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MHD unsteady thermal radiation transfer of mass under the porous oscillatory stretching surface impact of source/sink

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Abstract

The current work evaluates MHD thermal heat and transfer of mass of Casson fluid flow across a porous oscillatory stretching sheet with uniform source heat, sink and thermal radiation. Governing flow equations are modified to non-linear coupled differential equations by applying the dimensionless variables. Results of flow velocity and profile temperature, concentration profile for some characteristics parametersare evaluated and discussed graphs.

Keywords: Casson fluid, Oscillatory stretching sheet, Uniform heat sourceor sink, Thermal radiation, Perturbation method.

Introduction

The explore of stretching surface flow has an vast utilization in engineering and industrial process. Non-Newtonian fluid plays a most important role in food products, extrusion and injection moulding of plastic items, chemicals and petroleum industry and the preparation of paints. Relation between the non-Newtonian fluid stress of tangential and the rate of strain defined non-linear and also described by time dependent. Therefore there is no way to defining constant viscosity coefficient. Generally non-Newtonian fluids are complex mixture such as polymer solution, pasters, slurries, gels, quick sand, cornflour, starch suspensions, paints, clay suspensions, ketch up, paint etc.

Pseudoplastic fluid with infinite viscosity at zero shear rate, a yield strength without flow exist and a viscosity of zero at an infinite shear rate is a Casson fluid. Casson's model commonly known as rheological time independent model was created by Casson. Casson fluid viscosity decreases with increasing of shear stress i.e) which flow freely at high rate of deformation. Sarpkaya[1] examined flow of uniformly conducting flow of non-Newtonian model in the impact of magnetic induction. Several authors have developed Casson fluid theory in various geometries[2]-[5]. Gopal et.al., [6] analyzed numerical approach on flow of Casson fluid in stretching surface in the effect of inclined magnetic induction, dissipation of viscous and joule, heat source or sink and chemical rate reaction with multiple slips.

Machireddy[7] evaluated the analytical approach on magnetohydrodynamic steady state of laminar electrical conducting viscous flow along in a vertical permeable sheet under the impact of viscous and Ohmic dissipation, radiationabsorption, and chemical dispersal reaction. Manjula Jonnadula et.al.,[8] examined numerical study on boundary layer electrically conducting fluid flow with combined result of heat radiation and chemical reaction over the porous medium. Bala Anki Reddy[9]exhibited the outcome of heat radiation and chemical dispersal rate reaction of Casson fluid over an the exponentially inclined surface. Zeeshan et.al., [10] evaluated the non-Newtonian flow in vertical plate under the existence of heat source or sink, radiation, and rate of chemical dispersal.

Abbas et.al., [11] examined the numerical and analytical study on MHD viscoelastic fluid flow on second grade model along a oscillatory channel. Sami Ullah Khan et.al., [12] evaluated the Darcy-Forcheimer model of unsteady MHD flow along saturated permeable oscillatory stretching surface under a influence thermophoresis and heat generation/apsorption by employing the homotopy technique. Sheikh and Zaheer Abbas [13] investigated occurrence of absorption of heat and generation, thermophoresis and chemical reaction onmagnetohydrodynamic viscous flow by cause of an oscillatory sheet.

1 Mathematical formulation

Assuming unsteady 2-D magnetohydrodynamic incompressible oscillatory Casson fluid flow across an stretching porous sheet. Alongside the sheet x^*-axis is considered and y^*- axis is chosen vertical of the sheet. Suppose a sheetis stretched with the axial velocity $u = bx^* \sin \omega t$, here b refers the rate of stretching and ω defines angular velocity. The outcome of heat and mass transfer under the existence of radiation and source or sink has been evaluated. $T\omega$ are assumed as sheet temperature and T_∞ refers ambient temperature at the value of $y \to \infty$. C_ω represents wall concentration. C_∞ refers the ambient concentration at the value of $y \to \infty$. A magnetic induction B_0 is given vertical to the sheet. The isotropic equation for a Casson fluid's rheological flow is described by [14]

$$\tau_{ij} = \begin{Bmatrix} 2\left(\frac{\mu_D+P_y}{\sqrt{2\pi}}\right)e_{ij}, & \pi > \pi_a \\ 2\left(\frac{\mu_D+P_y}{\sqrt{2\pi_a}}\right)e_{ij}, & \pi < \pi_a \end{Bmatrix}$$

where, (π_{ij}) tensor of stress, ($\pi = e_{ij}e_{ij}$) and (e_{ij}) deformation component (i,j) , (π) product of deformation rate, (π_a) product critical value, (μ_D) plastic dynamic viscosity, (Py) yield stress, ($\beta = \frac{\mu_D\sqrt{2\pi_a}}{P_y}$) parameter of casson fluid.

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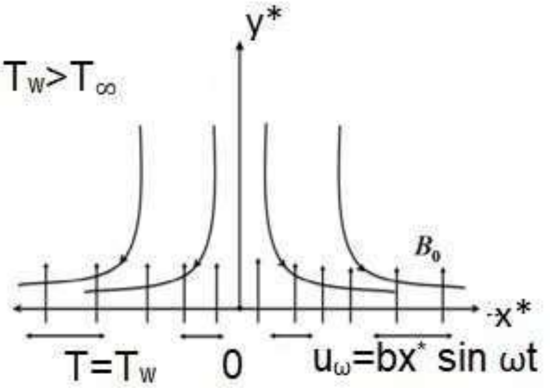

The conservative approximation of boundary layer flow equations derivedby,

$$\frac{\partial u}{\partial x^*} + \frac{\partial v}{\partial y^*} = 0 \qquad (1)$$

$$u\frac{\partial u}{\partial x^*} + v\frac{\partial v}{\partial y^*} = \nu\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^{*2}} - \frac{\sigma {B_0}^2}{\rho}u - \frac{\nu}{k}\Phi u \qquad (2)$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x^*} + v\frac{\partial T}{\partial y^*} = \frac{\kappa}{\rho c_p}\frac{\partial^2 T}{\partial y^{*2}} + \frac{Q}{\rho c_p}(T - T_\infty) - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y^*} \qquad (3)$$

$$u\frac{\partial C}{\partial x^*} + v\frac{\partial C}{\partial y^*} = \frac{\partial^2 C}{\partial y^{*2}} + K_0(C - C_\infty) \qquad (4)$$

In which (u), (v) velocity over the (x^*), (y^*) direction, (ν) kinematicviscosity, (ρ) density, (β) couple stress parameter, (σ) electrical conductivity, (B_0) strength of constant magnetic induction, (T) fluid temperature within boundary layer, (κ) thermal conductivity, (Q) source coefficient, (c_p) specific heat.

The fluid flow is considered in the sustained boundary condition,

$$\left.\begin{matrix} u = u_\omega = bx^*\sin\omega t, v = 0, T = T_\omega, C = C_\omega,\ at\ y^* = 0, t > 0 \\ u = 0, T \to T_\infty, C \to C_\infty\ at\ y^* \to \infty \end{matrix}\right\} \qquad (5)$$

By Rosseland utilized approximation the radiation flux is written by (Brewster15)

$$q_r = -\frac{4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y} \qquad (6)$$

whereas (σ^*) Stefan's constant and (k^*) coefficient of mean absorption.

Taylor expansion T^4 over T_∞ and omitted terms with the higher order,

$$T^4 \approx 4{T_\infty}^3 T - 3{T_\infty}^4 \qquad (7)$$

above equation applying in equation (6) we get,

$$q_r = -\frac{4\sigma^* 3k^* \partial(4T_\infty{}^3 T - 3T_\infty{}^4)}{\partial y^*}$$

$$q_r = -\frac{16T_\infty{}^3}{3k^*}\frac{\partial T}{\partial y^*} \tag{8}$$

applying equation (8) in equation (3) we get,

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x^*} + v\frac{\partial T}{\partial y^*} = \frac{\kappa}{\rho c_p}\frac{\partial^2 T}{\partial y^{*2}} + \frac{Q}{\rho c_p}(T - T_\infty) - \frac{16T_\infty{}^3}{3k^*}\frac{\partial^2 T}{\partial y^{*2}} \tag{9}$$

To non-dimensionalize the flow equations, we initiate the suitable variables,

$$\left.\begin{array}{c} y = \sqrt{\frac{b}{\nu}}y^*, \tau = t\omega, u = bx^* f_y(y,\tau), v = -\sqrt{b\nu}\, f(y,\tau), \\ \theta(y,\tau) = \frac{T-T_\infty}{T_\omega - T_\infty}, C(y,\tau) = \frac{C-C_\infty}{C_\omega - C_\infty} \end{array}\right\} \tag{10}$$

By using the above variables(10), equations(2),(9) and(4) are transforming thefollowing equations,

$$\left(1+\frac{1}{\beta}\right) f_{yyy} - S f_{y\tau} + f f_{yy} - f_y{}^2 - M f_y = 0 \tag{11}$$

$$(1+R)\theta_{yy} + \Pr\left(f\theta_y - S\theta_\tau + \lambda\theta\right) = 0 \tag{12}$$

$$\varphi_{yy} + Sc\left(f\varphi_y - S\varphi_\tau - \gamma\varphi\right) = 0 \tag{13}$$

transformed boundary conditions are,

$$\left.\begin{array}{c} f_y(0,\tau) = \sin\tau, f(0,\tau) = 0, \theta(0,\tau) = 1, \varphi(0,\tau) = 1 \; at \; y = 0 \\ f_y(\infty,\tau) = 0, \theta(\infty,\tau) = 0, \varphi(\infty,\tau) = 0 \; at \; y = \infty \end{array}\right\} \tag{14}$$

In above equations (β) Casson fluid parameter, $\left(S = \frac{\omega}{b}\right)$ unsteady parameter, $(M = \frac{\sigma B_0{}^2}{\rho b} + \nu\frac{\Phi}{kb})$ magneto-porous parameter, $(Pr = \frac{\mu C_p}{\kappa})$ Prandtl number, $(\lambda = \frac{Q}{b\rho c_p})$ heat source/sink parameter, $(R = \frac{16\sigma^* T_\infty{}^3}{3\kappa k^*})$ radiation parameter, $(Sc = \frac{D}{\nu})$ Schmidth number, $(\gamma = \frac{K_0}{b})$ chemical reaction parameter.

2 Method of solution

Velocity flow, temperature and species concentration are calculated in perturbation method. Since, the system of non linear governing non linear equations are two dimensional. We decompose the flow variables into base part and perturbed part.

$$\left.\begin{array}{c} f(y,\tau) = f_0(y) + \in e^{n\tau} f_1(y) + o(\in^2) \\ \theta(y,\tau) = \theta_0(y) + \in e^{n\tau}\theta_1(y) + o(\in^2) \\ \varphi(y,\tau) = \varphi_0(y) + \in e^{n\tau}\varphi_1(y) + o(\in^2) \end{array}\right\} \tag{15}$$

the above equations substituting in equation (11) to (13), the higher orders of perturbation parameter ($\in^2$) neglecting and equating the zeroth and first order terms.

Base part:

$$\left(1+\frac{1}{\beta}\right) f_0{}''' + f_0 f_0{}'' + f_0{}^2 - M f_0{}' = 0 \tag{16}$$

$$(1+R)\theta_0{}'' + \Pr(f_0\theta_0{}' + \lambda\theta_0) = 0 \tag{17}$$

$$\varphi_0{}'' + Sc(f_0\varphi_0{}' - \gamma\varphi_0) = 0 \tag{18}$$

Perturbed part:

$$\left(1+\frac{1}{\beta}\right)f_1''' - Snf_1' + f_0f_1'' + f_1f_0'' - 2f_0f_1 - Mf_1' = 0 \qquad (19)$$

$$(1+R)\theta_1'' + \Pr(f_0\theta_1' + f_1\theta_0' - Sn\theta_1 - \lambda\theta_1) = 0 \qquad (20)$$

$$\varphi_1'' + Sc(f_0\varphi_1' + f_1\varphi_0' - Sn\varphi_1 - \gamma\varphi_1) = 0 \qquad (21)$$

Base part boundary condition:

$$\left.\begin{array}{c} f_0' = \sin\tau, f_0 = 0, \theta_0 = 1, \varphi_0 = 1 \; at \; y = 0 \\ f_0' = 0, \theta_0 = 0, \varphi_0 = 0 \; at \; y = \infty \end{array}\right\} \qquad (22)$$

Perturbed part boundary condition:

$$\left.\begin{array}{c} f_1' = 0, f_1 = 0, \theta_1 = 0, \varphi_1 = 0 \; at \; y = 0 \\ f_1' = 0, \theta_1 = 0, \varphi_1 = 0 \; at \; y = \infty \end{array}\right\} \qquad (23)$$

These base and perturbed non linear partial differential equation are solved numerically subject to the boundary condition equation (22) and (23) , respectively, the graphs are plotted for the axial flow problems are calculated employing Mathematica software.

3 Result and Discussion

The major intention of this analysis is to examine thermal and mass transfer of Casson fluid flow over an oscillatory stretching surface. Impact of several parameter on flow profile, heat and concentration of species exposed in graphs. Figure 2 interpreted the axial velocity of parameter β. It indicates $f(y)$ falling with rising values of parameter β . Figure 3 lay out the outcome of Magneto-porous parameter M on velocity $f(y)$. It is observes that $f(y)$ reduces with enhancing values of M . Figure 4 exhibits the effect of parameter S on velocity field (y) . It describes $f(y)$ falling with extending values of S .

The outcome parameter R on heat profile display in figure 5 . It is shown that $\theta(y)$ falling with various values of R . The consequence of Pr on $\theta(y)$ is exhibit in figure 6 . It illustrates that $\theta(y)$ falling with raising values of Pr . Impact of source heat or sink parameter λ on heat transfer $\theta(y)$ is displayed in figure 7 . It is noticed that $\theta(y)$ falling with parameter λ . The influence of unsteady parameter S on heat transfer $\theta(y)$ is exhibit in figure 8 . It demonstrates that $\theta(y)$ decreases with parameter S . Figure 9 and 10 shows that impact of Sc and γ on mass transfer $\varphi(y)$. Itis observes that $\varphi(y)$ falling for both values of Sc and γ .

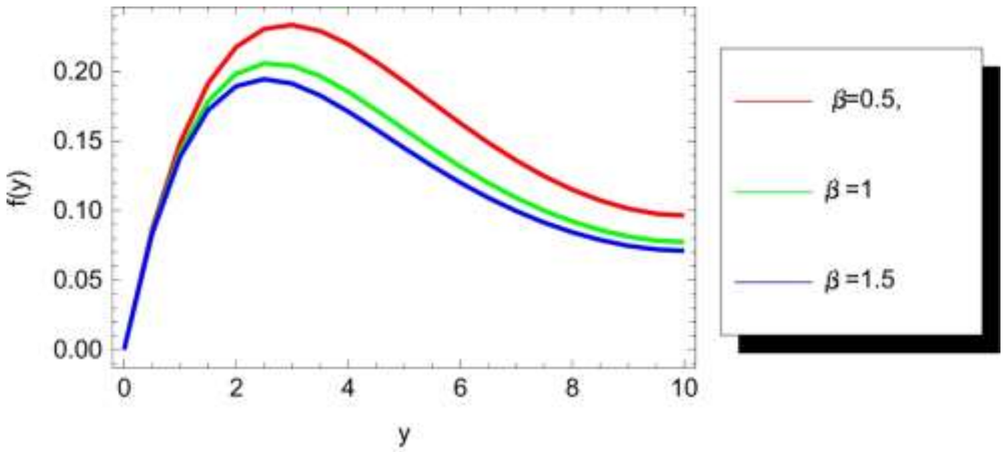

Figure 2: velocity profile of different parameter β

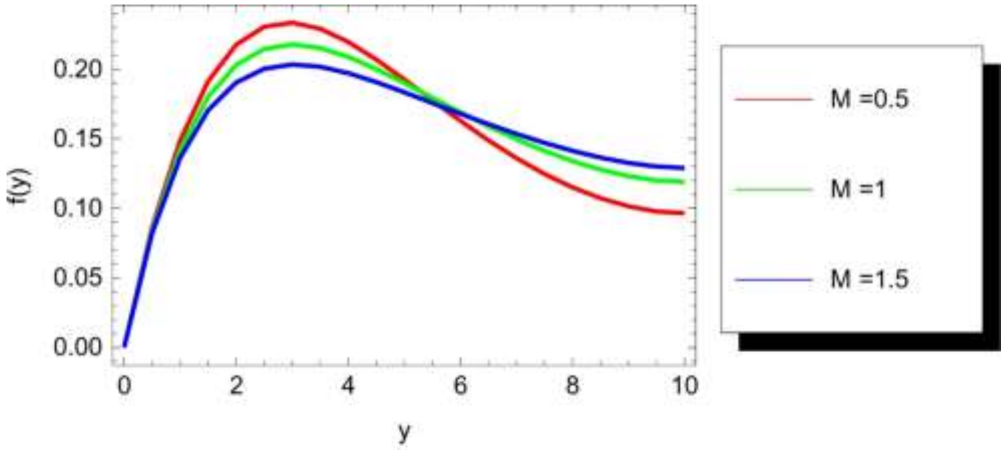

Figure 3: Impact of M on different flow variation

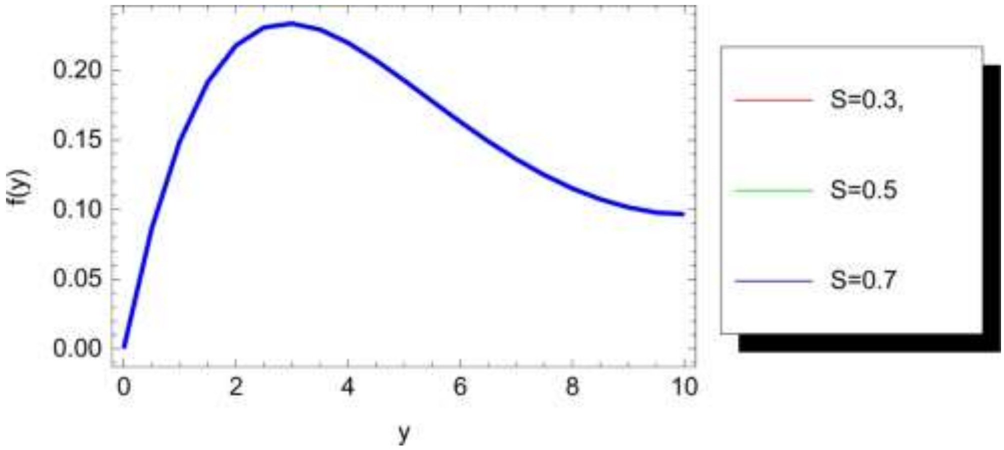

Figure 4: Variation of S on velocity profile

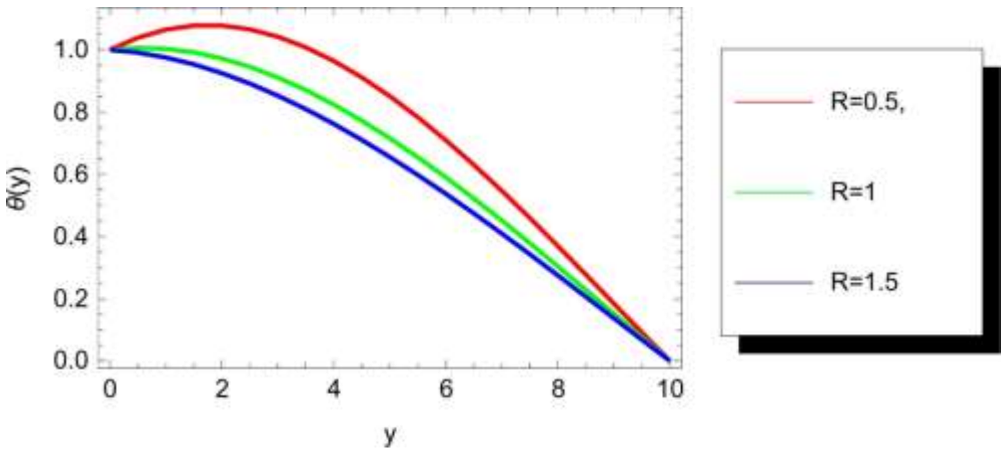

Figure 5: Variation of R on temperature

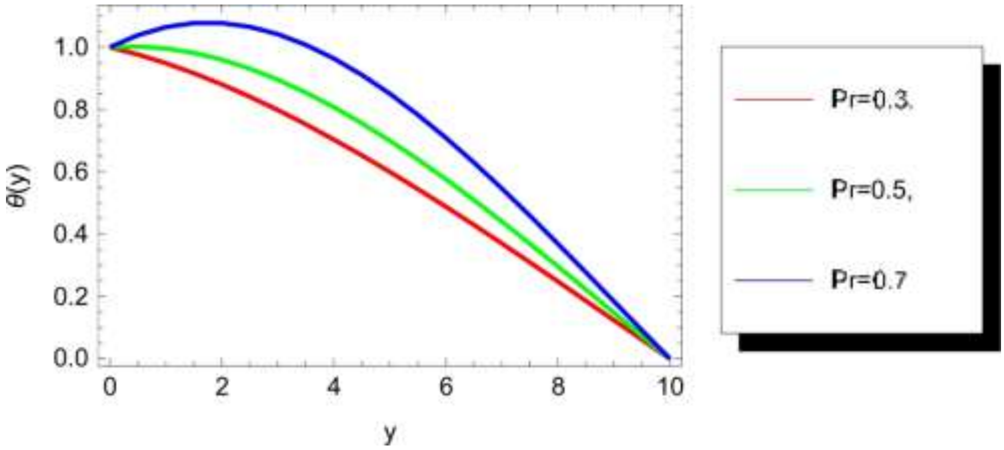

Figure 6: Variation of Pr on rate of heat transfer

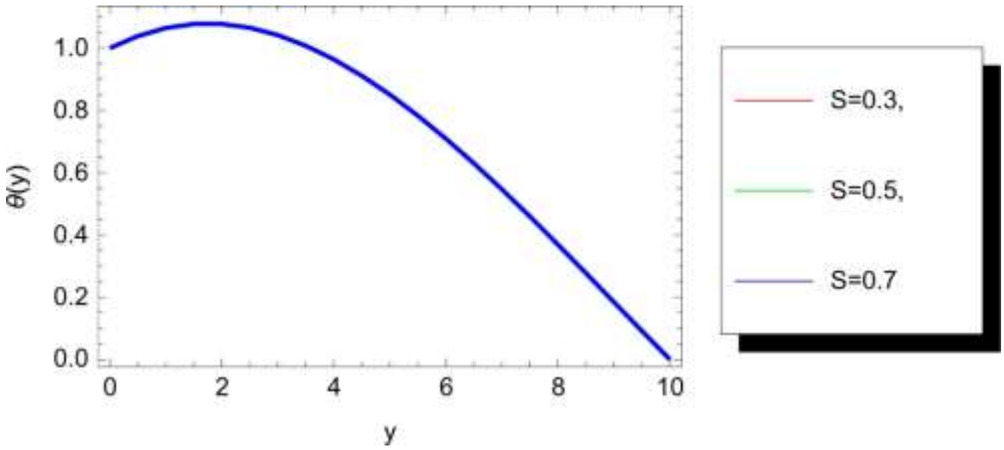

Figure 7: Variation of λ on rate of thermal energy transfer

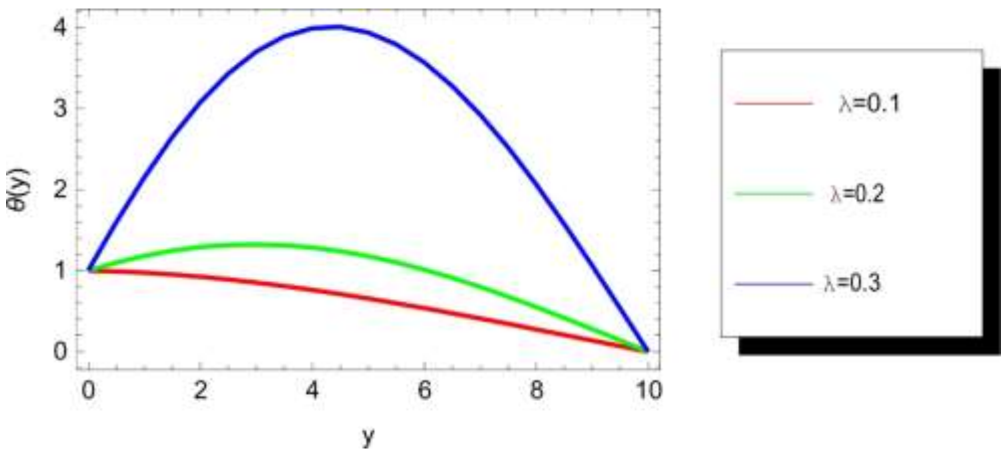

Figure 8: Variation of S on temperature

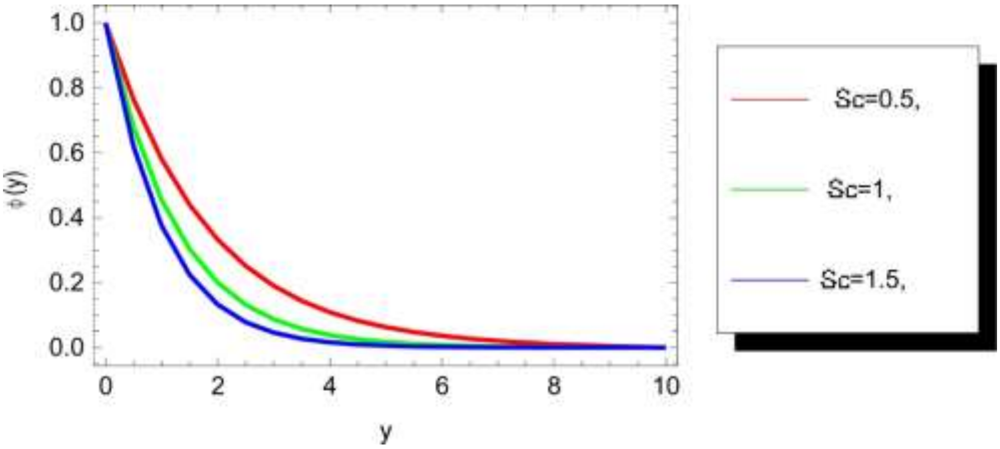

Figure 9: Effect of Sc on rate of concentration

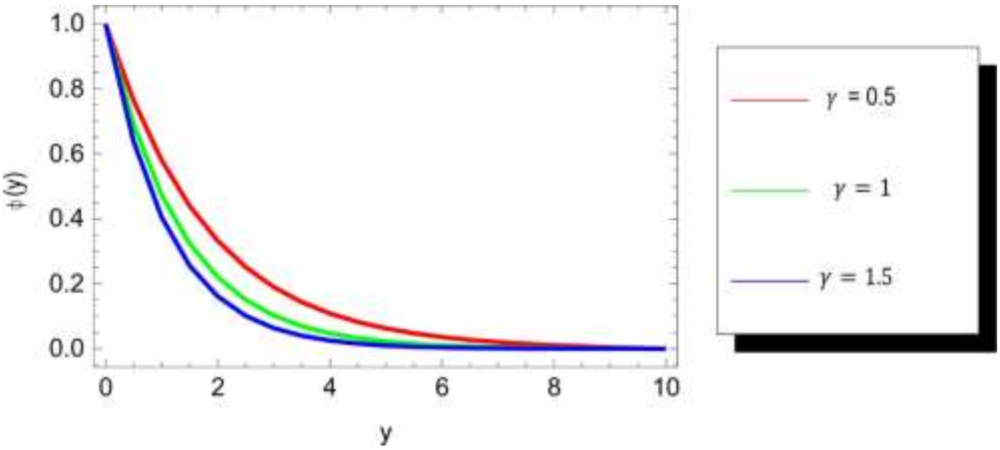

Figure 10: Consequence of γ on concentration profile

5 Conclusion

The flow of a MHD Casson fluid along an oscillatory surface in the influenceof heat source or sink and thermal radiation is analyzed using perturbation techniques. The existence of the several variables on flow velocity, thermal energy and chemical reaction are explored in graphs. It represents influence of all the variables decreases on flow field, heat energy and mass transfer.

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