 Volume-7 | Issue-10 | October-2018 | PRINT ISSN No 2250-1991

ORIGINAL RESEARCH PAPER

Mathematics

HEAT TRANSFER ON MHD CONVECTIVE FLOW OF HEAT GENERATING/ABSORBING SECOND GRADE FLUID THROUGH POROUS MEDIUM IN A ROTATING PARALLEL PLATES

KEY WORDS: heat transfer, second grade fluid, MHD flows, parallel plate channel, porous medium.

G Suresh Babu Research Scholar, Department of Mathematics, S.K.University, Anantapur, Andhra Pradesh, India.

Dr R Siva Prasad* Professor, Department of Mathematics, S.K.University, Anantapur, Andhra Pradesh, India.*Corresponding Author

ABSTRACT

In this paper, we have considered the heat transfer on the unsteady hydro magnetic convective flow of an incompressible viscous electrically conducting heat generating/ absorbing second grade fluid through porous medium in a rotating parallel plate channel under the influence of uniform transfer magnetic field normal to the channel. The momentum equation for the flow is governed by the Brinkman's model. The analytical solutions for the velocity and temperature distributions are obtained by making use of regular perturbation technique and computationally discussed with reference to flow parameters through the graphs. The skin friction and Nusselt number are also evaluated analytically and computationally discussed with reference to pertinent parameters in detail.

1. INTRODUCTION

The phenomenon of free convection arises in fluid when temperature changes cause density variation leading to buoyancy forces acting on the fluid elements. It can be observed in our daily life in atmospheric flow, which is driven by temperature differences. Channel flows through porous medium have varied applications in the field of chemical engineering, agriculture engineering and petroleum technology. In some applications e.g. in microfluidic and nanofluidic device where the surface to volume ratio is large , the slip behavior is more typical and slip boundary condition is usually used for the velocity field. Makinde and Osalusi [1] considered MHD steady flow in a channel with slip at the permeable boundaries. Sharma and Mehta [2] investigated MHD Unsteady slip flow and heat transfer in a channel with slip at the permeable boundaries. Sharma et al.[3] observed radiation effects on unsteady MHD free convective flow with Hall current and mass transfer through viscous incompressible fluid past a vertical porous plate immersed in porous medium with heat source / sink. Sharma et al. [4] presented unsteady MHD free convective flow and heat transfer between heated inclined plates with magnetic field in the presence of radian effects. Analysis of MHD convective flow along a moving semi-vertical plate with internal heat generation was presented by Sharma and Yadav [5]. Sharma et al.[6] presented unsteady MHD free convective flow and heat transfer between heated inclined plates with magnetic field in the presence of radian effects. Zanchini [7] presented mixed convection with variable viscosity in a vertical annulus with uniform wall temperature. Oscillatory MHD free convective flow and mass transfer flow of a viscous incompressible electrically conducting fluid through a porous medium bounded by two infinite vertical parallel porous plates under slip boundary conditions in the presence of heat source is investigated by Sharma et al. [8].Recently Raghunath and Siva Prasad [19] have investigated Heat and mass transfer on MHD flow of Non-Newtonian fluid over an infinite vertical porous plate. Raghunath and Siva [10] Prasad Indigested Heat and mass transfer on Unsteady MHD flow of a second grade fluid through porous medium between two vertical plates. Recently, Krishna and Swarnalathamma [11] discussed the peristaltic MHD flow of an incompressible and electrically conducting Williamson fluid in a symmetric planar channel with heat and mass transfer under the effect of inclined magnetic field. Krishna and G.S.Reddy [12] discussed unsteady MHD convective flow of second grade fluid through a porous medium in a Rotating parallel plate channel with temperature dependent source.

Motivated by the above studies, in this paper, we have discussed the heat transfer on the unsteady hydromagnetic convective flow of an incompressible viscous electrically conducting heat generating/absorbing second grade fluid through porous medium in a rotating parallel plate channel under the influence of uniform transfer magnetic field normal to the channel.

2. FORMULATION AND SOLUTION OF THE PROBLEM

We consider the unsteady hydromagnetic convective flow of an incompressible viscous electrically conducting heat generating/absorbing second grade fluid through porous medium in a rotating parallel plate channel under the influence of uniform transfer magnetic field Ho normal to the channel. In undisturbed state both the plates and the fluid rotate with the same angular velocity Ω. Since, the plates are widening to infinity along x and y paths, electrically non-conducting and flow is fully developed, so that all the physical quantities except the pressure depend on z and t alone. The physical configuration of the problem is as shown in Fig. 1.

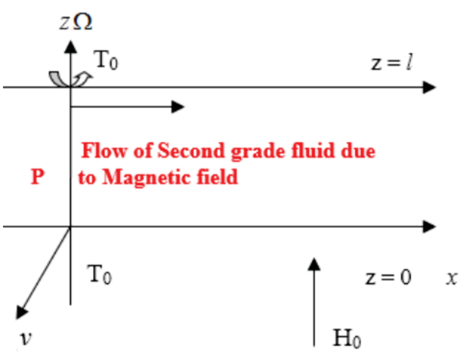


Fig. 1 Physical configuration of the Problem

We choose a Cartesian co-ordinate system O(x, y, z) such that the plates are at and and the z- axis consider with the axis of rotation of the plates. The unsteady hydromagnetic boundary layer equation of motion with respect to a rotating frame moving with angular velocity Ω in the absence of any input electric field are,

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

$$\frac{\partial u}{\partial t}-2\Omega v=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\frac{\partial^2 u}{\partial z^2}+\frac{\alpha_1}{\rho}\frac{\partial^3 u}{\partial z^2\partial t}-\frac{\sigma B_0^2}{\rho}u-\frac{\nu}{k}u+g\beta(T-T_0) \qquad (2)$$

$$\frac{\partial v}{\partial t}+2\Omega u=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\frac{\partial^2 v}{\partial z^2}+\frac{\alpha_1}{\rho}\frac{\partial^3 v}{\partial z^2\partial t}-\frac{\sigma B_0^2}{\rho}v-\frac{\nu}{k}v \qquad (3)$$

$$\frac{\partial T}{\partial t}=\frac{K_1}{\rho C_p}\frac{\partial^2 T}{\partial z^2}-\frac{Q_0}{\rho C_p}(T-T_0) \qquad (4)$$

We have considered oscillatory Hartmann convective flow so pressure p is assumed in the following form

$$p = 2Rx\cos(\omega t) + F(y) + G(z) \tag{5}$$

It is noticed from equations (1), (2), (3), (4) and (5) that pressure p is constant along the axis of rotation i.e., $\frac{\partial p}{\partial z} = G'(z) = 0$. The absence of pressure gradient term $\frac{\partial p}{\partial y} = F'(y)$ in equation (2) implies that there is a net cross flow in y-direction. Buoyancy term $g\beta(T - T_0)$ is considered in equation (1) only because free-convection in this problem takes place under gravitational force. Boundary conditions for the fluid velocity are hydrodynamic slip boundary conditions which are given by

$$\mu\frac{du}{dz} = -\beta_1 u \text{ and } \mu\frac{dv}{dz} = -\beta_1 v \text{ at } z = 0 \tag{6}$$

$$\mu\frac{du}{dz} = \beta_1 u \text{ and } \mu\frac{dv}{dz} = \beta_1 v \text{ at } z = l \tag{7}$$

Boundary conditions (6-7) for the fluid velocity are well known hydrodynamic slip boundary conditions derived by Beavers and Joseph (1967). Here μ and are respectively the coefficient of dynamic viscosity and coefficient of sliding friction. Boundary conditions for the fluid temperature are

$$T = T_0, \quad \text{at } z = 0 \tag{8}$$

$$T = T_0 + (T_w - T_0)\cos\omega t \quad \text{at } z = l \tag{9}$$

here, $T_0 < T < T_w$.

Equations (2)and (3), in compact form , become

$$\frac{\partial F}{\partial t} + 2i\Omega F = -\frac{1}{\rho}\frac{\partial p}{\partial \xi} + v\frac{\partial^2 F}{\partial z^2} + \frac{\alpha_1}{\rho}\frac{\partial^3 F}{\partial z^2 \partial t} - \frac{\sigma B_0^2}{\rho}F - \frac{v}{k}F + g\beta(T - T_0) \tag{10}$$

Where, $F = u + iv$.

We introduce non-dimensional variables

$$\xi^* = \frac{\xi}{l}, \eta = \frac{z}{l}, u^* = \frac{ul}{v}, v^* = \frac{vl}{v}, t^* = \frac{tv}{l^2}, p^* = \frac{l^2 p}{\rho v^2}, T^* = \frac{(T - T_0)}{(T_w - T_0)}$$

Equations (10) and (4) in non-dimensional form are

$$(1 + \alpha i\omega)\frac{d^2 F}{d\eta^2} - \left\{M^2 + \frac{1}{K_1} + i(2K^2 + \omega)\right\}F = R - G_r T \tag{11}$$

$$\frac{\partial T}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 T}{\partial \eta^2} - \phi T, \tag{12}$$

Boundary conditions (6) and (7), in dimensionless from, are

$$u = -\beta\frac{\partial u}{\partial \eta} \text{ and } v = -\beta\frac{\partial v}{\partial \eta} \text{ at } \eta = 0 \tag{13}$$

$$u = \beta\frac{\partial u}{\partial \eta} \text{ and } v = \beta\frac{\partial v}{\partial \eta} \text{ at } \eta = 1 \tag{14}$$

$$T = 0 \quad \text{at } \eta = 0 \tag{15}$$

$$T = \cos\omega t \quad \text{at } \eta = 1 \tag{16}$$

Boundary conditions (15) and (16), in dimensionless from, are

$$F + \beta\frac{\partial F}{\partial \eta} = 0 \text{ at } \eta = 0, F - \beta\frac{\partial F}{\partial \eta} = 0 \text{ at } \eta = 1 \tag{17}$$

It may be noted that the fluid flow past a plate may be induced due to either by motion of the plate or free stream or by heating of the fluid or by both. We have considered oscillatory Hartmann convective flow so fluid flow, in our case, is induced due to applied and oscillatory pressure gradient and by heating of the fluid because lower and upper plates. Therefore, pressure gradient $\frac{\partial p}{\partial \varsigma}$, fluid velocity $F(z,t)$ and fluid temperature $T(z,t)$ are assumed in non-dimensional form, as $\frac{\partial p}{\partial \varsigma} = R(e^{i\omega t} + e^{-i\omega t})$,

(18) $F(z,t) = F_1(z)e^{i\omega t} + F_2(z)e^{-i\omega t}$

(19) $\theta(z,t) = T_1(z)e^{i\omega t} + T_2(z)e^{-i\omega t}$

x(20)

Where $R < 0$ for favourable pressure.Equations (11) and (12) with the use of (19) and (20) reduce to

$$(1 + \alpha i\omega)\frac{d^2 F_1}{d\eta^2} - \left\{M^2 + \frac{1}{K_1} + i(2K^2 + \omega)\right\}F_1 = R - \mathrm{Gr}T_1 \tag{21}$$

$$(1 - \alpha i\omega)\frac{d^2 F_2}{d\eta^2} - \left\{M^2 + \frac{1}{K_1} + i(2K^2 - \omega)\right\}F_2 = R - \mathrm{Gr}T_2 \tag{22}$$

$$\frac{d^2 T_1}{d\eta^2} - \Pr(\phi + i\omega)T_1 = 0 \tag{23}$$

$$\frac{d^2 T_2}{d\eta^2} - \Pr(\phi + i\omega)T_2 = 0 \tag{24}$$

Boundary conditions (27) and (29) becomes

$$F_1 + \beta\frac{\partial F_1}{\partial \eta} = 0 \text{ and } F_2 + \beta\frac{\partial F_2}{\partial \eta} = 0 \text{ at } \eta = 0 \tag{25}$$

$$F_1 - \beta\frac{\partial F_1}{\partial \eta} = 0 \text{ and } F_2 - \beta\frac{\partial F_2}{\partial \eta} = 0 \text{ at } \eta = 1 \tag{26}$$

$$T_1 = 0 \text{ and } T_2 = 0 \text{ at } \eta = 0 \tag{27}$$

$$T_1 = 1/2 \text{ and } T_2 = 1/2 \text{ at } \eta = 1 \tag{28}$$

Equations (21) to (24) subject to boundary conditions (25) to (28) are solved and the solution for velocity and temperature of the fluid is presented in the following form

$$\theta(\eta,t) = \frac{1}{2}\left[\frac{\sinh m_1\eta}{\sinh m_1}e^{i\omega t} + \frac{\sinh m_3\eta}{\sinh m_3}e^{-i\omega t}\right], \tag{29}$$

$$F(\eta,t) = \left\{C_1\cosh m_2\eta + C_2\sinh m_2\eta - \frac{R}{m_2^2} - \frac{G_r\sinh m_1\eta}{2(m_1^2 - m_2^2)\sinh m_1}\right\}e^{i\omega t} + \left\{C_3\cosh m_4\eta + C_4\sinh m_4\eta - \frac{R}{m_4^2} - \frac{G_r\sinh m_3\eta}{2(m_3^2 - m_4^2)\sinh m_3}\right\}e^{-i\omega t} \tag{30}$$

The non-dimensional skin friction at the lower plate *n=0* in term of amplitude and phase angle is given by

$$\tau = \left(\frac{dF}{d\eta}\right)_{\eta=0} = \left(\frac{dF_1}{d\eta}\right)_{\eta=0} e^{i\omega t} + \left(\frac{dF_2}{d\eta}\right)_{\eta=0} e^{-i\omega t} \tag{31}$$

The rate of heat transfer co-efficient at the lower plate *n=0* in term of amplitude and phase angle is given by

$$Nu = \left(\frac{dT}{d\eta}\right)_{\eta=0} = \left(\frac{dT_1}{d\eta}\right)_{\eta=0} e^{i\omega t} + \left(\frac{dT_2}{d\eta}\right)_{\eta=0} e^{-i\omega t} \quad (32)$$

3. RESULTS AND DISCUSSIONS

We discussed the heat transfer on the unsteady hydromagnetic convective flow of an incompressible viscous electrically conducting heat generating/absorbing second grade fluid through porous medium in a rotating parallel plate channel under the influence of uniform transfer magnetic field normal to the channel. The momentum equation for the flow is governed by the Brinkman's model. The analytical solutions for the velocity and temperature distributions are obtained by making use of regular perturbation technique. The closed form solutions for the velocity $F = u + iv$ and temperature θ are obtained making use of perturbation technique. The velocity expression consists of steady state and oscillatory state. It reveals that, the steady part of the velocity field has three layer characters while the oscillatory part of the fluid field exhibits a multi layer character. The Figures (2-4) exhibit the temperature distribution with different variations in the governing parameters P_r and frequency of oscillation θ The Figures (5-11) shows the effects of non-dimensional parameters M the Hartmann number, K_1 permeability parameter, parameter , α the second grade fluid parameter, Gr thermal Grashof number, , K^2 rotation parameter and source/sink parameter ϕ

The numerical values of fluid temperature and are computed from analytical solution mentioned by MATHEMATICA software, are depicted graphically in Figs. 2 to 4 for different values of heat generation coefficient $\varphi (< 0)$, heat absorption coefficient $\varphi (> 0)$, Prandtl number Pr and frequency parameter ω taking $\omega t = \pi / 2$. Figure 2 reveals that fluid temperature T increases on increasing φ (< 0) and decreases on increasing φ (> 0) which imply that thermal source tends to increase fluid temperature whereas thermal sink has reverse effect on it. Figure 3 shows that, for both heat generating and absorbing fluids, fluid temperature T increases on increasing Prandtl number Pr . Since Prandtl number Pr is ratio of viscosity to thermal diffusivity. An increase in thermal diffusivity leads to a decrease in Prandtl number. Therefore, thermal diffusion has tendency to reduce fluid temperature for both heat generating/absorbing fluids. It is observed that Prandtl number Pr leads to decrease the temperature uniformly in all layers being the heat source parameter fixed. It is found that the temperature decreases in all layers with increase in the heat source. It is concluded that Prandtl number Pr reduces the temperature in all layers. It is noticed from Fig. 4 that, for both heat generating/absorbing fluids, fluid temperature T decreases in the lower of the channel whereas it decreases, attains a minimum and then increases in magnitude in the upper of the channel on increasing ω which implies that there exists reverse flow of heat in the upper of the channel due to oscillating temperature of plate $\eta = 1$.

To study the effects of magnetic field, rotation, thermal buoyancy force, porosity of medium, oscillations and thermal source/sink on the flow-field numerical values of both primary and secondary fluid velocities, computed from analytical solution are displayed graphically versus channel width variable η for various values of second grade fluid parameter α , magnetic parameter M^2 , rotation parameter K^2 , Grashof number Gr , permeability parameter K1, frequency parameter ω, heat generation coefficient φ (< 0) and heat absorption coefficient φ (> 0) in Figs. 5 to 11 taking , Pr = 0.71, $\omega t = \pi / 2$ and $R = -1$.

It is evident from Figs. 5 (a-b) to 6 (a-b) that primary velocity u and secondary velocity v decrease on increasing either second grade fluid parameter α or magnetic parameter M2 for both heat generating and absorbing fluids which implies that wall slip and magnetic field have tendency to retard fluid flow in the primary and secondary flow directions for both heat generating and absorbing fluids. The application of the transverse magnetic field plays the important role of a resistive type force (Lorentz force) similar to drag force (that acts in the opposite direction of the fluid motion) which tends to resist the flow thereby reducing its velocity. Figures 7 (a-b) show that, for both heat generating and absorbing fluids, primary velocity u decreases whereas secondary velocity v increases with the increase in rotation parameter K^2 which implies that, for both heat generating and absorbing fluids, rotation tends to retard fluid flow in the primary flow direction whereas it has reverse effect on the fluid flow in secondary flow direction. Figures 8 (a-b) to 10 (a-b) reveal that, for both heat generating and absorbing fluids, u and v increase on increasing either Gr or K1 or ω which implies that, for both heat generating and absorbing fluids, thermal buoyancy force, porosity of medium and oscillations have tendency to accelerate fluid flow in both the primary and secondary flow directions. It is noticed from Figs. 11(a-b) that u and v increase on increasing φ (< 0) and decrease on increasing φ (> 0) which implies that thermal source accelerates fluid flow in both the primary and secondary flow directions whereas thermal sink has reverse effect on it.

It is noted from the table 1 that the magnitudes of both the skin friction components τ_{xz} and τ_{yz} increase with increase in permeability parameter K^1, second grade fluid parameter k_1 and rotation parameter K^2 and where as it reduces with increase in Hartmann number M, thermal Grashof number Gr, Prandtl number Pr. From the table 2 that the magnitude of the Nusselt number Nu increases for the parameters and Prandtl number Pr or time t, and it reduces with the frequency of oscillation .φ

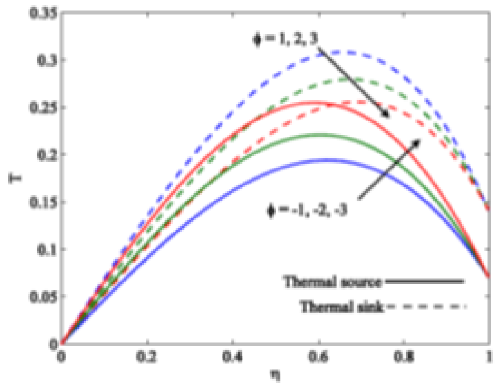


Fig 2. Temperature Profile Pr=0.71 and φ =3

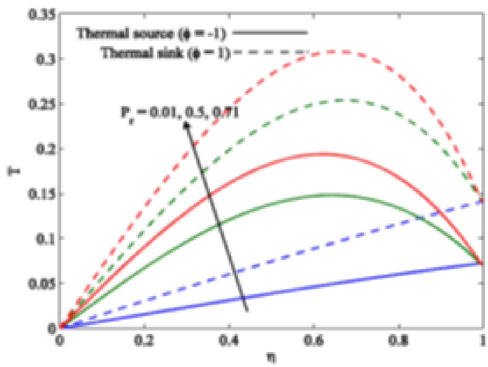


Fig. 3 Temperature Profile with ω=3

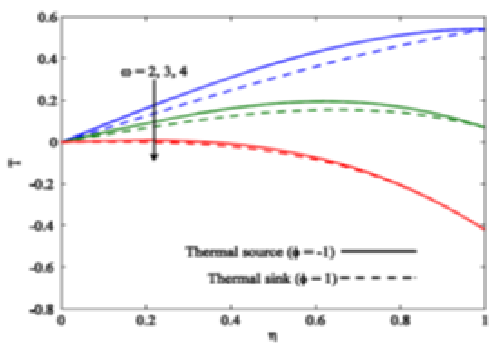
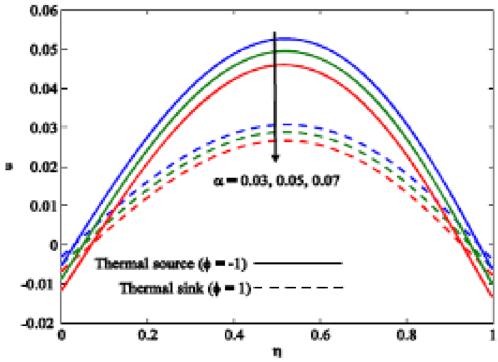
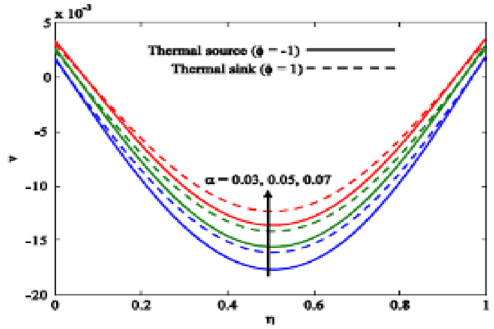


Fig. 4 Temperature Profile with Pr = 071



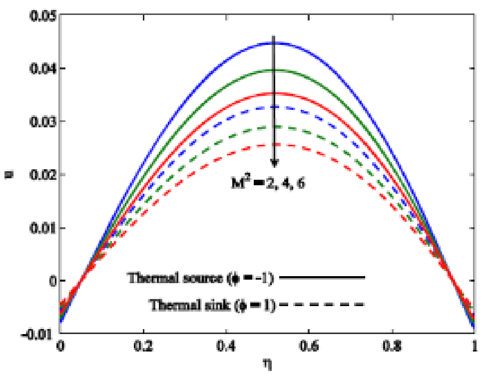
Figs. 5(a) The velocity Profile for *u* against *a with*

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3$$



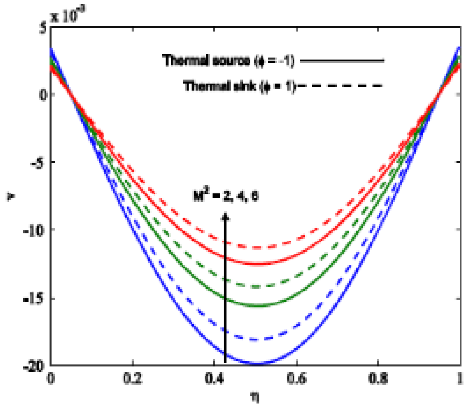
Figs. 5(b) The velocity Profile for v against *a* with

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3$$



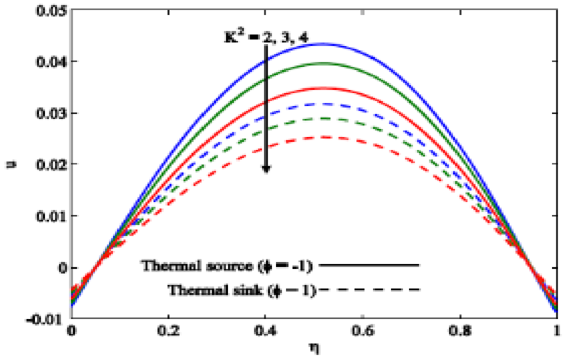
Figs. 6(a) The velocity Profile for u against M with

$$K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



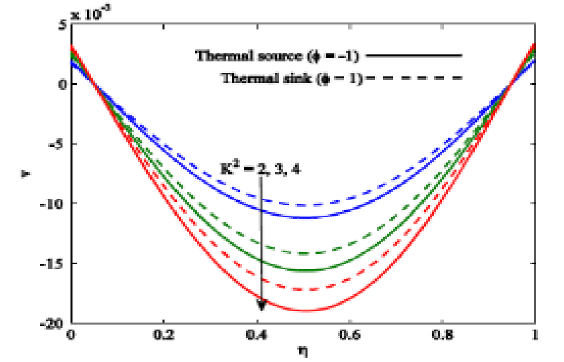
Figs. 6(b) The velocity Profile for v against M with

$$K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



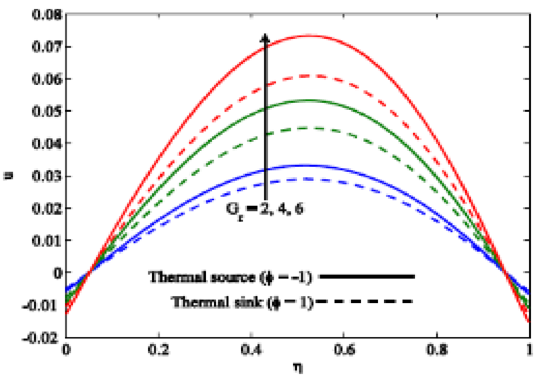
Figs. 7 (a) The velocity Profile for u and v agains K^2 with

$$M^2 = 4, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



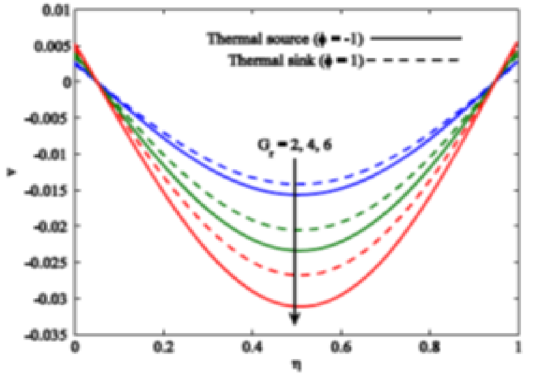
Figs. 7 (b)The velocity Profile for u and v against K^2 with

$$M^2 = 4, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



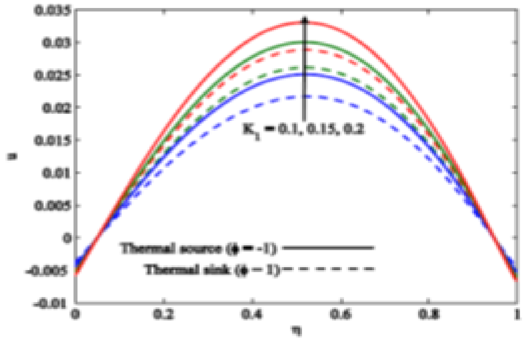
Figs. 8 (a) The velocity Profile for u against G_r with

$$M^2 = 4,\ K^2 = 3, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



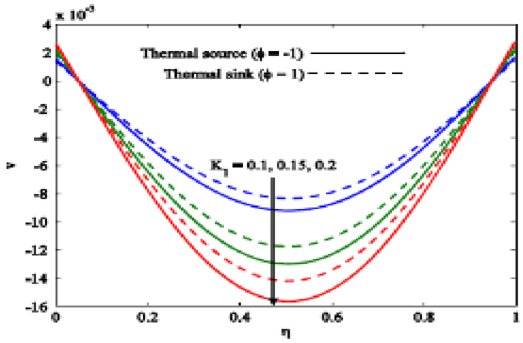
Figs. 8 (b) The velocity Profile for v against G_r with

$$M^2 = 4,\ K^2 = 3, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



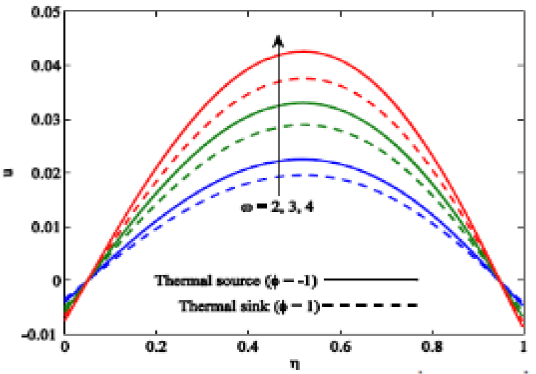
Figs. 9 (a)The velocity Profile for u and v against K_1 with

$$M^2 = 4,\ K^2 = 3, G_r = 2,\ \omega = 3, \alpha = 0.05$$



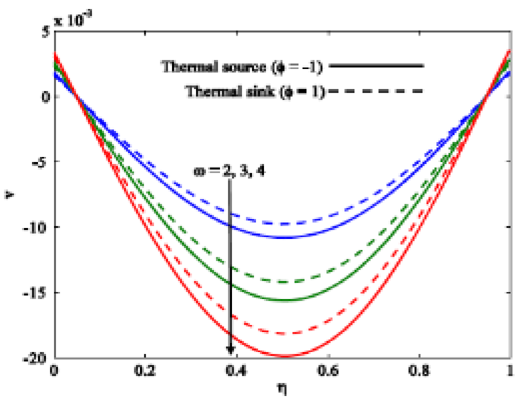
Figs. 9 (b)The velocity Profile for u and v against K_1 with

$$M^2 = 4,\ K^2 = 3, G_r = 2,\ \omega = 3, \alpha = 0.05$$



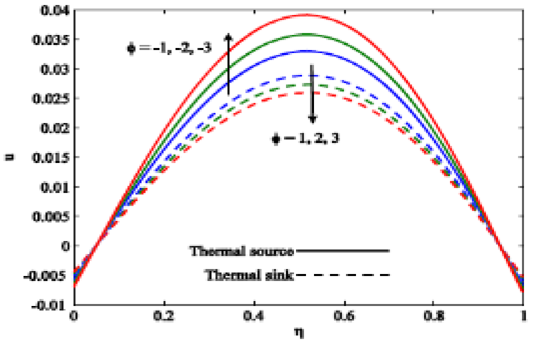
Figs. 10(a) The velocity Profile for u against ω with

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2, \alpha = 0.05$$



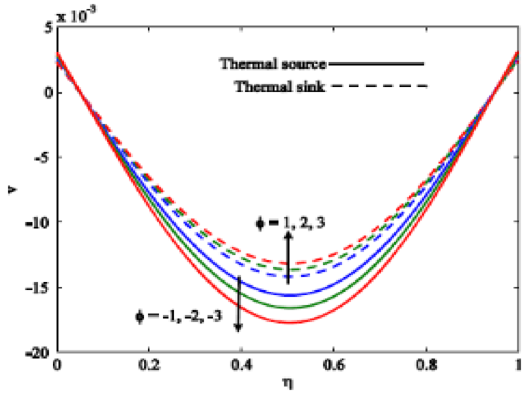
Figs. 10(b) The velocity Profile for v against ω with

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2, \alpha = 0.05$$



Figs. 11(a) The velocity Profile for u against *f* with

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$



Figs. 11 (b) The velocity Profile for v against ϕ with

$$M^2 = 4,\ K^2 = 3, G_r = 2, K_1 = 0.2,\ \omega = 3, \alpha = 0.05$$

Table. 1. Skin Friction

M^2	K_1	α	K^2	Gr	Pr	τ_{xz}	τ_{yz}
2	0.2	0.05	2	2	0.71	5.455874	-2.685635
4	0.2	0.05	2	2	0.71	5.180014	-2.431979
6	0.2	0.05	2	2	0.71	4.994062	-2.238778
2	0.4	0.05	2	2	0.71	5.630854	-2.798579
2	0.6	0.05	2	2	0.71	5.833692	-2.856412
2	0.2	0.07	2	2	0.71	5.900142	-2.855569
2	0.2	0.1	2	2	0.71	6.874566	-3.552145
2	0.2	0.05	3	2	0.71	5.938664	-2.802852
2	0.2	0.05	4	2	0.71	6.285566	-2.919556
2	0.2	0.05	2	3	0.71	3.606121	-1.635212
2	0.2	0.05	2	4	0.71	2.814612	-1.265465
2	0.2	0.05	2	2	3	4.900744	-2.261745
2	0.2	0.05	2	2	7	4.533414	-2.153403

Table. 2. Nusselt Number

Pr	ω	*t*	Nu
0.71	$5\pi/2$	0.2	-1.60653
3	$5\pi/2$	0.2	-4.45861
7	$5\pi/2$	0.2	-8.61827
0.71	$7\pi/2$	0.2	-1.61538
0.71	$9\pi/2$	0.2	-1.61431
0.71	$5\pi/2$	0.4	-1.61854
0.71	$5\pi/2$	0.6	-1.60026

REFERENCES

[1]. Kesavaiah, D.Ch.; Satyanarayana, P.V. and Sudhakaraiah A.(2013) 'Effects of radiation and free convection currents on unsteady couette flow between two

vertical parallel plates with constant heat flux and heat source through porous medium'. Int. J. of Engineering Research, Vol. 2, pp. 113-118.
[2]. Khem Chand and Sapna(2012) 'Hydromagnetic free convective oscillatory couette flow through a porous vertical channel with periodic wall temperature'. Int. J. of Mathematical Archive, Vol.3, pp. 3484-3491.
[3]. Makinde, O.D. and Osalusi, E.(2006) 'MHD steady flow in a channel with slip at the permeable boundaries'. Rom. J. Phys. Vol. 51, pp.319.
[4]. Sharma, P.R. and Mehta, R.(2009) 'MHD Unsteady slip flow and heat transfer in a channel with slip at the permeable boundaries'. J. Int. Academy of Physical Sciences, India, Vol. 13, pp.73-92.
[5]. Sharma, P.R.; Kumar, N and Sharma, Pooja (2009) 'Radiation effects on unsteady MHD free convective flow with Hall current and mass transfer through viscous incompressible fluid past a vertical porous plate immersed in porous medium with heat source / sink'. J. Int. Academy Physical Sciences , India, Vol. 13, pp. 231-252.
[6]. Sharma, P.R.; Kumar, N. and Sharma, Pooja. (2010) 'Unsteady MHD free convective flow and heat transfer between heated inclined plates with magnetic field in the presence of radian effects'. J. Int. Academy of Physical Sciences, India, Vol. 14, pp. 181-193.
[7]. Sharma, P.R. and Yadav, R.S.(2014) 'Analysis of MHD convective flow along a moving semivertical plate with internal heat generation'. Int. J. Eng. Research and Technology, Vol. 3, pp.2342- 2348.
[8]. Singh, K.D. (2012) 'Solution of MHD oscillatory convection flow through porous medium in a vertical porous channel in slip flow regime'. J. of Energy, Heat and Mass Transfer, Vol. 34, pp. 217- 232.
[9]. Zanchini, E.(2008) 'Mixed convection with variable viscosity in a vertical annulus with uniform wall temperatures'. Int. J. of heat and mass transfer, Vol. 51, pp. 30-40.
[10]. P R Sharma and Manisha Sharma (2014), 'Oscillatory MHD Free Convective Flow and Mass transfer through Porous Medium bounded by a Vertical Porous Channel with Thermal Source and Slip Boundary Conditions,' Asian Journal of Multidisciplinary Studies, Vol. 2 (9), pp. 70-85.
[11]. Raghunath and Siva prsad. Heat and mass transfer on MHD flow of Non-Newtonian fluid over an infinite vertical porous plate, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13,Number 13 (2018) pp. 11156-11163.
[12]. Raghunath and Siva Prasad Heat and mass transfer on Unsteady MHD flow of a second grade fluid through porous medium between two vertical plates, JUSPS-B Vol. 30(2), 1-11 (2018).
[13]. VeeraKrishna/M and G.Subba Reddy (2016) Unsteady MHD convective flow of Second grade fluid through a porous medium in a Rotating parallel plate channel with temperature dependent source IOP Conf. Series: Materials Science and Engineering, 149:012216
[14]. VeeraKrishna.M and B.V.Swarnalathamma (2016) Convective Heat and Mass Transfer on MHD Peristaltic Flow of Williamson Fluid with the Effect of Inclined Magnetic Field," AIP Conference Proceedings 1728:020461