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CHEMICAL REACTION ON UNSTEADY FLOW PAST AN ACCELERATED INFINITE VERTICAL PLATE WITH VARIABLE TEMPERATURE AND UNIFORM MASS DIFFUSION

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ABSTRACT
In this paper we made an attempt to study the solution of unsteady flow past an uniformly accelerated infinite vertical plate has been presented in the presence of variable temperature radiation absorption and uniform mass diffusion. The plate temperature is raised linearly woth time and species concentration level near the plate is made to rise C_w'. The dimensionless governing equations are solved using Laplace transform technique. The velocity profiles and concentration are studied for different physical parameters like Thermal Grashof number, mass Grashof number, Schmidt number and time. It is observed that the velocity increases with increase of G and G* and Schmidt number.

Key Words:
Accelerated, Vertical plate, heat transfer, mass diffusion.

1. INTRODUCTION
Heat and mass transfer plays an important role in manufacturing industries for the design of fins, steel rolling, nuclear power plants, gas turbines and various propulsion device for aircraft , missiles, spacecraft design, solar energy collectors, design of chemical processing equipment, satellites and space vehicles are examples of such engineering applications.
Gupta et al. (Gupta et al. 1979) have studied free convection on flow past an linearly accelerated vertical plate in the presence of viscous dissipative heat using perturbation method. Kafousias and Raptis extended the above problem to include mass transfer effects subjected to variable suction or injection. Free convection effects on flow past an accelerated vertical plate with variable suction and uniform heat flux in the presence of magnetic field was studied by Raptis et al. (Raptis et al. 1981). Mass transfer effects on flow pas an uniformly accelerated vertical plate was studied by Soundalgekar (Soundalgekar 1982). Again, mass transfer effects on flow past an accelerated vertical plate with uniform heat flux was analyzed by Singh and Singh (Singh and Singh 1983). Basant Kumar Jha and Ravindra Prasad (Basant Kumar Jha and Ravindra Prasad 1990) analyzed mass transfer effects on the flow past an accelerated infinite vertical plate with heat sources. Hence, it is proposed to study the effects of on flow past an uniformly accelerated infinite vertical plate in the presence of variable temperature and uniform mass diffusion. The dimensionless governing equations are solved using perturbation technique. The solutions are in terms of exponential and complementary error function.

2. MATHEMATICAL ANALYSIS
The unsteady flow of a viscous incompressible fluid past an uniformly accelerated vertical infinite plate with variable temperature first order chemical reaction and uniform mass diffusion has been considered. It is assumed that the effect of viscous dissipation is negligible in the energy equation and there is a first order chemical reaction between the diffusing species and the plate. The x- axis is taken along the plate in the vertically upward direction and y-axis us taken normal to the plate. At time $t' \leq 0$, the plate and fluid are at the same temperature T_∞ and the concentration C'_∞. At time $t' > 0$, the plate is accelerated with a velocity $u = u_0 t'$ in its own plane and the temperature from the plate is raised linearly with respect time and the concentration level near the plate is also raised to C_ω'. Then under usual Boussinesq's approximation the unsteady flow is governed by the following equations:

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

$$\rho C_p\frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y^2} \quad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y^2} - K_1 C' \quad (3)$$

With the following initial and boundary conditions:

$$\begin{array}{lllll} & u = 0, & T = T_\infty, & C' = C'_\infty & for\ all\ y,\ t' \le 0 \\ t' > 0: & u = u_0 t', & T = T_\infty + (T_\omega - T_\infty)At', & C' = C'_\infty + (C'_\omega - C'_\infty)At' & at\ \ y = 0 \\ & u \to 0 & T \to T_\infty, & C' \to C'_\infty & as\ \ y \to \infty \end{array} \quad (4)$$

Where $A = \frac{u_0^2}{\vartheta}$

On introducing the following non dimensional quantities:

$$U = \frac{u}{(\vartheta u_0)^{1/3}},\ t = t'(\frac{u_0^2}{\vartheta})^{\frac{1}{3}},\ Y = y(\frac{u_0}{\vartheta^2})^{1/3},\ \theta = \frac{T - T_\infty}{T_\omega - T_\infty},\ Gr = \frac{g\beta(T_\omega - T_\infty)}{u_0}$$

$$C = \frac{C' - C'_\omega}{C'_\omega - C'_\infty},\ Gc = \frac{g\beta^*(C'_\omega - C'_\infty)}{u_0},\ Pr = \frac{\mu C_p}{k},\ Sc = \frac{\vartheta}{D},\ K = K_1(\frac{\vartheta}{u_0^2})^{1/3})$$

In equations (1) to (4), leads to

$$\frac{\partial U}{\partial t} = Gr\theta + Gc\,C + \frac{\partial^2 U}{\partial Y^2} \quad (6)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial Y^2} \quad (7)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial Y^2} - KC \quad (8)$$

The initial and boundary conditions in non-dimensional quantities are

$$\begin{array}{lllll} & U = 0, & \theta = 0, & C = 0 & for\ all\ Y,\ t \le 0 \\ t > 0: & U = t, & \theta = t, & C = t & at\ \ Y = 0 \\ & U \to 0 & \theta \to 0, & C \to 0 & as\ \ Y \to \infty \end{array} \quad (9)$$

3. SOLUTION PROCEDURE

The dimensionless governing equations (6) to (8) subject to the initial and boundary conditions (9), are solved by usual Laplace transform technique and the solutions are derived as

$$\theta = t[(1 + 2\eta^2\,\mathrm{Pr})\mathrm{erfc}(\eta\sqrt{\mathrm{Pr}}) - 2\eta\sqrt{\frac{\mathrm{Pr}}{\pi}}\exp(-\eta^2)]$$

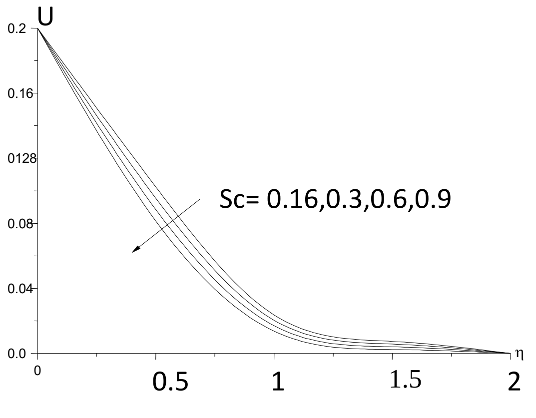
$$C = \frac{t}{2}[\exp(2\eta\sqrt{KtSc})\,erfc\left(\eta\sqrt{Sc} + \sqrt{Kt}) + \exp(-2\eta\sqrt{Ktsc}\,)\,erfc(\eta\sqrt{Sc} - \sqrt{kt}\right) - \frac{\eta\sqrt{Sct}}{2\sqrt{K}}[\exp(-2\eta\sqrt{KtSc})erfc(\eta\sqrt{Sc} - \sqrt{Kt}) - \exp(2\eta\sqrt{KtSc}\,)\,erfc(\eta\sqrt{Sc} + \sqrt{Kt})]$$

$$U = (1+2cb)t\left[(1+\eta^2)erfc(\eta) - \frac{2\eta}{\sqrt{\pi}}\exp(-\eta^2)\right] + 2\,erfc(\eta) - \frac{a}{6}t^2[(3+12\eta^2 + 4\eta^4\Big)\,erfc(\eta) - \frac{\eta}{\sqrt{\pi}}(10+4\eta^2)\exp(-\eta^2) - (3+12\eta^2 Pr - 4\eta^4 Pr^2)erfc(\eta\sqrt{\text{Pr}}) + \frac{\eta\sqrt{Pr}}{\sqrt{\pi}}(10 + 4\eta^2 Pr)\exp(-\eta^2 Pr)] - bexp(ct)[\exp\,(2\eta\sqrt{ct})erfc(\eta+\sqrt{ct}) + \exp(-2\eta\sqrt{ct})\,erfc(\eta - \sqrt{ct}) - b[\exp\,(2\eta\,\sqrt{KtSc})erfc(\eta\sqrt{Sc}+\sqrt{kt}) + \exp(-2\eta\sqrt{KtSc})\,erfc(\eta\sqrt{Sc}-\sqrt{kt})] + bexp(ct)[\exp\left(-2\eta\sqrt{Sc(K+c)t}\right)erfc\left(\eta\sqrt{Sc+}\sqrt{(K+c)t}\right) + \exp\left(2\eta\sqrt{Sc(K+c)t}\right)erfc(\eta\sqrt{Sc+}\sqrt{(K+c)t})] - bct[\exp\,(2\eta\sqrt{KtSc}\,erfc(\eta\sqrt{Sc} + \sqrt{kt}) + \exp(-2\eta\sqrt{KtSc})\,erfc(\eta\sqrt{Sc}-\sqrt{kt}] + bc\eta\sqrt{\frac{tSc}{K}}[\exp(-2\eta\sqrt{KtSc})\,erfc(\eta\sqrt{Sc}-\sqrt{kt})] - \exp\,(2\eta\sqrt{KtSc})erfc(\eta\sqrt{Sc}+\sqrt{kt})]$$

Where $= \frac{Gr}{(1-Pr)}$, $b = \frac{Gc}{2c^2(1-Sc)}$, $c = \frac{K\,Sc}{1-Sc}$ and $\eta = \frac{Y}{2\sqrt{t}}$

4. RESULTS AND DISCUSSION

For the physical understanding of the problem numerical computations are carried out for different physical parameters Gr, Gc, Sc, Pr , K and t upon the nature of the flow and transport. The value of the Schmidt number Sc is taken to be 0.6 which corresponds to water vapour. Also, the values of Prandtl number Pr are chosen such that they represent air (Pr=0.71). The numerical values of the velocity and concentration are computed for different physical parameters like Prandtl number, thermal Grashof number, mass Grashof number, Schmidt number, Chemical reaction parameter and time.
The effect of velocity for different values of the Schmidt number (Sc=0.16, 0.3,0.6, 2.01), Gr = Gc=5 and time t=0.4 are shown in figure 1. The trend shows that the velocity increases with decreasing Sc. It is observed that the relative variation of te velocity with the magnitude of the Schmidt number.



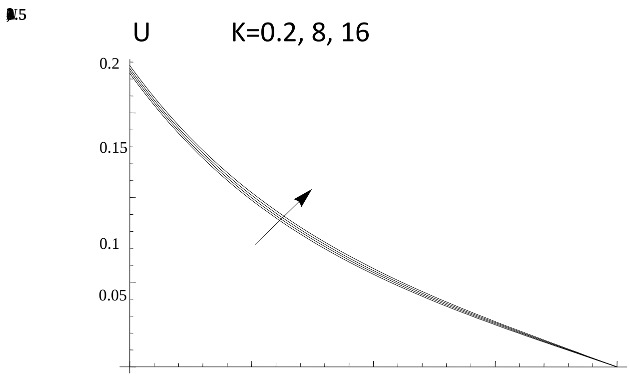
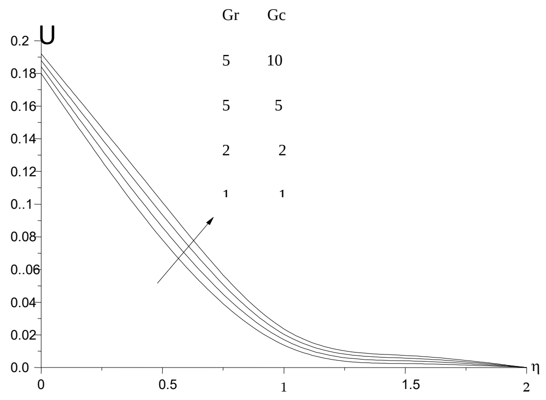


Fig.1 Velocity Profile for different values of Sc   Fig.1 Velocity Profile for different values of K

Figure 2 illustrates the effect of velocity for different values of the chemical reaction parameter (K= 0.2, 1,15), Gr=5, Gc=5 , Pr=0.71 and t=0.4. This shows that the increase in the chemical reaction parameter leads to a fall in the velocity.
Figure 3 explains that the effect of velocity fields for different thermal Grashof number (Gr= 1,2,5) mass Grashof number (Gc=1,2,5,10), K=0.2, Pr=0.71 and t= 0.2. It is observed tgat the velocity increases with increasing values of the thermal Grashof number or mass Grashof number.



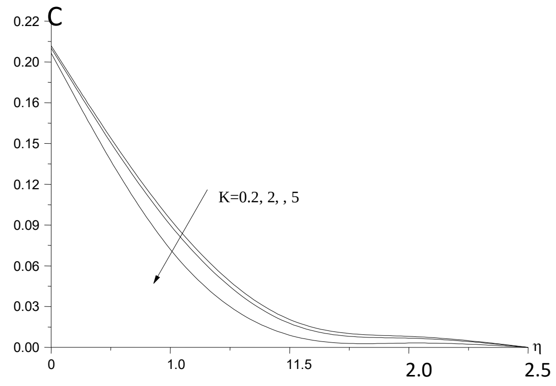


Fig.3 Velocity Profile for different Gr,Gc Fig 4. Concentration Profile for different values of K

Figure 4 represents the effect of concentration profiles for different values of chemical reaction parameter (K=0.2, 2, 5) and time t=0.4. The effect of chemical reaction parameter is dominant in concentration field. The profiles have the common feature that the concentration decreases in a monotone fashion from the surface to a zero value far away in the free stream. It is also observed that the wall concentration increases with decreasing values of the chemical reaction parameter. It is observed that the concentration increases with decreasing chemical reaction parameter.

5. **CONCLUDING REMARKS**

An exact solution of unsteady flow past an uniformly accelerated infinite vertical plate in the presence of variable temperature and uniform mass diffusion in the presence of uniform chemical reaction have been studied. The dimensionless governing equations are solved by the usual Laplace transform technique. The effect of different parameters like thermal Grashof number, mass Grashof number, Schmidt number, chemical reaction parameter, and t are studied graphically. It is observed that the velocity increases with increasing values of Gr, Gc, and t. But the trend is just reversed with respect to the chemical reaction parameter and Schmidt number.

6. NOMENCLATURE

A	constant
C’	species concentration in the fluid
C	dimensionless concentration
C_p	specific heat at constant pressure
D	mass diffusion coefficient
G_c	mass diffusion Grashof number
G_r	thermal Grashof number
g	accelerated due to gravity
k	thermal conductivity
Pr	Prandtl number
Sc	Schmidt number
T	Temperature of the fluid near the plate K
t	dimensionless time
u	velocity of the fluid
u_0	velocity of the plate
U	dimensionless velocity
T_∞	Concentration of the plate.
T_w	Concentration of the fluid far away from the plate
x	spatial coordinate along the plate

y’ coordinate axis normal to the plate.
y dimensionless coordinate axis normal to the plate.
β volumetric coefficient of thermal expansion
β^8 volumetric coefficient of thermal expansion with concentration
μ coefficient of viscosity
ϑ kinematic viscosity
ρ density of the fluid
τ dimensionless skin friction
θ dimensionless temperature
η similarity parameter
erfc complementary error function.

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