0 > t^*$ plate is retained at the uniform temperature T_w^*. Here about t_0 is characteristic time. It is assumed that the induced magnetic field is negligible in comparison to the transverse magnetic field and the magnetic Reynolds number is very little. It is also assumed that the result of viscous dissipation is negligible in the energy equation and the level of concentration is low so the Dufour effects and Soret are negligible. As the plate is infinite in extent, so the derivatives of all the flow variables with respect to x^*

vanish and they can be assumed to be functions of y^* and t^* only. Thus the motion is one dimensional with only non-zero vertical velocity component u, varying with y^* and t^* only. The dimensionless governing equations are solved using Laplace transform method and the solutions are expressed in terms of exponential and complementary error functions. In this paper talk about the unsteady MHD natural convection flow with heat and mass transfer of an electrically conducting, viscous, chemically reacting, incompressible and temperature dependent heat absorbing fluid past an accelerated infinite inclined plate embedded in a porous medium in the presence of thermal and mass diffusions.

Figure 1 Proposed Physical model of the problem



Then the flow model is defined as follows

$$\frac{\partial u^*}{\partial t^*} = \nu \frac{\partial^2 u^*}{\partial t^{*2}} - \nu \frac{u^*}{k_0^*} - \frac{\sigma B^2{}_0 u^*}{\rho} + g\beta (T^* - T^*{}_\infty)\cos\alpha + g\beta^* (C^* - C^*{}_\infty)\cos\alpha, \tag{1}$$

$$\frac{\partial T^*}{\partial t^*} = \frac{k}{\rho c_p}\frac{\partial^2 T^*}{\partial t^{*2}} - \frac{1}{\rho c_p}\frac{\partial q_r^*}{\partial y^*} - \frac{Q_0^*(T^* - T_\infty^*)}{\rho c_p} + \frac{D_m k_T}{\rho c_p C_s^*}\frac{\partial^2 C^*}{\partial y^{*2}}, \tag{2}$$

$$\frac{\partial C^*}{\partial t^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - k_1^*(C^* - C_\infty^*), \tag{3}$$

and the boundary conditions for the flow are given by

$$\left.\begin{array}{l} u^* = 0,\ T^* = T_\infty^*, C^* = C_\infty^* \ \ for\ t^* \le 0\ and\ y^* \ge 0, \\ u^* = u_0 \exp(t),\ at\ y^* = 0\ \ for\ t^* \ge 0, \\ T^* = T_\infty^* + (T_w^* - T_\infty^*)\dfrac{t^*}{t_0}\ \text{at}\ y^* = 0\ for\ 0 < t^* \le t_0, \\ C^* = C_\infty^* + (C_w^* - C_\infty^*)\dfrac{t^*}{t_0}\ \text{at}\ y^* = 0\ for\ t^* > 0, \\ u^* \to 0,\ T^* \to T_\infty^*,\ C^* \to C_\infty^*,\ \ as\ y^* \to \infty\ for\ t^* > 0 \end{array}\right] \tag{4}$$

The local gradient for the case of an optically thin gas is expressed as in the following form

$$\frac{\partial q_r^*}{\partial t^*} = -4a^*\sigma(T_\infty^{*4} - T^{*4}), \tag{5}$$

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

$$T^{*4} = 4T_\infty^{*3}T^* - 3T_\infty^{*4}, \tag{6}$$

Substituting equations (5) and (6) in (2) we get

$$\rho c_p \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial t^{*2}} + 16a^*\sigma T_\infty^{*3}(T_\infty^* - T^*) + \frac{D_m k_t \rho}{c_s}\frac{\partial^2 C^*}{\partial y^{*2}}. \tag{7}$$

On introducing the following non dimensional parameters and variables

$$\left.\begin{array}{l} y = \dfrac{y^* u_0}{\nu}, u = \dfrac{u^*}{u_0}, t = \dfrac{t^*}{t_0}, T = \dfrac{T^* - T_\infty^*}{T_w^* - T_\infty^*}, \\ C = \dfrac{C^* - C_\infty^*}{C_w^* - C_\infty^*}, \mu = \rho\nu, G_r = \dfrac{g\beta^*\nu(T_w^* - T_\infty^*)}{u_0^3}, \\ G_m = \dfrac{g\beta'\nu(C_w^* - C_\infty^*)}{u_0^3}, P_r = \dfrac{\mu c_p}{k}, k_1 = \dfrac{\nu k_1^*}{u_0^2}, \\ S_c = \dfrac{\nu}{D},\ M = \dfrac{\sigma B_0^2 \nu}{\rho u_0^2},\ R = \dfrac{16a^*\sigma\nu^2\sigma T_\infty^{*3}}{k u_0^2}, \\ k_0 = \dfrac{u_0^2 k_0^*}{\nu^2}, Du = \dfrac{D_m k_t (C_w^* - C_\infty^*)}{c_s c_p \nu (T_w^* - T_\infty^*)},\ Q_0 = \dfrac{Q_0^*}{\rho c_p u_0^2} \end{array}\right] \tag{8}$$

We have the following governing equation which is dimensionless form

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}-\frac{\left(M k_0+1\right)}{k_0}u+G_r\cos\alpha\theta+G_m\cos\alpha C, \quad (9)$$

$$\frac{\partial T}{\partial t}=\frac{1}{P_r}\frac{\partial^2 T}{\partial y^2}-\left(\frac{R}{P_r}+Q_0\right)T+D_u\frac{\partial^2 C}{\partial y^2}, \quad (10)$$

$$\frac{\partial C}{\partial t}=\frac{1}{S_c}\frac{\partial^2 C}{\partial y^2}-k_1C, \quad (11)$$

According to above non dimensional process, Charteristic t_0 time may be defined as

$$t_0=\frac{v}{u_0^2} \quad (12)$$

The corresponding boundary becomes

$$\left.\begin{array}{l} u=0,\ T=0,\ C=0 \text{ for } y\ge 0 \ and\ t\le 0 \\ u=\exp(t), C=1 \text{ at } y=0\ for\ t>0 \\ T=t \quad at\ y=0\ for\ 0<t\le 1 \\ T=1 \quad at\ y=0\ for\ t>1 \\ u\to 0,\ T\to 0,\ C\to 0,\ as\ y\to\infty for\ t>0 \end{array}\right] \quad (13)$$

The above equation can written in the form

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}-\lambda u+G_r\cos\alpha\theta+G_m\cos\alpha C, \quad (14)$$

$$\frac{\partial\theta}{\partial t}=\frac{1}{P_r}\frac{\partial^2\theta}{\partial y^2}-\delta\theta+D_u\frac{\partial^2 C}{\partial y^2}, \quad (15)$$

$$\frac{\partial C}{\partial t}=\frac{1}{S_c}\frac{\partial^2 C}{\partial y^2}-k_1C, \quad (16)$$

And the corresponding boundary

$$\left.\begin{array}{l} u=0,\ T=0,\ C=0 \text{ for } y\ge 0 \ and\ t\le 0 \\ u=\exp(t), C=1 \text{ at } y=0\ for\ t>0 \\ T=t \quad at\ y=0\ for\ 0<t\le 1 \\ T=1 \quad at\ y=0\ for\ t>1 \\ u\to 0,\ T\to 0,\ C\to 0,\ as\ y\to\infty for\ t>0 \end{array}\right] \quad (17)$$

Where $\lambda=\frac{\left(M k_0+1\right)}{k_0}$, $\delta=\frac{R}{P_r}+Q_0$

3. THE METHOD OF SOLUTION

To find the exact solution for fluid velocity, fluid temperature and concentration by solving the dimensionless governing equations from (14) to (16) subject to the boundary conditions (17) using Laplace transforms method and after simplification is presented in the following form. Here $H(y,t-1)$ is called unit Heaviside function.

$$C(y,t)=\left[\begin{array}{l}\exp(y\sqrt{S_c})\,erfc(\sqrt{k_1t}+\mu) \\ +\exp(-y\sqrt{S_c})\,erfc(-\sqrt{k_1t}+\mu)\end{array}\right] \quad (18)$$

$$T(y,t)=f_1(y,t)-H(y,t-1)f_1(y,t-1)+p_1(y,t) \quad (19)$$

Where

$$f_1(y,t)=\left[\begin{array}{l}\left(\frac{t}{2}+\frac{yp_r}{4\sqrt{\delta p_r}}\right)\exp(y\sqrt{R})\,erfc\left(\mu+\sqrt{\delta t}\right) \\ +\left(\frac{t}{2}-\frac{yp_r}{4\sqrt{\delta p_r}}\right)\exp(-y\sqrt{R})\,erfc\left(\mu-\sqrt{\delta t}\right)\end{array}\right]$$

$$p_1(y,t)=-\frac{b_4}{2}\left[\begin{array}{l}\exp(y\sqrt{\delta p_r}\ erfc\left(\mu+\sqrt{\delta p_r t}\right) \\ +\exp(-y\sqrt{\delta p_r}\ erfc\left(-\mu+\sqrt{\delta p_r t}\right)\end{array}\right]$$

$$+\frac{(b_4-b_3)}{2}\exp(-b_2t)\left[\begin{array}{l}\exp(y\sqrt{(\delta-b_2)p_r})erfc\left(\mu+\sqrt{(\delta-b_2)t}\right) \\ +\exp(-y\sqrt{(\delta-b_2)p_r})\,erfc\left(\mu+\sqrt{(\delta-b_2)t}\right)\end{array}\right]$$

$$+\frac{b_4}{2}[\exp(y\sqrt{k_1S_c})\,erfc(\mu\sqrt{S_c}+\sqrt{k_1t})$$
$$+exp(-y\sqrt{k_1S_c})\,erfc(\mu\sqrt{S_c}-\sqrt{k_1t})]$$
$$+\frac{(b_3-b_4)}{2}\exp(-b_2t)[\exp(y\sqrt{(k_1-b_2)S_c})\,erfc(\mu\sqrt{S_c}+\sqrt{(k_1-b_2)t})$$
$$+\exp(-y\sqrt{(k_1-b_2)S_c})erfc(\mu\sqrt{S_c}-\sqrt{(k_1-b_2)t})],$$
$$-\frac{b_{10}}{2}\exp(-A_6t)$$
$$\left[\begin{array}{l}\exp(y\sqrt{(\delta-A_6)p_r})\,erfc\ (\mu\sqrt{p_r}+\sqrt{(\delta-A_6)t}) \\ +\exp(-y\sqrt{(\delta-A_6)p_r})\,erfc\ (\mu\sqrt{p_r}-\sqrt{(\delta-A_6)t}\end{array}\right]$$

$$u(y,t)=f_2(y,t)-H(y,t-1)f_2(y,t-1)+p_2(y,t) \quad (20)$$

where

$$f_2(y,t)=\tfrac{e^t}{2}[\exp(y\sqrt{(\lambda+1)}\,erfc(\mu+\sqrt{(\lambda+1)t})$$
$$+\exp(-y\sqrt{(\lambda+1)}erfc(\mu-\sqrt{(\lambda+1)t})]$$
$$-\frac{b_{10}}{2}[\exp(y\sqrt{\lambda})\,erfc(\mu+\sqrt{\lambda t})$$
$$+\exp(-y\sqrt{\lambda})\,erfc(\mu-\sqrt{\lambda t})]$$
$$+b_{11}[(\tfrac{t}{2}+\tfrac{y}{4\sqrt{\lambda}})\exp(y\sqrt{\lambda})\,erfc(\mu+\sqrt{\lambda t})$$

$$+(\tfrac{t}{2}-\tfrac{y}{4\sqrt{\lambda}})\exp(-y\sqrt{\lambda})\,erfc(\mu-\sqrt{\lambda t})]$$
$$+\frac{b_{10}}{2}\exp(-b_6 t)[\exp(y\sqrt{\lambda-b_6})$$
$$erfc(\mu+\sqrt{(\lambda-b_6)t})$$
$$+\exp(-y\sqrt{\lambda-b_6})erfc(\mu-\sqrt{(\lambda-b_6)t})]$$

$$-\frac{b_{10}}{2}\exp(-A_6 t)$$
$$\begin{bmatrix}\exp(y\sqrt{(\delta-A_6)p_r})\,erfc\,(\mu\sqrt{p_r}+\sqrt{(\delta-A_6)t}) \\ +\exp(-y\sqrt{(\delta-A_6)p_r})\,erfc\,(\mu\sqrt{p_r}-\sqrt{(\delta-A_6)t}\end{bmatrix}$$
$$+\frac{b_{10}}{2}\begin{bmatrix}\exp(y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}+\sqrt{\delta t}\right) \\ +\exp(-y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}-\sqrt{\delta t}\right)\end{bmatrix}$$
$$-\frac{b_{11}}{2}\begin{bmatrix}(\tfrac{t}{2}+\tfrac{y p_r}{4\sqrt{\delta P_r}})\exp(y\sqrt{\delta p_r})\,erfc\left(\mu\sqrt{p_r}+\sqrt{\delta t}\right) \\ +(\tfrac{t}{2}-\tfrac{yP_r}{4\sqrt{\delta P_r}})\exp(-y\sqrt{\delta p_r})\,erfc\left(\mu\sqrt{p_r}-\sqrt{\delta t}\right)\end{bmatrix}$$

$$p_2(y,t)=\tfrac{c_1}{2}[\exp(y\sqrt{\lambda})\,erfc\,(\mu+\sqrt{\lambda t})$$
$$+\exp(-y\sqrt{\lambda})\,erfc(\mu-\sqrt{\lambda t})]$$
$$+\tfrac{c_2}{2}\exp(-b_2 t)[\exp\,(y\sqrt{\lambda-b_2})$$
$$erfc(\mu+\sqrt{(\lambda-b_2)t})$$
$$+\exp(-y\sqrt{\lambda-b_2})$$
$$erfc\,(\mu-\sqrt{(\lambda-b_2)t})]$$
$$+\tfrac{c_3}{2}\exp(-b_6 t)[\exp(y\sqrt{\lambda-b_6})$$
$$erfc(\mu+\sqrt{(\lambda-b_6)t})$$

$$+\exp(-y\sqrt{\lambda-b_6})\,erfc\,(\mu-\sqrt{(\lambda-b_6)t})]$$
$$+\tfrac{c_4}{2}\exp(-b_8 t)[\exp\,(y\sqrt{\lambda-b_8})\,erfc(\mu+\sqrt{(\lambda-b_8)t})$$
$$+\exp(-y\sqrt{\lambda-b_8})\,erfc\,(\mu-\sqrt{(\lambda-b_8)t})]$$
$$+\frac{b_{13}}{2}\begin{bmatrix}\exp(y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}+\sqrt{\delta t}\right) \\ +\exp(-y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}-\sqrt{\delta t}\right)\end{bmatrix}$$
$$+\frac{c_5}{2}\exp(-A_6 t)\begin{bmatrix}\exp(y\sqrt{(\delta-A_6)p_r}) \\ erfc\,(\mu\sqrt{p_r}+\sqrt{(\delta-A_6)t}) \\ +\exp(-y\sqrt{(\delta-A_6)p_r}) \\ erfc\,(\mu\sqrt{p_r}-\sqrt{(\delta-A_6)t}\end{bmatrix}$$

$$+\tfrac{c_7}{2}[\exp(y\sqrt{kS_c})\,erfc\,(\eta\sqrt{S_c}+\sqrt{kt})$$
$$+exp(-y\sqrt{kS_c})\,erfc\,(\eta\sqrt{S_c}-\sqrt{kt})]$$
$$+\tfrac{c_8}{2}\exp(-A_2 t)$$
$$[\exp(y\sqrt{(k-A_2)S_c})\,erfc\,(\eta\sqrt{S_c}+\sqrt{(k-A_2)t})$$
$$+\exp(-y\sqrt{(k-A_2)S_c})\,erfc\,(\eta\sqrt{S_c}-\sqrt{(k-A_2)t})]$$
$$+\tfrac{c_9}{2}\exp(-A_8 t)$$
$$[\exp(y\sqrt{(k-A_8)S_c})\,erfc\,(\eta\sqrt{S_c}+\sqrt{(k-A_8)t})$$
$$+\exp(-y\sqrt{(k-A_8)S_c})\,erfc\,(\eta\sqrt{S_c}-\sqrt{(k-A_8)t})].$$

4. SOLUTION WHERE FLUD IN THE CASE OF ISOTHERMAL PLATE

In order to mention the effects of ramped temperature and concentration on fluid flow, it may be worthwhile to compare such flow with the one near an accelerated moving vertical plate with uniform temperature. In this paper, the solution for fluid velocity, fluid temperature and species concentration for natural convection flow past an accelerated isothermal plate with uniform surface concentration is obtained and can be presented in the following form.

$$T(y,t)=\frac{(1-b_4)}{2}\begin{bmatrix}\exp(y\sqrt{\delta p_r})\,erfc\left(\mu+\sqrt{\delta p_r t}\right) \\ +\exp(-y\sqrt{\delta p_r})\,erfc\left(\mu-\sqrt{\delta p_r t}\right)\end{bmatrix}$$

$$+\tfrac{(b_4-b_3)}{2}\exp(-b_2 t)$$
$$\begin{bmatrix}\exp(y\sqrt{(\delta-b_2)p_r}) \\ erfc\left(\mu+\sqrt{(\delta-b_2)t}\right) \\ +\exp(-y\sqrt{(\delta-b_2)p_r}) \\ erfc\left(\mu+\sqrt{(\delta-b_2)t}\right)\end{bmatrix}$$
$$+\tfrac{b_4}{2}[\exp(y\sqrt{k_1 S_c})\,erfc(\mu\sqrt{S_c}+\sqrt{k_1 t})$$
$$+exp(-y\sqrt{k_1 S_c})\,erfc(\mu\sqrt{S_c}-\sqrt{k_1 t})]$$
$$+\tfrac{(b_3-b_4)}{2}\exp(-b_2 t)$$
$$[\exp(y\sqrt{(k_1-b_2)S_c})$$
$$erfc(\mu\sqrt{S_c}+\sqrt{(k_1-b_2)t})$$
$$+\exp(-y\sqrt{(k_1-b_2)S_c})$$
$$erfc(\mu\sqrt{S_c}-\sqrt{(k_1-b_2)t})] \quad (21)$$

$$u(y,t)=\frac{e^t}{2}[\exp(y\sqrt{(\lambda+1)}\,erfc(\mu+\sqrt{(\lambda+1)t})$$
$$+\exp(-y\sqrt{(\lambda+1)}erfc(\mu-\sqrt{(\lambda+1)t})]$$
$$+\frac{b_{11}}{2}[\exp(y\sqrt{\lambda})\,erfc(\mu+\sqrt{\lambda t})$$
$$+\exp(-y\sqrt{\lambda})\,erfc(\mu-\sqrt{\lambda t})]$$
$$-\frac{b_{11}}{2}\exp(-b_6 t)$$
$$[\exp(y\sqrt{\lambda-b_6})erfc(\mu+\sqrt{(\lambda-b_6)t})$$
$$+\exp(-y\sqrt{\lambda-b_6})erfc(\mu-\sqrt{(\lambda-b_6)t})]$$

$$-\frac{b_{11}}{2}\begin{bmatrix}\exp(y\sqrt{\delta p_r}erfc\left(\mu\sqrt{p_r}+\sqrt{\delta t}\right)\\ +\exp(-y\sqrt{\delta p_r}erfc\left(\mu\sqrt{p_r}-\sqrt{\delta t}\right)\end{bmatrix}$$

$$+\frac{b_{11}}{2}\exp(-A_6 t)$$
$$\begin{bmatrix}\exp(y\sqrt{(\delta-A_6)p_r})erfc\,(\mu\sqrt{p_r}+\sqrt{(\delta-A_6)t})\\ +\exp(-y\sqrt{(\delta-A_6)p_r})\,erfc\,(\mu\sqrt{p_r}-\sqrt{(\delta-A_6)t}\end{bmatrix}$$
$$+p_3(y,t) \qquad (22)$$

$$p_3(y,t)=\frac{c_1}{2}[\exp(y\sqrt{\lambda})\,erfc\,(\mu+\sqrt{\lambda t})$$
$$+\exp(-y\sqrt{\lambda})\,erfc(\mu-\sqrt{\lambda t})]$$
$$+\frac{c2}{2}\exp(-b_2 t)[\exp(y\sqrt{\lambda-b_2})\,erfc(\mu+\sqrt{(\lambda-b_2)t})$$
$$+\exp(-y\sqrt{\lambda-b_2})\,erfc\,(\mu-\sqrt{(\lambda-b_2)t})]$$
$$+\frac{c3}{2}\exp(-b_6 t)[\exp(y\sqrt{\lambda-b_6})erfc(\mu+\sqrt{(\lambda-b_6)t})$$
$$+\exp(-y\sqrt{\lambda-b_6})erfc\,(\mu-\sqrt{(\lambda-b_6)t})]$$
$$+\frac{c4}{2}\exp(-b_8 t)[\exp(y\sqrt{\lambda-b_8})\,erfc(\mu+\sqrt{(\lambda-b_8)t})$$
$$+\exp(-y\sqrt{\lambda-b_8})\,erfc\,(\mu-\sqrt{(\lambda-b_8)t})]$$
$$+\frac{b_{13}}{2}\begin{bmatrix}\exp(y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}+\sqrt{\delta t}\right)\\ +\exp(-y\sqrt{\delta p_r}\,erfc\left(\mu\sqrt{p_r}-\sqrt{\delta t}\right)\end{bmatrix}$$

$$+\frac{c_5}{2}\exp(-A_6 t)$$
$$\begin{bmatrix}\exp(y\sqrt{(\delta-A_6)p_r})erfc(\mu\sqrt{p_r}+\sqrt{(\delta-A_6)t})\\ +\exp(-y\sqrt{(\delta-A_6)p_r})\,erfc\,(\mu\sqrt{p_r}-\sqrt{(\delta-A_6)t}\end{bmatrix}$$

$$+\frac{c6}{2}\exp(-A_2 t)$$
$$\begin{bmatrix}\exp(y\sqrt{(\delta-A_2)p_r})\\ erfc\,(\mu\sqrt{p_r}+\sqrt{(\delta-A_2)t})\\ +\exp(-y\sqrt{(\delta-A_2)p_r})\\ erfc\,(\mu\sqrt{p_r}-\sqrt{(\delta-A_2)t})\end{bmatrix}$$

$$+\frac{c7}{2}[\exp(y\sqrt{kS_c})\,erfc(\eta\sqrt{S_c}+\sqrt{kt})$$
$$+exp(-y\sqrt{kS_c})\,erfc(\eta\sqrt{S_c}-\sqrt{kt})]$$
$$+\frac{c8}{2}\exp(-A_2 t)$$
$$[\exp(y\sqrt{(k-A_2)S_c})\,erfc(\eta\sqrt{S_c}+\sqrt{(k-A_2)t})$$
$$+\exp(-y\sqrt{(k-A_2)S_c})\,erfc(\eta\sqrt{S_c}-\sqrt{(k-A_2)t})]$$
$$+\frac{c9}{2}\exp(-A_8 t)$$
$$[\exp(y\sqrt{(k-A_8)S_c})\,erfc(\eta\sqrt{S_c}+\sqrt{(k-A_8)t})$$
$$+\exp(-y\sqrt{(k-A_8)S_c})\,erfc(\eta\sqrt{S_c}-\sqrt{(k-A_8)t})].$$

5. NUSSELT NUMBER

The Nusselt number obtained from ramped temperature and is given in non-dimensional form is given by

$$Nu=-\left[\frac{\partial T}{\partial y}\right]_{y=0},$$

$$T(y,t)=f_4(0,t)-H(y,t-1)\,f_4(0,t-1)+p_4(0,t) \quad (23)$$

Where

$$f_4(0,t)=-\begin{bmatrix}t\sqrt{\delta P_r}\,erf\sqrt{\delta t}-\sqrt{\frac{P_r t}{\pi}}\exp(-\delta t)\\ -\frac{P_r}{2\sqrt{\delta P_r}}erf\sqrt{\delta t}\end{bmatrix}$$

$$p_4(0,t)=-B_4\left[(-\exp(-\delta t)\sqrt{\tfrac{P_r}{\pi t}}-\sqrt{\delta}erf(\delta t))\right]$$
$$-(B_3-B_4)\exp(-B_2 t)$$
$$\begin{bmatrix}(-\exp(-\delta+B_2)t)\sqrt{\frac{P_r}{\pi t}}-\\ \sqrt{(\delta-B_2)P_r}erf\sqrt{(\delta-B_2)t}\end{bmatrix}$$
$$+B_4\left[\sqrt{\tfrac{S_c}{\pi t}}\exp(-kt)+\sqrt{kS_c}\,erf(kt)\right]$$
$$-(B_3-B_4)[-\exp(-kt+A_2 t)\sqrt{\tfrac{S_c}{\pi t}}$$
$$-\sqrt{kS_c-B_2S_c}\,erf(\sqrt{kt-B_2 t})].$$

The Nusselt number obtained from isothermal temperature and is given in non-dimensional form is given by

$$Nu=-\left[\frac{\partial T}{\partial y}\right]_{y=0},$$

$$T(y,t)=f_5(0,t)+p_4(0,t) \qquad (24)$$

Where

$$f_5(0,t) = -\left[\sqrt{\delta P_r}\, erf\sqrt{\delta t} - \sqrt{\tfrac{P_r t}{\pi}}\exp(-\delta t)\right]$$

6. SHERWOOD NUMBER

The Sherwood number obtained by concentration field and is given in non-dimensional form as

$$S_h = (1 - erf\sqrt{kt})\left(\tfrac{1}{2}\sqrt{\frac{S_c}{k}} + t\sqrt{S_c k}\right) + \sqrt{\frac{tS_c}{\pi}}\exp(-kt) \quad (25)$$

The utilized constant expressions are described in the Appendix section.

7. NUMERICAL RESULTS AND DISCUSSION

In order to analyze the influence of magnetic field, species buoyancy force, thermal buoyancy force, chemical reaction ,heat absorption, and time on flow-field in the boundary layer region, the numerical values of fluid velocity, calculated from the analytical solutions described in Sections 2 and 3, are showed graphically afterwards boundary layer co-ordinate y in Figs. 2 to 5 for various values of thermal Grashof number G_r, magnetic parameter M, Solutal Grashof number G_m, chemical reaction parameter k_1 and time t taking $P_r = 0.1,\ S_c = 2.01,\ Q_0 = 0.5,\ \alpha = \frac{\pi}{3}$.

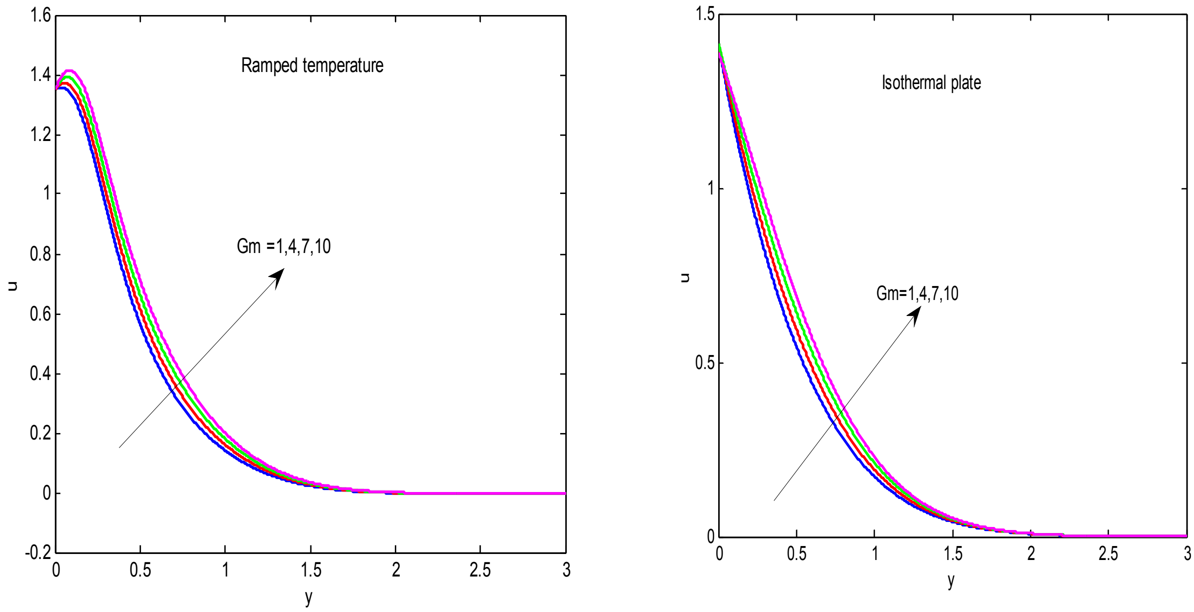


Figure 2 Velocity profiles for different values Gm with M=0.1, $Gr = 0.1$, $K_0 = 0.5$, $R=4$, $Du = 1$ and $t = 0.3$.

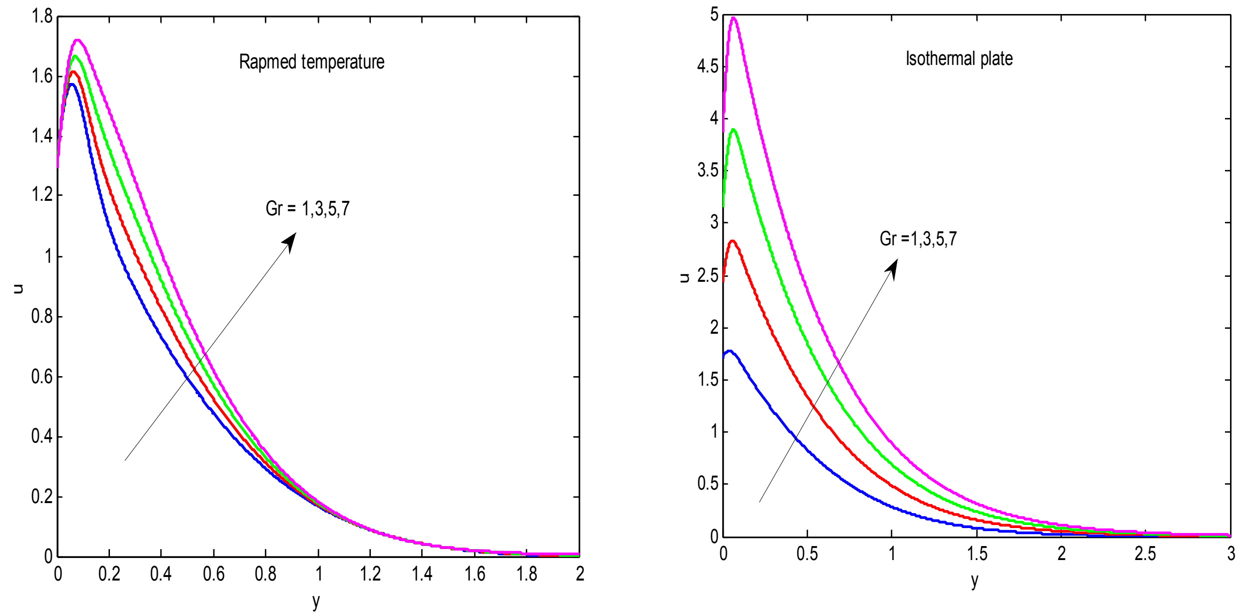


Figure 3 Velocity profiles for different values Gr with M=0.1, $Gm = 5$, $K_0 = 0.5$, $R=4$, $Du = 1$ and $t = 0.3$.

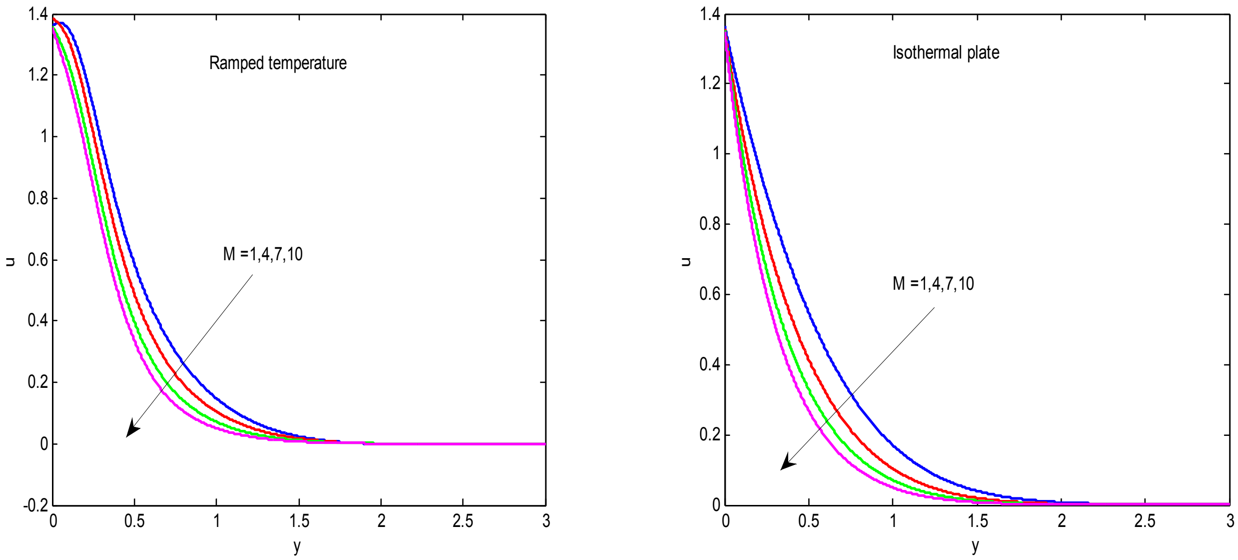


Figure 4 Velocity profiles for different values M with $Gm = 5$, $Gr = 0.1$, $K_0 = 0.5$, $R=4$, $Du = 1$ and $t = 0.3$.

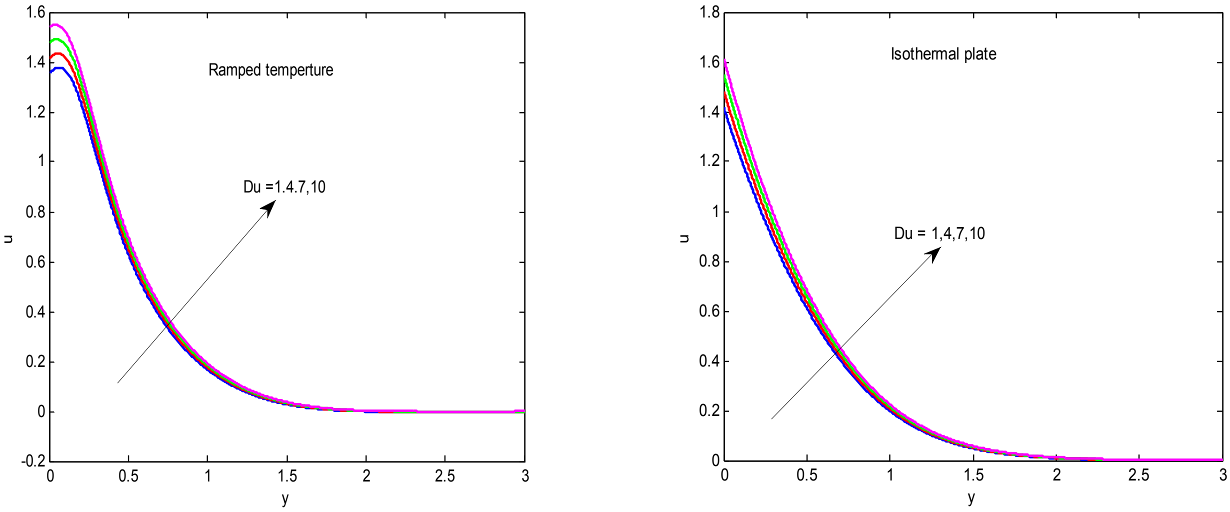


Figure 5 Velocity profiles for different values Du with $Gm = 5$, $Gr = 0.1$, $K_0 = 0.5$, $R = 4$, M=0.1 and $t = 0.3$.

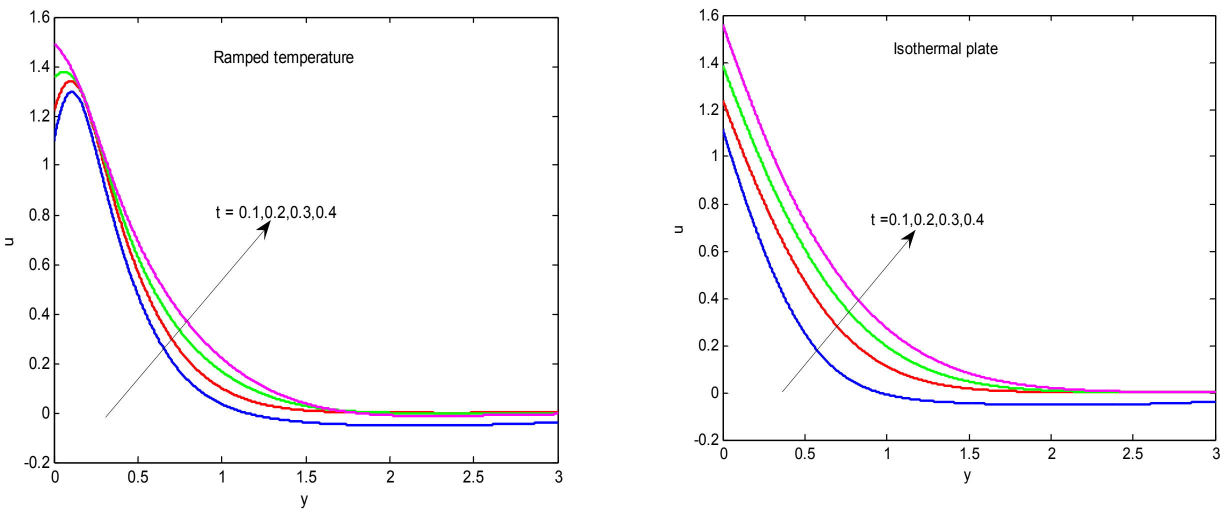
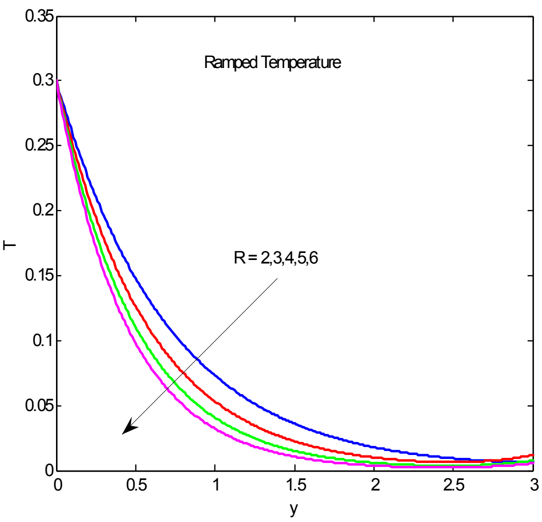


Figure 6 Velocity profiles for different values t with $Du = 1$, $Gm = 5$, $Gr = 0.1$, $K_0 = 0.5$, $R = 4$ and M=0.1

7.1 Velocity profile

The velocity, the temperature, the species concentration, Nusselt number and Sherwood number are obtained in terms of complementary error function and exponential function. It is evident from Figures 2–5 that, for both ramped temperature plate and isothermal plate with uniform surface concentration, fluid velocity u increases quickly in the region near the surface of the plate, attains a maximal distinctive value and then decreases properly on increasing limit level coordinate y to approach free current value. Figure 2 shows the influence of magnetic field on the fluid velocity. For both isothermal plate with uniform surface concentration and ramped temperature plate, increasing magnetic parameter M decreases the fluid velocity. We find that magnetic field has slowing determine on fluid flow for both isothermal plate with uniform surface concentration and ramped temperature plate. Figures 3 and 4 describe the find out of thermal buoyancy force and species buoyancy force on fluid velocity. The thermal Grashof number G_r intends the relative effect of the thermal buoyancy force to the viscous hydrodynamic force. The ratio of the viscous hydrodynamic force and species buoyancy force characterizes of the solutal Grashof number G_m. We have for both ramped temperature plate and isothermal plate with uniform surface concentration, fluid velocity increases on increasing either G_r or G_m. This implies that fluid velocity is getting accelerated due to improvement in either thermal buoyancy force or species buoyancy force. Figure 5 show the effects of Duffer effect on fluid velocity. It is mentioned that the velocities of fluid increasing with are increases values of Dufour effect. That is the Dufour effect has slowing influence on fluid flow for both ramped temperature plate and isothermal plate with uniform surface concentration. Figure 6 show the effects of time on fluid velocity. It is found that fluid velocity increases on increasing time t. we find that there is a sweetening in fluid velocity for both isothermal plate and ramped temperature plate with uniform surface concentration with the act on of time.



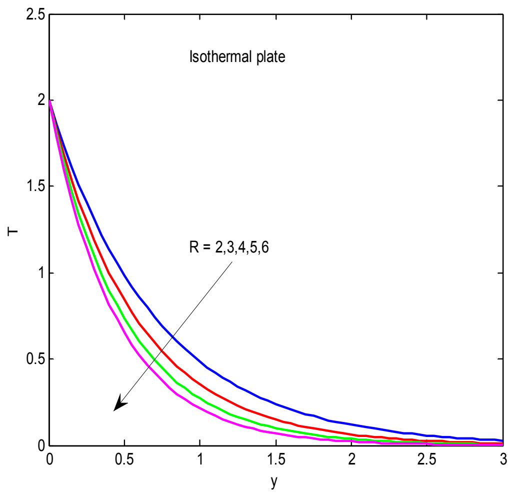


Figure 7 Temperature profiles for different values R with $Gr = 0.1$, $K_0 = 0.5$, M=0.1, $Gr = 0.1$, and $t = 0.3$.

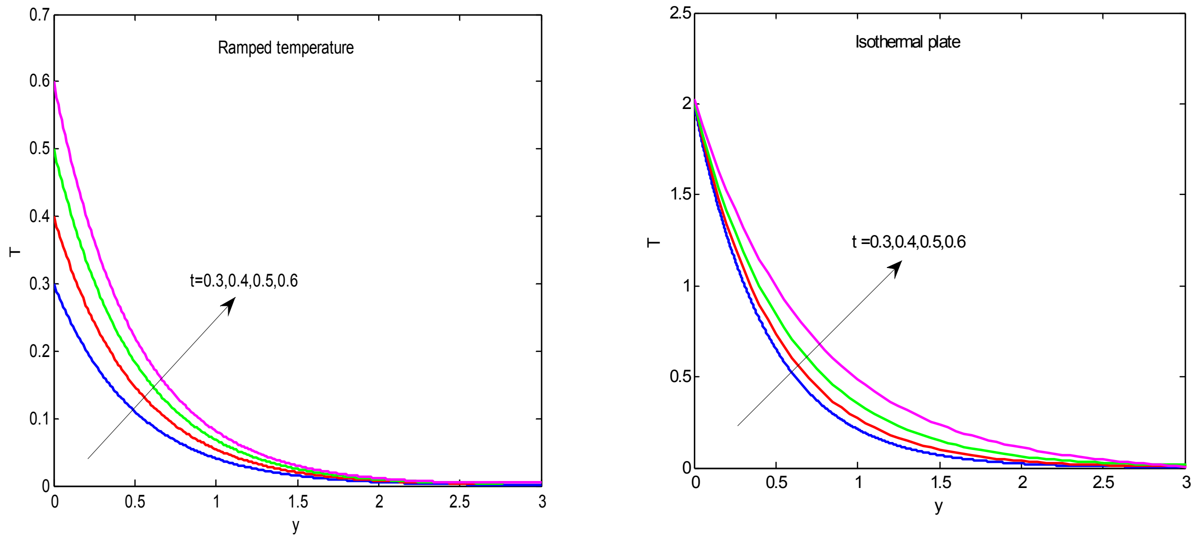


Figure 8 Temperature profiles for different values R with $Gr = 0.1$, $K_0 = 0.5$, $R=4$ $M = 0.1$, and $t = 0.3$.

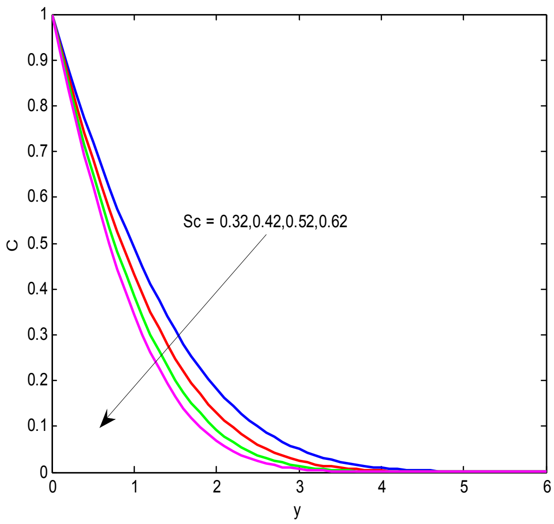


Figure 9 Concentration for different values S_c

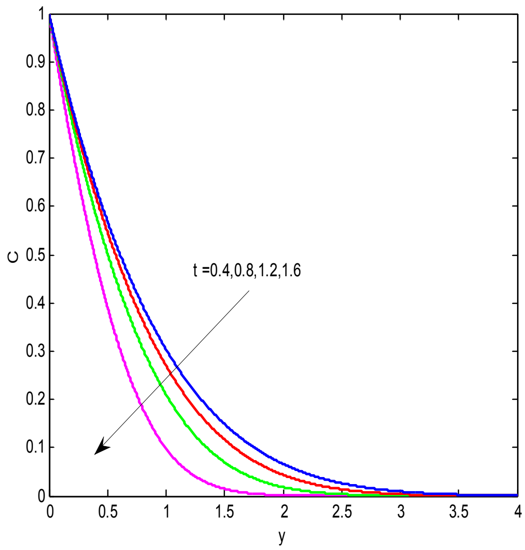


Figure 10 Concentration profiles for different values t

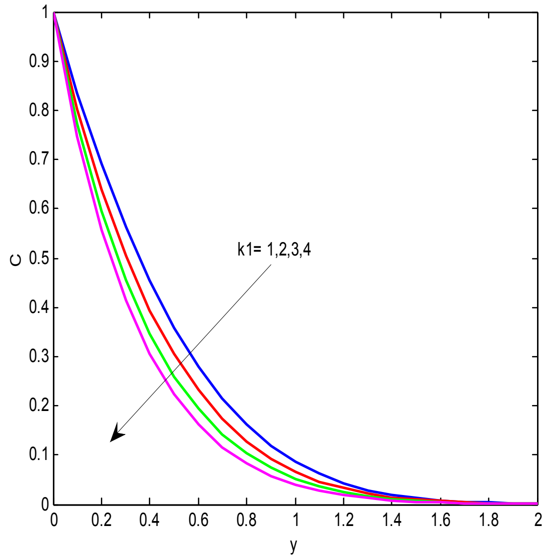


Figure 11 Concentration profiles for different values k

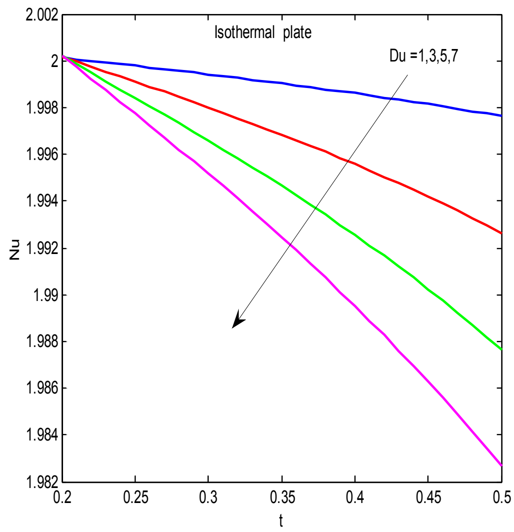


Figure 12 Nusselt number of different values Du

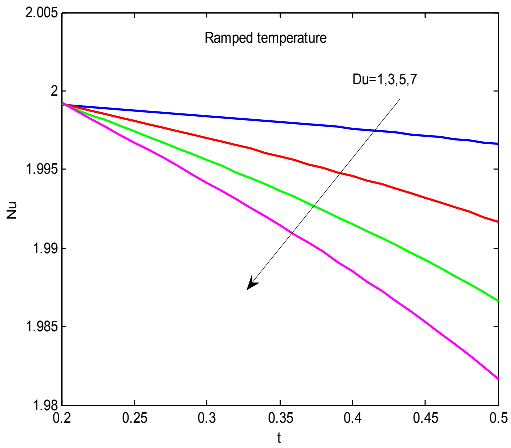


Figure 13 Sherwood number of different values Du

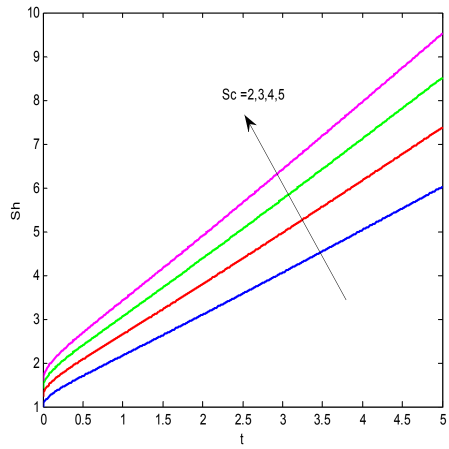


Figure 14 Sherwood number of different values S_c

7.2 Temperature profile

We have found that Figures 7 and 8 for different values of radiation parameter and time t. It is observed that for both ramped temperature plate and isothermal plate with uniform surface concentration, fluid temperature decreases on increasing value radiation parameter and increasing on increasing value of time t. we have the ramped temperature plate and isothermal plate with uniform surface concentration, heat absorption has a tendency to reduce the fluid temperature and there is a rise in fluid temperature with the progress of time in the boundary layer region.

7.3 Concentration profile

The numerical values of species concentration C, computed from analytical solution (18), are presented graphically against boundary layer coordinate y in Figures 9 and 10 for various values of Schmidt number Sc and time t. It is evident from Figures 9 and 10 that species concentration C decreases on increasing Sc whereas it increases on increasing t. we found that mass diffusion tends to enhancement species concentration and there is an enhancement in species concentration with passage of time. Figure 9 for different values of thermal conductivity of the fluid

$k1$. it is evident from Figure 9 those species concentration C decreases on increasing $k1$.

7.4 Nusselt number and Shear wood number profile

Figure 12 and 13 for different values of Dufour effect number. It is observed that for both ramped temperature plate and isothermal plate with uniform surface concentration, Nusselt number decreases on increasing value Dufour effect. The rate at mass transfers and the rate at which mass transfers are studied through the figures 14 and 15. Figure 13 it is observed that the Sherwood number increased with are increases values of Schmidt number and figure 14 represents that the Sherwood number decreased with are increasing the values thermal conductivity of the fluid $k1$.

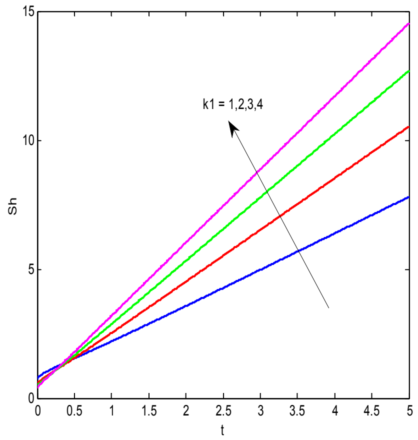


Figure 15 Sherwood number of different values $k1$

8. CONCLUSION

Influence of thermal diffusion effects on the Unsteady MHD natural convection flow past an exponentially conducting, chemically reacting, incompressible, viscous and heat absorbing fluid past an accelerated inclined plate with ramped wall temperature is studied through a porous medium in the presence of thermal and mass diffusions. The solutions of velocity, temperature and concentration equations are found in closed form by using Laplace Transform technique. The expressions for Nusselt number, Sherwood number are also derived. Convection Natural flow near a ramped temperature plate is also compared with the flow near an isothermal plate with uniform surface concentration. The solutions of velocity, temperature and concentration equations are obtained in closed form by Laplace Transform technique. The expressions for Nusselt number and Sherwood number are also found. The effects of the flow parameters on the dimensionless axial and transverse velocities, temperature, concentration, Sherwood number and Nusselt number are explored through most appropriate graphs. In this paper we conclude that the following.

- We found that for both ramped temperature plate and isothermal plate with uniform surface concentration, Magnetic field, Dufour effect, thermal Grashof number, solutal Grashof number and chemical reaction have slowing determine on fluid flow. Fluid velocity is getting accelerated with the move on of time. Chemical reaction tends to dilute concentration and there is improvement in concentration with the move on of time.
- The ramped temperature plate and isothermal plate with uniform surface concentration, fluid velocity decreases on increasing magnetic parameter M.
- The concentration increases with the decreasing values of the thermal conductivity and Schmidt number.
- For different values of Dufour effect number both ramped temperature plate and isothermal plate with uniform surface concentration, Nusselt number decreases on increasing value Dufour effect.
- The rate at mass transfers and the rate at which mass transfers are examined through it is observed that the Sherwood number increased with are increases.

NOMENCLATURE

B_0-Uniform magnetic field

k_0 - Permeability parameter

k_0' -Permeability of porous medium

C^* - Species concentration

C_w^* -Concentration of the plate

C_∞^* - Concentration of the fluid far away from the plate

C -Dimensionless concentration

C_p-Specific heat at constant pressure

Du - Dufour effect

g -Acceleration due to gravity
G_r -Thermal Grash of number
G_m- Mass Grash of number
M -Magnetic field parameter
Nu- Nusselt number
P_r - Prandtl number
q_r - Radiative heat fluxes in the - y^* direction
D_m -Coefficient of mass diffusivity
R -Radiation parameter
Sc -Schmidt number
μ- Coefficient of viscosity
k_1 -Thermal conductivity of the
T -dimensionless fluid Temperature
T_w^* -Temperature of the plate
T_∞^* -Temperature of the fluid far away from the plate
t -Time
u^* -Velocity of the fluid in the y^* direction
u_0 -Velocity of the plate
u -Dimensionless velocity
y^* -Coordinate axis normal to the plate
y -Dimensionless Coordinate axis normal to the plate
α -Thermal diffusivity
β -Volumetric coefficient of thermal expansion
β^* -Volumetric coefficient of expansion with Concentration
ρ -Density of the fluid
σ - Electric conductivity
Q_0 - Dimensionless heat source

APPENDIX

$$b_1 = \frac{DuP_r kS_c}{S_c - P_r}, b_2 = \frac{kS_c - \delta Pr}{S_c - P_r}, b_3 = \frac{-DuP_r S_c}{S_c - P_r},$$

$$b_4 = \frac{b_1}{b_2}, b_5 = \frac{G_r \cos\alpha}{P_r - 1}, b_6 = \frac{\delta P_r - M}{P_r - 1},$$

$$b_7 = \frac{G_r \cos\alpha}{S_c - 1}, b_8 = \frac{kS_c - M}{S_c - 1}, b_9 = \frac{-G_m \cos\alpha}{S_c - 1},$$

$$b_{10} = \frac{b_5}{b_6^2}, b_{11} = \frac{b_5}{b_6}, b_{12} = \frac{b_1 b_5}{b_2 b_6}, b_{13} = \frac{b_1 b_5}{b_6 (b_2 - b_6)},$$

$$b_{14} = \frac{b_1 b_5}{b_2 (b_2 - b_6)}, b_{16} = \frac{b_1 b_5}{(b_2 - b_6)}, b_{17} = \frac{b_1 b_7}{b_2 b_8},$$

$$b_{18} = \frac{b_1 b_7}{b_8 (b_2 - b_6)}, b_{19} = \frac{b_1 b_7}{b_2 (b_2 - b_8)}, b_{20} = \frac{b_3 b_7}{(b_2 - b_8)},$$

$$b_{21} = \frac{b_9}{b_8}, c_1 = (-A_{13} + A_{17} - A_{21}),$$

$$c_2 = (-A_{15} + A_{16} + A_{19} - A_{20}), c_3 = (A_{14} - A_{16}),$$

$$c_4 = (-A_{18} + A_{20} + A_{21}), c_5 = (A_{16} - A_{14}),$$

$$c_6 = (A_{15} - A_{16}), c_7 = (A_{21} - A_{17}),$$

$$c_8 = (-A_{19} + A_{20}), c_9 = (A_{18} - A_{20} + A_{21}), \ \mu = \frac{y}{2\sqrt{t}}$$

REFERENCES

[1] P. Chandran, N.C. Sacheti and A.K. Singh, Natural convection near a vertical plate with ramped wall temperature, Heat Mass Transfer.41 (2005) 459-464.
[2] R.Hari Kataria, R.Harshad, Patel, Effect of thermo-diffusion and parabolic motion on MHD second grade fluid flow with ramped wall temperature and ramped surface concentration, Alexandria Engineering Journal. 57 (2018) 73–85.
[3] S. M. Hussain, J. Jain, G. S. Seth, Hall effects on MHD natural convection flow with heat and mass transfer of heat absorbing and chemically reacting fluid past a vertical plate with ramped temperature and ramped surface concentration, Bulgarian Chemical Communications. 48 (4) (2016) 659 – 670.
[4] N. Ahmed and M. Dutta, Transient mass transfer flows past an impulsively started infinite vertical plate with ramped plate velocity and ramped temperature, International Journal of the Physical Sciences. 8(7) (2013) 254-263.
[5] L.R. Reddy, M.C. Raju and G.S.S. Raju, Convective Ramped Wall Temperature and Concentration Boundary Layer Flow of a Chemically Reactive Heat Absorbing and Radiating Fluid over a Vertical Plate in Conducting Field with Hall Current, Innovative Energy & Research. 5(1) (2016).
[6] G.C. Hazarik, Chemical Reaction on a Transient MHD Flow Past an Impulsively Started Vertical Plate with Ramped Temperature and Concentration with Viscous Dissipation, International Journal of Fluids Engineering . 6(1) (2014) 39-51.
[7] G. S. Seth, R. Sharma and B. Kumbhakar, the Heat and Mass Transfer Effects on Unsteady MHD Natural Convection Flow of a

Chemically Reactive and Radiating Fluid through a Porous Medium Past a Moving Vertical Plate with Arbitrary Ramped Temperature, Journal of Applied Fluid Mechanic. 9(1) (2016) 103-117.

[8] S. Sinha, Effect of chemical reaction on an unsteady MHD free convective flow past a porous plate with ramped temperature, International Conference on Frontiers in Mathematics.(2015) 204-210.

[9] S. Das, R.N Jana & S. K Ghosh, Hall effects on unsteady MHD natural convective flow past an impulsively moving plate with ramped temperature and concentration, Indian Journal of Pure & Applied Physics .54 (2016) 517-534.

[10] Nehad Ali Shah, Azhar Ali Zafar, Shehraz Akhtar, General Solution for MHD-free convection flow over a vertical plate with ramped wall temperature and chemical reaction, Arabian Journal of Mathematics. 7(2018) 49–60.

[11] V. Rajesh, Radiation Effects and Chemical Reaction on the Transient MHD Free Convection Flow of Dissipative Fluid Past an Infinite Vertical Porous Plate with Ramped Wall Temperature, Chemical Industry & Chemical Engineering.17(2) (2011)189-198.

[12] D. Kalidas, Magneto hydrodynamics Free Convection Flow of a Radiating and Chemically Reacting Fluid Past an Impulsively Moving Plate with Ramped Wall Temperature, Journal of Applied Mechanics. .79 (2012) 061017-1-11.

[13] A.J. Chamkha, and A.R.A. Khaled, Similarity Solutions for Hydromagnetic Simultaneous Heat and Mass Transfer by Natural Convection from an Inclined Plate with Heat Generation or Absorption, Heat Mass Transfer.37 (2001) 117–123.

[14] A.J. Chamkha, Unsteady MHD Convective Heat and Mass Transfer past a Semi-Infinite Vertical Permeable Moving Plate with Heat Absorption, Int. J. Eng. Sci. 42 (2004) 217–230.

[15] G.S. Seth, M.S. Ansari, and R. Nandkeolyar, MHD Natural Convection Flow with Radiative Heat Transfer past an Impulsively Moving Plate with Ramped Wall Temperature, Heat Mass Transfer.47 (2011) 551–561.

[16] L.R Reddy, M.C Raju and G.S.S. Raju, Convective Ramped Wall Temperature and Concentration Boundary Layer Flow of a Chemically Reactive Heat Absorbing and Radiating Fluid over a Vertical Plate in Conducting Field with Hall Current, innovative Energy and Research. 5 (1)(2016) 1-20.

[17] R. Hari Kataria, R. Harshad Patel, Effect of thermo-diffusion and parabolic motion on MHD second grade fluid flow with ramped wall temperature and ramped surface concentration. Alexandria Engineering.57 (2018) 73–85.

[18] P. K. Rout, S. N. Sahoo and G. C. Dash, Effect of heat source and chemical reaction on MHD flow past a vertical plate with variable temperature Journal of Naval Architecture and Marine Engineering.13(1) (2016)101-110.

[19] B. Prabhakar Reddy, P. M. Matao ,Viscous Dissipation Effects on MHD Flow over a Vertical Plate with Ramped Wall Temperature and Chemical Reaction in the Presence of Radiation International Journal of Mathematics and Physical Sciences Research .5(1) (2017) 102-112.

[20] M.Veera Krishna, and G. Subba Reddy, Unsteady MHD Convective Flow of Second Grade Fluid through a Porous Medium in a Rotating Parallel Plate Channel with Temperature Dependent Source, IOP Conf. Series: Mat. Sci. Eng.149 (2016) 012216.

[21] R. Vijayaragavan, V. Bharathi, chemical reaction and thermal Diffusion effects on unsteady MHD Free convectrion with exponentially Accelerated inclined plate Journal of Emerging Technologies and Innovative Research.5(7) (2018) 554-556.

[22] R. Muthucumaraswamy and K. M. A. Prema Hall Effects on Flow past an Exponentially Accelerated Infinite Isothermal Vertical Plate with Mass Diffusion Journal of Applied Fluid Mechanics. 9(2) (2016) 889-897.

[23] U.S. Rajput, gaurav kumar Dufour effect on unsteady MHD flow past an impulsively started Inclined oscillating plate with variable temperature and mass diffusion International

Journal of Mathematical Archive.7(1) (2016) 153-158.
[24] B.P Garg and Deepti, Analysis of radiative free convective flow past a flat plate in the presence of transverse magnetic field with ramped wall temperature International Journal of Statistics and Applied Mathematics. 3(4) (2018) 130-139.
[25] Farhad Ali, Muhammad Arif, Ilyas Khan, Nadeem A. Sheikh, Muhammad Saqib, Natural convection in polyethylene glycol based molybdenum disulfide nanofluid with thermal radiation, chemical reaction and ramped wall temperature International Journal of Heat and Technology.36(2) (2018) 619-631.
[26] K.Rajeshwar Reddy, M.chenna krishna Reddy Unsteady MHD natural convection flow past animpulsively moving plate with ramped temperature SCIREA Journal of Mathematics.3(1)(2018) 67-82.
[27] Hari R. Kataria Harshad R. Patel , Heat and mass transfer in magneto hydrodynamic (MHD) Casson fluid flow past over an oscillating vertical plate embedded in porous medium with ramped wall temperature Propulsion and Power Research .7(3)(2018):257–267.
[28] Nehad Ali Shah, Azhar Ali Zafar, Shehraz Akhtar, General solution for MHD-free convection flow over a vertical plate with ramped wall temperature and chemical reaction Arabian Journal of Mathematics Arab. J. Math.7 (2018) 49–60.
[29] M. Narahari, sowmya Tippa, Rajashekhar Pendyala, M.Yunus Nayan, Ramped Temperature Effect on Unsteady MHD Natural Convection Flow an Infinite Inclined Plate in the Presence of Radiation, Heat Source and Chemical Reaction, Recent Advances in Applied and Theoretical Mechanics. (2015) 126-137.
[30] G.S. Seth, Md. S. Ansari and R.Nandkeolyar, MHD Natural Convection Flow with Radiative Heat Transfer past an Impulsively Moving Plate with Ramped Wall Temperature, Heat Mass Transfer.47 (2011) 551–561.
[31] G.S. Seth a, S.M. Hussain b, S. Sarkar, Hydromagnetic natural convection flow with heat and mass transfer of a chemically reacting and heat absorbing fluid past an accelerated moving vertical plate with ramped surface concentration and ramped temperature through a porous medium, Journal of the Egyptian Mathematical Society. 23 (2015) 197–207.