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ORIGINAL ARTICLE

Numerical investigation of MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of thermal diffusion and radiation absorption

M. Umamaheswar [a], M.C. Raju [a,*], S.V.K. Varma [b], J. Gireeshkumar [c]

[a] Department of Mathematics, Annamacharya Institute of Technology and Sciences (Autonomous), Rajampet, Cuddapah District, A.P., India
[b] Department of Mathematics, S.V. University, Tirupathi, A.P., India
[c] Department of Mathematics, Govt. Degree college, Jammalamadugu, A.P., India

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Abstract A numerical investigation is carried out on an unsteady MHD free convection flow of a well-known non-Newtonian visco elastic second order Rivlin-Erickson fluid past an impulsively started semi-infinite vertical plate in the presence of homogeneous chemical reaction, thermal radiation, thermal diffusion, radiation absorption and heat absorption with constant mass flux. The presence of viscous dissipation is also considered at the plate under the influence of uniform transverse magnetic field. The flow is governed by a coupled nonlinear system of partial differential equations which are solved numerically by using finite difference method. The effects of various physical parameters on the flow quantities viz. velocity, temperature, concentration, Skin friction, Nusselt number and Sherwood number are studied numerically. The results are discussed with the help of graphs. We observed that the velocity decreases with an increase in magnetic field parameter, Schmidt number, and Prandtl number while it increases with an increase in Grashof number, modified Grashof number, visco-elastic parameter and Soret number. Temperature increases with an increase in radiation absorption parameter, Eckert number and visco-elastic parameter while it decreases with increasing values of radiation parameter, Prandtl number and heat absorption parameter. Concentration increases with increase in Soret number while it decreases with an increase in Schmidt number and chemical reaction parameter.

* Corresponding author.
E-mail addresses: umasvu8@gmail.com (M. Umamaheswar), mcrmaths@yahoo.co.in (M.C. Raju).
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1. Introduction

MHD free convective flow plays an important role in petrochemical industry, cooling of nuclear reactors, heat exchanger design and geophysics as well as magneto-hydrodynamic power generation system. Chen [1] studied combined heat and mass transfer in MHD free convection from a vertical surface with Ohmic heating and viscous dissipation. Chamkha [2] analyzed MHD flow of a uniformly stretched vertical permeable surface in the presence of heat generation/absorption and a chemical reaction. Hayat and Mehmood [3] analyzed slip effects on MHD flow of third order fluid in a planar channel. Pal and Chatterjee [4] found heat and mass transfer in MHD non-Darcian flow of a micro polar fluid over a stretching sheet embedded in a porous media with non-uniform heat source and thermal radiation. Kim [5] studied unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction. Chamkha [6] discussed unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption.

Convective flows with simultaneous heat and mass transfer under the influence of the chemical reaction arise in many transport processes both naturally and artificially in various branches of science and engineering. This phenomenon plays an important role in the chemical industry, power and cooling industry for drying, chemical vapor deposition on surfaces, cooling of nuclear reactors, and petroleum industries. Das [7] studied free convective MHD flow and heat transfer in a viscous incompressible fluid confined between a long vertical wavy wall and a parallel flat wall. Soundalgekar [8] examined free—convection effects on steady MHD flow past a vertical porous plate. Hossain et al. [9] studied the effect of radiation on free convection from a porous vertical plate. Srinivasacharya and Mendu [10] studied free convection in MHD micro polar fluid with radiation and chemical reaction effects. Srinivasacharya and RamReddy [11] studied natural convection heat and mass transfer in a micro polar fluid with thermal and mass stratification.

The fluid under consideration undergoes in some chemical reactions e.g. air and benzene reacts chemically, so also water and sulfuric acid. During such chemical reactions, there is always generation of heat. Combined heat and mass transfer problems with chemical reaction have importance in many processes and therefore received a considerable amount of attention in the recent years. In many chemical engineering processes chemical reactions take place between a foreign mass and working fluid which moves due to the stretch of a surface. The order of the chemical reactions depends on several factors. One of the simplest chemical reactions is the first-order reaction in which the rate of the reaction is directly proportional to the species concentration. The chemical reactions can be codified as either heterogeneous or homogenous processes. In most cases of chemical reactions the reaction rate depends on the concentration of the species itself. If the rate of reaction is directly proportional to the concentration then the reaction is said to be homogeneous reaction or first order reaction. Makinde et al. [12] investigated unsteady convection with chemical reaction and radiative heat transfer past a flat porous plate moving through a binary mixture. Kandasamy et al. [13] have analyzed effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection. Das et al. [14] analyzed effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. Anjalidevi and Kandasamy [15] studied effects of chemical reaction, heat and mass transfer on laminar flow along a semi-infinite horizontal plate. Seddeek et al. [16] found effects of chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through porous media with radiation. Ibrahim et al. [17] studied effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction. Patil and Kulkarni [18] investigated effects of chemical reaction on free convective flow of a polar fluid through a porous medium in the presence of internal heat generation. Pal and Mondal [19] discussed effects of Soret, Dufour, chemical reaction and thermal radiation on MHD non-Darcy unsteady mixed convective heat and mass transfer over a stretching sheet. Pal and Talukdar [20] analyzed analytically, unsteady magneto hydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Muthucumaraswamy and Ganesan [21] studied first-order chemical reaction on flow past an impulsively started vertical plate with uniform heat and mass flux. Dulal Pal [22] studied effect of chemical reaction on the dispersion of a solute in a porous medium. Mehta and Tiwari [23] analyzed dispersion in the presence of slip and chemical reactions in porous wall tube flow. Hayat and Nawaz [24] studied Soret and Dufour effects on the mixed convection flow of a second grade fluid subject to Hall and ion-slip currents. Patil et al. [25] analyzed double diffusive mixed convection flow over a moving vertical plate in the presence of internal heat generation and a chemical reaction. Srinivasacharya and Kaladhar [26] studied mixed convection flow of chemically reacting couple stress fluid in a vertical channel with Soret and Dufour effects. Srinivasacharya and Upendar [27] studied Soret and Dufour effects on MHD free convection in a micro polar fluid. Kaladhar and Srinivasacharya [28] analyzed mixed convection flow of chemically reacting couple stress fluid in an annulus with Soret and Dufour effects. Srinivasacharya and Kaladhar [29] examined Soret and Dufour effects on mixed convection flow of couple stress fluid in a non-Darcy porous medium with heat and mass fluxes. Srinivasacharya and Swamy Reddy [30] studied Soret and Dufour effects on mixed convection from a vertical plate in power-law fluid saturated porous medium. Hsiao [31] analyzed MHD mixed convection for visco-elastic fluid past a porous wedge. Hsiao [32] studied heat and Mass mixed convection for MHD visco-elastic fluid past a stretching Sheet with Ohmic dissipation.

Motivated by the above studies, an investigation has been carried out to study the MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of chemical reaction, thermal diffusion, radiation absorption, thermal radiation and heat absorption with constant mass flux. We have extended the work of Saravana et al. [33], who studied mass transfer effects on MHD viscous flow past an impulsively started infinite vertical plate with constant mass flux. This is not a simple extension of the previous work, and it varies in many aspects with the existing problem. The novelty of this study is the consideration of simultaneous effects of radiation parameter, heat absorption parameter, radiation absorption parameter, Soret number and chemical reaction parameter.

2. Formulation of the problem

Consider the flow of a viscous incompressible, electrically conducting, visco-elastic second order well-known non-Newtonian fluid namely Rivlin-Erickson fluid past an impulsively started semi-infinite vertical plate in the presence of homogeneous chemical reaction, thermal radiation, thermal diffusion, radiation absorption and heat absorption. The x^1-axis is taken along the plate in the vertically upward direction and the y^1-axis is chosen normal to the plate. Initially the temperature of the plate and the fluid is assumed to be T^1_∞, and the species concentration at the plate is C^1_w and in the fluid throughout C^1_∞ are assumed. At time $t^1 > 0$, the plate temperature is changed to T^1_w causing convection currents to flow near the plate and mass is supplied at a constant rate to the plate and the plate starts moving upward due to the impulsive motion, gaining a velocity of U_0. A uniform magnetic field of strength B_0 is applied in the y-direction. Therefore the velocity and the magnetic field are given by $\bar{q} = (u, 0, 0)$ and $\overline{B} = (0, B_0, O)$. The flow being slightly conducting the magnetic Reynolds number is much less than unity and hence the induced magnetic field can be neglected in comparison with the applied magnetic field. In the absence of any input electric field, the flow is governed by the following equations:

Equation of Momentum:

$$\frac{\partial u^1}{\partial t^1} = g\beta(T^1 - T^1_\infty) + g\beta^*(C^1 - C^1_\infty) + v\frac{\partial^2 u^1}{\partial y^{1^2}} + K_0^* \frac{\partial^3 u^1}{\partial y^{1^2}\partial t^1} - \frac{\sigma\mu_e^2 B_0^2}{\rho} u^1 \tag{1}$$

Equation of Energy:

$$\rho C_p \frac{\partial T^1}{\partial t^1} = K\frac{\partial^2 T^1}{\partial y^{1^2}} + \mu\left(\frac{\partial u^1}{\partial y^1}\right)^2 - \frac{\partial q_r}{\partial y^1} - Q_0(T^1 - T^1_\infty) + Q_l(C^1 - C^1_\infty) \tag{2}$$

Equation of Concentration:

$$\frac{\partial C^1}{\partial t^1} = D\frac{\partial^2 C^1}{\partial y^{1^2}} + D_1\frac{\partial^2 T^1}{\partial y^{1^2}} - K_r^*(C^1 - C^1_\infty) \tag{3}$$

Cogley et al. have shown that, in the optically thin limit for a non-gray gas near equilibrium, the radiative heat flux is represented by the following form:

$$\frac{\partial q_r^*}{\partial y^*} = 4(T^* - T_\infty)I^* \quad \text{Where} \quad I^* = \int K_{\lambda w}\frac{\partial e_{b\lambda}}{\partial T^*} d\lambda$$

The initial and boundary conditions are

$$\left.\begin{array}{lllll} u^1 = 0, & T^1 = T^1_\infty, & C^1 = C^1_\infty & \textit{for all } y^1, & t^1 \leqslant 0 \\ u^1 = U_0, & T^1 = T^1_w, & \frac{dC^1}{dy^1} = -\frac{j^{11}}{D} & \textit{at } y^1 = 0 & \\ u^1 = 0, & T^1 \to T^1_\infty, & C^1 \to C^1_\infty & \textit{as } y^1 \to \infty & \end{array}\right\} \tag{4}$$

where u^1 is the velocity of the fluid along the plate in the x^1-direction, t^1 is the time, g is the acceleration due to the gravity, β is the coefficient of volume expansion, β^* is the coefficient of thermal expansion with concentration, T^1 is the temperature of the fluid near the plate, T^1_∞ is the temperature of the fluid far away from the plate, T^1_w is the temperature of the fluid, C^1 is the species concentration in the fluid near the plate, C^1_∞ is the species concentration in the fluid far away from the plate, j^{11} is the mass flux per unit area at the plate, v is the kinematic viscosity, K_0^* is the coefficient of kinematic visco-elastic parameter, σ is the electrical conductivity of the fluid, μ_e is the magnetic permeability, B_0 is the strength of applied magnetic field, ρ is the density of the fluid, μ is the viscosity of the fluid, D is the molecular diffusivity, D_1 is the thermal diffusivity, Q_0 is the heat source/sink, Q_l is the radiation absorption parameter, K_r^* is the chemical reaction parameter, and U_0 is the velocity of the plate.

On introducing the following non-dimensional quantities

$$u = \frac{u^1}{U_0},\; t = \frac{t^1 U_0^2}{v},\; y = \frac{y^1 U_0}{v},\; \theta = \frac{T^1 - T^1_\infty}{T^1_w - T^1_\infty},\; C = \frac{C^1 - C^1_\infty}{(j^{11}v/DU_0)}$$

$Gr = \frac{vg\beta(T^1_w - T^1_\infty)}{U_0^3}$, (The Grashof number)

$Gc = \frac{vg\beta^*(j^{11}v/DU_0)}{U_0^3}$, (The modified Grashof number)

$\lambda = \frac{K_0^* U_0^2}{v^2}$, (Visco-elastic parameter)

$M = \frac{\sigma\mu_e^2 B_0^2 v}{\rho U_0^2}$, (Magnetic parameter)

$\Pr = \frac{v\rho C_p}{K}$, (Prandtl number)

$E = \frac{\mu U_0^2}{v\rho C_p(T^1_w - T^1_\infty)}$, (Eckert number)

$Sc = \frac{v}{D}$, (Schmidt number)

$\phi = \frac{Q_0 v}{\rho C_p U_0^2}$, (Heat absorption parameter)

$\chi = \frac{Q_l j^{11} v^2}{D\rho C_p U_0^3(T^1_w - T^1_\infty)}$, (Radiation absorption parameter)

$F = \frac{4vI^*}{\rho C_p U_0^2}$, (Radiation parameter)

$K_r = \frac{K_r^* v}{U_0^2}$, (Chemical reaction parameter)

$S_0 = \frac{DD_1(T^1_w - T^1_\infty)U_0}{j^{11}v^2}$, (Soret number)

In terms of the above non-dimensional quantities, Eqs. (1)–(3) reduce to

$$\frac{\partial u}{\partial t} = Gr\theta + GcC + \frac{\partial^2 u}{\partial y^2} + \lambda\left(\frac{\partial^3 u}{\partial y^2\partial t}\right) - Mu \tag{5}$$

$$\Pr\frac{\partial\theta}{\partial t} = \frac{\partial^2\theta}{\partial y^2} + \Pr E\left(\frac{\partial u}{\partial y}\right)^2 - \Pr F\theta - \Pr\phi\theta + \Pr\chi C \tag{6}$$

$$Sc\frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial y^2} + ScS_0\frac{\partial^2\theta}{\partial y^2} - ScKrC \tag{7}$$

The corresponding initial and boundary conditions are as follows:

$$\left.\begin{array}{llll} u = 0, & \theta = 0, & C = 0 \textit{ for all } y, & t \leqslant 0 \\ u = 1, & \theta = 1, & \frac{dC}{dy} = -1 \textit{ at } y = 0 & \\ u \to 0, & \theta \to 0, & C \to 0 \textit{ as } y \to \infty & \end{array}\right\} \tag{8}$$

3. Method of solution

Eqs. (5)–(7) are coupled nonlinear partial differential equations and are to be solved by using the initial and boundary conditions (8). However exact solution is not possible for this set of equations and hence we solve these equations by finite-difference method. The equivalent finite difference schemes of equations for (5)–(7) are as follows:

$$\left.\begin{array}{l}\frac{u_{i,j+1}-u_{i,j}}{\Delta t} = Gr\theta_{i,j} + GcC_{i,j} + \frac{u_{i-1,j}-2u_{i,j}+u_{i+1,j}}{(\Delta y)^2} \\ \quad +\lambda\left(\frac{u_{i-1,j+1}-2u_{i,j+1}+u_{i+1,j+1}-u_{i-1,j}+2u_{i,j}-u_{i+1,j}}{\Delta t(\Delta y)^2}\right) - Mu_{i,j}\end{array}\right\} \tag{9}$$

$$\Pr\left(\frac{\theta_{i,j+1}-\theta_{i,j}}{\Delta t}\right) = \left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}}{(\Delta y)^2}\right) + \Pr E\left(\frac{u_{i+1,j}-u_{i,j}}{\Delta y}\right)^2 - \Pr F\theta_{i,j} - \Pr\phi\theta_{i,j} + \Pr\chi C_{i,j} \tag{10}$$

$$Sc\left(\frac{C_{i,j+1}-C_{i,j}}{\Delta t}\right) = \left(\frac{C_{i-1,j}-2C_{i,j}+C_{i+1,j}}{(\Delta y)^2}\right) + ScS_0\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}}{(\Delta y)^2}\right) - ScKrC_{i,j} \tag{11}$$

Here, index i refer to y and j to time. The mesh system is divided by taking $\Delta y = 0.1$. From the initial condition in (8), we have the following equivalent:

$$u(i,0) = 0, \theta(i,0) = 0, C(i,0) = 0 \text{ for all } i \tag{12}$$

The boundary conditions from (8) are expressed in finite-difference form as follows

$$\begin{array}{l} u(0,j) = 1, \quad \theta(0,j) = 1, \quad C_{i-1,j} - C_{i+1,j} = -2.\Delta y \text{ for all } j \\ u(i_{\max},j) = 0, \quad \theta(i_{\max},j) = 0, \quad C(i_{\max},j) = 0 \text{ for all } j \end{array} \tag{13}$$

(Here $i_{\max}$ was taken as 20).

First the velocity at the end of time step viz, u (i, j + 1) (i = 1,20) is computed from (9) in terms of velocity, temperature and concentration at points on the earlier time-step. Then θ (i, j + 1) is computed from (10) and C (i, j + 1) is computed from (11). The procedure is repeated until t = 0.5 (i.e. j = 500). During computation Δt was chosen as 0.001.

Skin-friction:

The skin-friction in non-dimensional form is given by

$$\tau = -\left(\frac{du}{dy}\right)_{y=0}, \quad \text{where } \tau = \frac{\tau^1}{\rho U_0^2}$$

Nusselt number:

The Nusselt number in non-dimensional form is given by

$$Nu = -\left(\frac{d\theta}{dy}\right)_{y=0}$$

Sherwood number:

The Sherwood number in non-dimensional form is given by

$$Sh = -\left(\frac{dC}{dy}\right)_{y=0}$$

4. Results and discussion

In order to get into the physical insight of the problem, the expressions obtained for velocity, temperature and concentration are studied with the help of graphs from. In order to assess the accuracy of our present work, we have compared our results with accepted data sets for the effect of visco-elastic parameter on velocity distribution corresponding to the case computed by Hsiao et al. [31]. The outcomes of this comparison are found to be in very good agreement (see Fig. 25). The effects of various physical parameters viz., the Schmidt number (Sc), the thermal Grashof number (Gr), the mass Grashof number (Gm), magnetic parameter (M), Prandtl number

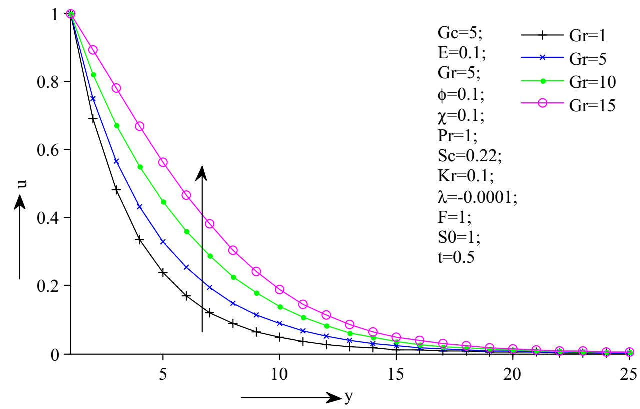

Figure 1 Effect of Grashof number on velocity.

(Pr), radiation parameter (F), radiation absorption parameter (χ), Soret number (S_0) and chemical reaction parameter (Kr) are studied numerically by choosing arbitrary values. In Fig. 1, effect of thermal Grashof number on velocity is presented. As Gr increases, velocity also increases. This is due to the buoyancy which is acting on the fluid particles due to gravitational force that enhances the fluid velocity. A similar effect is noticed in the presence of modified Grashof number, which is shown in Fig. 2. In Fig. 3, velocity profiles are displayed with the variation in magnetic parameter. From this figure it is noticed that velocity gets reduced by the increase in magnetic parameter. This is because the magnetic force which is applied perpendicular to the plate retards the flow, which is known as Lorentz force. Hence the presence of this retarding force reduces the fluid velocity. Fig. 4 depicts the variations in velocity profiles for different values of Schmidt number. From this figure it is noticed that the velocity decreases as Sc increases. Physically it is true as the concentration increases the density of the fluid increases which results a decrease in fluid particles. Fig. 5 shows that the velocity increases with the increase in Soret parameter S_0. From Figs. 6 and 7, we observe that as Pr increases, velocity and temperature decrease respectively. This happens because when Pr increases the thermal boundary layer thickness rapidly decreases. This causes an increase in fluid viscosity. Consequently the fluid velocity as well as temperature decreases. The effect of radiation absorption parameter on temperature is studied from Fig. 8. From this figure

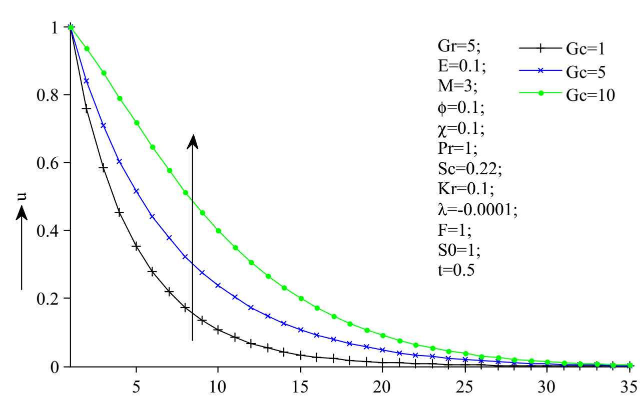

Figure 2 Effect of modified Grashof number on velocity.

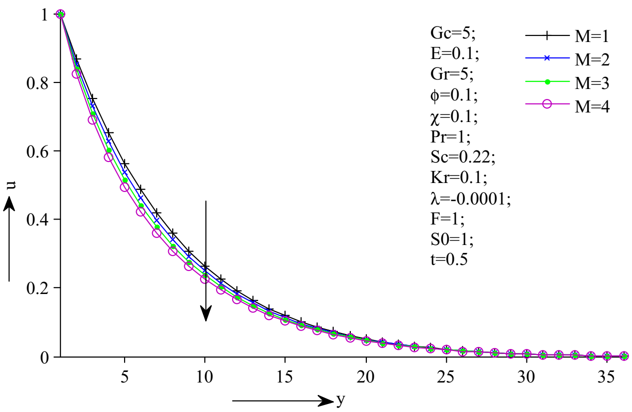

Figure 3 Effect of magnetic parameter on velocity.

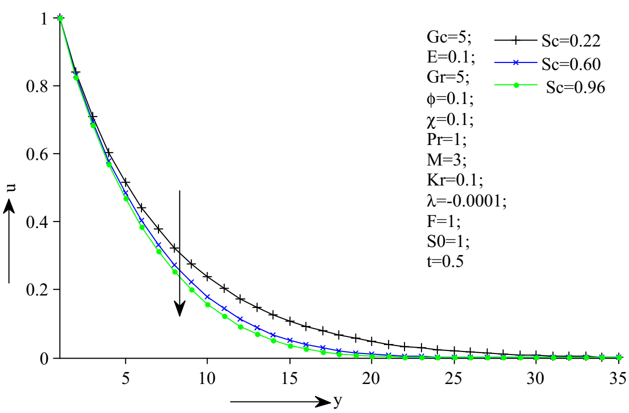

Figure 4 Effect of Schmidt number on velocity.

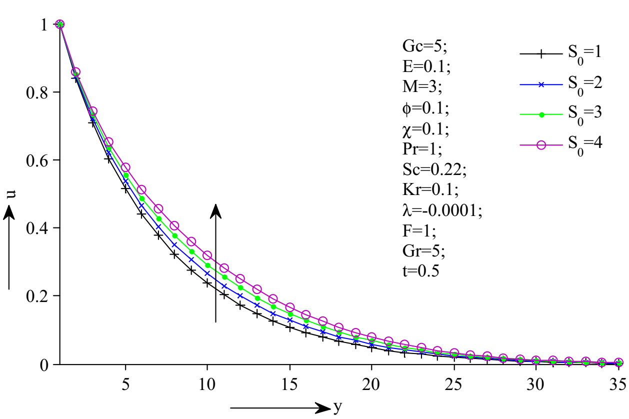

Figure 5 Effect of Soret number on velocity.

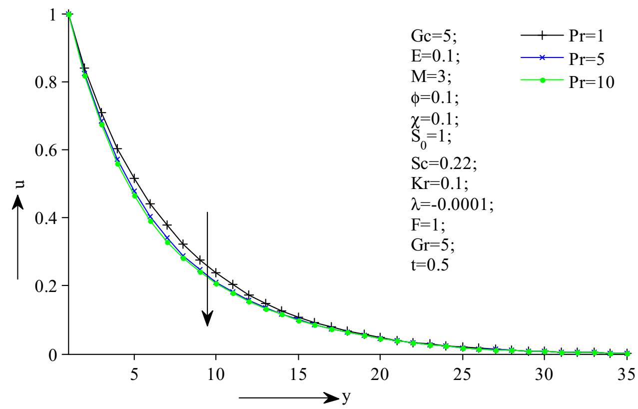

Figure 6 Effect of Prandtl number on velocity.

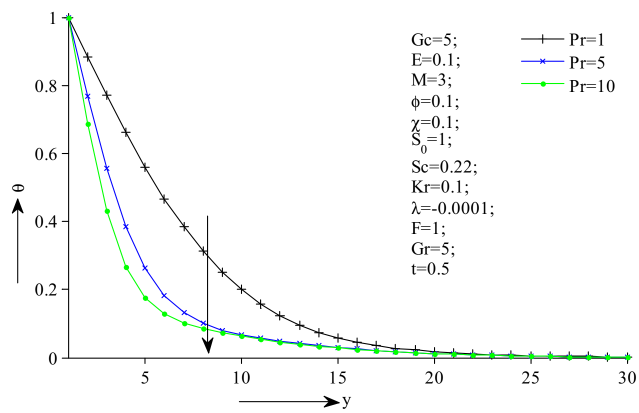

Figure 7 Effect of Prandtl number on temperature.

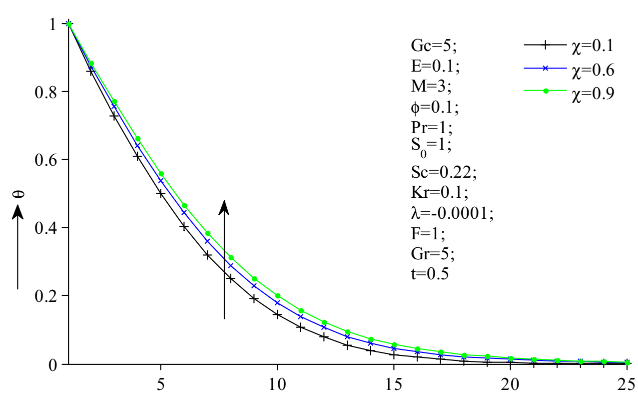

Figure 8 Effect of radiation absorption parameter on temperature.

it is noticed that temperature increases as radiation absorption parameter increases. This is because the thermal radiation is associated with high temperature, thereby increasing the temperature distribution of the fluid flow. Fig. 9 depicts the effect of heat absorption on temperature. It is noticed that the temperature is decreased by an increase in the heat absorption by the fluid. The central reason behind this effect is that the heat absorption causes a decrease in the kinetic energy as well as thermal energy of the fluid. Fig. 10 demonstrates the effect of radiation parameter (F) on temperature. It is observed that temperature decreases as radiation parameter increases. From the Fig. 11, we observe that as Eckert number (E) increases, the temperature increases. This is due to the fact that heat energy is stored in liquid due to the frictional heating. Thus the effect of increasing Eckert number is to enhance the temperature. From Fig. 12, it is noticed that the concentration (C) increases as Soret number (S_0) increases. The influence of

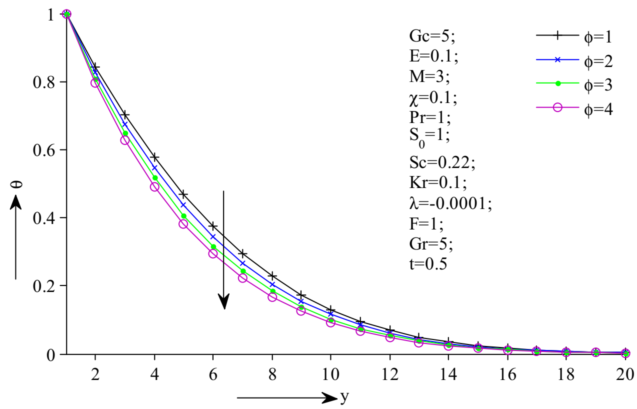

Figure 9 Effect of heat absorption parameter on temperature.

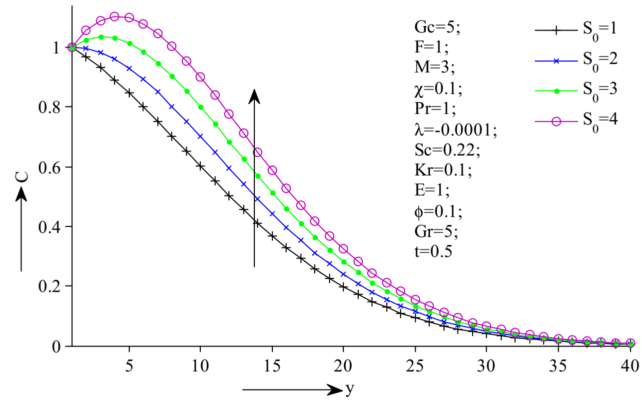

Figure 12 Effect of Soret number on concentration.

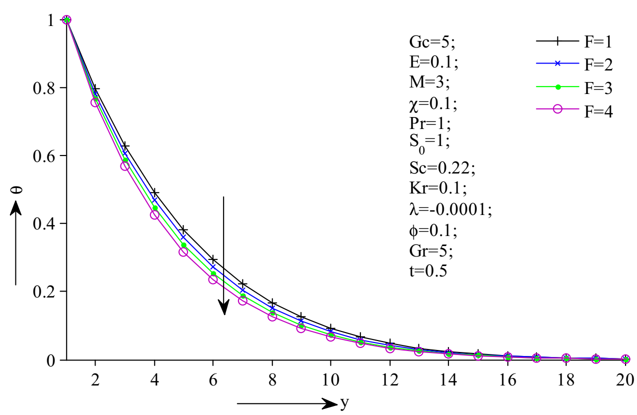

Figure 10 Effect of radiation parameter on temperature.

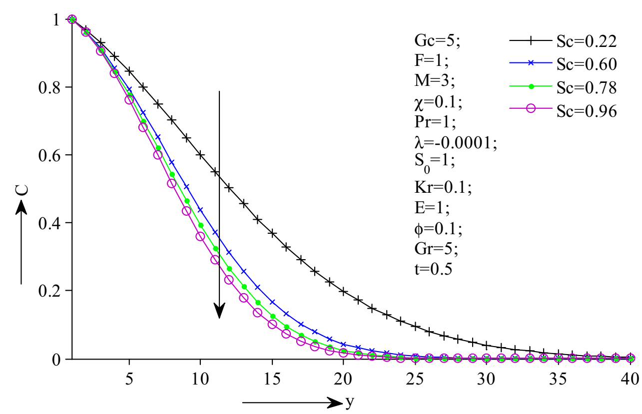

Figure 13 Effect of Schmidt number on concentration.

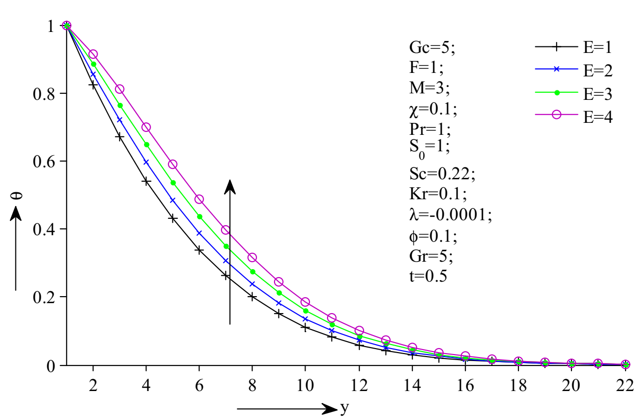

Figure 11 Effect of Eckert number on temperature.

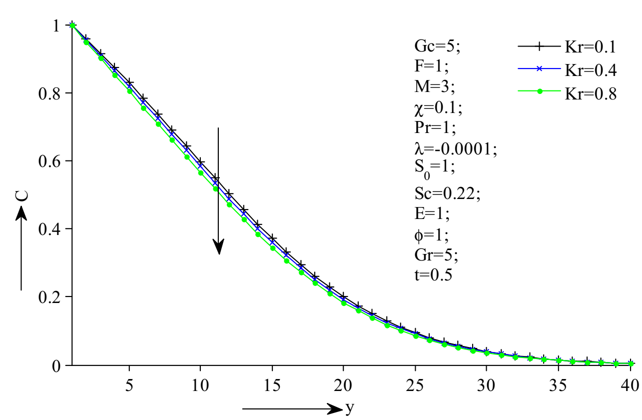

Figure 14 Effect of chemical reaction parameter on concentration.

Schmidt number on concentration is shown in Fig. 13. From this figure it is noticed that concentration decreases with an increase in Schmidt number. Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity which is used to characterize fluid flows with simultaneous momentum and mass diffusion convection processes. Therefore concentration boundary layer decreases with an increase in Schmidt number. From Fig. 14 we observed that the concentration (C) decreases as the values of chemical reaction (Kr) increase. The effects of Grashof number (G), modified Grashof number (Gc) and Soret number S_0 on Skin friction are represented in Figs. 15–17. From these figures it is noticed skin friction decreases as an increase in Grashof number, modified Grashof number and Soret number. Figs. 18–20 demonstrate the effect of radiation parameter (F), heat absorption parameter (ϕ) and radiation absorption parameter (χ) on Nusselt number (Nu). It is observed that

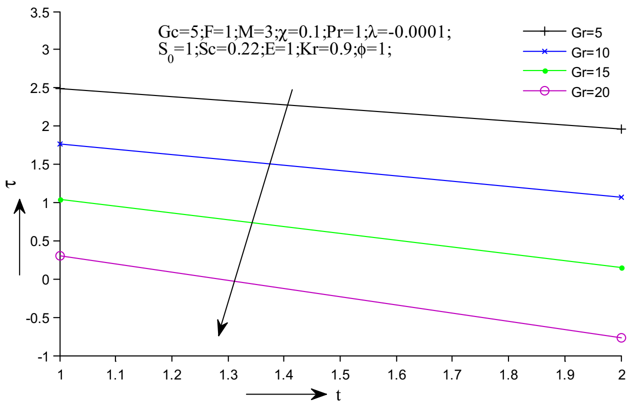

Figure 15 Effect of Grashof number on skin friction.

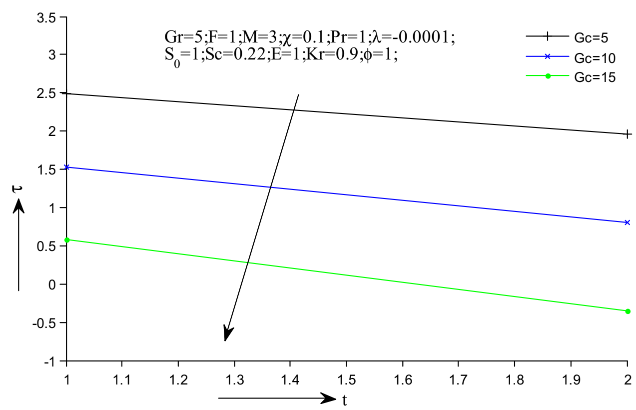

Figure 16 Effect of modified Grashof number on skin friction.

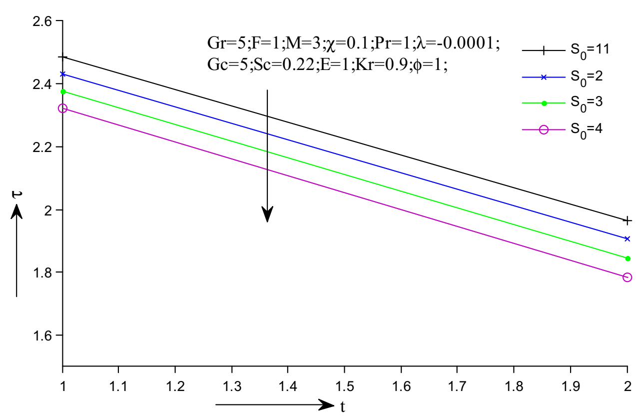

Figure 17 Effect of Soret number on skin friction.

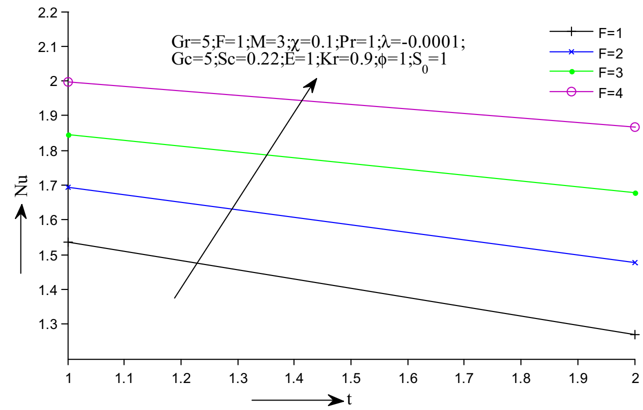

Figure 18 Effect of radiation parameter on Nusselt number.

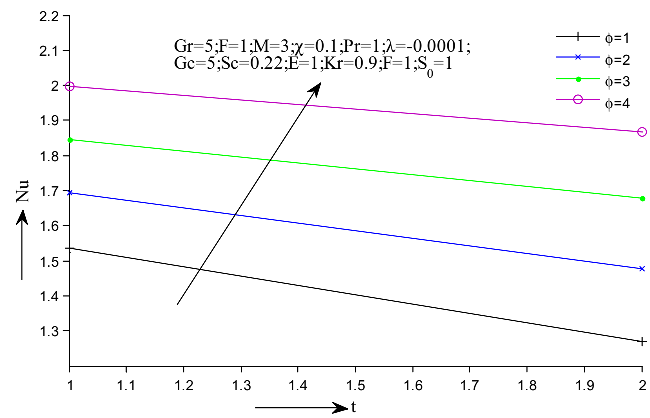

Figure 19 Effect of heat absorption parameter on Nusselt number.

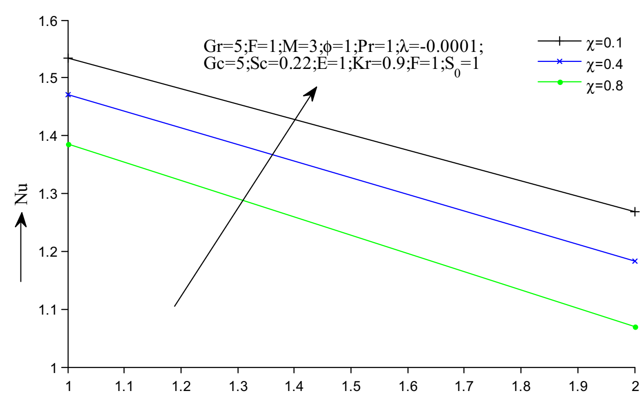

Figure 20 Effect of radiation absorption parameter on Nusselt number.

Nusselt number increases as radiation parameter, heat absorption parameter increases and Nusselt number decreases as radiation absorption parameter increases. Figs. 21 and 22 display the effect of visco-elastic parameter on velocity and skin friction. It is evident that increasing values of visco-elastic parameter leads to enhance the velocity and decreases the skin friction. Figs. 23 and 24 demonstrate the effect of visco-elastic parameter on temperature and Nusselt number. It is noticed that the temperature rises for increasing values of visco-elastic parameter whereas an opposite an opposite trend is noticed in the case of Nusselt number.

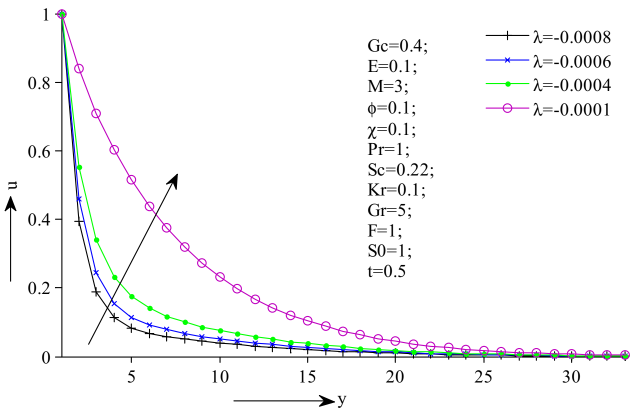

Figure 21 Effect of visco-elastic parameter on velocity.

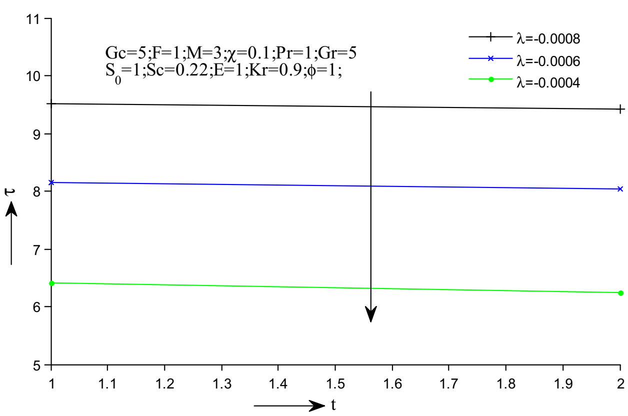

Figure 22 Effect of visco-elastic parameter on skin friction.

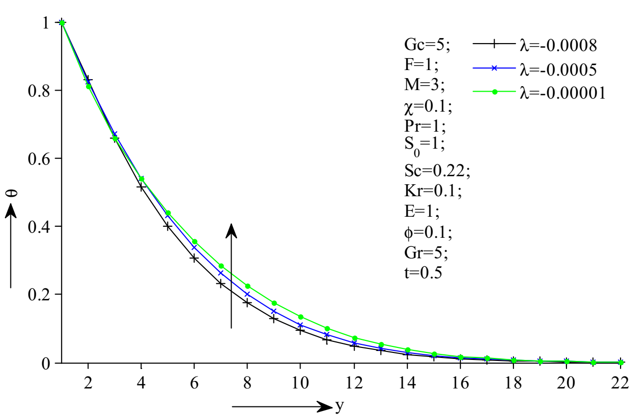

Figure 23 Effect of visco-elastic parameter on temperature.

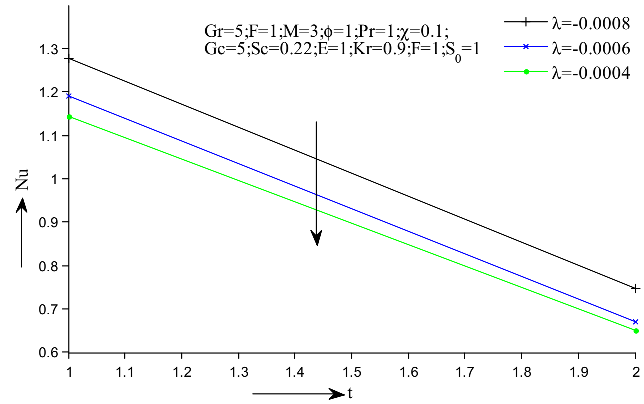

Figure 24 Effect of visco-elastic parameter on Nusselt number.

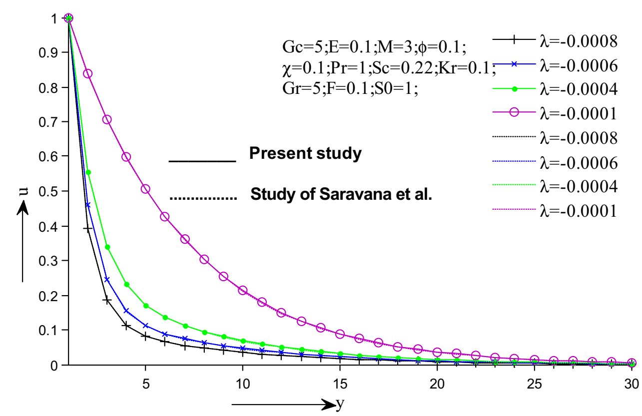

Figure 25 Effect of visco-elastic parameter on velocity in the absence of radiation parameter, heat absorption, radiation absorption parameter, Soret number and chemical reaction parameter.

5. Conclusion

We investigated the MHD free convection flow of a non-Newtonian fluid past an impulsively started vertical plate in the presence of chemical reaction, thermal diffusion, radiation absorption, thermal radiation and heat absorption with constant mass flux. The governing boundary-layer equations are formulated with appropriate boundary conditions. The governing boundary layer equations are simplified and non-dimensionalized. The dimensionless equations are solved by using the finite difference method. The effects of various physical parameters such as Grashof number (Gr), modified Grashof number (Gc), magnetic field parameter (M), Schmidt number (Sc), Soret number (S_0), Prandtl number (Pr), radiation absorption parameter (χ), heat absorption parameter (ϕ), radiation parameter (F), Eckert number (E), chemical reaction parameter (Kr) are considered on the dimensionless velocity, temperature and concentration. Computations on the variation of local skin friction, Nusselt number and Sherwood number are also recorded. From the graphs plotted, we discover that:

(1) Velocity decreases with an increase in magnetic field parameter, Schmidt number, Prandtl number and visco-elastic parameter while it increases with an increase in Grashof number, modified Grashof number and Soret number.
(2) Temperature increases with an increase in radiation absorption parameter, visco-elastic parameter, Eckert number while it decreases with an increase in radiation parameter, Prandtl number and heat absorption parameter.

(3) Concentration increases with an increase in Soret number while it decreases with an increase in Schmidt number and chemical reaction parameter.
(4) Local skin friction decreases for rising values of Grashof number, modified Grashof number, visco-elastic parameter and Soret number.
(5) Nusselt number increases with an increase in radiation parameter and heat absorption parameter whereas it shows a reverse effect in the case of radiation absorption parameter and visco-elastic parameter.

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