Available online at: http://www.ijmtst.com/vol5issue02.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 05, Issue No: 02, February 2019

Effects of Cosinusoidally Fluctuating Temperature and Casson Fluid Model On MHD Free Convective Flow past a Vertical Porous Plate in Presence of Hall, Ion-Slip Current and Chemical Reaction

N.Ranganath[1] | C. Srinivasa kumar[2] | K.V.B. Rajakumar[3]

[1]Department of Mathematics, Research Scholar of Rayalaseema University, Kurnool. Reg No: PP. MAT.0259, Andhra Pradesh, India.

[2]Department Name of Mathematics, Vignan Institute of Technology and Science, Hyderabad, Telangana State. India

[3]Department of Mathematics, Kallam Haranadhareddy Institute of technology, Guntur, Andhra Pradesh,India.

To Cite this Article

N. Ranganath1, C. Srinivasa kumar, K.V.B.Rajakumar "Effects of cosinusoidally fluctuating temperature and Casson fluid model on MHD free convective Flow past a Vertical Porous Plate in Presence of Hall, Ion-Slip Current and Chemical", *International Journal for Modern Trends in Science and Technology*, Vol. 05, Issue 02, February 2019, pp.-15-23.

Article Info

Received on 29-Jan-2019, Revised on 21-Jan-2019, Accepted on 01-Mar-2019.

ABSTRACT

In this paper the Influence of cosinusoidally fluctuating temperature and Casson fluid model on MHD free convective flow past a vertical porous plate in presence of hall, ion-slip current and chemical reaction effects have been analyzed. The exact solution of the governing equations for velocity, temperature and concentration are attained using Perturbation method. The influence of dissimilar parameters on velocity, temperature and concentration fields are shown graphically, whereas the expression for the skin friction, nusselt number and Sherwood number profiles are presented in tabular. In this investigation it was conclude that as rise in hall and ion-slip current parameter leads to rise in velocity, but reverse effect was occurred in case of heat source and prandtl number. In addition concentration and velocity are declined with rise in Reynolds number and soret parameter.

Keywords: *Hall and Ion-slip parameter, MHD, perturbation, Chemical reaction, Radiation*

I. INTRODUCTION

Natural convection flow is an important factor in numerous practical applications that include, for instance, in designs connected to thermal insulation, fabric processing, geothermal system, cooling of electronic mechanism, industrial as well as environmental situations such as air conditioning systems, etc. Transient natural convection is of fundamental interest in many engineering as well as ecological situations such as air conditioning systems, atmospheric flows, motors, thermal regulation process, cooling of electronic devices, and security of energy systems. Buoyancy is also of importance in an environment where dissimilarity among land and air temperatures can provide increase to complicated flow patterns. MHD has attracted the attention of a large number of scholars due to its diverse applications. In astrophysics and geophysics, it is applied to study the stellar and solar structures, interstellar matter, radio propagation through the ionosphere etc. In engineering it finds its application in MHD pumps, MHD bearings etc. Convection in porous media has applications in geothermal energy recovery, oil extraction, thermal energy storage and flow through filtering devices. Convective heat transfer in porous media has received considerable attention in recent years owing to its importance in various technological applications such as fibers and granular insulation, electronic system cooling, cool combustors, and porous material regenerative heat exchangers. Sudhakar Reddy et al.[1] discussed on MHD free convective heat and mass transfer flow through a porous medium bounded by a vertical surface in presence of Hall current. Ijaz Khan. et al. [2] investigated behaviour of stratification phenomenon in flow of Maxwell nanomaterial with motile gyrotactic microorganisms in the presence of magnetic field. Odero et al.[3] reported on unsteady MHD flow over an infinite porous plate subjected to convective surface boundary conditions. Hayat et al.[4] diffusion of chemically reactive species in third grade fluid flow over an exponentially stretching sheet considering magnetic field effects has been investigated. Sheikholeslami. M et al. [5] investigated effect of thermal diffusion and heat generation on MHD Nano-fluid flow past an oscillating vertical plate through porous medium. Kataria et al. [6] examined effect of thermo-diffusion and parabolic motion on MHD second grade fluid flow with ramped wall temperature and ramped surface concentration. Muhammad Waqas et al. [7] described MHD mixed convection flow of micropolar liquid due to nonlinear stretched sheet with convective condition. Waqas et al.[8] discussed on transport of Magneto Hydrodynamic nanomaterial in a stratified medium considering gyrotactic microorganisms. Hayat et al.[9] investigated on Magneto Hydrodynamic stretched flow of tangent hyperbolic Nano liquid with variable thickness. Ramakrishna et al. [10] MHD free convective flow past a porous plate.

The role of radiation on the flow and heat transfer process is of major important in the design of many advanced energy conversion system operation at higher temperature. It is renowned that radiative heat transfer and flow is exceptionally imperative in manufacturing industries for the design of reliable equipments, nuclear plants, gas turbines and various propulsion devices for aircraft, missiles, satellites and space vehicles. Also, the influence of thermal radiation on forced as well as free convection flows are essential in the content of space technology as well as process involving high temperature. Molla et al.[11] described the influence of thermal radiation on steady 2D natural convection viscous, incompressible and laminar optically thick fluid along a perpendicular horizontal plate with stream wise sinusoidal surface temperature. Mansour et al. [12] reported that the impact of thermal radiation on MHD free convection flows in a fluid saturated permeable media. Plumb et al. [13] analyzed the influence of flat cross-flow as well as radiation on free convection from perpendicular heated surface in a saturated porous media. Keeping in mind some specific industrial applications such as a polymer processing technology, several attempts have been made to analyze the effect of transverse magnetic field on a boundary layer flow characteristics. Pal [14] studied numerically, the effect of thermal radiation on MHD double diffusion in stagnation point flow in the direction of a stretching sheet in the influence of buoyancy force. Rajakumar et al. [15] Radiation absorption and viscous dissipation effects on MHD free convective flow past a semi-infinite moving vertical porous plate has been analyzed. Rajakumar et al. [16] Radiation, Dissipation as well as Dufour Effects on MHD free Convection Flow through a Vertical Oscillatory Porous Plate with Ion-slip Current**.** Rajakumar et al. [17] reported radiation and Chemical reaction effects on MHD free convective flow past a semi-infinite moving vertical porous plate with viscous dissipation.

The exploration of Casson fluid has brought considerable concentration in research due to its increasing importance in industry and applications, especially those related to the food and biomedical industries. Casson fluid behaves like elastic solids, and for this kind of fluid a yield shear stress exists in the constitutive equation. The Casson fluid model is one of the non-Newtonian fluid models which reveal the characteristics of yield stress. Also Casson fluid acts like a solid when the shear stress less than the yield stress is applied, and it moves if the applied shear stress is greater than the yield stress. It is one of the pseudo plastic fluids that were introduced by Casson in 1995. The examples of

Casson fluid are Human blood, Honey, gypsum paste, cream, Aloe era juices etc. Bhattacharyya et al. [18] studied analytically solution of a MHD flow of a Casson fluid over a permeable stretching sheet. Attia *et al.* [19] reported that the unsteady Magneto Hydrodynamic flow of an electrically conducting viscous incompressible non-Newtonian Casson fluid bounded by two parallel non-conducting porous plates in presence of viscous dissipation effect were studied with heat transfer considering the Hall Effect. Srinivasa Raju [20] analyzed the effects of chemical reaction and combined buoyancy effects on an unsteady Magneto Hydrodynamic mixed convective flow along an infinite vertical porous plate in the presence of hall current. Srinivasa Raju *et al* [21] investigated on unsteady MHD natural convective, heat and mass transfer, electrically conducting Casson fluid flow over on an vertical surface taken in to the account with angle of inclination, chemical reaction, viscous dissipation and constant heat flux. The governing non-linear partial differential equations are solved by using finite element method. In this paper it was observed that the velocity diminished with rise in magnetic field parameter, Schmidt number, chemical reaction parameter, Casson fluid parameter, angle of inclination parameter and Prandtl number. Saidulu *et al* [22] portraying the boundary layer flow of a non-Newtonian Casson fluid accompanied by heat transfer towards a porous exponentially stretching sheet with velocity slip and thermal slip conditions in the presence of thermal radiation, suction/blowing, viscous dissipation and heat source/sink effects. In this examination Hall and Ion-slip current was not consider. Biswas *et al.* [23] analyzed Casson fluid flow past a perpendicular plate in presence of radiation as well as chemical reaction. From this paper it was found that explicit finite difference method was utilized for solving the governing equations. Mythili *et al* [24] discussed chemically reacting Casson fluid flow over a vertical cone and flat plate saturated by means of non-Darcy porous medium with heat absorption. Rajakumar et al. [25] analyzed the significance of Casson fluid model on MHD free convection fluid flow through a vertical Oscillatory porous plate with Ion-slip current in presence of radiation, dissipation and Dufour effects.

The main objective of this paper is to analyze the influence of cosinusoidally fluctuating Temperature and Casson fluid model on MHD Free Convective Flow past a Vertical Porous Plate in Presence of Hall, Ion-Slip Current and Chemical Reaction. In this investigation the governing equations are solved by using perturbation method. This examination is extended work of Rama Krishna et al. [18] and the results are good agreement with previous outcomes. In this investigation hall and ion-slip current is very important in fundamental in flows of lab plasma when a solid magnetic field of a uniform quality is connected and drawn the consideration of the analysts because of their differed hugeness in fluid metals electrolytes arrive ionized gasses.

II. Formulation and Solution of the Problem

Consider the flow of a conducting fluid past an infinite hot porous plate lying vertically on $x^*y^*z^*$ plane. The plate is supposed to be infinite in lengthened taken along the fluid in x^* direction, therefore all physical quantities are independent of x^* and is subjected to normally applied uniform magnetic field of strength B_0. Let (u^*, v^*, w^*) be the components of the velocity in the (x^*, y^*, z^*) directions respectively. Owing to suction at the surface of the plate with constant velocity $v^* = -V$, w^* is independent of z^* and assumed as zero. Further, we assume that the magnetic Reynolds number is very small so that the induced magnetic field is negligible in comparison to the applied magnetic field. The fluid is considered here to be gray, absorbing/emitting radiation but a non-scatterering medium. No external electrical field is applied and effect of polarization of ionized fluid is negligible, therefore, electrical field is assumed to be zero. There exists a first order chemical reaction between the fluid and species concentration, the heat generation during chemical reaction cannot be neglected.

The rheological equation of state for the Cauchy stress tensor of Casson fluid can be written as $\tau = \tau_0 + \mu\alpha^*$ (Srinivasa Raju et al (2017)).

equivalently $$\tau_{ij} = \begin{cases} 2\left[\mu_B + \dfrac{p_y}{\sqrt{2\pi}}\right]e_{ij} & \pi > \pi_c \\ 2\left[\mu_B + \dfrac{p_y}{\sqrt{2\pi_c}}\right]e_{ij} & \pi < \pi_c \end{cases}$$

$\pi = e_{ij}e_{ij}$ and e_{ij} is the $(i, j)^{th}$ component of deformation rate,

τ_0 = Casson yield stress,

π i= the product based on the non-Newtonian fluid,

π_c = critical value of this product,

μ_B = plastic dynamic viscosity of the non-Newtonian fluid,

μ = the dynamic velocity,

α^* = shear rate.

$p_y = \frac{\mu_B \sqrt{2\pi}}{\gamma}$ denotes the yield stress of fluid.

Some fluids require a gradually increasing shear stress to maintain a constant strain rate and are called Rheopectic, in the case of Casson fluid flow.

Where $\tau > \tau_c$, $\mu = \mu_B + \frac{p_y}{\sqrt{2\pi}}$,

The kinematic velocity can be writing as $v = \frac{\mu}{\rho} = \frac{\mu_B}{\rho}\left[1+\frac{1}{\gamma}\right]$.

Finally $\gamma = \frac{\mu_B\sqrt{2\pi_c}}{p_y}$ is the Casson fluid parameter

The flow field is governed by the following set of equations.

Continuity equation:

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

Equation of momentum:

$$\left.\begin{aligned}\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} &= g\beta\left(T^* - T_\infty\right) + g\beta^*\left(C^* - C_\infty\right)\\ &- \frac{\upsilon}{k^*}\left[1+\frac{1}{\gamma}\right]u^* + \upsilon\left[1+\frac{1}{\gamma}\right]\left[\frac{\partial^2 u^*}{\partial y^{*2}} + \frac{\partial^2 u^*}{\partial z^{*2}}\right]\\ &- \frac{\sigma_e B_0^2\left[\alpha_e u^* + \beta_e w^*\right]}{\rho\left[\alpha_e^2 + \beta_e^2\right]}\end{aligned}\right\} \qquad (2)$$

$$\left.\begin{aligned}\frac{\partial w^*}{\partial t^*} + v^*\frac{\partial w^*}{\partial y^*} &= \upsilon\left[1+\frac{1}{\gamma}\right]\left[\frac{\partial^2 w^*}{\partial y^{*2}} + \frac{\partial^2 w^*}{\partial z^{*2}}\right] - \left[1+\frac{1}{\gamma}\right]\frac{\upsilon}{k^*}w^*\\ &+ \frac{\sigma_e B_0^2\left[\beta_e u^* - \alpha_e w^*\right]}{\rho\left[\alpha_e^2 + \beta_e^2\right]}\end{aligned}\right\} \qquad (3)$$

Equation of energy

$$\left.\begin{aligned}\rho C_P\left[\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*}\right] &= \kappa\left[\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\partial^2 T^*}{\partial z^{*2}}\right] - \frac{\partial q_r}{\partial y^*}\\ &+ Q_0\left(T^* - T_\infty\right)\end{aligned}\right\} \qquad (4)$$

Equation of Concentration:

$$\left.\begin{aligned}\rho C_P\left[\frac{\partial C^*}{\partial t^*} + v^*\frac{\partial C^*}{\partial y^*}\right] &= D\left[\frac{\partial^2 C^*}{\partial y^{*2}} + \frac{\partial^2 C^*}{\partial z^{*2}}\right]\\ &- \Gamma\left(C^* - C_\infty\right) + D_1\left[\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\partial^2 T^*}{\partial z^{*2}}\right]\end{aligned}\right\} \qquad (5)$$

Consider the temperature of the plate is to vary spanwise cosinusoidally fluctuation with time and suppose to be of the form

$$T_W(z^*, t^*) = T_0 + \varepsilon\left(T_0 - T_\infty\right)\cos\left(\frac{\pi z^*}{l} - w^* t^*\right) \qquad (7)$$

The corresponding initial and boundary conditions are as follows:

$$\left.\begin{aligned}&As\quad y^* = 0: \begin{cases} u^* = 0,\ T^* = T_0 + \varepsilon\left(T_0 - T_\infty\right)\cos\left(\frac{\pi z^*}{l} - w^* t^*\right)\\ C^* = C_w\end{cases}\\ &y \to \infty \qquad u^* = 0,\ T^* = T_0,\ C^* = C_0\end{aligned}\right\} \qquad (8)$$

For the case of an optimality thin gray gas, local radiative heat flux in the energy equation

$$\frac{\partial q_r}{\partial y^*} = 4\sigma_s k_e\left(T^{*4} - T_\infty^4\right) \qquad (9)$$

If the temperature differences within the flow are sufficiently small, then equation (8) can be linearized by expanding T^{*4} into the Taylors series about T^∞, which after neglecting higher order terms, takes the form

$$T^{*4} \cong 4T_\infty^3 T^* - 3T_\infty^4 \qquad (10)$$

Form the equation (9), (10) and (4) the modified energy equation is

$$\left.\begin{aligned}\rho C_P\left[\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*}\right] &= \kappa\left[\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\partial^2 T^*}{\partial z^{*2}}\right] + Q_0\left(T^* - T_\infty\right)\\ &+ 16k_e\sigma T_\infty^3\left(T^* - T_\infty\right)\end{aligned}\right\} \qquad (11)$$

The non-dimensional parameters as follows

$$\left.\begin{aligned}&y = \frac{y^*}{l}, t = \omega^* t^*, u = \frac{u^*}{\nu}, z = \frac{z^*}{l}, k = \frac{k^*}{l}\\ &t = w^* t^*,\ \omega = \frac{\omega^* l^*}{\nu},\ z = \frac{z^*}{l},\ \gamma = \frac{l^2 k_1}{\nu}\\ &\phi = \frac{C^* - C_\infty}{C_w - C_\infty}, \theta = \frac{T^* - T_\infty}{T_w - T_\infty}\end{aligned}\right\} \qquad (12)$$

Using the transformation (12) and equation (7), the momentum equation (2), (3), equation (11) and concentration equation (5) reduce to the following dimensionless form

$$\left.\begin{aligned}\omega\frac{\partial u}{\partial t}-Re\frac{\partial u}{\partial y}&=Re^2\,Gr\,\theta+Re^2Gm\,C-\left[1+\frac{1}{\gamma}\right]\frac{u}{k}\\&+\left[1+\frac{1}{\gamma}\right]\left(\frac{\partial^2u}{\partial y^2}+\frac{\partial^2u}{\partial z^2}\right)-M^2\frac{[\alpha_eu+\beta_ew]}{[\alpha_e^2+\beta_e^2]}\end{aligned}\right\}\quad(13)$$

$$\left.\begin{aligned}\omega\frac{\partial w}{\partial t}-\mathrm{Re}\frac{\partial w}{\partial y}&=\left[1+\frac{1}{\gamma}\right]\left(\frac{\partial^2w}{\partial y^2}+\frac{\partial^2w}{\partial z^2}\right)-\left[1+\frac{1}{\gamma}\right]\frac{w}{k}\\&-M^2\frac{[\beta_eu-\alpha_ew]}{[\alpha_e^2+\beta_e^2]}\end{aligned}\right\}\quad(14)$$

$$\omega\frac{\partial\theta}{\partial t}-\mathrm{Re}\frac{\partial\theta}{\partial y}=\frac{1}{\mathrm{Pr}}\left(\frac{\partial^2\theta}{\partial y^2}+\frac{\partial^2\theta}{\partial z^2}\right)-\left(\frac{R\,\mathrm{Re}}{\mathrm{Pr}}\right)\theta+\chi\theta\quad(15)$$

$$\left.\begin{aligned}\omega\frac{\partial\phi}{\partial t}-\mathrm{Re}\frac{\partial\phi}{\partial y}&=\frac{1}{Sc}\left(\frac{\partial^2\phi}{\partial y^2}+\frac{\partial^2\phi}{\partial z^2}\right)-K_C\phi\\&+So\left(\frac{\partial^2\theta}{\partial y^2}+\frac{\partial^2\theta}{\partial z^2}\right)\end{aligned}\right\}\quad(16)$$

The corresponding boundary conditions are

$$\left.\begin{aligned}&u=0,\ \theta=1+\varepsilon\cos(\pi z-t),\ \phi=1\ \ at\ \ y=0\\&u=0,\ \ \theta=0,\ \phi=0\ \ as\qquad\qquad y\to\infty\end{aligned}\right\}$$

(17)

Where

$$\left.\begin{aligned}&Re=\frac{V\,l}{\nu},Gr=\frac{\nu g\beta(T_0-T_\infty)}{V^3},\ Gm=\frac{\nu g\beta(C_0-C_\infty)}{V^3}\\&,Sc=\frac{\nu}{D}\ M^2=\frac{l\,\sigma_eB_0^2}{\nu},\quad R=\frac{16k_e\nu^2T_\infty^3}{kV^2},\quad Pr=\frac{\mu C_p}{k}\\&\chi=\frac{l^2Q_0}{\nu\,pC_p}\ N=\left[\frac{1}{k}\left[1+\frac{1}{\gamma}\right]+\frac{M^2[-\alpha_e+i\beta_e]}{[\alpha_e^2+\beta_e^2]}\right]\\&So=\frac{D}{\nu}\left(\frac{T_0-T_\infty}{C_0-C_\infty}\right),\end{aligned}\right\}\quad(18)$$

Equations (13) and (14) are displayed, in a reduced form, as

$$\left.\begin{aligned}\omega\frac{\partial F}{\partial t}-Re\frac{\partial F}{\partial y}&=Re^2\,Gr\,\theta+Re^2Gm\,C-NF\\&+\left[1+\frac{1}{\gamma}\right]\left(\frac{\partial^2F}{\partial y^2}+\frac{\partial^2F}{\partial z^2}\right)\end{aligned}\right\}\quad(19)$$

The related boundary conditions are

$$\left.\begin{aligned}&F=0,\theta=1+\varepsilon\cos(\pi z-t),\phi=1\ \ at\ \ y=0\\&F=0,\ \theta=0,\phi=0\ as\qquad\qquad y\to\infty\end{aligned}\right\}\quad(20)$$

To examine the influence of dissimilar parameters on velocity as well as temperature distributions in the boundary layer generated on the surface, the solution of partial differential equations [(15), (16) & (18)] in conjunction with boundary condition (20) is attained utilizing regular perturbation method similar to one used in Ramakrishna Reddy (2018) through which is assumed the components of velocity, temperature and concentration respectively as follows

$$\left.\begin{aligned}F&=F_0+\varepsilon\ F_1e^{i(\pi z-l)}+\varepsilon^2F_2e^{2i(\pi z-l)}......\\\theta&=\theta_0+\varepsilon\ \theta_1e^{i(\pi z-l)}+\varepsilon^2\theta_2e^{2i(\pi z-l)}.......\\\phi&=\phi_0+\varepsilon\,\phi_1e^{i(\pi z-l)}+\varepsilon^2\phi_2e^{2i(\pi z-l)}........\end{aligned}\right\}\quad(21)$$

Substituting equation (21) into set of equations (15),(16) & (19) and equating the like powers then we obtained

$$\left[1+\frac{1}{\gamma}\right]F_0''+\mathrm{Re}\,F_0'-NF_0=-Re^2Gr\theta_0-Re^2Gm\phi_0\quad(22)$$

$$\left.\begin{aligned}\left[1+\frac{1}{\gamma}\right]F_1''+Re\,F_1'-(N-wi)F_1&=-Re^2\,Gr\theta_1\\&-Re^2Gm\phi_1\end{aligned}\right\}\quad(23)$$

$$\left.\begin{aligned}\left[1+\frac{1}{\gamma}\right]F_2''+\mathrm{Re}\,F_2'-\left(N-2wi+4\pi^2\right)F_2&=\\-Re^2\,Gr\,\theta_2-Re^2\,Gm\,\phi_2&\end{aligned}\right\}\quad(24)$$

$$\theta_0''+Re\,\mathrm{Pr}\,\theta_0'-\left(Re^2R-Pr\ \chi\right)\theta_0=0\quad(25)$$

$$\theta_1''+Re\,\mathrm{Pr}\,\theta_1'-\left(\pi^2+Re^2R-\chi Pr-iwPr\right)\theta_1=0\quad(26)$$

$$\theta_2''+Re\,\mathrm{Pr}\,\theta_2'-\left(\pi^2+Re^2R\ N-\chi Pr-2iwPr\right)\theta_1=0$$

(27)

$$\phi_0''+Sc\ Re\ \phi_0'-Kc\ Sc\ \ \phi_0=\left(\theta_0''-4\pi^2\theta_0\right)So\ Sc\quad(28)$$

$$\left.\begin{aligned}\phi_1''+Sc\ Re\ \phi_1'-\left(\pi^2+Kc\ Sc-i\ w\ Sc\right)\phi_1&=\\\left(-\theta_1''+\pi^2\theta_1\right)So\ Sc&\end{aligned}\right\}\quad(29)$$

$$\phi_2''+Sc\ Re\ \phi_2'-\left(4\pi^2+Kc\ Sc-2i\ w\ Sc\right)\ \phi_2=0\quad(30)$$

The corresponding boundary conditions are

$$\left.\begin{aligned}&\left.\begin{aligned}&F_0=0,F_1=0,F_2=0\\&\theta_0=1,\theta_1=1,\theta_2=0\\&\phi_0=1,\phi_1=0,\phi_2=0\end{aligned}\right\}\ \ at\ \ y=0\\&\left.\begin{aligned}&F_0=0,F_1=0,F_2=0\\&\theta_0=0,\theta_1=0,\theta_2=0\\&\phi_0=0,\phi_1=0,\phi_2=0\end{aligned}\right\}\ \ at\ \ y\to\infty\end{aligned}\right\}\quad(31)$$

Solve equation (22)-(32) and substitute in the equation (21) then we get

$$F=\left[\left(-k_3-k_4\right)e^{-m_{13}y}+k_3e^{-m_1y}+k_4e^{-m_7y}\right]+\varepsilon\left[\left(\left(-k_5-k_6\right)e^{-m_{15}y}+k_5e^{-m_3y}+k_6e^{-m_9y}\right)e^{i(\pi z-t)}\right] \quad (32)$$

$$\theta=\left[e^{-m_1y}\right]+\varepsilon\left[\theta_1e^{-m_3y}\right] \quad (33)$$

$$\phi=\left[\left(1-k_1\right)e^{-m_7y}+k_1e^{-m_1y}\right]+\varepsilon\left[-k_2e^{-m_9y}+k_2e^{-m_2y}\right] \quad (34)$$

III. RESULTS AND DISCUSSION

The effect of Casson fluid parameter on the velocity was shown in the Fig 1: From this figure it was observed that for different incremental values of Casson fluid parameter γ leads to rise in velocity. The influence of thermal Grashof number (Gr) on velocity is illustrated in the Fig 2: From this figure it was noticed that the enhancement of dissimilar estimators of *Gr* leads to rise in velocity close to the plate and after attaining its peak value, it diminished and finally converges to its limiting value. In the absence of Hall as well as Ion slip parameter i.e. and, the velocity follow the equivalent pattern as given in Ramakrishna Reddy (2018). Fig 3: Represents for dissimilar values of Hall parameter on the velocity. In this figure reflects that velocity rises with the enhancement of (β_e) near the plate and ultimately converges to its limiting value. Due to the production of an extra prospective dissimilarity transverse to the direction of accumulate free charge and applied magnetic field among the opposite surfaces induces an electric current perpendicular to both magnetic and electric. Fig 4: Shows that velocity variation for diverse values of Ion- slip parameter (β_i). From this figure the outcomes reflects that the incremental values of β_i leads to rise in velocity and it is very close to the plate and reached converging point it is depend on the hall. The influence of Magnetic field parameter M on the velocity is reported in the Fig 5: From this figure it was observed that the velocity reduced with the enhancement of M. Due to magnetic field exerts a retarding force on free convection flow. Fig 6: &Fig 7: Exhibits the influence of chemical reaction parameter *Kc* on velocity and concentration. Here the incremental values of *Kc* leads to reduced in velocity and concentration. Chemical reaction (Kc > 0) well-known as destructive reaction reduces the flow velocity. Fig 8: & Fig 9: Reflects that for diverse values of Soret (*So)* on velocity as well as concentration. From this figures it was found that velocity and concentration rises with the enhancement of Soret. Fig 10: Represents the influence of modified Grashof number *Gm* on the velocity. From this figure it is evident that for dissimilar incremental values of *Gm* leads to enhance in velocity. It is due to the fact that rise in the value of modified grashof number has the tendency to enhance the influence of mass buoyancy. The influence of Prandtl number *Pr* on the velocity and temperature is illustrated in the Fig 11: and Fig 12: From this figure is obvious that for diverse values of Pr rises then it leads to reduce in velocity and temperature. The fact that thermal boundary layer decreases with increased value of Pr.

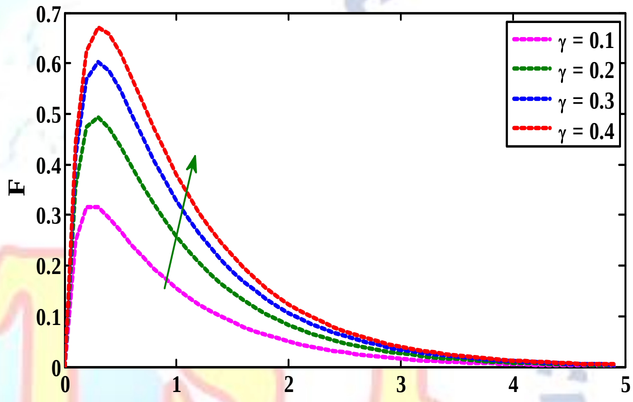

Fig 1: Influence of γ on Velocity

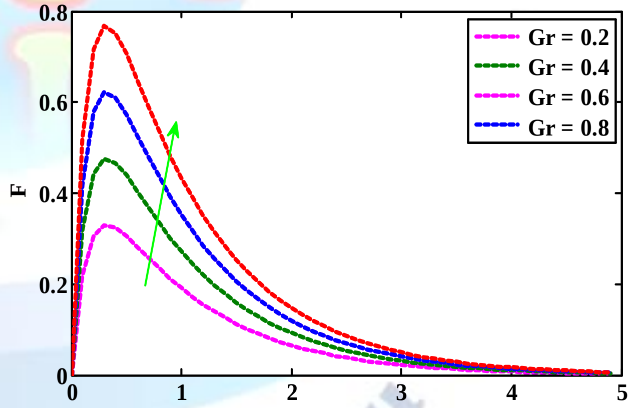

Fig 2: Influence of Gr on Velocity

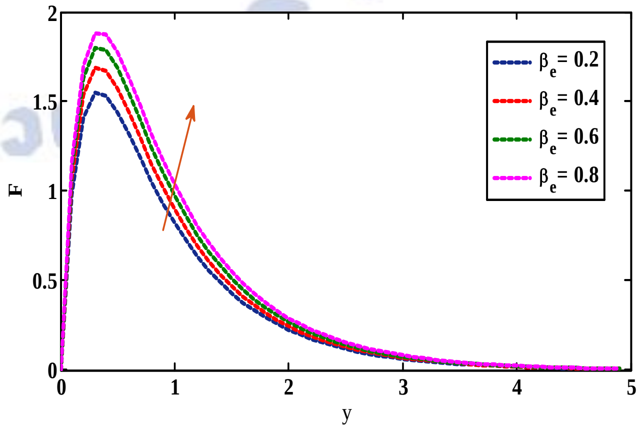

Fig 3: Influence of β_e on Velocity

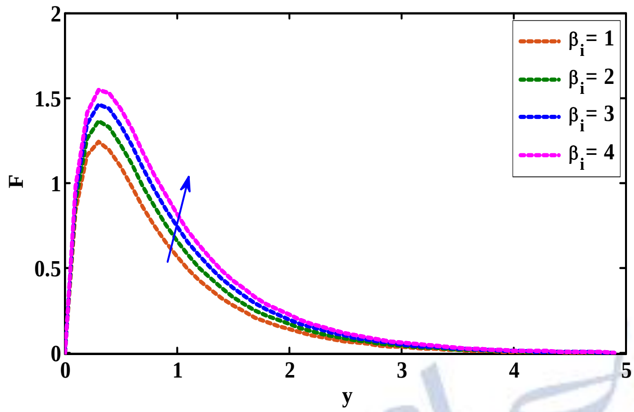

Fig 4: Influence of β_i on Velocity

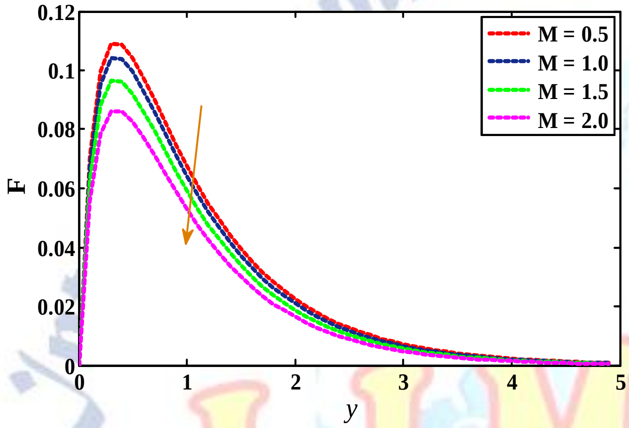

Fig 5: Influence of M on Velocity

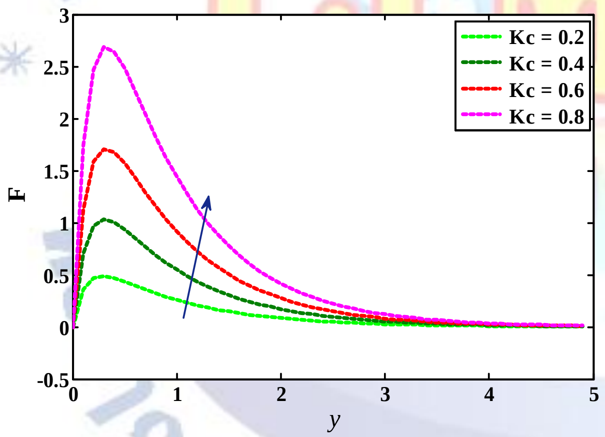

Fig 6: Influence of Kr on Velocity

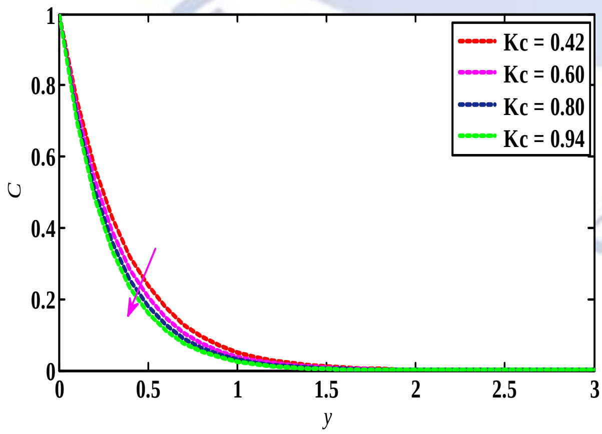

Fig 7: Influence of Kc on Concentration

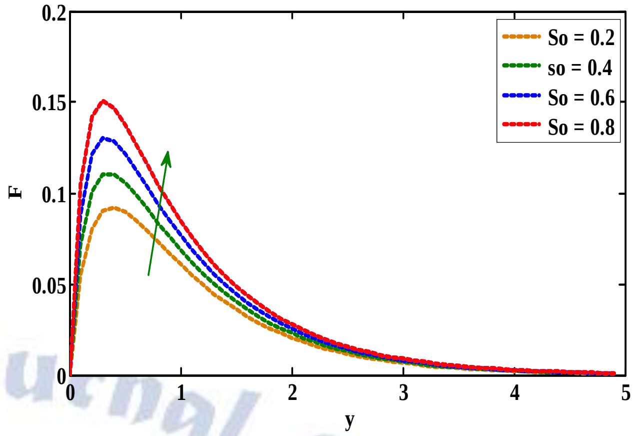

Fig 8: Influence of So on Velocity

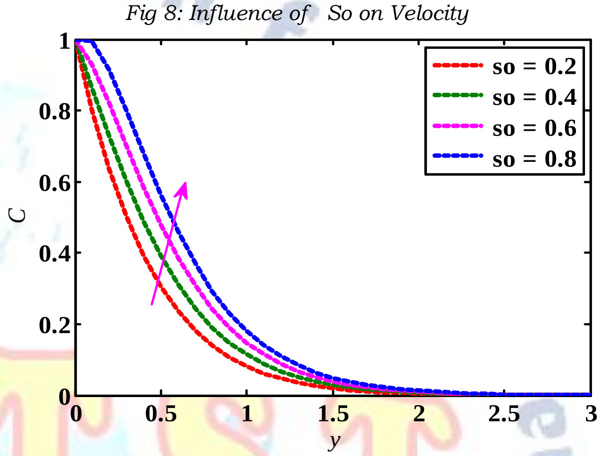

Fig 9: Influence of So on Concentration

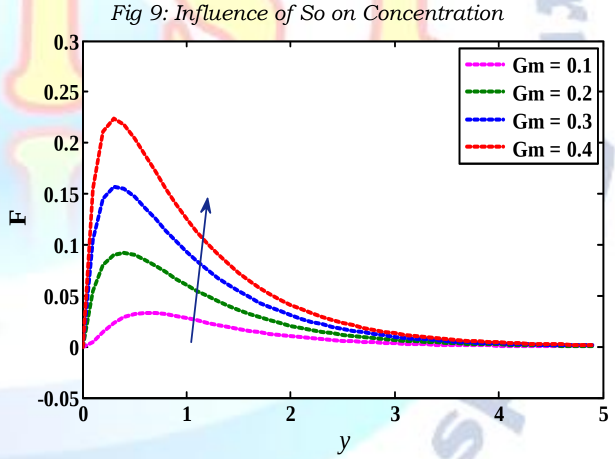

Fig 10: Influence of Gm on Velocity

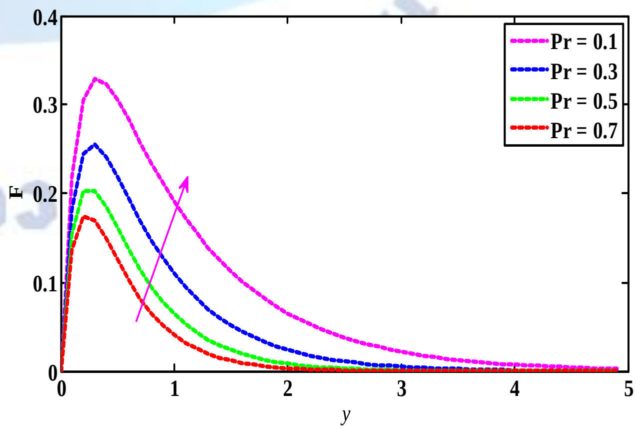

Fig 11: Influence of Pr on Velocity

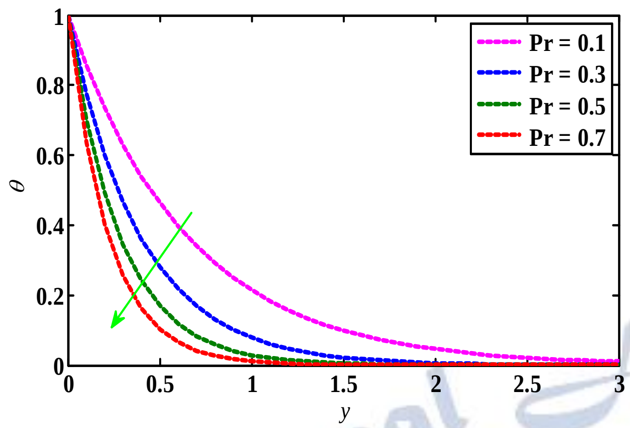

Fig 12: Influence of Pr on Temperature

IV. CONCLUSIONS

- The velocity and temperature diminished with the rise in prandtl number (Pr).
- As rise in Hall and ion-slip parameter, leads to rise in velocity.
- The velocity rises with the enhancement of Grashof number (Gr), modified Grashof number (Gm) and soret number (So), but reverse effect was occurred in case of magnetic field.

As Concentration and velocity declined with the rise in chemical reaction and soret parameter.

REFERENCES

[1] Sudhakar Reddy, Siva Prasad Reddy O, Raju M.C, Varma S V K. MHD free convection heat and mass transfer flow through a porous medium bounded by a vertical surface in presence of Hall current, Advances in applied science research, Vol. 3, no. 6, Pp. 3482-3490, 2012.

[2] ImranKhan. Significance of nonlinear radiation in mixed convection flow of magneto Walter-B nanoliquid. International journal of Hydrogen engery, Vol. 42, no. 42, Pp. 26408-26416, 2017.

[3] Odero. I.O,, Manyonge, Unsteady MHD flow over an infinite porous plate subjected to convective surface boundary conditions. International journal of contemporary mathematical sciences. Vol.12, no.1, Pp. 1-12, 2017.

[4] Hayat. T, Ijazkhan M, Waqas. M, Alsaedi T, Yasmeen. Diffusion of chemically reactive species in third grade fluid flow over an exponentially stretching sheet considering magnetic field effects. Chinese journal of chemical engineering Vol. 25, no.3, Pp. 257-263, 2017a.

[5] Sheikholeslami. M, Hari R. Kataria, Akhil, Mittal. S. Effect of thermal diffusion and heat generation on MHD nano fluid flow past an oscillating vertical plate through porous medium. Journal of Molecular liquids, Vol. 257, Pp. 12-25, 2018.

[6] Hari R. Kataria, Harshad R. Patel. Effect of thermo-diffusion and parabolic motion on MHD second grade fluid flow with ramped wall temperature and ramped surface concentration. Alexandria engineering journal, Vol. 57, no.1, Pp. 73-85, 2018.

[7] Muhammad Waqas, Muhammad Farooq, and Muhammad Ijaz Khan. MHD mixed convection flow of micropolar liquid due to nonlinear stretched sheet with convective condition. International journal of heat and mass transfer. Vol. 102, Pp. 766-772, 2016.

[8] Waqas. M, Hayat.T, Shehzad. S.A, Alsaedi.A. Transport of magnetohydrodynamic nanomaterial in a stratified medium considering gyrotactic microorganisms. Physica B: Condensed Matter, Vol. 526, Pp. 33-40, 2018.

[9] Hayat. T, Waqas M, Alsaedi. A, Bashir. G., Alzahrani F MHD stretched flow of tangent hyperbolic nanoliquid with variable thickness. Journal of Molecular liquids, vol. 229, no.1, Pp. 178-184, 2017.

[10] Ramakrishna P., M. C. Raju,. (2018)MHD free convective flow past a porous plate. International journal of pure and applied mathematics. 118(5), 507-529.

[11] Molla Md. Saha S.C, Md.A. Hossain. Md.A, Radiation effect on free convection laminar flow along a vertical flat plate with streamwise sinusoidal surface temperature, Math. Comput. Modelling Vol.53, Pp.1310–1319, 2011.

[12] Mansour .M.A, El-Shaer N.A, Radiative effects on magnetohydrodynamic natural convection flows saturated in porous media, J. Magn. Magn. Mater. Vol.237, Pp. 327–341, 2001.

[13] Plumb. O.A, Huenfeld. J.S, Eschbach. E.J,. The effect of cross flow and radiation on natural convection from vertical heated surfaces in saturated porous media, in: AIAA 16th Thermophysics Conference, June 23–25, Palo Alto, California, USA, 1981.

[14] Pal D, Heat and mass transfer in stagnation-point flow towards a stretching surface in the presence of buoyancy force and thermal radiation, Meccanica Vol.44, Pp.145–158, 2005.

[15] Rajakumar. K.V.B Ramana Murthy.Ch. V. & Balamurugan. K.S., Radiation absorption and viscous dissipation effects on MHD free convective flow past a semi-infinite moving vertical porous plate. International Journal of Fluid Mechanics Research. Vol.45, no.5. Pp.439–458, 2018.

[16] Rajakumar. K.V.B., Ramana Murthy, Ch. V., & K.S.Balamurugan., Radiation, Dissipation and Dufour Effects on MHD free Convection Flow through a Vertical Oscillatory Porous Plate with Ion-slip Current. Text Book-Numerical Heat Transfer and Fluid Flow, Publisher -Springer, Singapore, 587-596, 2019.

[17] Rajakumar. K.V.B., Ramana Murthy. Ch. V. & Balamurugan. K.S., Chemical reaction and viscous dissipation effects on MHD free convective flow past a

semi-infinite moving vertical porous plate with radiation absorption. Global journal of pure and applied mathematics. Vol. 13, no. 12, Pp. 8297-8322, 2017

[18] Bhattacharyya K., Hayat.T., and Alsaedi. A, Analytic solution for MHD boundary layer flow of Casson fluid over a stretching\shrinking sheet with wall mass transfer. Chinese physics B, Vol. 22, no.2, 2013.

[19] Hazem Ali Attia, Transient MHD Couette flow of a Casson fluid between parallel plates with heat transfer. Italian journal of pure and applied mathematics. Vol .27, Pp. 19–38, 2010.

[20] Srinivasa Raju R., Transfer effects on an unsteady MHD mixed convective flow past a vertical plate with chemical reaction. Engineering transactions eng. trans. Vol. 65, no.2, Pp. 221—249, 2017.

[21] Srinivasa Raju R, Reddy, B. Mahesh; Reddy, Jithender, Influence of angle of inclination on unsteady MHD Casson fluid flow past a vertical surface filled by porous medium in presence of constant heat flux, chemical reaction and viscous dissipation. Journal of Nano fluids. Vol. 6, no.4, Pp. 668-679, 2017.

[22] Saidulu N, Venkata Lakshman A. MHD Flow of Casson Fluid With Slip Effects over an Exponentially Porous Stretching Sheet in Presence of Thermal Radiation, Viscous Dissipation and Heat Source/Sink. American research J. of mathematics. Vol12, no.2, 2016.

[23] Biswas, Mondal, Sarkar and Ahmmed. Effects of radiation and chemical reaction on MHD unsteady heat and mass transfer of Casson fluid flow past a vertical plate. Journal of advances in mathematics and computer science. Vol.23, no.2, Pp.1-16, 2017.

[24] Mythili D, Siva raj R, Rashid M.M., Heat generating/absorbing and chemically reacting Casson fluid flow over a vertical cone and flat plate saturated with non-Darcy porous medium, International Journal of Numerical Methods for Heat and Fluid Flow. Vol. 27, Pp. 156 – 173, 2017.

[25] Rajakumar K.V.B, Balamurugan K.S.., Umasankara Reddy. M., & Ch.V.Ramana Murthy., Radiation, dissipation and Dufour effects on MHD free convection Casson fluid flow through a vertical Oscillatory porous plate with Ion-slip current. International Journal of Heat and Technology, Vol. 36, no. 2, Pp. 494-508, 2018.