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Chemical reaction effect on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection

S. Shivaiah* **J. Anand Rao†**

Abstract

The objective of this paper is to analyze the effect of chemical reaction on unsteady magneto hydrodynamic free convective fluid flow past a vertical porous plate in the presence of suction or injection. The governing equations of the flow field are solved numerically by a finite element method. The effects of the various parameters on the velocity, temperature and concentration profiles are presented graphically and values of skin-friction coefficient, Nusselt number and Sherwood number for various values of physical parameters are presented through tables.

Keywords: Chemical reaction, MHD, Vertical plate, Suction, Finite element method.

1 Introduction

All industrial chemical processes are designed to transform cheaper raw materials to high value products (usually via chemical reaction). A 'reactor', in which such chemical transformations take place, has to carry out several functions like bringing reactants into intimate contact, providing an appropriate environment (temperature and concentration fields) for adequate time and allowing for removal of products. Fluid dynamics plays a pivotal role in establishing relationship between reactor hardware and reactor performance.

*Department of Mathematics, GITAM University, Hyderabad, A.P, India, email: sreddy7@yahoo.co.in

†Department of Mathematics, Osmania University, Hyderabad, A.P, India

For a specific chemistry catalyst, the reactor performance is a complex function of the underlying transport processes. The first step in any reaction engineering analysis is formulating a mathematical framework to describe the rate (and mechanisms) by which one chemical species is converted into another in the absence of any transport limitations (chemical kinetics). Once the intrinsic kinetics is available, the production rate and composition of the products can be related, in principle, to reactor volume, reactor configuration and mode of operation by solving mass, momentum and energy balances over the reactor. This is the central task of a reaction and reactor engineering activity. Analysis of the transport processes and their interaction with chemical reactions can be quite difficult and is intimately connected to the underlying fluid dynamics. Such a combined analysis of chemical and physical processes constitutes the core of chemical reaction engineering. Recent advances in understanding the physics of flows and computational flow modeling (CFM) can make tremendous contributions in chemical engineering.

Combined heat and mass transfer problems with chemical reaction are of importance in many processes and have, therefore, received a considerable amount of attention in recent years. The study of heat and mass transfer with chemical reaction is of great practical importance to engineers and scientists because of its almost universal occurrence in many branches of science and engineering. Possible applications of this type of flow can be found in many industries. Many natural phenomena and engineering applications are susceptible to magneto-hydrodynamic (MHD) analysis. From technological point of view, magneto-hydrodynamic flow finds application in the fields of stellar and planetary magneto-spheres, aeronautics, meteorology, solar physics, cosmic fluid dynamics, chemical engineering, electronics, MHD generators, MHD accelerators, construction of turbine and other centrifugal machines. Very often, along with the free convection currents caused by the temperature difference, the flow is also affected by the difference in concentration of material constituents. In engineering application, the concentration differences are created either by injecting foreign gases or by coating a substrate with a material, and subsequently heating it, so that the material evaporates. Ajay Kumar Singh [1] has studied unsteady free convection flow of an incompressible micro-polar fluid past in infinite vertical plate with temperature gradient dependent heat source. Ajay Kumar Singh [2] who studied the effects of thermal diffusion on MHD free convection flow through a vertical channel. Acharya et al.[3] studied heat and mass transfer over an accelerating surface with heat source in presence of suction and injection. Atul Kumar Singh [4] investigated the effects of mass transfer on free convection in MHD flow of a viscous fluid. Cortell [5] studied flow and heat transfer of an electrically conducting fluid of second grade over a stretching sheet subject to suction and to a transverse magnetic field. Gebhart and Pera [6] made extensive studies to such a combined heat and mass transfer flow to highlight the insight of the flow phenomena. Helmy [7] has studied MHD unsteady free convection flow past a vertical porous plate. Kandasamy [8] studied the effects of heat and mass transfer along a wedge with heat source and convection in the presence of suction or injection.

Kumari and Nath [9] have studied development of two-dimensional boundary layer with an applied magnetic field due to an impulsive motion. Muthukumaraswamy and Ganesan [10] have studied unsteady flow past an impulsively started vertical plate with heat and mass transfer. Kim [11] presented an analysis of an unsteady MHD convection flow past a vertical moving plate embedded in a porous medium in the presence of transverse magnetic field. Helmy [12] studied MHD unsteady free convection flow past a vertical porous plate. Raptis [13] analyzed the thermal radiation and free convection flow through a porous medium bounded by a vertical infinite porous plate by using a regular perturbation technique. Pantokratoras [14] studied Non-Darcian forced convection heat transfer over a flat plate in a porous medium with variable viscosity and variable Prandtl number. Sacheti et al.[16] have studied exact solutions for unsteady magneto-hydrodynamics free convection flow with constant heat flux. Ibrahim [**?**] studied the effects of chemical reaction and radiation absorption on transient hydro magnetic natural convection flow with wall transpiration and heat source. Anjalidevi and Kandasamy [17] have examined the effect of a chemical reaction on the flow in the presence of heat transfer and magnetic field. Mansour et al.[18] analyzed the effect of chemical reaction and viscous on MHD natural convection flows saturated in porous media with suction or injection. However, in engineering and technology, there are occasions where a heat source is needed to maintain the desired heat transfer. At the same time, the suction velocity has also to be normal to the porous plate.

The object of the present paper is to analyze the effect of chemical reaction on unsteady MHD free convective fluid flow past a vertical porous plate in the presence of suction or injection. The dimensionless equations are solved by using the finite element method. The effects of various governing parameters on the velocity, temperature, concentration, skin-friction coefficient, Nusselt number and Sherwood number are shown in figures and tables and discussed in detail.

2 Mathematical analysis

An unsteady two-dimensional magnetohydrodynamic free convection flow of a viscous incompressible and electrically conducting fluid past a vertical porous plate in the presence of suction or injection is considered. The x- axis is taken along the plate in the upward direction and the y- axis is taken normal to the plate. A uniform magnetic field is applied in the direction perpendicular to the plate. The fluid is assumed to be slightly conducting, and hence the magnetic Reynolds number is much less than unity and the induced magnetic field is negligible in comparison with the applied magnetic field. It is assumed that the external electric field is zero and the electric field due to the polarization of charges is negligible. Initially, the plate and the fluid are at the same temperature T_∞ and the concentrationC_∞. At time $t > 0$, the plate temperature and concentration are raised to T_w and C_w respectively and are maintained constantly thereafter. It is also assumed that all the fluid properties are constant except that of the influence of the density variation with temperature and concentration in the body force term (Boussinesq's approximation). Also, there is a chemical reaction between the diffusing species and the fluid. The foreign mass present in the flow is assumed to be at low level and hence Soret and Dufour effects are negligible. Under these assumptions, the governing boundary layer equations of the flow field are:

Conservation of Mass

$$\frac{\partial v'}{\partial y'} = 0 \tag{1}$$

Conservation of Momentum

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = v\frac{\partial^2 u'}{\partial y'^2} + g\beta\left(T - T_\infty\right) + g\beta^*\left(C - C_\infty\right) - \left(\frac{\sigma B_0^2}{\rho} + \frac{\nu}{k_p}\right)u' \tag{2}$$

Conservation of Energy (Heat)

$$\frac{\partial T}{\partial t'} + v'\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y'^2} + \frac{Q_0}{\rho c_p}\left(T - T_\infty\right) \tag{3}$$

Conservation of Species (Concentration)

$$\frac{\partial C}{\partial t'} + v' \frac{\partial C}{\partial y'} = D \frac{\partial^2 C}{\partial y'^2} - K_r' C \tag{4}$$

The initial and boundary conditions are

$$\begin{aligned} t \leq 0: \; & u' = 0, \;\; v' = 0, \quad T = T_\infty, \quad C = C_\infty \quad for \;\; all \;\; y' \\ t > 0: \; & u' = 0, \;\; v' = v(t), \; T = T_w, \quad C = C_w \quad at \;\; y' = 0 \\ & u' \to 0, \;\; v' \to 0, \quad T \to T_\infty \;, \; C \to T_\infty, \quad as \;\; y' \to \infty \end{aligned} \tag{5}$$

where $v\,(t)$ is the suction velocity at the plate and u,v - the velocity components in x, y directions respectively, ρ- the fluid density, g - the acceleration due to gravity, β and β^*- the thermal and concentration expansion coefficients respectively, T - the temperature of the fluid in the boundary layer, ν- the kinematic viscosity, σ- the electrical conductivity of the fluid, T_∞ - the temperature of the fluid far away from the plate, α - the thermal diffusivity, C - the species concentration in the boundary layer, C_∞ - the species concentration in the fluid far away from the plate, B_0- the magnetic induction, c_p- the specific heat at constant pressure and D- the mass diffusivity.

In order to write the governing equations and the boundary condition in dimension less form, the following non- dimensional quantities are introduced.

$$\begin{aligned} u &= \frac{u'}{V_0}, \;\; \nu = \frac{\nu'}{V_0}, \;\; y = \frac{V_0 y'}{\nu}, \;\; t = \frac{V_0^2 t'}{\nu}, \\ n &= \frac{\nu n'}{V_0^2}, \;\; \theta = \frac{T - T_\infty}{T_w - T_\infty}, \;\; \phi = \frac{C - C_\infty}{C_w - C_\infty} \end{aligned}$$

$$\begin{aligned} M &= \frac{\sigma B_0^2 \nu}{\rho V_0^2}, \;\; K = \frac{k_p V_0^2}{\nu^2}, \;\; \mathrm{Pr} = \frac{\nu \rho C_p}{k} = \frac{\nu}{\alpha}, \\ Gr &= \frac{g \beta v\,(T_w - T_\infty)}{V_0^3}, \quad Gm = \frac{g \beta^* v\,(C_w - C_\infty)}{V_0^3}, \end{aligned}$$

$$Q = \frac{Q_0 \nu}{\rho c_p V_0^2}, \;\; K_r = \frac{K_r^2 \nu}{V_0^2}, \;\; Sc = \frac{\nu}{D} \tag{6}$$

In view of Equations (6) - (9), Equations (2) - (4) reduced to the

$$\frac{\partial u}{\partial t} - v_0\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr\theta + Gm\phi - \left(M + \frac{1}{K}\right)u \tag{7}$$

$$\frac{\partial \theta}{\partial t} - v_0\frac{\partial \theta}{\partial y} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} + Q\theta \tag{8}$$

$$\frac{\partial \phi}{\partial t} - v_0\frac{\partial \phi}{\partial y} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - K_r\phi \tag{9}$$

And the boundary conditions (8) in the non-dimensional form are:

$$\begin{aligned} &t \leq 0: \quad u = 0, \quad \theta = 0, \quad \phi = 0 \quad for \quad all \quad y \\ &t > 0: \quad u = 0, \quad \theta = 1, \quad \phi = 1 \quad at \quad y = 0 \\ &\qquad u \to 0, \quad \theta \to 0, \quad \phi \to 0 \quad as \quad y \to \infty \end{aligned} \tag{10}$$

3 Method of solution

The set of differential Equations (7) to (9) subject to the boundary conditions (10) are highly nonlinear, coupled and therefore it cannot be solved analytically. Hence, following Reddy [19] and Bathe [20] the finite element method is used to obtain an accurate and efficient solution to the boundary value problem under consideration. The fundamental steps comprising the method are as follows:

Step 1: Discretization of the domain into elements:

The whole domain is divided into finite number of *sub-domains*, a process known as discretization of the domain. Each sub-domain is termed a *finite element*. The collection of elements is designated the *finite element mesh*.

Step 2: Derivation of the element equations:

The derivation of finite element equations i.e. algebraic equations among the unknown parameters of the finite element approximation, involves the following three steps:

a Construct the variational formulation of the differential equation.

b Assume the form of the approximate solution over a typical finite element.

c Derive the finite element equations by substituting the approximate solution into variational formulation.

Step 3: Assembly of element equations:

The algebraic equations so obtained are assembled by imposing the *inter-element* continuity conditions. This yields a large number of algebraic equations, constituting the *global finite element model*, which governs the whole flow domain.

Step 4: Impositions of boundary conditions:

The physical boundary conditions defined in equation (10) are imposed on the assembled equations.

Step 5: Solution of the assembled equations:

The final matrix equation can be solved by a direct or indirect (iterative) method. For computational purposes, the coordinate y is varied from 0 to $y_{\max} = 4$, where $y_{\max}$ represents infinity i.e. external to the momentum, energy and concentration boundary layers. Numerical solutions for these equations are obtained by C-program. In order to prove the convergence and stability of finite element method, the same C-program was run with slightly changed values of h and k and no significant change was observed in the values of u, θ and ϕ. This process is repeated until the desired accuracy of 0.0005 is obtained. Hence, the finite element method is stable and convergent.

Skin-friction, Rate of heat and Mass Transfer

Skin-friction coefficient (C_f) is given by

$$C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0} \tag{11}$$

Nusselt number (Nu) at the plate is

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} \tag{12}$$

Sherwood number (Sh) at the plate is

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} \tag{13}$$

4 Results and discussion

The effect of chemical reaction on unsteady MHD free convective fluid flow past a vertical porous plate in the presence of suction or injection has been studied. The governing equations are solved by using the finite element method and approximate solutions are obtained for velocity field, temperature field, concentration distribution,, skin-friction coefficient, Nusselt number and Sherwood number. The effects of the pertinent parameters on the flow field are analyzed and discussed with the help of velocity profiles Figs.1-9, temperature profiles Figs.10-12, concentration distribution Figs.13-15 and Tables 1-3.

4.1 Velocity field

The velocity of the flow field is found to change more or less with the variation of the flow parameters. The major factors affecting the velocity the flow field are the thermal Grashof number Gr, solutal Grashof number Gm, Magnetic parameter M, Permeability parameter K, Prandtl number Pr, heat source parameter Q, Schmidt number Sc, chemical reaction parameter K_r and Suction/ Injecton parameter v_0. The effects of these parameters on the velocity field have been analyzed with the help of Figs.1-9.

4.1.1 Effect of thermal Grashof number (Gr)

The influence of the thermal Grashof number on the velocity is presented in Figure 1. The thermal Grashof number signifies the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer. As expected, it is observed that there is a rise in the velocity due to the enhancement of thermal buoyancy force. Here, the positive values of Gr correspond to cooling of the plate. Also, as Gr increases, the peak values of the velocity increases rapidly near the porous plate and then decays smoothly to the free stream velocity.

4.1.2 Effect of solutal Grashof number (Gm)

Figure 2 presents typical velocity profiles in the boundary layer for various values of the solutal Grashof number Gm, while all other parameters are kept at some fixed values. The solutal Grashof number Gm defines the ratio of the species buoyancy force to the viscous hydrodynamic force. As expected, the fluid velocity increases and the peak value is more distinctive due to increase in the species buoyancy force.The velocity distribution attains a distinctive maximum value in the vicinity of the plate and then decreases properly to approach the free stream value.

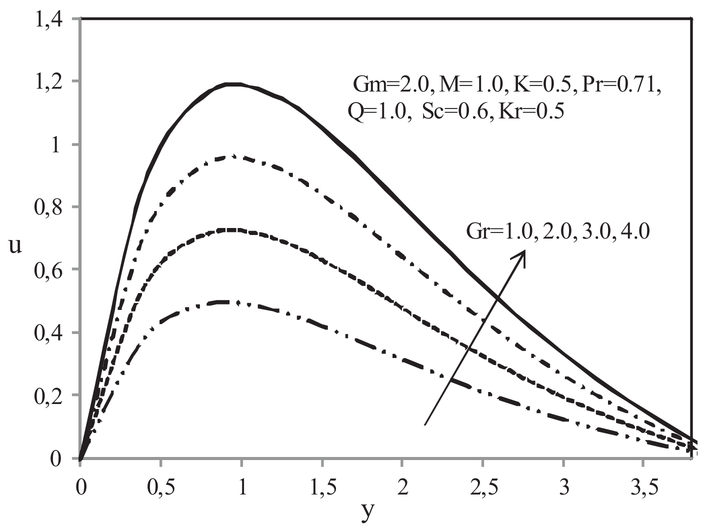

Figure 1: Velocity profiles for different values of Gr

4.1.3 Effect of magnetic parameter (M)

The effect of the magnetic field parameter (M) is shown in Figure 3. It is observed that the velocity of the fluid decreases with the increase of the magnetic field parameter values, because the presence of a magnetic field in an electrically conducting fluid introduces a force called the Lorentz force, which acts against the flow if the magnetic field is applied in the normal direction, as in the present study. Velocity profiles for different values of M

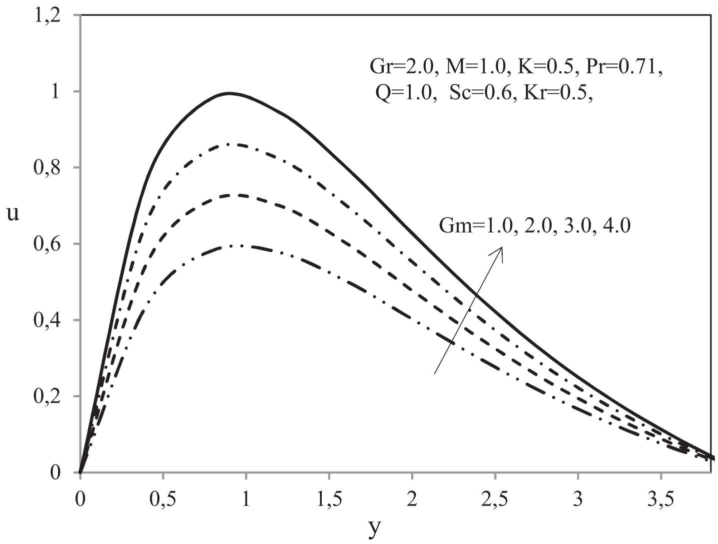

Figure 2: Velocity profiles for different values of Gm

4.1.4 Effect of permeability parameter (K)

Figure 4, shows the effect of the permeability parameter K on the velocity distribution. As shown, the velocity is increasing with the increasing dimensionless porous medium parameter.

4.1.5 Effect of Prandtl number (Pr)

Figure 5, shows the behavior velocity for different values Prandtl number Pr. The numerical results show that the effect of increasing values of Prandtl number results in a decreasing velocity. It is observed that an increase in the Prandtl number results a decrease of the thermal boundary layer thickness within the boundary layer.

4.1.6 Effect of heat source parameter (Q)

Figure 6, depicts the velocity profiles for different values of the heat source parameter Q. It is noticed that an increase in the heat absorption parameter

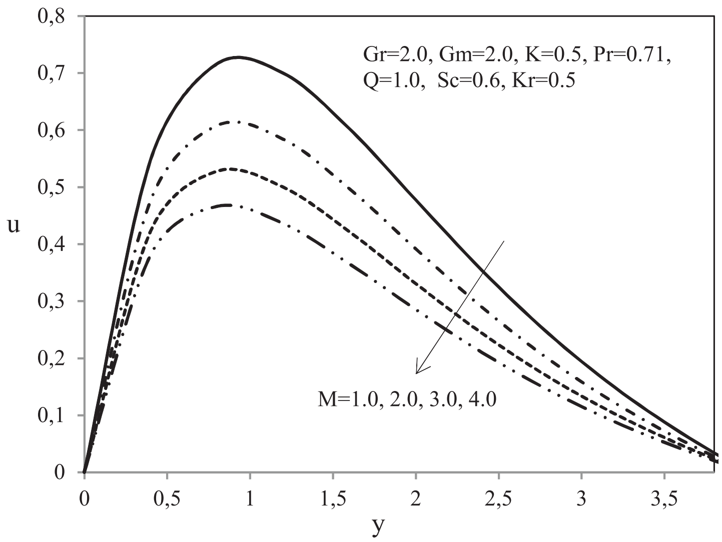

Figure 3: Velocity profiles for different values of M

Q results in an increase in the velocity within the boundary layer.

4.1.7 Effect of Schmidt number (Sc)

The nature of velocity profiles in presence of foreign species such as hydrogen ($Sc = 0.22$), water-vapour ($Sc = 0.60$), ammonia ($Sc = 0.78$), methanol ($Sc = 1.0$) are shown in Figure 7. The flow field suffers a decrease in velocity at all points in presence of heavier diffusing species.

4.1.8 Effect of chemical reaction parameter (K_r)

Figure 8, shows that the velocity for different values of chemical reaction parameter K_r. It is observed that the velocity slightly decreases with the increase of the chemical reaction parameter.

4.1.9 Effect of suction/injecton parameter (v_0)

Figure 9, we present the variation in the velocity of the flow field due to the change of the suction/injection keeping other parameters of the flow field

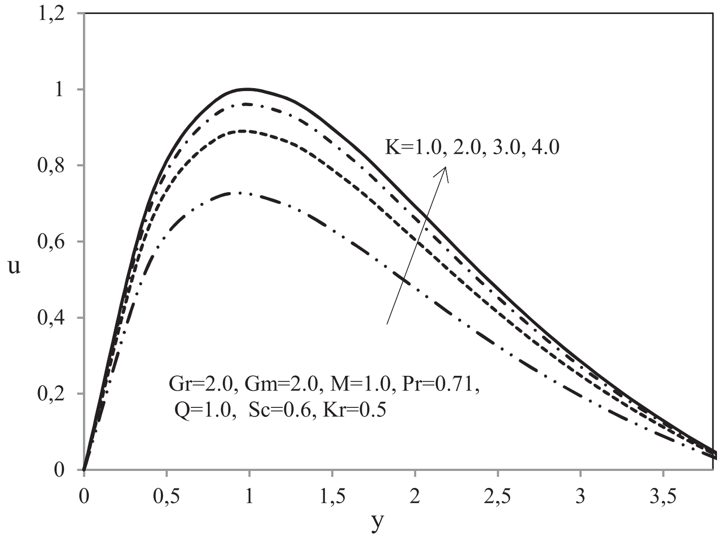

Figure 4: Velocity profiles for different values of K

constant. It is observed that suction/injection parameter retards the velocity of flow field at all points. As the suction/injection of the fluid through the plate increases the plate is cooled down and in consequence of which the viscosity of the flowing fluid increases. Therefore, there is a gradual decrease in the velocity of the fluid as v_0 increases.

4.2 Temperature field

The temperature of the flow suffers a substantial change with the variation of the flow parameters such as Prandtl number (Pr), Heat source parameter (Q) , Suction or Injection parameter (v_0), these variations are shown in Figs.10-12.

4.2.1 Effect of Prandtl number (Pr)

From figure 10 depicts the effect of Prandtl number against y on the temperature field keeping other parameters of the flow field constant. It is interesting to observe that an increase in the Prandtl number Pr decreases the temper-

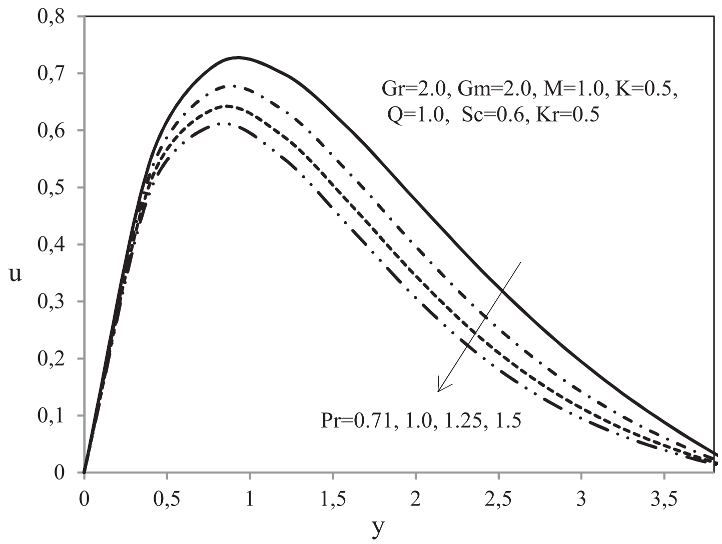

Figure 5: Velocity profiles for different values of Pr

ature of the flow field.

4.2.2 Effect of heat source parameter (Q)

Figure 11, discusses the effect of heat source parameter on the velocity of the flow field. In the velocity of the flow field agrowing heat source parameter enhances of the flow field.

4.2.3 Effect of suction/injection parameter (v_0)

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The effect of suction/injection parameter on the temperature of the flow field is shown in Fig.12. The temperature of the flow field is found to decrease in the presence of the growing suction/injection. The temperature profile becomes very much linear in absence of suction/injection v_0. In presence of higher suction/injection more amount of fluid is pushed into the flow field through the plate due to which the flow field suffers a decrease in temperature at all points.

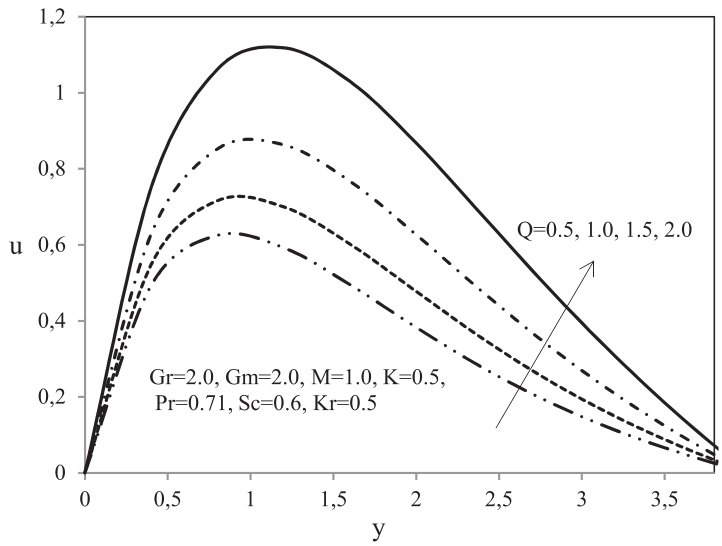

Figure 6: Velocity profiles for different values of Q

4.3 Concentration distribution:

The variation in the concentration boundary layer of the flow field with the flow parameters Schmidt number Sc, Chemical reaction parameter K_r and Suction/ Injecton parameter (v_0) are shown in Figs.13,14 and 15.

4.3.1 Effect of Schmidt number (Sc)

The concentration distribution is vastlyaffected by the presence of foreign species such as hydrogen ($Sc = 0.22$), water-vapor ($Sc = 0.60$), ammonia ($Sc = 0.78$), methanol ($Sc = 1.0$) are shown in Figure 13. Figure 13, depicts the effect of Sc on the concentration distribution of the flow field. The concentration distribution is found to decrease faster as the diffusing foreign species becomes heavier. Thus higher Sc leads to a faster decrease in concentration of the flow field.

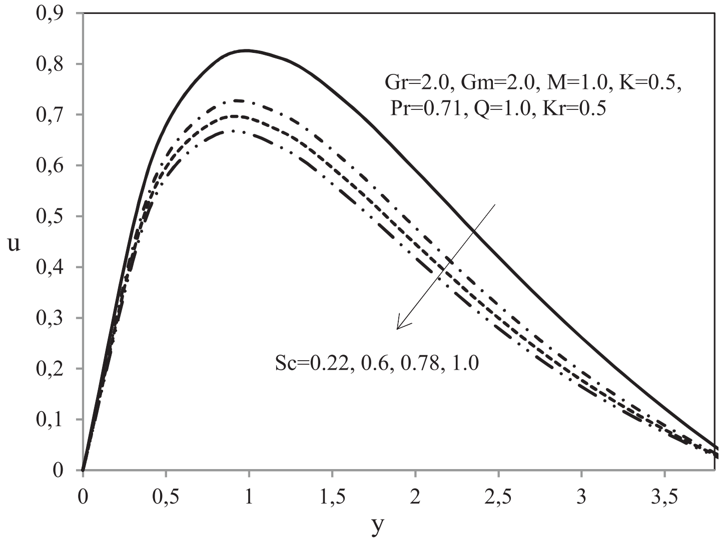

Figure 7: Velocity profiles for different values of Sc

4.3.2 Effect of chemical reaction parameter (K_r)

Figure 14, represents the effect of concentration profiles for different chemical reaction parameter. The effect of chemical reaction parameter plays an important role in concentration field. There is a fall in concentration due to increase in the values of the chemical reaction parameter.

4.3.3 Effect of suction/injection parameter (v_0)

Figure 15, depicts the concentration profiles against y for various values of suction parameter v_0 keeping other parameters are constant. Suction parameter is found to decrease the concentration of the flow field at all points. In other words, cooling of the plate is faster as the suction parameter becomes larger. Thus it may be concluded that larger suction leads to faster cooling of the plate.

Tables 1-3, show numerical values of the skin-friction coefficient (C_f) for various values of thermal Grashof number Gr, solutal Grashof number Gm, Magnetic parameter M, Permeability parameter K, Prandtl number Pr, heat

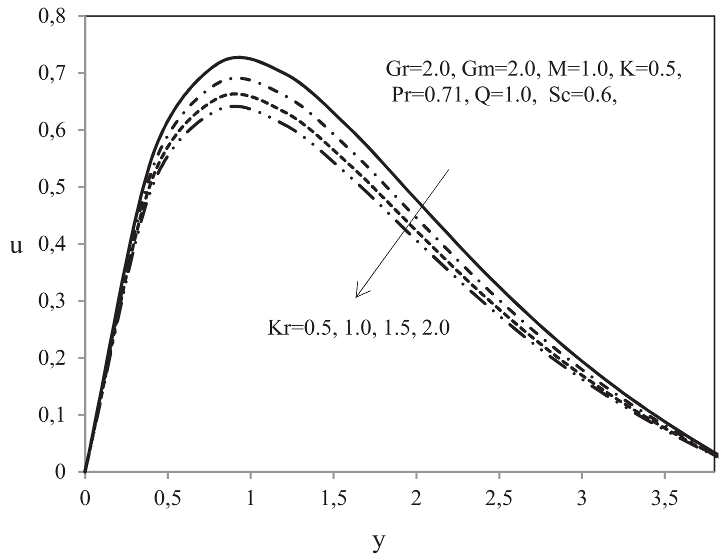

Figure 8: Velocity profiles for different values of Kr

source parameter Q, Schmidt number Sc, chemical reaction parameter K_r and suction/ injection parameter v_0. Table-1 observed that, an increase in the Magnetic parameter decrease in the value of the skin-friction coefficient while an increase in the thermal Grashof number, solutal Grashof number, Permeability parameter increase in the value of the skin-friction coefficient.

Table-2 show numerical values of heat transfer coefficient in terms of Nusselt number (Nu) for various values of Prandtl number Pr, heat source parameter Q and suction/injection parameter v_0. It is observed that, an increase in the Prandtl number or suction/injection parameter increase in the value of heat transfer coefficient while an increase in the heat source parameter decrease in the value of heat transfer coefficient and an increase in the Prandtl number or suction/injection parameter decrease in the value of the skin-friction coefficient. while an increase in the heat absorption parameter increase in the value of the skin-friction coefficient.

Table-3 show numerical values of mass transfer coefficient in terms of Sherwood number (Sh) for various values of Schmidt number Sc, chemical reaction parameter K_r and suction/injection parameter v_0. It is observed that, an increase in the Schmidt number or chemical reaction parameter or

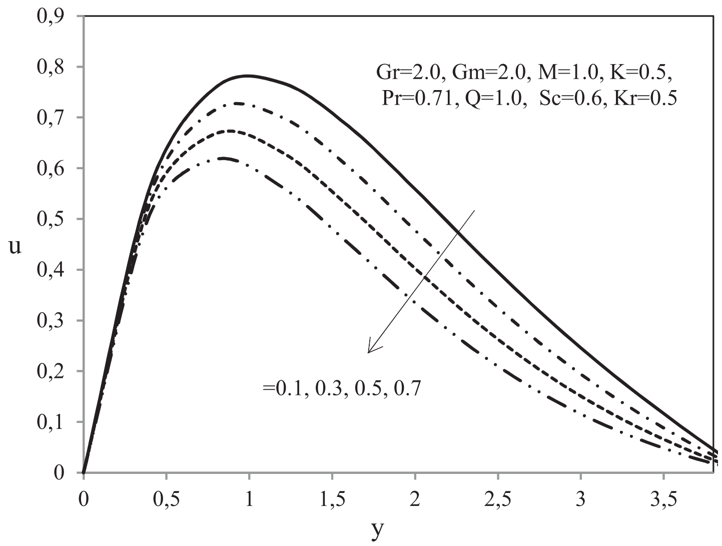

Figure 9: Velocity profiles for different values of ν_0

suction/injection parameter increase in the value of mass transfer coefficient and an increase in the Schmidt number or chemical reaction parameter or suction/injection parameter decrease in the value of the skin-friction coefficient.

Table 1: Effect of Gr ,Gm, M and K on C_f ($\mathrm{Pr} = 0.71, Q = 1.0, Sc = 0.6, K_r = 0.5, v_0 = 0.3$)

Gr	Gm	M	K	C_f
2.0	2.0	1.0	0.5	1.8853
4.0	2.0	1.0	0.5	2.9804
2.0	4.0	1.0	0.5	2.6755
2.0	2.0	2.0	0.5	1.6810
2.0	2.0	1.0	1.0	2.1658

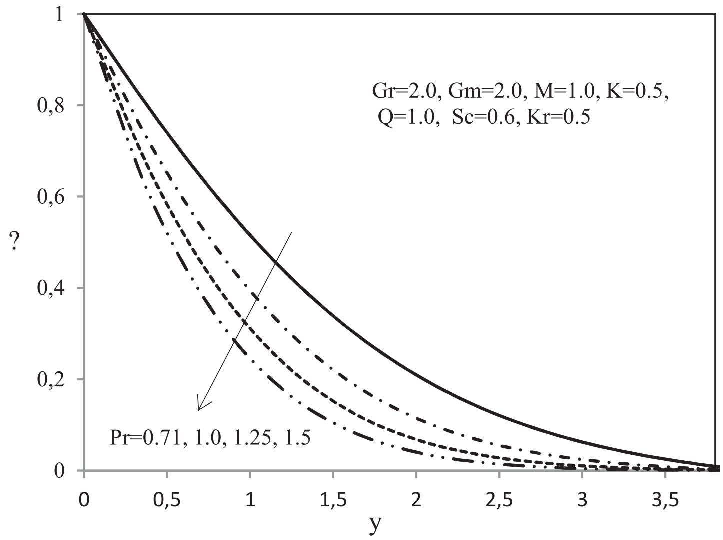

Figure 10: Temperature profiles for different values of Pr

Table 2: Effect ofPr , $Q$and v_0 on C_f and Nu (Gr=2.0, Gm =2.0, M=1.0, K=0.5, Sc=0.6, K_r=0.5)

Pr	Q	v_0	C_f	Nu
0.71	1.0	0.3	1.8853	-0.2362
7.0	1.0	0.3	1.3315	0.5674
0.71	2.0	0.3	2.4289	-1.7953
0.71	1.0	0.5	1.8763	-0.1358

Table 3: Effect of Sc , $K_r$and v_0 on C_f and Sh (Gr=2.0, Gm =2.0, M=1.0K=0.5, Pr=0.71,Q=1.0)

Sc	K_r	v_0	C_f	Sh
0.22	0.5	0.3	2.0218	0.4122
0.60	0.5	0.3	1.8853	0.6710
0.22	1.0	0.3	1.9756	0.5143
0.22	0.5	0.5	2.0176	0.4353

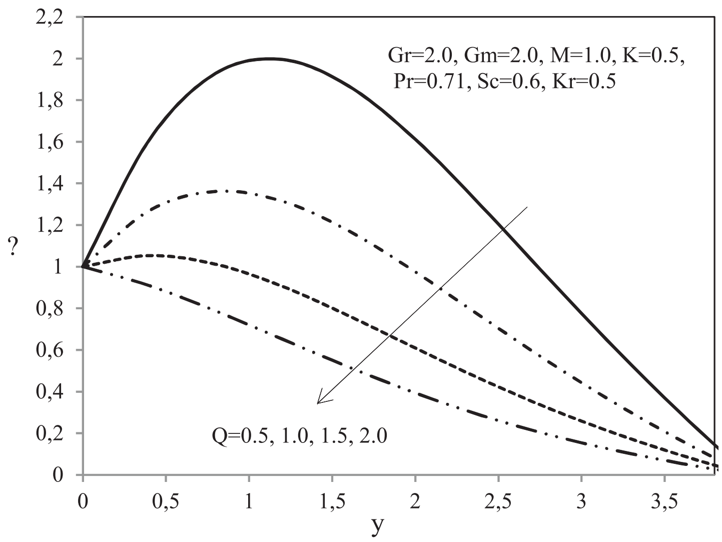

Figure 11: Temperature profiles for different values of Q

5 Conclusions

In this study examined the effect of chemical reaction on unsteady MHD free convective fluid flow past a vertical porous plate in the presence of suction or injection. The leading governing equations are solved numerically employing the highly efficient finite element method. We present results to illustrate the flow characteristics for the velocity, temperature, concentration, skin-friction coefficient, Nusselt number and Sherwood number and show how the flow fields are influenced by the material parameters of the flow problem. We can conclude from these results that

i) An increase in M, Pr, Sc, K_r, v_0 decrease the velocity field while an increase in Gr, Gm, K, Q increase the velocity field.

ii) An increase in Pr, $v_0$decrease in the temperature field while an increase in Q increase in the temperature field.

iii) An increase in Sc, K_r, v_0 decrease in the concentration field.

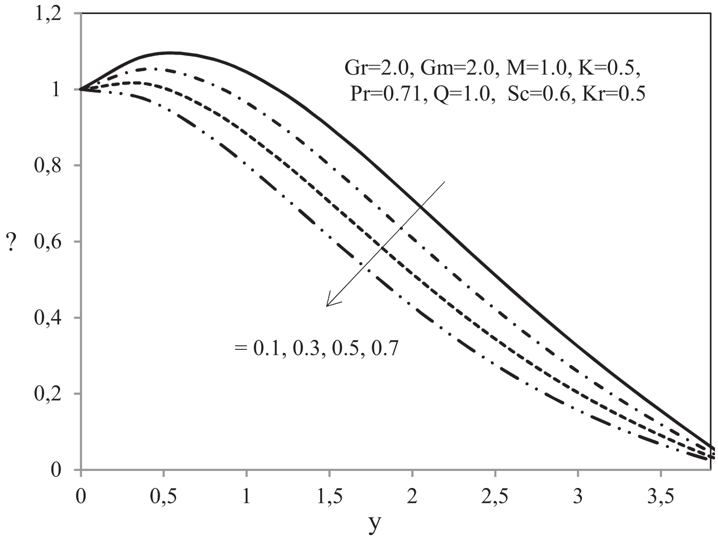

Figure 12: Temperature profiles for different values of ν_0

iv) An increase in M, Pr, Sc, K_r, v_0 decrease in the value of skin-friction while an increase in Gr, Gm, K, Q increase the value of skin-friction.

v) An increase in Pr, v_0 increase in the value of heat transfer coefficient while an increase in Q decrease in heat transfer coefficient.

vi) An increase in Sc, K_r, v_0 increase in the value of mass transfer coefficient.

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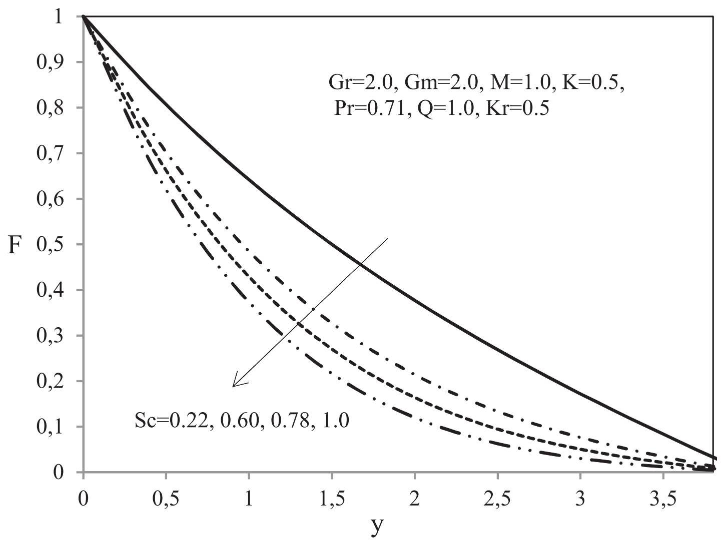

Figure 13: Concentration profiles for different values of Sc

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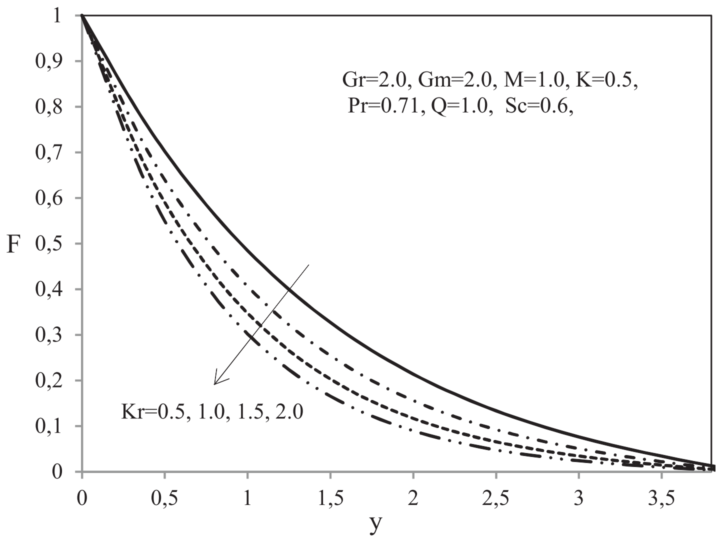

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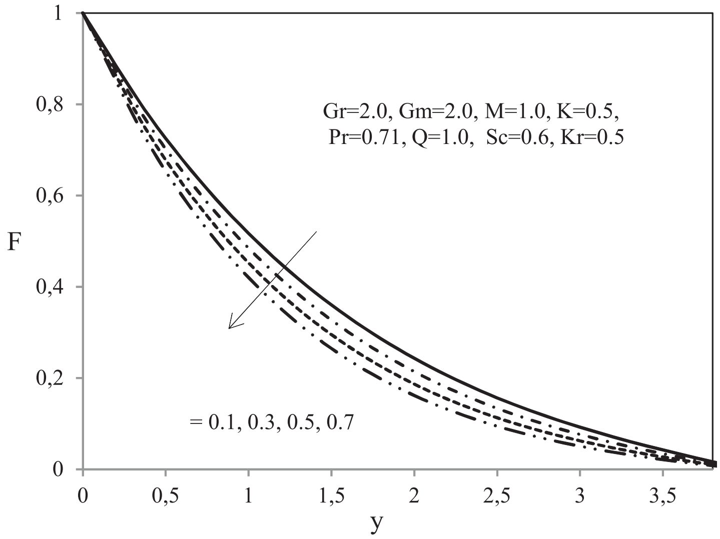

Figure 15: Concentration profiles for different values of ν_0

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Chemical reaction effect on an unsteady MHD free convection flow past a vertical porous plate in the presence of suction or injection

The objective of this paper is to analyze the effect of chemical reaction on unsteady magneto hydrodynamic free convective fluid flow past a vertical porous plate in the presence of suction or injection. The governing equations of the flow field are solved numerically by a finite element method. The effects of the various parameters on the velocity, temperature and concentration profiles are presented graphically and values of skin-friction coefficient, Nusselt number and Sherwood number for various values of physical parameters are presented through tables.

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