EFFECT OF HALL CURRENTS ON CONVECTIVE HEAT TRANSFER IN A NON-UNIFORMLY VERTICAL CHANNEL IN THE PRESENCE OF HEAT SOURCES

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Abstract. The effect of Hall currents on the Convective Heat Transfer flow of a viscous electrically conducting fluid in a vertical channel bounded by the flat plates at $x = \pm$ L which . Which are maintained at Non-uniform Temperature in the presence of Heat sources taking the slope δ of the boundary temperature. The Non-linear coupled equations governing the flow and Heat Transfer are solved by employing a regular perturbation technique the Velocity and Temperature distributions are analysed for different values of the Hartmann Number M,Hall current parameter m,Grashoff Number G,Heat source parameter α inclination λ of the magnetic field Radiation parameter N_1,amplitude α_1 of the boundary temperature. The rate of Heat Transfer has been calculated numerically for different values of the governing parameters.

Key words: Heat Transfer, Hall effects, Heat sources, Vertical channel.

1. INTRODUCTION

The magneto hydrodynamic heat transfer has gained significance in recent times owing to its applications in recent advancement of space technology. The process of free convection as a mode of heat transfer has wide applications in the fields of chemical Engineering, Aeronautics and Nuclear power generation. Natural convection in porous media with internal heat generation is of interest in such situations as post accident heat removal in nuclear power reactors and the geothermal problems arising during the storage of nuclear waste in the earth[2].Rajeswara Rao[6] has analysed the combined free and forced convective flow of an electrically conducting ,viscous ,incompressible fluid confined in a vertical channel whose

boundaries are maintained at a non-uniform temperature He has not considered induced magnetic field into account Taking induced magnetic field into account Ram Chandra [7] has discussed the free and forced convective flow of an electrically conducting fluid in a vertical channel whose walls are maintained at non-uniform temperature Ravindra [8] has investigated the natural convective flow and heat transfer through a porous medium in a vertical channel maintained at Non-uniform temperature with constant heat sources.

The unsteady flow of a rotating viscous fluid in a channel maintained by non-tensional oscillations of one or both the boundaries has been studied by several authors to analyse the growth and development of boundary layers associated with geothermal flows for possible applications in geophysical fluid dynamics [2,3,4,5,9]. Later Singh et al [10] studied free convection in MHD flow of a rotating viscous liquid in porous media. Singh et al [11] have also studied free convective MHD flow of a rotating viscous fluid in a porous medium past an infinite vertical porous plate. However, in a partially ionized gas, there occurs a Hall current when the strength of the impressed magnetic field is very strong.

2. FORMULATION OF THE PROBLEM

We consider the steady flow of an incompressible, viscous ,electrically conducting fluid confined in a vertical channel bounded by two flat walls under the influence of an inclined magnetic field of intensity Ho lying in the plane (y-z).The magnetic field is inclined at an angle α to the axial direction k and hence its components are $(0, H_0 Sin(\alpha), H_0 Cos(\alpha))$.The walls are maintained at non-uniform temperature. In view of the non-uniform boundary temperature the velocity field has components(u,0,w)The magnetic field in the presence of fluid flow induces the current $(J_x, 0, J_z)$.We choose a rectangular cartesian co-ordinate system O(x,y,z) with z-axis in the vertical direction and the walls at $x = \pm L$.
When the strength of the magnetic field is very large we include the Hall current so that the generalized Ohm's law is modified to

$$\bar{J} + \omega_e \tau_e \bar{J} x \bar{H} = \sigma(\bar{E} + \mu_e \bar{q} x \bar{H}) \tag{2.1}$$

where q is the velocity vector. H is the magnetic field intensity vector.E is the electric field, J is the current density vector, ω_e is the cyclotron frequency, τ_e is the electron collision time,σ is the fluid conductivity and μ_e is the magnetic permeability.
Neglecting the electron pressure gradiention-slip and thermo-electric effects ans assuming the electric field E=0,

$$J_x - m H_0 J_z Sin(\alpha) = -\sigma\mu_e H_0 w Sin(\alpha) \tag{2.2}$$

$$J_z + m H_0 J_x Sin(\alpha) = \sigma\mu_e H_0 u\, Sin(\alpha) \tag{2.3}$$

where m= $\omega_e \tau_e$ is the Hall parameter.
On solving equations (2.2)&(2.3) we obtain

$$J_x = \left(\frac{\sigma\mu_e H_0 Sin(\alpha)}{1 + m^2 H_0^2 Sin^2(\alpha)} \right) (m H_0 Sin(\alpha) - w) \tag{2.4}$$

$$J_z = \left(\frac{\sigma\mu_e H_0 Sin(\alpha)}{1 + m^2 H_0^2 Sin^2(\alpha)} \right) (u + m H_0 w\, Sin(\alpha)) \tag{2.5}$$

where u,w are the velocity components along x and z directions respectively,
The Momentum equations are

$$u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial z^2} \right) + \mu_e(-H_0 J_z Sin(\alpha)) \tag{2.6}$$

$$u\frac{\partial W}{\partial x} + w\frac{\partial W}{\partial z} = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial z^2} \right) + \mu_e(H_0 J_x Sin(\alpha)) \tag{2.7}$$

Substituting J_x and J_z from equations (2.4)&(2.5)in equations (2.6)&(2.7) we obtain

$$u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial z^2} \right) - \left(\frac{\sigma\mu_e H_{0\,0}^{2} Sin^2(\alpha)}{1 + m^2 H_0^2 Sin^2(\alpha)} \right) (u + m H_0 w Sin(\alpha)) \tag{2.8}$$

$$u\frac{\partial W}{\partial x} + w\frac{\partial W}{\partial z} = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial z^2} \right)$$
$$-\left(\frac{\sigma\mu_e H_0^2 Sin^2(\alpha)}{1 + m^2 H_0^2 Sin^2(\alpha)} \right) (w - m H_0 u Sin(\alpha)) + \beta g (T - T_e) \tag{2.9}$$

The flow is maintained by a constant volume flux for which a characteristic velocity is defined as

$$q = \frac{1}{L} \int_{-L}^{L} u\, dy \tag{2.10}$$

The boundary conditions are
u= 0, w=0 T= γ(δz/L) on x = -L (2.11)
u=0, w=0, T= γ(δz/L) on x = +L
Eliminating the pressure from equations(2.8)&(2.9) and introducing the Stokes Stream function ψ as

$$u = -\left(\frac{\partial \psi}{\partial z}\right) \quad , w = \left(\frac{\partial \psi}{\partial x}\right) \tag{2.12}$$

the equations (2.8)&(2.9) in terms of ψ is

$$\left(\frac{\partial \psi}{\partial z}\frac{\partial(\nabla^2\psi)}{\partial x}\right) - \left(\frac{\partial \psi}{\partial x}\frac{\partial(\nabla^2\psi)}{\partial z}\right) = \mu\nabla^4\psi + \left(\beta g\frac{\partial(T-T_e)}{\partial x}\right)$$
$$-\left(\frac{\sigma\mu_e^2 H_0^2 Sin^2(\alpha)}{1+m^2H_0^2\,Sin^2(\alpha)}\right)\nabla^2\psi \tag{2.13}$$

$$\rho_0 C_p\left(\frac{\partial \psi}{\partial x}\frac{\partial T}{\partial z} - \frac{\partial \psi}{\partial z}\frac{\partial T}{\partial x}\right) = K_f(\nabla^2 T) - Q(T-T_e) \tag{2.14}$$

On introducing the following non-dimensional variables

$$(x', z') = \frac{(x,z)}{L}, \psi' = \frac{\psi}{qL},\ \theta = \frac{T-T_e}{\Delta T_e}$$

The equations of momentum and energy in the presence of heat generating sources in the non-dimensional form are

$$\nabla^4\psi - M_1^2\nabla^2\psi + \left(\left(\frac{G}{R}\right)\left(\frac{\partial\theta}{\partial x}\right)\right) = R\left(\left(\frac{\partial \psi}{\partial z}\right)\left(\frac{\partial(\nabla^2\psi)}{\partial x}\right) - \left(\frac{\partial \psi}{\partial x}\right)\left(\frac{\partial(\nabla^2\psi)}{\partial z}\right)\right) \tag{2.15}$$

$$PR\left(\left(\frac{\partial \psi}{\partial x}\right)\left(\frac{\partial\theta}{\partial z}\right) - \left(\frac{\partial \psi}{\partial z}\right)\left(\frac{\partial\theta}{\partial x}\right)\right) = \nabla^2\theta - \alpha\theta \tag{2.16}$$

where

$G = \left(\frac{\beta g\,\Delta T_e L^3}{\nu^2}\right)$ (Grashof Number) $M^2 = \left(\frac{\sigma\mu_e^2 H_o^2 L^2}{\nu^2}\right)$ (Hartman Number)

$R = \left(\frac{qL}{\nu}\right)$ (Reynolds Number) $P = \left(\frac{\mu C_p}{K_f}\right)$ (Prandtl Number)

$\alpha = \left(\frac{QL^2}{K_f}\right)$ (Heat Source Parameter)

The corresponding boundary conditions are

$$\psi(1) - \psi(-1) = 1$$

$$\frac{\partial \psi}{\partial z} = 0, \frac{\partial \psi}{\partial x} = 0, \theta = \gamma(\delta z) \quad at\ x = -L$$

$$\frac{\partial \psi}{\partial z} = 0, \frac{\partial \psi}{\partial x} = 0, \theta = \gamma(\delta z) \quad at\ x = +L$$

3. ANALYSIS OF THE FLOW

Introduce the transformation such that $\bar{z} = \delta\, z,\ \frac{\partial}{\partial z} = \delta\frac{\partial}{\partial \bar{z}}$

Then $\frac{\partial}{\partial z} \approx O(\delta) \rightarrow \frac{\partial}{\partial \bar{z}} \approx O(1)$

For small values of δ <<1, the flow develops slowly with axial gradient of order δ and hence we take $\frac{\partial}{\partial \bar{z}} \approx O(1)$.

Using the above transformation the equations governing equations (2.15) and (2.16) reduces to

$$F^4\psi - M_1^2F^2\psi + \left(\left(\frac{G}{R}\right)\left(\frac{\partial\theta}{\partial x}\right)\right) = \delta R\left(\frac{\partial\psi}{\partial\bar{z}}\frac{\partial(F^2\psi)}{\partial x} - \frac{\partial\psi}{\partial x}\frac{\partial(F^2\psi)}{\partial\bar{z}}\right) \quad (3.1)$$

$$\delta PR\left(\left(\frac{\partial\psi}{\partial x}\right)\left(\frac{\partial\theta}{\partial z}\right) - \left(\frac{\partial\psi}{\partial z}\right)\left(\frac{\partial\theta}{\partial x}\right)\right) = F^2\theta - \alpha\theta \quad (3.2)$$

Where $F^2 = \frac{\partial}{\partial x^2} + \delta^2\frac{\partial}{\partial\bar{z}^2}$

Assuming the slope δ of the wavy boundary to be small we take

$$\psi(x,z) = \psi_0(x,y) + \delta\psi_1(x,z) + \delta^2\psi_2(x,z) + \dots\dots\dots\dots\dots$$
$$\theta(x,z) = \theta_o(x,z) + \delta\theta_1(x,z) + \delta^2\theta_2(x,z) + \dots\dots\dots\dots\dots\dots \quad (3.3)$$

Substituting (3.7) in equations (3.1)&(3.2) and equating the like powers of δ the equations and the respective boundary conditions to the zeroth order are

$$\frac{\partial^2\theta_0}{\partial x^2} - \alpha_1\theta_0 = 0 \quad (3.4)$$

$$\left(\frac{\partial^4\psi_0}{\partial x^4} - (M_1^2)\frac{\partial^2\psi_0}{\partial x^2}\right) = -\left(\left(\frac{G}{R}\right)\left(\frac{\partial\theta_0}{\partial z}\right)\right) \quad (3.5)$$

with

$$\psi_0(+1) - \psi_0(-1) = 1$$

$$\frac{\partial\psi_0}{\partial x} = 0,\ \frac{\partial\psi_0}{\partial\bar{z}} = 0,\quad \theta_0 = \gamma(\bar{z}) \quad at \quad x = -1$$
$$\frac{\partial\psi_0}{\partial x} = 0,\ \frac{\partial\psi_0}{\partial\bar{z}} = 0,\quad \theta_0 = \gamma(\bar{z}) \quad at \quad x = +1 \quad (3.6)$$

and to the first order are

$$\left(\frac{\partial^2\theta_1}{\partial x^2} - \alpha\theta_1\right) = PR\left(\left(\frac{\partial\psi_0}{\partial x}\right)\left(\frac{\partial\theta_0}{\partial\bar{z}}\right) - \left(\frac{\partial\psi_0}{\partial\bar{z}}\right)\left(\frac{\partial\theta_0}{\partial x}\right)\right) \quad (3.7)$$

$$\left(\frac{\partial^4\psi_1}{\partial x^4} - (M_1^2)\frac{\partial^2\psi_1}{\partial x^2}\right) = -\left(\left(\frac{G}{R}\right)\left(\frac{\partial\theta_1}{\partial\bar{z}}\right)\right) + R\left(\left(\frac{\partial\psi_0}{\partial x}\right)\left(\frac{\partial^3\psi_0}{\partial\bar{z}^3}\right) - \left(\frac{\partial\psi_0}{\partial\bar{z}}\right)\left(\frac{\partial^3\psi_0}{\partial x^3}\right)\right) \quad (3.8)$$

With

$$\psi_1(+1) - \psi_1(-1) = 0$$
$$\frac{\partial\psi_1}{\partial x} = 0,\ \frac{\partial\psi_1}{\partial\bar{z}} = 0,\quad \theta_1 = 0 \quad at \quad x = -1$$
$$\frac{\partial\psi_1}{\partial x} = 0,\ \frac{\partial\psi_1}{\partial\bar{z}} = 0,\quad \theta_1 = 0 \quad at \quad x = +1 \quad (3.9)$$

Where $N_2 = \frac{3N_1}{3N_1+4}$, $\alpha_1 = \alpha N_2, P_1 = PN_2$

4. DISCUSSION OF THE NUMERICAL RESULTS

In this analysis we investigate the effect of Hall currents on Convective Heat Transfer flow of a Viscous Incompressible electrically conducting fluid in a Non-Uniformly vertical channel. We take the Prandtl Number P=0.71 and $\delta = 0.01$.The Velocity components u ,w and The Non-dimensional Temperature distribution θ are shown in Figs.1-6 .For different values.The Secondary velocity (u) which is due to the Non-uniform Temperature on the boundary is depicted in Figs.1and 2. It is noticed from Fig.1 represents the variation of u with M and m it is found that the secondary velocity retards with increase in Hall parameter m while it enhances with increase in the Hall parameter m in the entire flow region. The variation of u with Heat source parameter α exhibits a decrease in tendency in $|u|$ with increase in the strength of the heat source (Fig.2).

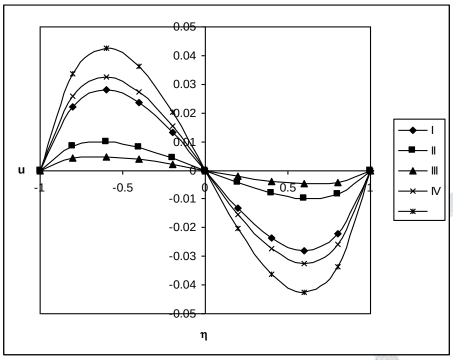

Fig. 1 : u with M & m

	I	II	III	IV	V
M	10	15	20	10	10
m	0.5	0.5	0.5	1.5	2.5

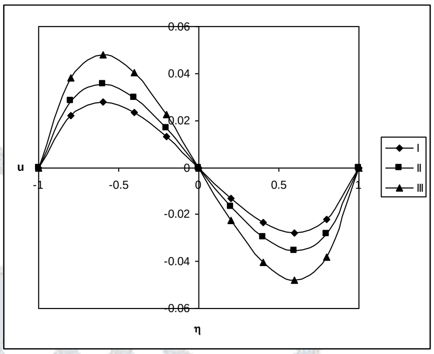

Fig. 2 : u with α

	I	II	III
α	2	4	6

The axial velocity w is shown in Figs.3and 4. The variation of w with Hartmann number M and Hall parameter m is exhibited in Fig.3.It is observed that higher the lorent force smaller $|w|$ in the flow region also $|w|$ enhances with increase in the Hall parameter m. Fig.4 . shows that an increase in the strength of the heat source depreciation in the magnitude of w every where in the flow region.

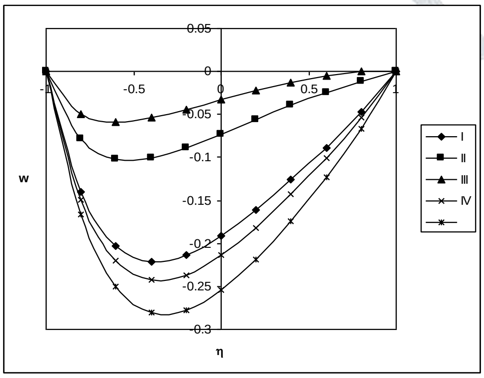

Fig. 3 : w with M & m

	I	II	III	IV	V
M	10	15	20	10	10
m	0.5	0.5	0.5	1.5	2.5

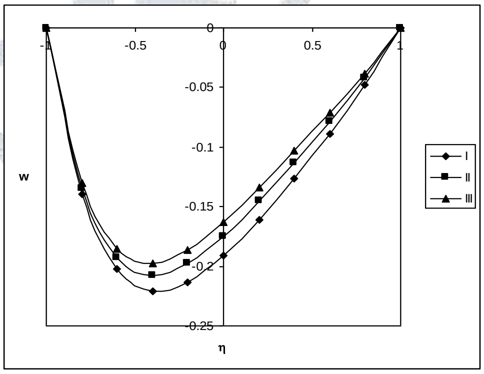

Fig. 4 : w with α

	I	II	III
α	2	4	6

The Non-dimensional Temperature distribution (θ) is exhibited in Figs.5 and 6 for different values .We notice an enhancement in the vicinity of the boundary $\eta = \pm 1$ and depreciates marginally in the central region of the flow (Fig.5).It is noticed from Fig.6.The variation of θ with Heat Source parameter α shows that the actual temperature reduces with α in the flow region. The inclusion of temperature dependent in the flow region depreciates the actual temperature in the entire flow region.

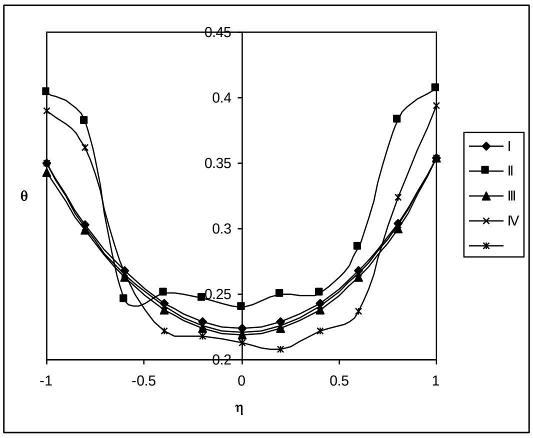

Fig. 5 : θ with M & m

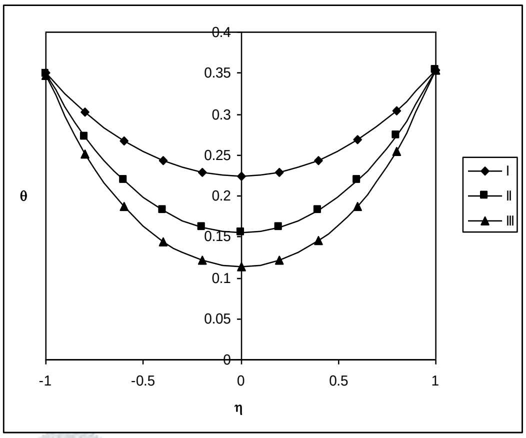

Fig. 6 : θ with α

	I	II	III	IV	V
M	10	15	20	10	10
m	0.5	0.5	0.5	1.5	2.5

	I	II	III
α	2	4	6

The average Nusselt Number (Nu) which represents the which measures the rate of Heat Transfer at $\eta = \pm 1$ is shown in Tables.1-4 for different variations of G,M,m,α R,α_1,λ,N_1, and x. It is found that the rate of Heat Transfer depreciates with increase in the G>0 and enhances with G<0 at both the boundaries. The variation of Nu with Hartmann Number M shows that the higher the lorentz force larges $|Nu|$ at $\eta = +1$ and smaller $|Nu|$ at $\eta = -1$. In the heating case while in the cooling case smaller $|Nu|$ for M≤15 and larger $|Nu|$ with M≥20 at $\eta = +1$ and $\eta = -1$. Smaller $|Nu|$ an increase in the Hall parameter m enhances $|Nu|$ in the heating case and in the cooling case it reduces with m≤1.5 and enhances with m≥2.5. Also it enhances with increase in the Heat source parameter α and Reynolds Number R.(Tables.1 and 3).

We noticed that for Tables.2 we find that the rate of Heat Transfer experiences an enhancement with increase in the amplitude α_1 and the Radiation parameter N_1. Moving along the axial direction the rate of Heat transfer enhances with $x \le \pi$ and depreciates with higher $x \ge 2\pi$. In general we find that the rate of Heat Transfer at $\eta = +1$ is larger than that at $\eta = -1$ (Tables.2 and 4).

Table – 1 Average Nusselt Number (Nu) at η =+1P=0.71, x= π /4, α_1=0.3, N_1=1.5

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	0.5514	0.5822	0.7438	0.6635	0.6915	2.3829	-12.9774	0.6228	0.7665
$2X10^3$	0.5097	0.5593	0.7272	0.7312	0.7780	2.4844	-19.5531	0.6015	0.7561
-10^3	0.6364	0.6288	0.7772	0.5379	0.6405	2.2118	13.4060	0.6657	0.7872
$-2X10^3$	0.6797	0.6524	0.7941	0.4797	0.6161	2.1390	8.7229	0.6872	0.7974

M	10	15	20	10	10	10	10	10	10
m	0.5	0.5	0.5	1.5	2.5	0.5	0.5	0.5	0.5
α	2	2	2	2	2	4	6	2	2
R	35	35	35	35	35	35	35	70	140

Table – 2 Average Nusselt Number (Nu) at η =+1 P=0.71, R=35, α=2, M=10

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-0.2144	0.8542	0.9548	3.0022	13.9736	0.5514	0.8624	6.9034	-2.8652
$2X10^3$	-0.2363	0.8018	0.9403	2.9918	13.9603	0.5097	0.8566	7.6225	-2.9301
-10^3	-0.1694	0.9589	0.9840	3.0230	14.0002	0.6364	0.8742	5.7333	-2.7189
$-2X10^3$	-0.1461	1.0112	0.9987	3.0334	14.0135	0.6797	0.8803	5.8508	-2.6360

α_1	0.30	0.70	0.50	0.50	0.50	0.50	0.50	0.50	0.50
N_1	1.5	1.5	2.5	5	10	10	10	10	10
x	$\pi/4$	$\pi/4$	$\pi/4$	$\pi/4$	$\pi/4$	$\pi/4$	$\pi/2$	π	2π

Table – 3 Average Nusselt Number (Nu) at η=-1 P=0.71, x= π /4, α_1=0.3, N_1=1.5

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	-0.4734	-0.3979	-0.2447	-0.5883	-0.6207	-0.21886	13.5318	-0.5378	-0.6635
$2X10^3$	-0.4323	-0.3757	-0.2295	-0.6541	-0.6863	-2.2773	18.3357	-0.5164	-0.6528
-10^3	-0.5574	-0.4428	-0.2753	-0.4664	-0.5718	-2.0373	-12.5995	-0.5805	-0.6848
$-2X10^3$	-0.6002	-0.4656	-0.2908	-0.4099	-0.5484	-1.9732	-8.2040	-0.6019	-0.6953

M	10	15	20	10	10	10	10	10	10
m	0.5	0.5	0.5	1.5	2.5	0.5	0.5	0.5	0.5
α	2	2	2	2	2	4	6	2	2
R	35	35	35	35	35	35	35	70	140

Table – 4 Average Nusselt Number (Nu) at η=-1 P=0.71, R=35, α=2, M=10, m=0.5, x= π /4

G	I	II	III	IV	V	VI	VII	VIII	IX
10^3	0.2965	-0.7777	-0.4210	1.0729	11.5777	-0.4734	0.8624	-6.3938	3.3346
$2X10^3$	0.3176	-0.7252	-0.4076	1.0796	11.5776	-0.4323	-0.8566	-7.0740	3.3817
-10^3	0.2531	-0.8824	-0.4479	1.0594	11.5781	-0.5574	-0.8743	-5.2870	3.2282
$-2X10^3$	0.2308	-0.9347	-0.4615	1.0526	11.5783	-0.6002	-0.8803	-4.8306	3.1679

α_1	0.30	0.70	0.50	0.50	0.50	0.50	0.50	0.50	0.50
N_1	1.5	1.5	2.5	5	10	10	10	10	10
x	1.5	1.5	1.5	1.5	1.5	π /4	π /2	π	2 π

5. REFERENCES

[1] Frosh,R.J and Cess,R.D : Heat transfer to fluids with low Prandtl numbers for flow across plates and cylinders of various cross-section ,Trans.Amer.Soc.Mech.Engs,V.80, p.667, (1958).
[2] Krishna,D.V,Prasada rao,D.R.V,Ramachandra Murty,A.S:Hydromagnetic convection flow through a porous medium in a rotating channel., J.Engg.Phy. and Thermo.Phy,V.75(2),pp.281-291(2002)

[3] Murthy,K,N,V.S:Oscillatory MHD flow past a flat plate.,Ind,J,Pure and Appl,Mathematics V.9,p.501(1979)
[4] Mohan,M and Srivastava,K.K:Combined convection flows through a porous channel rotating with angular velocity,Proc.Ind.Acad.Sci,V.87,p.14(1978).
[5] Rao,D.R.V,Krishna,D.V and Debnath,L:Combined effect of free and forced convection on MHD flow in a rotating porous channel,Int.J.Maths and Math.Sci,V.5,pp.165-182(1982)

[6] Rajeswara Rao,U : Mixed convection flows in the presence of internal heat sources,Ph.D thesis,S.K.University,Anantapur,India,(1986)

[7] Ramachadra,G.A : Nmon-uniform temperature effects on Mhd convective flows in channels .,Ph.D thesis,S.K.Unversity,Anantapur,India,(1992)

[8] Ravindra,M: Mhd convection flow through a porous medium with non-uniformwall temperature.,Ph.D thesis,S.K.University,Anatapur,India,(1994)
[9]Sarojamma,G and Krishna,D.V: Transient hydromagnetic convective flow in a rotating channel with porous boundaries, Acta Mechanica, V.39, p. 277(1981)
[10]Singh,N.P,Gupta,S.K and Singh,Atul Kumar:Free convection in MHD flow of a rotating viscous liquid in porous medium past a vertical porous plate,Proc.Nat.Acad.Sci,India,V.71A.,pp.149-157(2001)
[11] Singh,N.P,Singh,Ajay Kumar,Yadav,M.K and Singh Atul Kumar :Hydromantic oscillatory flow of a viscous liquid past a vertical porous plate in a rotating system.,Ind.Theor.Phy.,V.50,pp.37-43(2002)