

Unsteady MHD convective Casson fluid flow past a vertical porous plate in the presence of radiation and thermal diffusion

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Abstract

This manuscript presents a detailed numerical study on the influence of radiation, radiation absorption, chemical reaction and Soret number on unsteady magneto hydrodynamic free convective heat and mass transfer flow of a heat generating Casson fluid past an oscillating vertical plate embedded in a porous medium in the presence of constant wall temperature and concentration. The non dimensional governing equations along with the corresponding boundary conditions are solved using finite difference method numerically. Effects of various emerging flow parameters on velocity, temperature and concentration are presented graphically and analyzed. Expressions for skin-friction, Nusselt number and Sherwood number are also obtained.

Keywords: Casson fluid, MHD, porous medium, heat and mass transfer, chemical reaction, radiation absorption, heat generation.

1. Introduction:

Casson fluid is one type of non - Newtonian fluid. Casson fluid can be defined as a shear thinning liquid which is supposed to have an infinite viscosity at zero rate of shear and a yield stress under which no flow occurs and zero viscosity at an infinite rate of shear. If yield stress greater than the shear stress is applied to the fluid, it behaves like solid. If yield stress less than the shear stress then fluid starts move. Honey, soup, concentrated juices are few examples of Casson fluid.

In nature, a non-Newtonian fluid acts as elastic solid, i.e. the flow does not occur with small shear stress. Casson fluid is one of the non-Newtonian fluids. It is first invented by Casson in 1959. It is based on the structure of liquid phase and interactive behavior of solid of a two-phase

suspension. Some examples of Casson fluid are Jelly, honey, tomato sauce and concentrated fruit juices. Human blood can also be treated as a Casson fluid in the presence of several substances such as fibrinogen, globulin in aqueous base plasma, protein, and human red blood cells. Squeezing flows are generated by natural stresses or vertical velocities of the moving boundary layer. The practical examples of squeezing flow are compression, polymer processing, and injection molding. The system of lubrication can also be demonstrated by squeezing flow. Hayat et al. [1] studied three-dimensional MHD flow of Casson fluid in porous medium with heat generation. Ramesh and Devakar [2] presented some analytical solutions for flows of Casson fluid with slip boundary conditions. Sandeep et al. [3] analyzed the effects of induced magnetic field and homogeneous-heterogeneous reactions on stagnation flow of a Casson fluid. Umamaheswar et al. [4] discussed the effects of time dependent variable temperature and concentration boundary layer on MHD free convection flow past a vertical porous plate in the presence of thermal radiation and chemical reaction. Chandra Reddy et al. [5] analyzed diffusion thermo and thermal diffusion effects on MHD free convection flow of Rivlin-Ericksen fluid past a semi infinite vertical plate. Daba and Devaraj [6] established unsteady hydromagnetic chemically reacting mixed convection flow over a permeable stretching surface with slip and thermal radiation. Sathish Kumar et al. [7] considered unsteady MHD nonlinear radiative squeezing slip-flow of Casson fluid between parallel disks. Chandra Reddy et al. [8] studied magnetohydrodynamic convective double diffusive laminar boundary layer flow past an accelerated vertical plate. Rashidi et al. [9] examined free convective heat and mass transfer for MHD fluid flow over a permeable vertical stretching sheet in the presence of the radiation and buoyancy effects. Nadeem et al. [10] analyzed MHD three-dimensional Casson fluid flow past a

porous linearly stretching sheet. Shehzad et al. [11] established three dimensional MHD flow of Casson fluid in porous medium with heat generation. Mukhopadhyay et al. [12] considered MHD boundary layer flow of Casson fluid passing through an exponentially stretching permeable surface with thermal radiation. Umamaheswar et al. [13] presented a numerical study of Magneto-Convective and radiation absorption fluid flow past an exponentially accelerated vertical porous plate with variable temperature and concentration in the presence of Soret and Dufour effects. Sulochana et al. [14] discussed uniform heat source or sink effect on the flow of 3D Casson fluid in the presence of Soret and thermal radiation. Chandra Reddy et al. [15] examined thermal and solutal buoyancy effect on MHD boundary layer flow of a visco-elastic fluid past a porous plate with varying suction and heat source in the presence of thermal diffusion. Umamaheswar et al. [16] studied MHD convective heat and mass transfer flow of a Newtonian fluid past a vertical porous plate with chemical reaction, radiation absorption and thermal diffusion. Chandra Reddy et al. [17] considered free convective heat and mass transfer flow of heat generating nano fluid past a vertical moving porous plate in conducting field. Sidda Reddy et al. [18] analyzed thermal diffusion and Joule heating effects on MHD radiating fluid embedded in porous medium. Harinath Reddy et al. [19] examined Joule heating and radiation absorption effects on MHD convective and chemically reactive flow past a porous plate. Umamaheswar et al. [20] examined unsteady MHD free convective double diffusive visco-elastic fluid flow past an inclined permeable plate in the presence of viscous dissipation and heat absorption.

Keeping in mind the work done by previous researchers, we made an attempt to analyze radiation, radiation absorption and chemical reaction effects on unsteady magneto hydrodynamic free convective heat and mass transfer flow of a heat absorbing/generating Casson fluid past an oscillating vertical plate embedded in a porous medium in the presence of constant wall temperature and concentration. The novelty of this work is the consideration of radiation parameter, radiation absorption parameter, heat source/sink, thermal diffusion and chemical reaction in conservation of energy and mass diffusion equations respectively. We have extended the work of Khalid et al. [21] by including the presence of above mentioned flow parameters. This is not a simple extension of the previous work; it varies several aspects from that such as the presence of mass transfer in the momentum equation, radiation absorption inclusion in the energy equation and the

addition of species diffusion equation. Apart from the modification of set of governing equations, we also changed the method of solution due to the existence of non linear coupled partial differential equations which are solved by finite difference method instead of Laplace transform technique.

2. Formulation of the problem:

Influence of radiation absorption and homogeneous chemical reaction on unsteady MHD free convection heat and mass transfer flow of heat absorbing/generating Casson fluid past a semi-infinite oscillating vertical plate embedded in uniform porous medium with constant wall temperature and concentration is considered. Let x-axis taken towards upward direction along with the fluid and y-axis is taken normal to it. The fluid assumed here is an electrically conducting with a uniform magnetic field of strength B_0 is applied in a direction perpendicular to the plate. The magnetic Reynold's number is assumed to be very small so that it may be ignored in comparison with magnetic field. Initially at $t=0$, the fluid is assumed to be at rest and the plate and fluid are maintained at uniform temperature and concentration. For $t > 0$, the plate begins to oscillate in its own plane ($y=0$) in the form

$$V = UH(t)\cos(\omega t)i \text{ (or) } V = U\sin(\omega t)i$$

Where $H(t)$ is the unit step function, constant U is the amplitude of the plate oscillations, i is the unit vector in the vertical flow direction and ω is the frequency of oscillation of the plate. At the same time, the plate temperature is raised to T_w which is thereafter maintained constant.

The tensor of the Casson fluid can be written as

$$\tau = \tau_0 + \mu\gamma^*$$

or

$$\tau_{ij} = \begin{cases} 2 \left(\mu_B + \frac{P_y}{\sqrt{2\pi}} \right) e_{ij}, \pi > \pi_c \\ 2 \left(\mu_B + \frac{P_y}{\sqrt{2\pi_c}} \right) e_{ij}, \pi < \pi_c \end{cases}$$

Where $\pi = e_{ij} e_{ij}$ and e_{ij} is the $(i,j)^{th}$ component of deformation rate, π is the product of the component of deformation rate with itself, π_c is the critical value of this product based on the non-Newtonian fluid, μ_B is the plastic dynamic

viscosity of its fluid and is yield stress of the non-Newtonian fluid. Before forming the governing equations we have taken some assumptions that are unidirectional flow, one dimensional flow, free convection, rigid plate, incompressible flow, unsteady flow, non-Newtonian flow, oscillating vertical plate and viscous dissipation term in the energy equation is neglected. Considering the above assumptions we have formed the following set of partial differential equations.

$$\left. \begin{aligned} \rho \frac{\partial u'}{\partial t'} &= \mu_\beta \left(1 + \frac{1}{\gamma} \right) \frac{\partial^2 u'}{\partial y'^2} - \sigma B_0^2 u' - \frac{\mu \phi}{k_1} u' \\ &+ \rho g \beta (T' - T_\infty) + \rho g \beta^* (C' - C_\infty) \end{aligned} \right\} (1)$$

$$\left. \begin{aligned} \rho C_p \frac{\partial T'}{\partial t'} &= k \frac{\partial^2 T'}{\partial y'^2} - \frac{\partial q_r}{\partial y'} + Q'(T' - T_\infty) + \\ &Q_1(C' - C_\infty) + \sigma B_0^2 u'^2 \end{aligned} \right\} (2)$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y'^2} + D_1 \frac{\partial^2 T'}{\partial y'^2} - Kr'(C' - C_\infty) \quad (3)$$

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:

$$\frac{\partial q_r}{\partial y'} = 4(T' - T_\infty)I \quad \text{Where}$$

$$I = \int K_{\lambda w} \frac{\partial e_{b\lambda}}{\partial T^*} d\lambda = \frac{Q_1 \nu (C_w - C_\infty)}{\rho C_p u_0^2 (T_w - T_\infty)}, \quad (\text{Radiation absorption parameter})$$

The initial and boundary conditions are

$$\left. \begin{aligned} t' < 0: u' = 0, T' = T_\infty, C' = C_\infty & \quad \text{for all } y' < 0 \\ t' \geq 0: u' = u_0 \sin(w't'), T' = T_w, C' = C_w & \quad \text{at } y' = 0 \\ u' \rightarrow 0, T' \rightarrow T_\infty, C' \rightarrow C_\infty & \quad \text{as } y' \rightarrow \infty \end{aligned} \right\} (4)$$

On introducing the following non-dimensional quantities

$$\begin{aligned} u &= \frac{u'}{u_0}, \quad t = \frac{t' u_0^2}{\nu}, \quad y = \frac{y' u_0}{\nu}, \\ \theta &= \frac{T' - T_\infty}{T_w - T_\infty}, \quad C = \frac{C' - C_\infty}{C_w - C_\infty} \\ Gr &= \frac{\nu g \beta (T_w - T_\infty)}{u_0^3}, \quad (\text{Grashof number}) \end{aligned}$$

$$Gc = Gr = \frac{\nu g \beta^* (C_w - C_\infty)}{u_0^3}, \quad (\text{Modified Grashof number})$$

$$K = \frac{k_1 u_0^2}{\phi \nu^2}, \quad (\text{Permeability parameter})$$

$$M = \frac{\sigma B_0^2 \nu}{\rho u_0^2}, \quad (\text{Magnetic parameter})$$

$$Pr = \frac{\nu \rho C_p}{k}, \quad (\text{Prandtl number})$$

$$E = \frac{u_0^2}{C_p (T_w - T_\infty)}, \quad (\text{Eckert number})$$

$$(2) \quad Sc = \frac{\nu}{D}, \quad (\text{Schmidt number})$$

$$Q = \frac{Q' \nu}{\rho C_p u_0^2}, \quad (\text{Heat absorption parameter}) \quad (3)$$

$$R = \frac{4\nu I}{\rho C_p u_0^2}, \quad (\text{Radiation parameter})$$

$$Sr = \frac{D_1 (T_w - T_\infty)}{\nu (C_w - C_\infty)}, \quad (\text{Soret number})$$

$$(4) \quad Kr = \frac{Kr' \nu}{u_0^2}, \quad (\text{Chemical reaction parameter})$$

γ (Casson parameter)

In terms of the above non-dimension quantities, Equations (1)-(3) reduces to

$$\frac{\partial u}{\partial t} = \left(1 + \frac{1}{\gamma} \right) \frac{\partial^2 u}{\partial y^2} - M u - \frac{1}{K} u + Gr \theta + Gm C \quad (5)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial y^2} - R \theta + Q \theta + \chi C + M Ecu^2 \quad (6)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc} \frac{\partial^2 C}{\partial y^2} + Sr \frac{\partial^2 \theta}{\partial y^2} - Kr C \quad (7)$$

The corresponding initial and boundary conditions are:

$$\left. \begin{aligned} t < 0 : u = 0, T = 0, C = 0 \text{ for all } y < 0 \\ t \geq 0 : u = \sin(wt), \theta = 1, \\ C = 1 \\ u \rightarrow 0, T \rightarrow 0, C^* \rightarrow 0 \text{ as } y \rightarrow \infty \end{aligned} \right\} \text{at } y = 0 \quad (8)$$

3. Method of solution:

Equations (5)-(7) are coupled non-linear 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:

$$\left. \begin{aligned} \frac{u_{i,j+1} - u_{i,j}}{\Delta t} = \left(1 + \frac{1}{\gamma}\right) \left(\frac{u_{i-1,j} - 2u_{i,j} + u_{i+1,j}}{(\Delta y)^2} \right) - \\ M u_{i,j} - \frac{1}{K} u_{i,j} + Gr \theta_{i,j} + Gc C_{i,j} \end{aligned} \right\} \quad (9)$$

$$\left. \begin{aligned} \frac{\theta_{i,j+1} - \theta_{i,j}}{\Delta t} = \frac{1}{Pr} \left(\frac{\theta_{i-1,j} - 2\theta_{i,j} + \theta_{i+1,j}}{(\Delta y)^2} \right) - \\ R \theta_{i,j} + Q \theta_{i,j} + \chi C_{i,j} + M Ec (u_{i,j})^2 \end{aligned} \right\} \quad (10)$$

$$\left. \begin{aligned} \frac{C_{i,j+1} - C_{i,j}}{\Delta t} = \frac{1}{Sc} \left(\frac{C_{i-1,j} - 2C_{i,j} + C_{i+1,j}}{(\Delta y)^2} \right) + \\ Sr \left(\frac{\theta_{i-1,j} - 2\theta_{i,j} + \theta_{i+1,j}}{(\Delta y)^2} \right) - Kr C_{i,j} \end{aligned} \right\} \quad (11)$$

Here, index i refer to y and j to time. The mesh system is divided by taking $\Delta y = 0.04$. From the initial condition in (8), we have the following equivalent:

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

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

$$\left. \begin{aligned} u(0, j) = 1, \theta(0, j) = 1, C(0, j) = 1 \text{ for all } j \\ u(i_{\max}, j) = \sin(w * (j - 1) * \Delta t), \\ \theta(i_{\max}, j) = 1, C(i_{\max}, j) = 1 \end{aligned} \right\} \text{for all } j$$

(Here i_{\max} was taken as 201)

First the velocity at the end of time step viz, $u(i, j+1)$, ($i=1,201$) is computed from (9) in terms of velocity, temperature and concentration at points on the earlier time-step. Then $\theta(i, j+1)$ is computed from (10) and $C(i, j+1)$ is computed from (11). The procedure is repeated until $t = 0.05$ (i.e. $j = 500$). During computation Δt was chosen as 0.0001.

Skin-friction:

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

$$\tau = - \left(1 + \frac{1}{\gamma} \right) \left(\frac{du}{dy} \right)_{y=0}, \text{ where } \tau^* = \frac{\tau}{\rho u_0^2}$$

Rate of heat transfer:

The dimensionless rate of heat transfer is given by

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

Rate of mass transfer:

The dimensionless rate of mass transfer is given by

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

4. Result and Discussion:

(11) A Numerical study has been carried out on the MHD flow of a Casson fluid. The effects of various physical parameters such as Grashof number, modified Grashof number, Casson parameter, magnetic parameter, permeability parameter, Prandtl number, heat source, radiation parameter, Schmidt number and Sorret number on velocity, temperature and concentration are discussed with help of graphs whereas Skin friction, Nusselt number and Sherwood are also discussed with the help of tables. In Fig.1, the 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 from Fig.2, in the presence of modified Grashof number, which also increases fluid velocity. 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 of

magnetic parameter. 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 shows that the velocity increases with an increase in permeability parameter. This is due to the fact that increasing values of K reduces the drag force which assists the fluid considerably to move fast. Fig.5, demonstrates that the velocity decreases with an increase in Casson parameter. Fig.6 indicates that a rise in Pr substantially reduces the temperature in the viscous fluid. It can be found from Fig.6 that the solutal boundary layer thickness of the fluid enhances with the increase of Pr . Fig.7, depicts the effect of heat source on temperature. It is noticed that the temperature is increased by an increase in the heat source by the fluid. The central reason behind this effect is that the heat source causes a increase in the kinetic energy as well as thermal energy of the fluid. The momentum and thermal boundary layers get thinner in case of heat source fluids. Fig.8, demonstrates the effect of radiation parameter on temperature. It is observed that temperature decreases as radiation parameter increases. Fig.9 depicts the variations in temperature profile for different values of radiation absorption parameter. It is noticed that temperature increases as radiation absorption parameter

increases. Influence of Schmidt number on concentration is shown in fig.10, from this figure it is noticed that concentration decreases with an increase in Schmidt number. Because, Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity, and is used to characterize fluid flows in which there are simultaneous momentum and mass diffusion convection processes. Therefore concentration boundary layer decreases with an increase in Schmidt number. Fig.11 indicates that, concentration profile decreases with an increase in Kr . From Fig.12, we observe that the concentration increases as Soret number increases. Table.1, shows that Skin friction increase with an increase in magnetic parameter, heat source, chemical reaction parameter, Schmidt number, Prandtl number and radiation parameter while it decrease with an increase in Grashof number, modified Grashof number, permeability parameter and Soret number. From table.2, we observed that the Nusselt number increase with increasing values of Prandtl number and radiation parameter while it decreases with increasing value of heat source and radiation absorption parameter. From table.3, we have seen that the Sherwood number increase with increasing values of Schmidt number and chemical reaction parameter and it shows reverse trend in the case of Soret number.

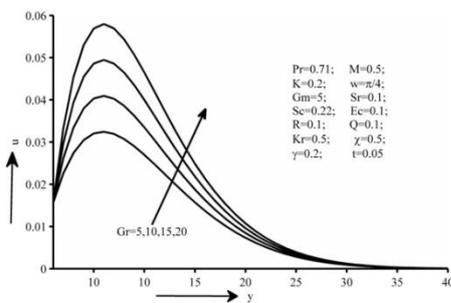


Fig.1: Effect of Grashof number on velocity

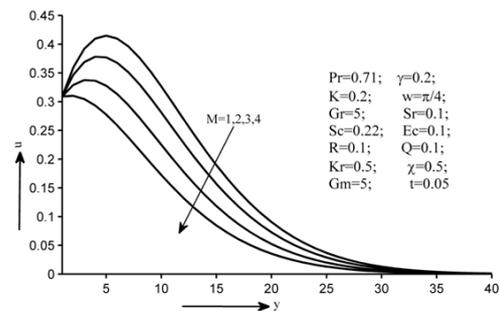


Fig.3: Effect of magnetic parameter on velocity

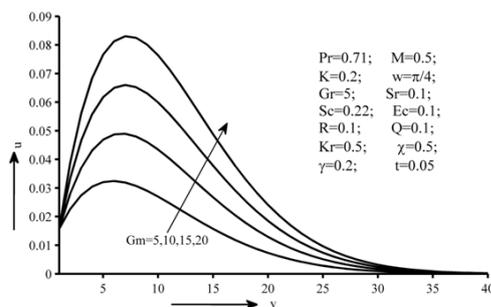


Fig.2: Effect of modified Grashof number on velocity

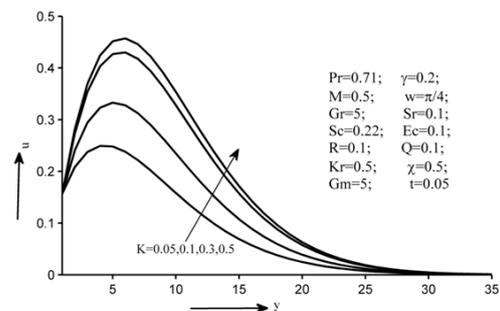


Fig.4: Effect of permeability parameter on velocity

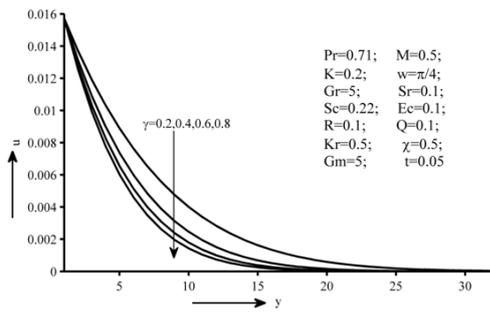


Fig.5: Effect Casson parameter on velocity

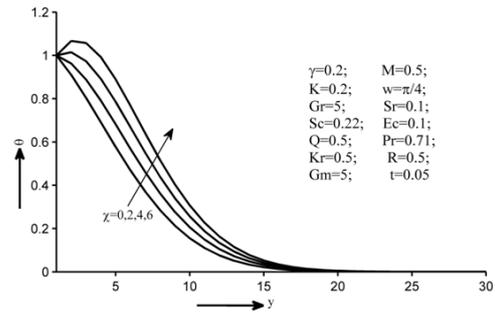


Fig.9: Effect of radiation absorption parameter on temperature

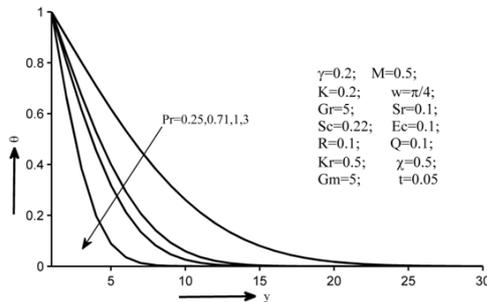


Fig.6: Effect of Prandtl number on temperature

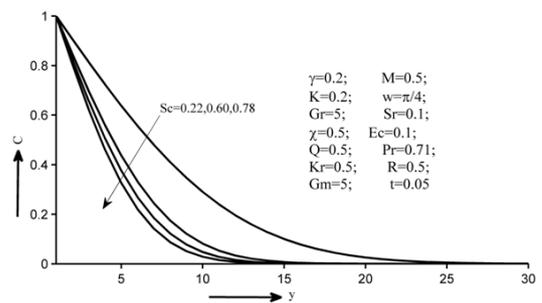


Fig.10: Effect of Schmidt number on concentration

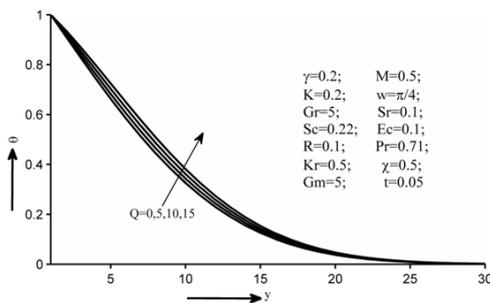


Fig.7: Effect of heat source on temperature

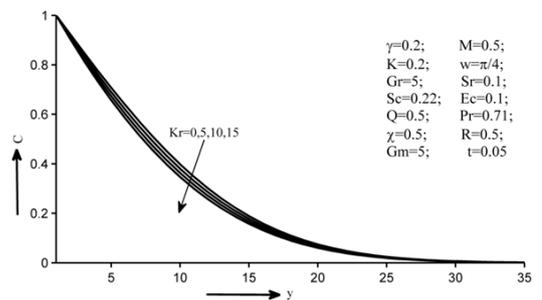


Fig.11: Effect of chemical parameter on concentration

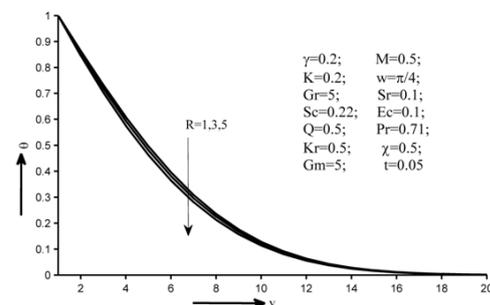


Fig.8: Effect of radiation parameter on temperature

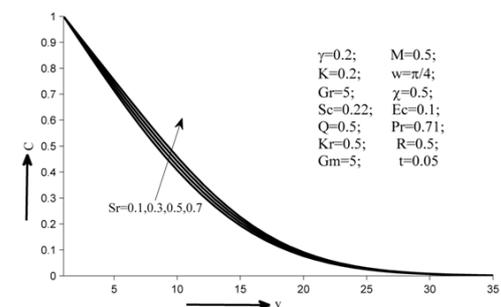


Fig.12: Effect of Soret number on concentration

Table.1: Variations in skin friction for different values of flow parameters

Gr	Gm	M	K	Pr	Q	R	Sc	Kr	Sr	τ
5	5	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.0307
10	5	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.0189
15	5	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	-0.0240
20	5	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	-0.0432
5	10	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.0483
5	15	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.0206
5	20	3	0.8	0.71	0.8	0.8	0.22	0.8	0.1	-0.0342
5	5	0.5	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.0892
5	5	1	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.1204
5	5	2	0.8	0.71	0.8	0.8	0.22	0.8	0.1	0.1686
5	5	3	0.1	0.71	0.8	0.8	0.22	0.8	0.1	0.0534
5	5	3	0.3	0.71	0.8	0.8	0.22	0.8	0.1	0.0421
5	5	3	0.5	0.71	0.8	0.8	0.22	0.8	0.1	0.0280
5	5	3	0.8	1	0.8	0.8	0.22	0.8	0.1	0.0584
5	5	3	0.8	3	0.8	0.8	0.22	0.8	0.1	0.0638
5	5	3	0.8	7.1	0.8	0.8	0.22	0.8	0.1	0.0872
5	5	3	0.8	0.71	0.5	0.8	0.22	0.8	0.1	0.0482
5	5	3	0.8	0.71	1	0.8	0.22	0.8	0.1	0.0496
5	5	3	0.8	0.71	2	0.8	0.22	0.8	0.1	0.0524
5	5	3	0.8	0.71	0.8	0.1	0.22	0.8	0.1	0.0708
5	5	3	0.8	0.71	0.8	0.5	0.22	0.8	0.1	0.0886
5	5	3	0.8	0.71	0.8	1	0.22	0.8	0.1	0.0920
5	5	3	0.8	0.71	0.8	0.8	0.60	0.8	0.1	0.0675
5	5	3	0.8	0.71	0.8	0.8	0.78	0.8	0.1	0.0898
5	5	3	0.8	0.71	0.8	0.8	0.96	0.8	0.1	0.0983
5	5	3	0.8	0.71	0.8	0.8	0.22	1	0.1	0.0468
5	5	3	0.8	0.71	0.8	0.8	0.22	2	0.1	0.0476
5	5	3	0.8	0.71	0.8	0.8	0.22	3	0.1	0.0496
5	5	3	0.8	0.71	0.8	0.8	0.22	0.8	1	0.0383
5	5	3	0.8	0.71	0.8	0.8	0.22	0.8	2	0.0365

Table.2: Variations in Nusselt number

Pr	Q	R	χ	Nu
0.71	0.8	0.8	0.1	5.4526
1	0.8	0.8	0.1	6.3029
3	0.8	0.8	0.1	9.6269
7.1	0.8	0.8	0.1	14.0283
0.71	0.1	0.8	0.1	5.3586
0.71	0.3	0.8	0.1	5.3391
0.71	0.5	0.8	0.1	5.3252
0.71	1	0.8	0.1	5.3064
0.71	0.8	0.5	0.1	5.4092
0.71	0.8	1	0.1	5.6124
0.71	0.8	2	0.1	5.8872
0.71	0.8	0.8	1	4.5234
0.71	0.8	0.8	2	3.6963
0.71	0.8	0.8	3	3.0623
0.71	0.8	0.8	4	2.6254

Table.3: Variations in Sherwood number

Sc	Kr	Sr	Sh
0.22	0.8	0.1	3.6834
0.60	0.8	0.1	4.6534
0.78	0.8	0.1	4.9342
0.96	0.8	0.1	5.6859
0.22	0.1	0.1	3.1460
0.22	0.3	0.1	3.2512
0.22	0.5	0.1	3.3663
0.22	0.9	0.1	3.3893
0.22	0.8	1	2.2005
0.22	0.8	2	1.6674
0.22	0.8	3	0.8215
0.22	0.8	4	0.6299

5. Conclusion:

In this manuscript a numerical analysis is carried out to investigate the radiation, radiation absorption, Soret number and chemical reaction effects on MHD heat and mass transfer flow of a Casson fluid past an oscillating vertical porous plate with heat generation. The non-dimensional governing equations are solved with the help of explicit finite difference method. The effects of various flow parameters on concentration, temperature and velocity profile are demonstrated through graphs. The effects of some flow parameter on Skin-friction, Nusselt number and Sherwood number are also presented in tables. The following are the conclusions of this manuscript.

1. Velocity of the Casson fluid decreases with increasing values of M , γ whereas it increases with increasing values of Gr , G_m and K .
2. Temperature of the Casson fluid increases with increasing values of R , Q and χ whereas reverse trend is seen in the case of R and Pr .
3. Concentration of Casson fluid decreases with an increasing value of Sr and shows reverse effect in the case of Sc and Kr .
4. Skin friction increase with an increase in magnetic parameter, heat source, chemical

reaction parameter, Schmidt number, Prandtl number and radiation parameter while it decrease with an increase in Grashof number, modified Grashof number, permeability parameter and Soret number.

5. Nusselt number increase with increasing values of Prandtl number and radiation parameter while it decreases with increasing value of heat source and radiation absorption parameter.
6. Sherwood number increase with increasing values of Schmidt number and chemical reaction parameter and it shows reverse trend in the case of Soret number.

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