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NUMERICAL STUDY OF PARABOLIC STARTED VERTICAL PLATE THE MAGNETIC FIELD PRESENCE WITH VARIABLE TEMPERATURE AND MASS DIFFUSION

V NAGARAJU[1], M VENKATA RAMANA REDDY[2]
[1] Assistant Professor, Malla Reddy Engineering College (Autonomous),
nagrajuvuppala@gmail.com
[2] Assistant Professor, Malla Reddy Engineering College (Autonomous),
vramanareddy.m85@gmail.com

Abstract
The aim of this paper is to investigate the numerical study of heat and mass transfer on an unsteady MHD flow past a parabolic starting motion of the infinite vertical plate in the presence of chemical reaction parameter,mass diffusion and variable temperature. Mathematical model of this mechanism have been constructed in the form of partial differential equations andthe coupled partial differential equations are solved by efficient finite element method. The effect of velocity, temperature and concentration profile are examined for different physical parameters and is presented graphically.

Keywords:- MHD, Viscous dissipation,Finite element method, Mass diffusion,Heat and Mass transfer, etc.

I. INTRODUCTION

The phenomena of hydroagnetic flow with heat and mass transfer in an electrically conducting fluid pastavertical plate embedded in a porous medium has attracted the interest of in many engineering problems such as plasma studies,solar physics,magneto hydrodynamics generator, in the study of geological formations, thermal reservoirs and underground nuclear in metrology, and in the movement of earth's core. It plays an important role in petroleum industries, geophysics and in astrophysics. The effect viscous dissipation on unsteady free convection flow past an infinite, vertical porous plate with constant suction studied by Soundalgekar [1].Radiation effects on MHD free convection flow over a vertical plate with heat and mass flux was studied by Sivaiah et al. [2].HemanthPoonia and Chaudhary [3] analyzed the MHD free convection and mass transfer flow over an infinite vertical porous plate with viscous dissipation.Kishore et.al[4] studied the effects of thermal radiation and viscous dissipation on MHD heat and mass diffusion flow past an oscillating vertical plate embedded in a porous medium with variable surface conditions . Hall effects on an unsteady MHD free convective flow past an impulsively started porous plate with viscous and Joule's dissipation have been studied by Anjali Devi et al. [5].Study of chemical reaction on effects on an unsteady MHD heat and

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mass transfer flow past a semi-infinite vertical porous moving plate in the presence of viscous dissipation was studied by Rajashekar and Shankar Goud [6]. Chandra Shekar et. al [7] studied the effect on unsteady MHD convective heat and mass transfer past a vertical plate with chemical reaction and viscous dissipation.Vijay Kumar and Vijay Kumar Varma [8] studied thermal radiation and mass transfer effects on MHD flow past an impulsively started exponentially accelerated vertical plate with variable temperature and mass diffusion.

D.Manohar, A.S. Nagarajan[9] have analysed the mass transfer effects on free convective flow of an incompressible viscous dissipative fluid.Effects of thermal radiation and MHD on the unsteady free convection and mass transform flow past an exponentially accelerated vertical plate with variable temperature a finite element solution was studied by Srilatha and Raja Rajashekar[10].

Inspired by the above mentioned investigation and applications, an effort is made to think about an unsteady flow of a viscous incompressible fluid past an infinite vertical plate with variable temperature and variable diffusion under the influence of magnetic field and viscous dissipation.Numerical results have been obtained for velocity, temperature and concentration by Galarken finite element method.

II. FORMULATION OF THE PROBLEM

Consider the unsteady flow of a viscous incompressible fluid past an infinite vertical plate with variable temperature, mass diffusion and chemical reaction parametein the presence of viscous dissipation. The x'-axis is taken along the plate in the vertically upward direction and the y'-axis is taken normal to the plate. At time $t' \leq 0$, the plate and fluid are at the same temperature T'_∞ and concentration C'_∞.At $t' > 0$, the plate is started with a velocity $u = u_0 t'^2$ in its own plane against gravitational field. The plate temperature is raised uniformly and the mass is diffused from the plate to the fluid is made to increase linearly with time t' also subjected to a uniform magnetic field of strength B_0 is assumed to be applied normal to the plate. Since the plate is infinite in length, all the terms in the governing equations will be independent of $x'$and there is no flow along y'- direction. Then under usual Boussinesq's approximation for unsteady parabolic starting motion is governed by the following equations.

$$
\left.
\begin{array}{ll}
t' \geq 0: u' = 0, \quad T' \to T'_\infty, \quad C' \to C'_\infty & \text{for all } y' \\
t' > 0: u' = u_0 t'^2, T' = T'_\infty + (T'_w - T'_\infty)At', & \\
C' = C'_\infty + (C'_w - C'_\infty)At' & \text{at } y' = 0. \\
u' \to 0, T' \to T'_\infty, C' \to C'_\infty, & \text{as } y' \to \infty
\end{array}
\right\}
$$
--- (1)

And we introduce the non-dimensional variables, as follows

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$$u=u'\left(\frac{u_0}{v^2}\right)^{\frac{1}{3}},\ A=\left(\frac{u_0^2}{v}\right)^{\frac{1}{3}},\ y=y'\left(\frac{u_0}{v^2}\right)^{\frac{1}{3}},\ \Pr=\frac{v\rho C_p}{k},\ M=\frac{\sigma B_0^2}{\rho}\left(\frac{v}{u_0^2}\right)^{\frac{1}{3}},$$
$$t=t'\left(\frac{u_0}{v^2}\right)^{\frac{1}{3}},\ Kr=Kr'\left(\frac{v}{u_0^2}\right)^{\frac{1}{3}},\ \theta=\frac{T'-T'_\infty}{T'_w-T'_\infty},\ C=\frac{C'-C'_\infty}{C'_w-C'_\infty},\ Sc=\frac{v}{D},$$
$$Gr=\frac{g\beta(T'_w-T'_\infty)}{(vu_0)^{\frac{1}{3}}},\ Gc=\frac{g\beta^*(C'_w-C'_\infty)}{(vu_0)^{\frac{1}{3}}},\ Ec=\left(\frac{u_0}{v}\right)^{\frac{1}{3}}\Big/C_p(T'_w-T'_\infty)$$

--- (2)

In the view of equation (2) to (4) the governing equations reduces to

$$\frac{\partial u}{\partial t}=\frac{\partial^2 u}{\partial y^2}+Gr\theta+GmC-Mu$$

--- (3)

$$\frac{\partial \theta}{\partial t}=\frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2}+Ec\left(\frac{\partial u}{\partial y}\right)^2$$

--- (4)

$$\frac{\partial C}{\partial t}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}-KrC$$

--- (5)

The boundary and initial conditions are

$$\left.\begin{array}{ll} t\le 0: u=0,\theta=0,C=0 & for\ all\ \ y \\ t>0: u=t^2,\theta=t,C=t & at\ \ y=0 \\ \quad u\to 0,\theta\to 0,C\to 0, & as\ \ y\to\infty \end{array}\right\}$$

--- (6)

III. SOLUTION OF THE PROBLEM

In this section the governing non-linear coupled non-dimensional partial differential equations (6)-(8) and initial and boundary conditions(9) have been solved by using Galerkin finite element method. After Applying the Galerkin finite element method to the equations (6)-(8) and imposing initial and boundary conditions the following equation are obtained.

$$A_1u_{i-1}^{n+1}+A_2u_i^{n+1}+A_3u_{i+1}^{n+1}=A_4u_{i-1}^{n}+A_5u_i^{n}+A_6u_{i+1}^{n}+R^*$$

--- (7)

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

--- (8)

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

-- (9)

Where

$A_1=A_3=2-6r+Mk \qquad A_4=A_6=2+6r-Mk$

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

$R^*=12R_1k=12k(Gr\theta_i^n+GmC_i^n),$

$B_1=B_3=\Pr-3r,\ B_4=B_6=\Pr-3r,\ B_2=4\Pr+6r,\quad B_5=4\Pr-6r$

$C_1=C_3=2*Sc+Kr.Sc.k-6r,\ C_4=C_6=2*Sc-Kr.Sc.k+6r;$

$C_2=8*Sc+4*Kr.Sc.k+12r; C_5=8*Sc+4*Kr.Sc.k+12r,$

$R^{**}=6R_2k=6k\Pr Ec\left(\frac{\partial u_i}{\partial y_i}\right)^2, r=\frac{k}{h^2}$

In order to prove the convergence and stability of finite element method, the solutions of the above systems of equations (10)-(11) are obtained by using the Thomas algorithm for velocity, temperature and concentration. With the smaller values of h and k, no significance change was found in the velocity, temperature and concentration and the numerical results are obtained by run the MATLAB program. No significant change was found in the velocity, Temperature and concentration. Hence the finite element method is stable and convergent.

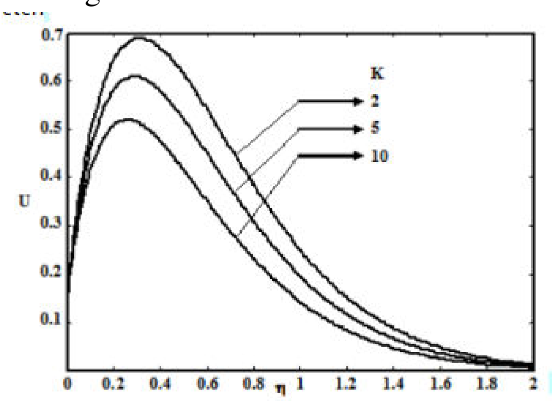

Fig.1: Velocity profile for different values of K

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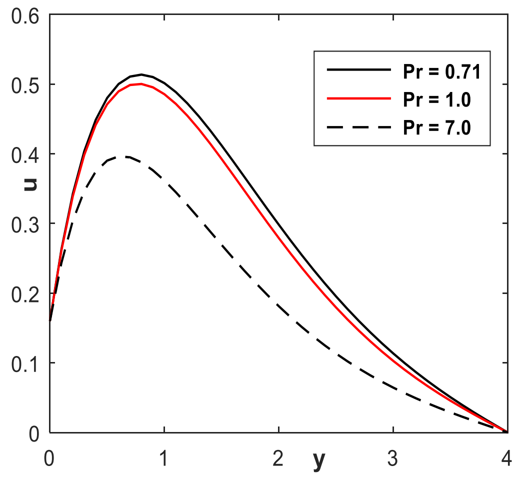

Fig.2: Velocity profile for different values of Pr

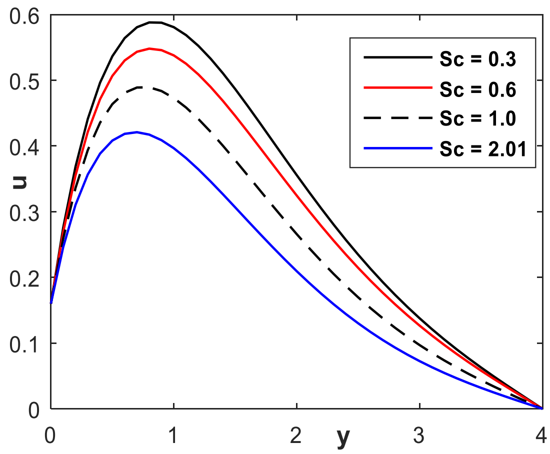

Fig.3: Velocity profile for different values of Sc

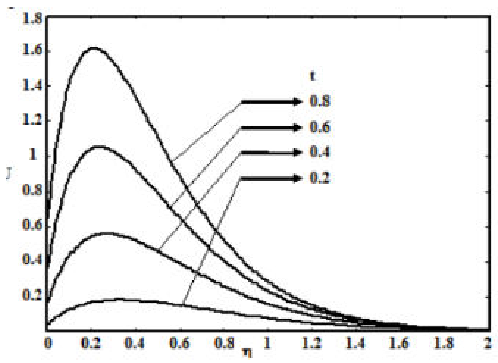

Fig.4: Velocity profile for different values of *t*

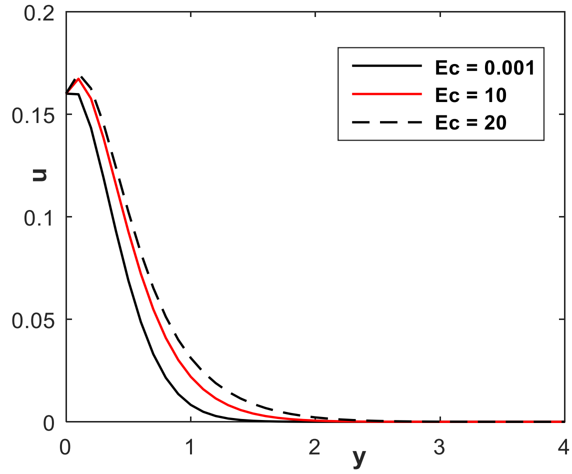

Fig.5: Velocity profile for different values of *Ec*

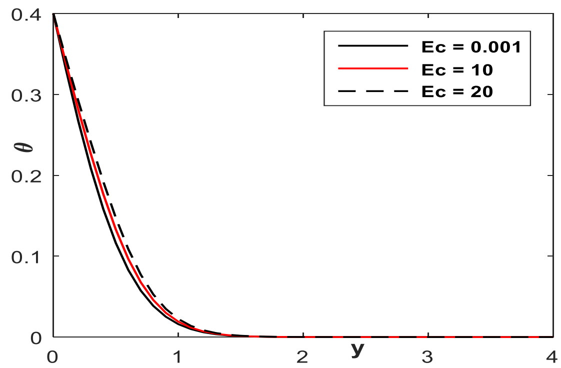

Fig.6: Temperature profile for different values of*Ec*

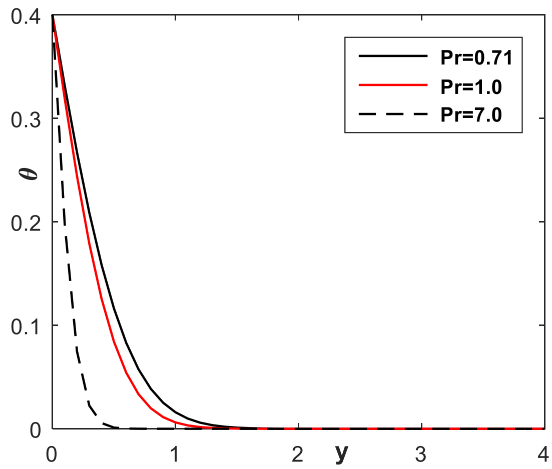

Fig.7: Temperature profile for different values of*Pr*

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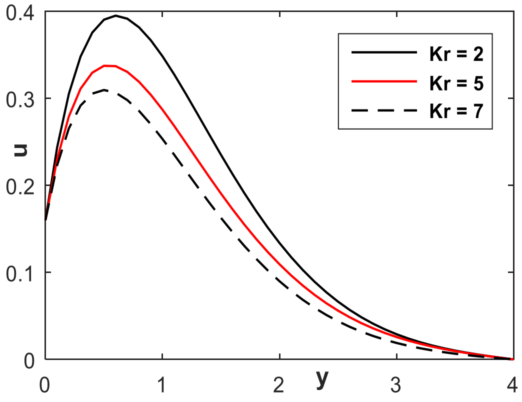

Fig 8: Velocity profile for different values of*Kr*

IV. RESULTS AND DISCUSSIONS

In order to analyze the effects of non-dimensional parameters*Pr = 0.71(air), Kr =2, M = 1,Gc = 5, Gr = 2,Sc=0.6(Water-vapour),Ec = 0.001* and *t = 0.4* by taking the various values computed the numerical solutions on the velocity, temperature and concentration profiles and explained with the help of figures.

Fig.1 shows the effect of the magnetic parameter (M) on the velocity profile. As shown, the velocity decreases as an increase of M.The effect of transverse magnetic field on an eclectrically fluid gives rise to a resistive type force called Lorentz force, it opposes the fluid flow.

Fig.2 illustratesthat an increase in Prandtl number (Pr)decreases the velocity distribution.Prandtlnumber is the ratio between the momentum diffusivity to thermal diffusivity will influence the fluid flow as long as the velocity field and the temperature field are coupled.

Figs.3 and 4 shows theeffect of the Schmidt number (*Sc*)on the velocity and concentration profiles, respectively.It is observed that velocity and concentration increases with decreasing the Schmidt number.The Schmidt number expresses the ratio of fluid boundary layer to mass transfer boundary layer thickness.The influence of timeon the velocity is shown in Fig.5. As the graph signifiesthe velocity increases with the increase of time *t*.

The influence of various values of Eckert number on velocity and temperature is plotted in Figs. 6 and 7 illustrate. Eckert number represents the relation between kinetic energy in the flow and the enthalpy. It is evident thatan increase viscous dissipative heat causes increasesin the velocity and temperature of the fluid.

Fig. 8 represents the effect of temperature profiles for different Prandtl number. It is discover that the temperature decrease with an increase of Prandtl number.

Fig.9 and 10 depict the velocity and concentration profiles for different values of chemical reaction parameter. It is evident from Fig.9 and 10 that, with an increase of Kr velocity decreases and concentration increases. The effect of thermal Grashof number $(Gr = 2, 5)$ and mass Grashof number $(Gc = 5, 10)$on the velocity is shown in fig.11. The velocity field increases with the thermal Grashof number or mass Grashof number increases. If the temperature of the plate is assumed to be uniform then the effect of thermal Grashof number is very dominant.

V. CONCLUSIONS

An exact solution of the MHD flow past a parabolic started an infinite vertical plate with variable temperature and mass diffusion, in the presence of chemical reaction of first order has been studied. The dimensionless governing equations are solved by theusual Laplace transform technique. The effect of the temperature, the concentration and the velocity fields for different physical parameters like chemical reaction parameter, magnetic field parameter, thermal Grashof number, mass Grashof number and t are studied graphically. It is observed that the velocity increases with increasing thermal Grashof number or mass Grashof number and time t in the presence of magnetic field parameter. But the trend is just reversed with respect to the chemical reaction parameter or magnetic field parameter. The plate concentration increases with decreasing values of the chemical reaction parameter.

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