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RADIATION AND CHEMICAL REACTION EFFECTS ON EXPONENTIALLY ACCELERATED ISOTHERMAL VERTICAL PLATE CUM MASS FLUX

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ABSTRACT

The solution of radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate has been presented in the presence of mass flux. The dimensionless governing equations are solved using Laplace transform technique. The velocity, temperature, and concentration profiles are studied for different physical parameters like radiation parameter R, accelerating parameter a, thermal Grashof number Gr, mass Grashof number Gc, chemical reaction parameter K, Prandtl number Pr, Schmidt number Sc and time t. It has been found that the velocity increases with increase in R and increases with decrease in K. Temperature rise with increasing R while concentration increases with decreasing K.

Key words: *Accelerated, Vertical plate, Radiation, Chemical reaction, Heat transfer, Mass flux.*

1. INTRODUCTION

Heat and mass transfer plays vital roles in nuclear reactors, space craft design, design of chemical processing equipment, pollution of the environment, formation and dispersion of fog and moisture of agricultural fields. Chamkha [5] studied the effects of heat absorption and thermal radiation on heat transfer in a fluid particle flow past a surface in the presence of a gravity field. Muthucumaraswamy and Valliamal [9] considered first order chemical reaction on exponentially accelerated isothermal vertical plate with mass diffusion, the dimensionless governing equations are solved using laplace-transform technique. Chandrakala [3] studied thermal radiation effects on moving infinite vertical plate with uniform heat flux. Further studies were made by Chandrakala and Bhaskar [4] they considered analytically thermal radiation effects on moving infinite vertical plate with uniform heat flux. Das *et al.* [6] studied radiation effects on flow past an impulsively started vertical infinite plate. Mass transfer effects on the flow past an exponentially accelerated vertical plate with constant heat flux were considered by Basanth *et al*. [2]. Mazumdar and Deka [7] considered MHD flow past an impulsively started infinite vertical plate in presence of thermal radiation. Rajesh and Vijaya [10] presented radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature. Muthucumaraswamy *et al.* [8] worked on the diffusion and Heat transfer effects on exponentially accelerated vertical plate with variable temperature. Sharma *et al.* [12] studied the influence of chemical reaction and radiation on unsteady MHD free convection flow and mass transfer through viscous incompressible fluid past a heated vertical plate immersed in porous medium in presence of heat source. Sahin and Dimbeswar [11] recently examine Laplace technique on Magnetohydrodynamica radiating and chemically reacting fluid over an infinite vertical surface. Asogwa *et al.* [1] worked on the flow past on an exponentially accelerated infinite vertical plate and temperature with variable mass diffusion. This study examines radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux. The dimensionless governing equations are solved using Laplace transform technique. The solutions are obtained in terms of exponential and complementary error functions.

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2. FORMULATION OF THE PROBLEM

Radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux has been considered. The x'-axis is taken along the plate in the vertically upward direction and also the y'-axis is taken normal to the plate. At $t' > 0$, the plate is accelerated with a velocity $u = u_0 \exp(at)$ in its own plane and the temperature of the plane is raise to T'_ω, and the level of concentration near the plate is raised to C'_ω. Then under the usual Boussinesq's approximation the unsteady flow equations are momentum equation, energy equation, and mass equation respectively.

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

$$\frac{\partial T}{\partial t'} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y} \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y^2} - K'\left(C' - C'_\infty\right) \tag{3}$$

where u is the velocity of the fluid, T is the fluid temperature, C' is the concentration, g is gravitational constant, β and β^* are the thermal expansions of fluid and concentration, t' is the time, ρ is the fluid density, C_p is the specific heat capacity, v is the viscosity of the fluid, k is the thermal conductivity, D is the diffusion term, K' is chemical reaction parameter and q_r is the radiative heat flux.

This research work is an extension of the work of Asogwa *et al.* [1] *International Journal of Computer Applications.* By Rosseland approximation, we assume that the temperature differences within the flow are such that T^{*4} may be expressed as a linear function of the temperature T^*. This is accomplished by expanding Taylor series about T_d^* neglecting higher order terms.

The initial and boundary conditions are;

$$\left.\begin{array}{ll} & u = 0, \quad T = T_\infty, \quad C' = C'_\infty, \quad for\,all\;\; y, t \le 0 \\ t' > 0: & u = u_0 e^{at}, T = T_\omega, \quad C' = C'_\omega \qquad\qquad y = 0 \\ & u \to 0, T \to 0, C' \to 0 \;\; as\; y \to \infty \end{array}\right\} \tag{4}$$

The local radiant absorption for the case of an optically thin gas gray is expressed as

$$\frac{\partial q_r}{\partial y'} = -4a\sigma^*\left(T_\infty^{*4} - T^{*4}\right) \tag{5}$$

where q_r is the radiative heat flux, a is the Mean absorption coefficient of the fluid and σ*Is the Stefan-Boltzmann constant. We assumed that the temperature differences within the flow are sufficiently small such that T^{*4} may be expressed as a linear function of the temperature. Expanding T^{*4} about T_∞^* in a Taylor's series and neglecting higher order terms, we have

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

By using equation (5) and (6).equation (2) reduces to

$$\frac{\partial T}{\partial t} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} + \frac{16\sigma^* T_d^3}{3a_R}\frac{\partial^2 T}{\partial y^2} \tag{7}$$

On introducing the following non-dimensional quantities

$$\left.\begin{aligned} &U=\frac{u}{(\nu u_0)^{\frac{1}{3}}}\quad t=t'\left(\frac{u_0^2}{\nu}\right)^{\frac{1}{3}}\quad Y=y\left(\frac{u_0}{\nu^2}\right)^{\frac{1}{3}}\\ &\theta=\frac{T-T_\infty}{T_\omega-T_\infty},C=\frac{C'-C'_\infty}{C'_\omega-C'_\infty},\\ &Gr=\frac{g\beta(T_\omega-T_\infty)}{u_0},Gc=\frac{g\beta^*(C'_\omega-C'_\infty)}{u_0},\\ &\Pr=\frac{\mu C_p}{k},\ Sc=\frac{\nu}{D},\ R=\frac{4\sigma^* T_d^3}{ka_R}\end{aligned}\right\} \tag{8}$$

Substituting the non-dimensional quantities of equation (8) into (1) to (4), leads to

$$\frac{\partial U}{\partial t}=Gr\theta+GcC+\frac{\partial^2 U}{\partial y^2} \tag{9}$$

$$\frac{\partial \theta}{\partial t}=\frac{1}{\xi}\frac{\partial^2\theta}{\partial y^2} \tag{10}$$

$$\frac{\partial C}{\partial t}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}-KC \tag{11}$$

where $\xi=3\Pr/(3+4R)$, Gr is the thermal Grashof number, Gc is the mass Grashof number, Sc is the Schmidt number, Pr is the Prandtl number and R is the radiation parameter

The initial and boundary conditions reduce:

$$\left.\begin{array}{lllll} & U=0,\ \theta=0,\ C=0, & \textit{for all} & y,t\le 0\\ t>0: & U=e^{at},\theta=1,C=1 & at & y=0\\ & U\to 0,\theta\to 0,\ C\to 0 & as & y\to\infty\end{array}\right\} \tag{12}$$

3. SOLUTION OF THE PROBLEM

To solve equations (6) – (8), subjected to the boundary conditions of (9), the solutions are obtained for concentration, temperature and velocity flow in terms of exponential and complementary error function using the Laplace- transform technique as follows;

$$C(y)=\frac{1}{2}\left[e^{2\eta\sqrt{ScKt}}erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)+e^{-2\eta\sqrt{ScKt}}erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)\right] \tag{13}$$

$$\theta(y,t)=\frac{1}{2}\left[e^{2\eta\sqrt{\xi at}}erfc\left(\eta\sqrt{\xi}+\sqrt{at}\right)+e^{-2\eta\sqrt{\xi at}}erfc\left(\eta\sqrt{\xi}-\sqrt{at}\right)\right] \tag{14}$$

$$\begin{aligned} U(y,t)=&\frac{e^{at}}{2}\left[e^{2\eta\sqrt{at}}erfc\left(\eta+\sqrt{at}\right)+e^{-2\eta\sqrt{at}}erfc\left(\eta-\sqrt{at}\right)\right]\\ &+\frac{Grt}{(\xi-1)}\left\{\left[\left(1+2\eta^2\right)erfc(\eta)-\frac{2\eta e^{-\eta^2}}{\sqrt{\pi}}\right]-\left[\left(1+2\eta^2\xi\right)erfc\left(\eta\sqrt{\xi}\right)-\frac{2\eta\sqrt{\xi}e^{-\eta^2\xi}}{\sqrt{\pi}}\right]\right\}\\ &+\frac{Gc}{2\psi(Sc-1)}\ \left\{\left[e^{\psi t}\left(e^{2\eta\sqrt{\psi t}}erfc\left(\eta+\sqrt{\psi t}\right)+e^{-2\eta\sqrt{\psi t}}erfc\left(\eta-\sqrt{\psi t}\right)\right)-2erfc(\eta)\right]\right.\end{aligned}$$

$$-e^{\Omega t}\left(e^{2\eta\sqrt{Sc\Omega t}}erfc\left(\eta\sqrt{Sc}+\sqrt{\Omega t}\right)+e^{-2\eta\sqrt{Sc\Omega t}}erfc\left(\eta\sqrt{Sc}-\sqrt{\Omega t}\right)\right)$$

$$-\left(e^{2\eta\sqrt{ScKt}}erfc\left(\eta\sqrt{Sc}+\sqrt{Kt}\right)+e^{-2\eta\sqrt{ScKt}}erfc\left(\eta\sqrt{Sc}-\sqrt{Kt}\right)\right)\Big\} \tag{15}$$

where $\eta=\frac{y}{\sqrt{2t}},\ \psi=\frac{kSc}{1-Sc}\ \ and\ \ \Omega=\psi+K$

4. RESULTS AND DISCUSSION

The solution of radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux has been obtained analytically. In order to point out the effects of physical parameters namely; Accelerating parameter a, thermal Grashof number Gr, mass Grashof number Gc, Prandtl number Pr, Schmidt number Sc, time t, radiation parameter R, and chemical reaction parameter K. on the flow patterns, the computation of the flow fields are carried out. The value of the Prandtl number Pr is chosen to represent air (Pr = 0.71). The value of Schmidt number is chosen to represent water vapour (Sc = 0.6). The values of velocity, temperature and concentration are obtained for the physical parameters as mention.

The velocity profiles has been studied and presented in figure 1 to 8. The effect of velocity for different values of Schmidt number (Sc = 0.16, 0.22, 0.3, 0.6) is presented in figure 1. The trend shows that the velocity increases with increasing Schmidt number. The effect of velocity for different values of time (t = 0.2, 0.4, 0.6, 0.8) is also presented in figure 2. It is then observed that the velocity increases with increasing values of time. The effect of velocity profiles again have been studied for different values of thermal Grashof number (Gr = 0.1, 0.3, 0.5, 0.7) and mass Grashof number (Gc = 0.2, 0.4, 0.6, 0.8) is studied and then presented in figure 3 and 4 respectively. The results are here observed that the increase in the values of velocity increases with increasing values of Gr and Gc respectively.

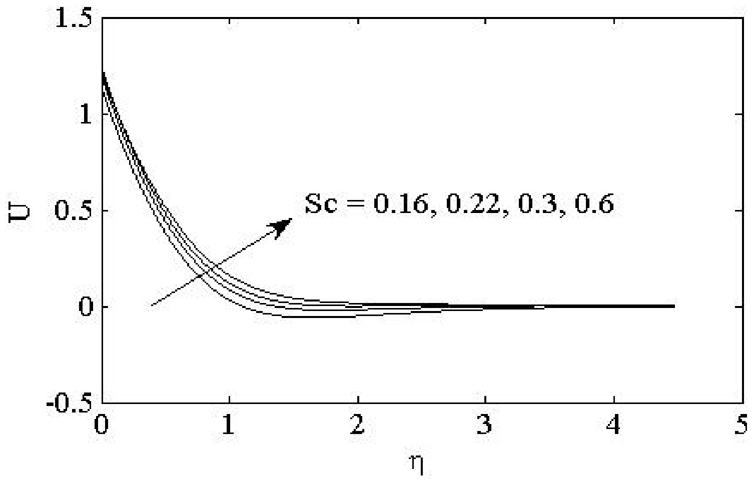

Figure 1. Velocity profiles for different values of Sc

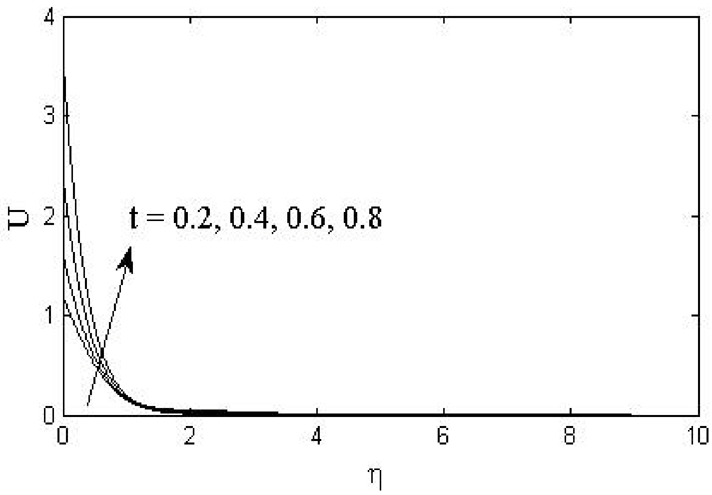

Figure 2. Velocity profiles for different values of t

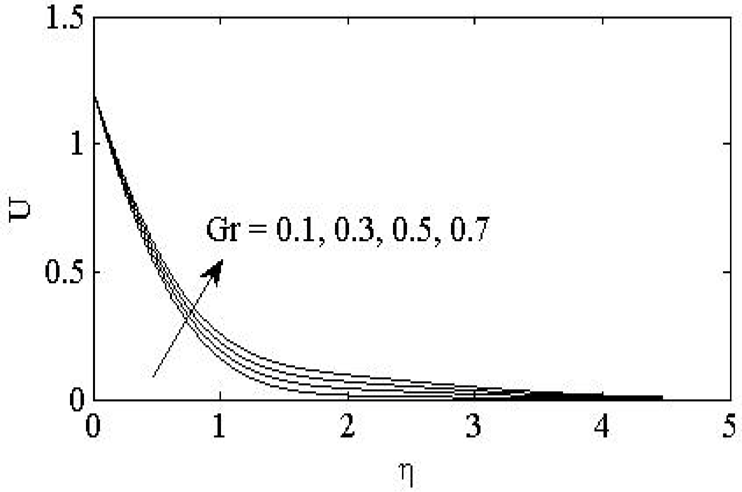

Figure 3. Velocity profiles for different values of Gr

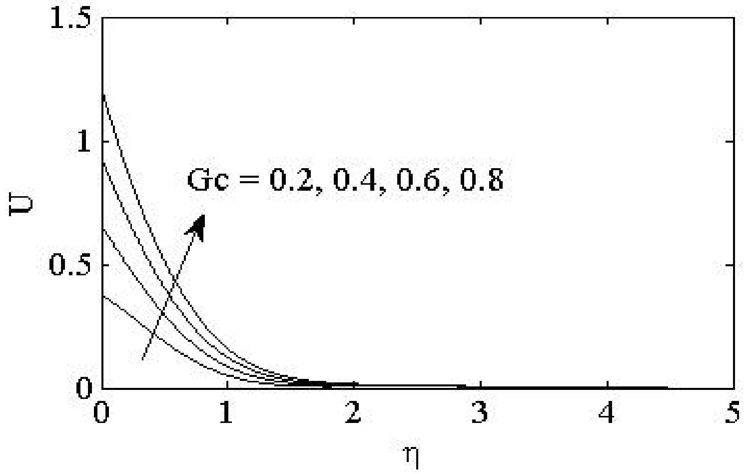

Figure 4. Velocity profiles for different values of Gc

The velocity profiles for different values of accelerating parameter (a = 2, 4, 6, 8) is seen in Figure 5. It is observed that velocity increases with increasing a. The velocity profiles for different values of radiation parameter (R = 2, 10, 20, 30) is presented in Figure 6. It is observed that velocity increases with increasing R

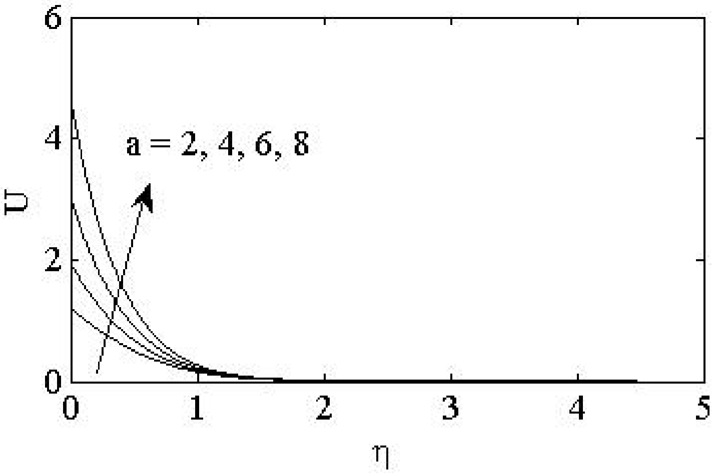

Figure 5. Velocity profiles for different values of a

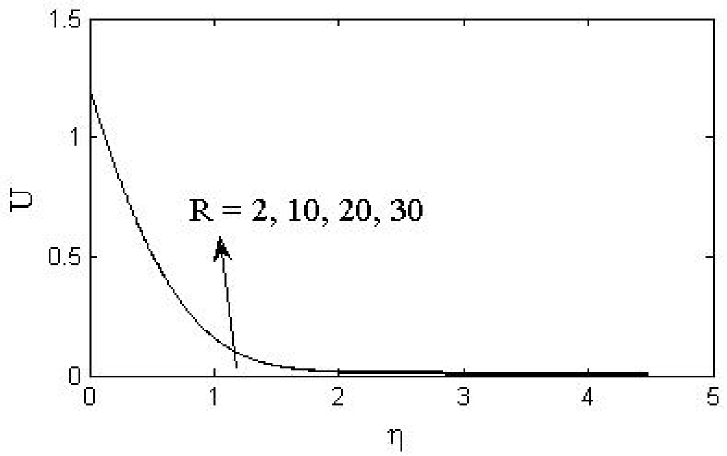

Figure 6. Velocity profiles for different values of R

The velocity profiles for different values of Prandtl number (Pr = 0.71, 1, 7, 10) is seen in Figure 7. It is observed that velocity increases with decreasing Pr. The velocity profiles for different values of chemical reaction parameter (K= 0.1, 2, 3, 4) is presented in Figure 8. It is observed that velocity increases with decreasing K.

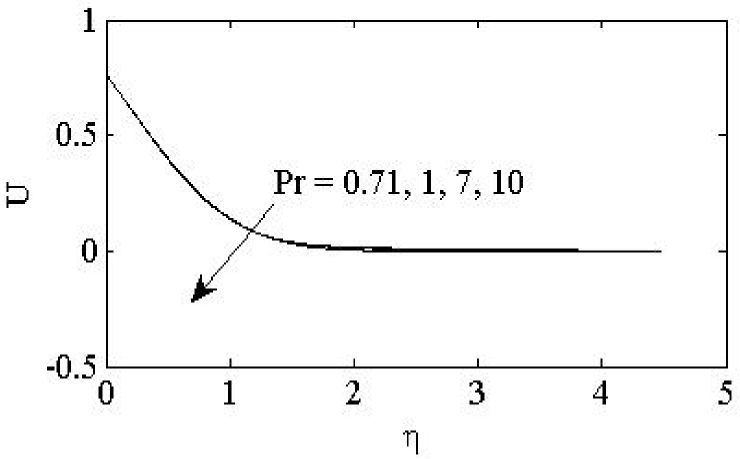

Figure 7. Velocity profiles for different values of Pr

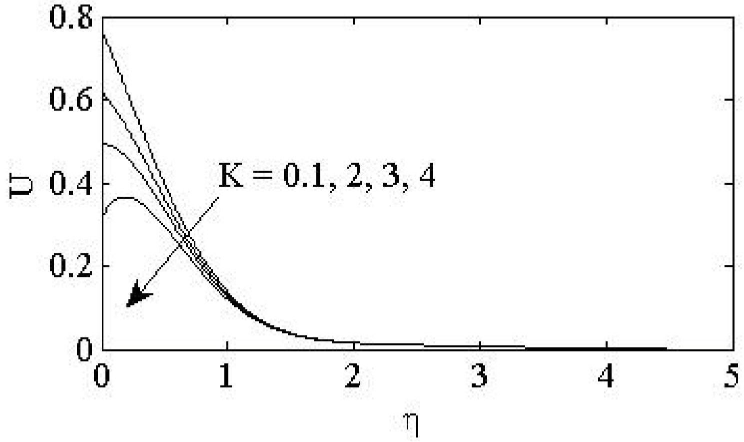

Figure 8. Velocity profiles for different values of K

The temperature profiles has been studied and presented in figure 9 to 11. The effect of temperature for different values of time (t = 0.2, 0.4, 0.6, 0.8) is presented in Figure 9 It shows that temperature decreases with increasing t. The temperature profiles for different values Prandtl number (Pr = 0.71, 1, 7, 10) is presented in figure 10 It is observed that increases in Prandtl number Pr decreases the temperature.

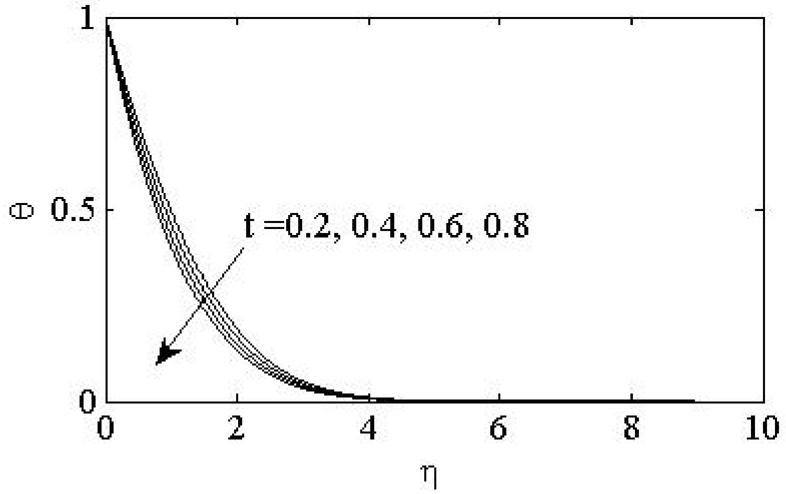

Figure 9. Temperature profiles for different values of t

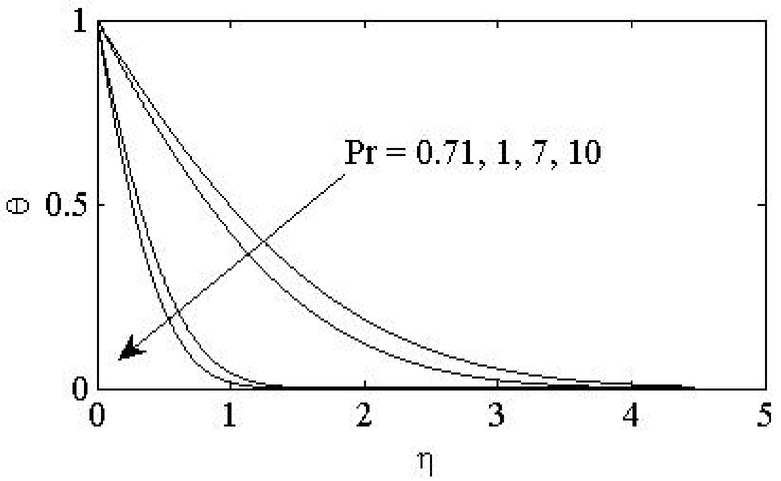

Figure 10. Temperature profiles for different values of Pr

The temperature profiles for different values radiation parameter (R = 2, 10, 20, 30) is presented figure 11 It is observed that temperature increases with increasing R

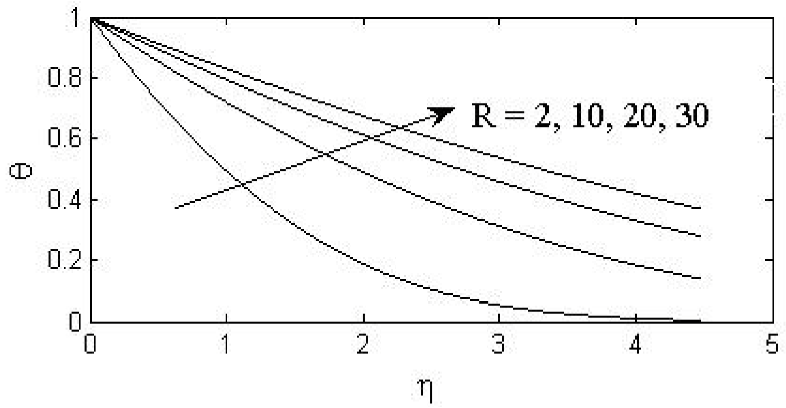

Figure 11. Temperature profiles for different values of R

The concentration profiles has been studied and presented in figure 12 to 13.

The concentration profiles for different values of Schmidt number (Sc = 0.16, 0.22, 0.3, 0.6) is presented in Figure 12. It is observed that the concentration decrease with increasing Sc. The effect of concentration for different values of chemical reaction parameter (K= 0.1, 2, 3, 4) is presented in Figure 13. It is observed that the concentration increases with a decrease in the values of K.

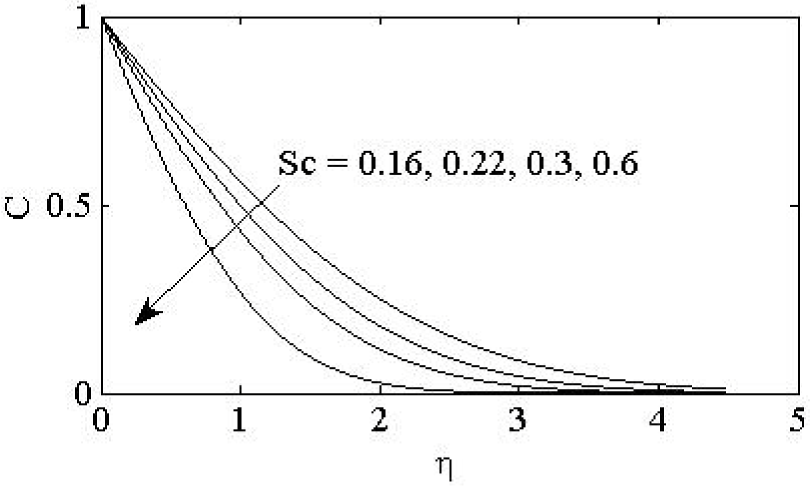

Figure 12. Concentration profiles for different values of Sc

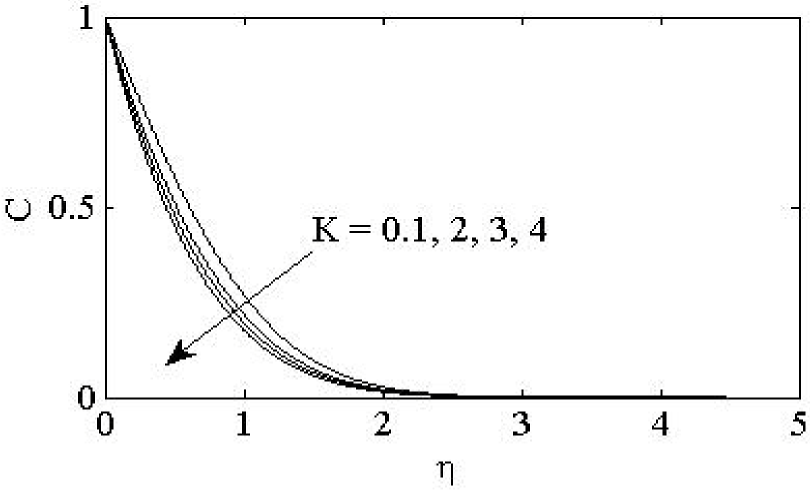

Figure 13. Concentration profiles for different values of K

5. CONCLUSION

Radiation and chemical reaction effects on exponentially accelerated isothermal vertical plate cum mass flux has been studied. The dimensional governing equations are solved by Laplace transform technique. The effect of different parameters like accelerating parameter, radiation parameter, chemical reaction parameter, Schmidt number, Prandtl number, mass Grashof number, thermal Grashof number, and time are presented graphically. It is observed that velocity profile increases with increasing parameter namely R, t, Gc, Gr, Sc and a while Pr and K decreases with increasing velocity. It also observed that temperature rise with increasing R while t, Pr decreases with increasing temperature. The concentration profiles increases with increasing t while Sc and K increases with decrease in concentration.

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REFERENCES

1. K.K. Asogwa, I.J. Uwanta, A.A. Aliero, Flow past an exponentially accelerated infinite vertical plate and temperature with variable mass diffusion, International Journal of Computer Applications 45 No 2 (2012), 1-7 (ISSN 0975-8887).
2. Basanth Kumar Jha, Ravindra Prasad, Surendra Raj, Mass transfer effects on the flow past an exponentially accelerated vertical plate with constant heat flux, Astrophysics and Space Science 181 (1991) 125-134.
3. P. Chandrakala, Thermal Radiation effects on moving infinite vertical plate with uniform heat flux, International Journal of dynamics fluids 1 (2010) 49-55.
4. P. Chandrakala and P. Bhaskar, Effects of heat transfer on flow past an exponentially accelerated vertical plate with uniform heat flux, International Journal of dynamics fluids 7(1) (2011) 9-16.

5. A.J. Chamkha, Effects of heat absorption and thermal radiation on heat transfer in a fluid particle flow past a surface in the presence of a gravity field, International Journal thermal sciences 39 (2000) 605-615.
6. U.N. Das, R.K. Deka, and V.M. Soundalgekar, Radiation effects on flow past an impulsively started vertical infinite plate, Journal of Theoretical Mechanics 1 (1996) 111-115.
7. M.K. Mazumdar and R.K. Deka, MHD flow past an impulsively started infinite vertical plate in presence of thermal radiation, Romanian Journal of Physics 52(5-6) (2007) 529-535.
8. R.Muthucumaraswamy, K.E. Sathappan and R. Nataragan, Diffusion and Heat transfer effects on exponentially accelerated vertical plate with variable temperature, Theoretical Applied Mechanics. 14(1) (2010) 73-77.
9. R.Muthucumaraswamy and V.Valliamal, First order chemical reaction on exponentially accelerated isothermal vertical plate with mass diffusion, International Journal of Engineering TUME VII fascicule I (2009) (ISSN 1584-2665).
10. V. Rajesh and Vijaya Kumar, Radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature, ARPN Journal of Engineering and Applied Sciences 4(6) (2009) ISSN 1819-6608.
11. Sahin Ahmed and Dimbeswar Kalika, Laplace technique on Magnetohydrodynamic radiating and chemically reacting fluid over an infinite vertical surface, International Journal of Science and Technology 1 No 5 (2012) 224-233.
12. P.R Sharma, Navin Kumar and Sharma Pooja, Influence of chemical reaction and radiation on unsteady MHD free convection flow and mass transfer through viscous incompressible fluid past a heated vertical plate immersed in porous medium in presence of heat source, Applied Mathematical Sciences 5 (2011) 2249-2260.

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