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Hall Current in a Rotating Channel on MHD Flow with Radiation and Viscous Dissipation

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Abstract: *Finite difference solution based on an iterative scheme is obtained to study the effects of Hall current and rotation on MHD free convection flow in a vertical rotating channel filled with porous medium. A uniform magneti field is applied in the direction normal to the planes of the plates. The system rotates about an axis normal to the planes of the plates with uniform angular velocity. The problem is solved assuming the temperature difference of the plates to be high to induce radiation and the temperature of one plate vary periodically. Viscous dissipation is also considered. The effects of various parameters on the velocity profiles and temperature field are shown graphically and the skin friction and rate of heat transfer are presented in tabular form .*

Keywords: *Hall current, Porous medium, Rotating channel, Thermal radiation, Viscous dissipation..*

1. INTRODUCTION

The study of unsteady hydro magnetic flow with radiation in rotating porous media, has considerable practical applications in geophysics and engineering. Among the applications of rotating flow in porous media are food processing industry, chemical process industry, centrifugation filtration processes and rotating machinery. In geophysics, it is applied to measure the positions and velocities with respect to a fixed frame of reference on the surface of earth, which rotate with respect to an inertial frame in the presence of its magnetic field. The subject of geophysical dynamics has become an important branch of fluid dynamics for study of environment. From the technological point of view and due to practical applications, free convective flow and heat transfer problems are always important. This process of heat transfer is encountered in cooling of nuclear reactors, providing heat sinks in turbine blades and aeronautics. In astrophysics, it is applied to study the stellar and solar structure, inter planetary and inter stellar matter, solar storms etc. In engineering, it applied in MHD generators, ion propulsion, MHD bearings, MHD pumps, MHD boundary layer control of re- entry vehicles etc. Several researcher viz. Crammer[and Pai[1], Ferraro and Plumpton[2], Shercliff[3] have studied such flows due to its varied importance. Chang and Lundgren[4] have studied a hydromagnetic flow in a duct. Yen and Chang[5] studied the effect of wall electrical conductance on the magneto hydrodynamic Couette flow. Ostrach[6] studied the combined effects of natural and forced convection laminar flow and heat transfer with and without heat sources in channels with linearly varying wall temperature. Jain and Gupta[7] studied three dimensional free convection Couette flow with transpiration cooling.

There are many other applications of channel flows through porous medium, in the fields of agricultural engineering for channel irrigation and to study the underground water resources, in petroleum technology to study the movement of natural gas, oil and water through the oil channels/reservoirs. Transient natural convection between two vertical walls with a porous material having variable porosity has been studied by Paul *et al[8]*• Sahin[9] investigated the three-dimensional free convective channel flow through porous medium.

In recent years, Attia and Kotb[10] studied MHD flow between two parallel plates with heat transfer. When the strength of the magnetic field is strong, one cannot neglect the effects of Hall current. The rotating flow of an electrically conducting fluid in the presence of a magnetic field is encountered in geophysical and cosmical fluid dynamics. Soundalgekar[11] studied the Hall effects in MHD Couette flow with heat transfer. Mazumder *et al.[12.13]* have studied the effects of Hall current on MHD Ekman layer flow and heat transfer over porous plate and on free and forced convective hydro magnetic flow through a channel. Hall effects on unsteady MHD free and forced convection flow in a porous rotating channel has been investigated by Sivaprasad *et al[14].* Singh and Kumar[15] studied the combined effects of Hall current and rotation on free convection MHD flow in a porous channel. Ghosh *et al[16]* studied the Hall effects on MHD flow in a rotating system with heat transfer characteristics.

Radiation plays a vital role in many engineering, environment and industrial processes e.g. heating and cooling chambers, fossil fuel combustion energy processes astrophysical flows and space vehicle re-entry. Raptis[17] studied the radiation and free convection flow through a porous medium. Alagoa *et al[18]* analysed the effects of radiation on free convective MHD flow through a porous medium between infinite parallel plates in the presence of time-dependent suction. Mebine[19] studied the radiation effects on MHD Couette flow with heat transfer between two parallel plates. Singh and Kumar [20] have studied radiation effects on the exact solution of free convective oscillatory flow through porous medium in a rotating vertical porous channel. Singh and Pathak[21] investigated the effect of Hall current on mixed convection MHD flow in presence of radiation in a vertical channel. Hazarika[22] has studied the Hall effects in a rotating system of transient unsteady Hydromagnetic coquette flow.

In the present paper the MHD free convective flow in a rotating channel filled with porous medium studied by Hazarika[22] has been investigated numerically with viscous dissipation. The transverse magnetic field applied is strong enough so that the Hall currents are induced. Viscous dissipation is considered and assumed that the temperature difference between the walls of the channel is sufficiently high to radiate the heat. The governing partial differential equations of the motion are solved by using an iterative method based on Crank-Nicolson finite difference scheme. The results are presented in graphs and tables.

2. Basic Equations

The equations governing the unsteady free convective flow of an incompressible, viscous and electrically conducting fluid in a rotating vertical channel filled with porous medium in the presence of magnetic field are:

Equation of Continuity:

$$\text{div}\,\vec{V} = 0 \tag{1}$$

Momentum Equation:

$$\rho\left[\frac{\partial\vec{V}}{\partial t^*} + \vec{\Omega}\,X\,\vec{V} + (\vec{V}.\nabla)\vec{V}\right] = -\nabla p + \vec{j}\,X\,\vec{B} + \mu\nabla^2\vec{V} - \frac{u}{K^*}\vec{V} + g\beta T^* \tag{2}$$

Energy Equation:

$$\rho C_p\left[\frac{\partial T^*}{\partial t^*} + (\vec{V}.\nabla)T^*\right] = k\nabla^2 T^* - \nabla q + \Phi \tag{3}$$

Kirchhoff's First Law:

$$\text{div}\,\vec{j} = 0 \tag{4}$$

General Ohm's Law:

$$\vec{j} + \frac{\omega_e\tau_e}{B_0}(\vec{j}\,X\,\vec{B}) = \sigma\left[\vec{E} + \vec{V}X\vec{B} + \frac{1}{e\eta_e}\nabla P_e\right] \tag{5}$$

Gauss's law of Magnetism:

$$\text{div}\,\vec{B} = 0 \tag{6}$$

where $\vec{V}$ is the velocity vector, $\vec{\Omega}$ the angular velocity of the fluid, P the pressure, ρ the density, $\vec{B}$ the magnetic induction vector, $\vec{j}$ the current density, μ the coefficient of viscosity, t* the time, g the acceleration due to gravity, β the coefficient of volume expansion, *K** is the permeability of the porous medium, C_p the specific heat at constant pressure, T* the temperature, T_o the reference temperature of the left plate, *k* the thermal conductivity, Φ is the viscous dissipation, *q* the radiative heat, σ the electrical conductivity, *Bo* the strength of the applied magnetic field, *e* the electron charge, ω_e the electron frequency, τ_e the electron collision time, p_e the electron pressure, $\vec{E}$ the electric field and η_e is the number density of electron.

2.1 Formulation of the Problem

Consider an unsteady MHD free convective flow of an electrically conducting, viscous, incompressible fluid through a porous medium bounded between two insulated infinite vertical plates in the presence of Hall current and thermal radiation. The plates are at a distance 'd' apart. A Cartesian coordinate system with x*-axis oriented vertically upward along the center line of the channel is introduced. The z*-axis taken perpendicular to the planes of the plates is the axis of the rotation and the entire system rotates about this axis with uniform angular velocity **Ω***. Since the plates of the channel are of infinite extent, all the physical quantities depend only on z* and *t** only. The temperature $T^*_w \cos\omega^* t^*$ of the right plate at *z*=d/2* is considered to be varying periodically with time and the temperature *T*=To=O* of the left plate at *z*=d/2* is taken to be zero. Let *(u *, v*, w*)* be the components of velocity in the directions *(x*, y*,* z''), respectively. Since the plates are non-porous, therefore equation of continuity (1) on integration gives *w** = 0. A strong transverse magnetic field of uniform strength *Bo* is applied along the z*-axis. So Eg. (6) for the magnetic field $\vec{B} = (B^*_x, B^*_y, B^*_z)$ gives $B^*_z = B_o$ (constant).

If (j^*_x, j^*_y, j^*_z) are the components of electric current density $\vec{j}$. The equation of conservation of electric charge in Eg.(4) gives j^*_z = constant. .

For non-conducting plates

$J^*_z = 0.$ (7)

at the plates and hence zero everywhere in the fluid.

Under the usual assumptions that the electron pressure (for a weakly ionized gas), the thermoelectric pressure, ion slip and the external electric field arising due to polarization of charges are negligible.

It is assumed that no applied and polarization voltage exists. This corresponds to the case where no energy is being added or extracted from the fluid by electrical means (Meyer[21]) i.e. electrical field $\vec{E} = 0$.

Therefore, Eq. (5) takes the form:

$$\bar{j} + \frac{\omega_e \tau_e}{B_0}\left(\bar{j}\times\bar{B}\right) = \sigma\left(\bar{V}\times\bar{B}\right) \qquad \ldots(8)$$

After using Eq. (7), Eq. (8) in component form becomes:

$$j^*_x + \omega_e \tau_e j^*_y = \sigma B_0 v^* \qquad \ldots(9)$$

$$j^*_y - \omega_e \tau_e j^*_x = -\sigma B_0 u^* \qquad \ldots(10)$$

Solving Eqs (9) and (10) for j^*_x and j^*_y , we get :

$$j^*_x = \frac{\sigma B_0}{\left(1+m^2\right)}\left(mu^* + v^*\right)$$

and $j^*_y = \dfrac{\sigma B_0}{\left(1+m^2\right)}\left(mv^* - u^*\right)$

Where, m = $\omega_e \tau_e$ is the Hall parameter.

Under the foregoing assumptions and the reference temperature *To*=0, Eq. (2) in Cartesian components reduces to:

$$\frac{\partial u^*}{\partial t^*} = -\frac{1}{p}\frac{\partial p^*}{\partial x^*} + \upsilon \frac{\partial^2 u^*}{\partial z^{*2}} + 2\Omega^* v^* - \frac{\sigma B_0^2}{\rho(1+m^2)}(mv^* - u^*) - \frac{\upsilon}{K^*}u^* + g\beta T^* \quad (11)$$

$$\frac{\partial v^*}{\partial t^*} = -\frac{1}{p}\frac{\partial p^*}{\partial y^*} + \upsilon \frac{\partial^2 v^*}{\partial z^{*2}} - 2\Omega^* v^* - \frac{\sigma B_0^2}{\rho(1+m^2)}(mu^* + v^*) - \frac{\upsilon}{K^*}u^* \quad (12)$$

And Eq^n (3) becomes:

$$\rho C_p \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial z^{*2}} - \frac{\partial q}{\partial z^*} + \mu\left[\left(\frac{\partial u^*}{\partial z^*}\right)^2 + \left(\frac{\partial v^*}{\partial z^*}\right)^2\right] \quad (13)$$

The boundary conditions for the flow problem are:

$$u^* = v^* = T^* = 0 \; at \; z^* = -\frac{d}{2} \quad (14)$$

$$u^* = v^* = 0$$

$$T^* = T_w \cos \omega^* t^* \; at \; z^* = \frac{d}{2} \quad (15)$$

where T_w is the mean temperature of the plate at *z*d/2*and ω^* is the frequency of oscillations. Following Cogley *et al[22].* the last term in the energy Eq.(13)

$\frac{\partial q}{\partial z^*} = 4\alpha^2 (T^* - T_o)$

stands for radiative heat flux modifies to:

$$\frac{\partial q}{\partial z^*} = 4\alpha^2 T^* \quad (16)$$

In view of the reference temperature T_0=0, where α is the mean radiation absorption coefficient.

Introducing the following non-dimensional quantities

$\eta = \frac{z^*}{d}$, $x = \frac{x^*}{d}$, $y = \frac{y^*}{d}$, $u = \frac{u^*}{U}$, $v = \frac{v^*}{V}$, $T = \frac{T^*}{T_w}$, $t = \frac{t^* U}{d}$, $\omega = \frac{\omega^* d}{U}$, $p = \frac{p^*}{tU^2}$,

into Eqs (11-13) and using Eq. (16), we get:

$$\frac{\partial u}{\partial t} = \frac{\partial p}{\partial x} + \frac{1}{Re}\frac{\partial^2 u}{\partial \eta^2} + \frac{2\Omega}{Re} v + \frac{M^2(mv-u)}{Re\;(1+m^2)} - \frac{1}{KRe}u + \frac{Gr}{Re}T \quad (17)$$

$$\frac{\partial v}{\partial t} = \frac{\partial p}{\partial y} + \frac{1}{Re}\frac{\partial^2 v}{\partial \eta^2} - \frac{2\Omega}{Re} u - \frac{M^2(mu+v)}{Re\;(1+m^2)} - \frac{1}{KRe}v \quad (18)$$

$$\frac{\delta T}{\delta t} = \frac{1}{Pe}\frac{\delta^2 T}{\delta \eta^2} - \frac{N^2}{Pe}T + \frac{E_c}{R_e}\left[\left(\frac{\partial u}{\partial \eta}\right)^2 + \left(\frac{\partial v}{\partial \eta}\right)^2\right] \quad (19)$$

Where U is the mean axial velocity,

$Re = \frac{Ud}{\upsilon}$ (Reynolds number),

$\Omega = \frac{\Omega^* d^2}{\upsilon}$ (Rotation parameter),

$K = \frac{K^*}{d^2}$ (The permeability of the porous medium),

Gr = $\frac{g\beta\, d^2 T_W}{\nu U}$ (Grashoff number),

Pe = $\frac{\rho\, C_p\, dU}{K}$ (Peclet number),

N = $\frac{2\alpha d}{\sqrt{K}}$ (radiation parameter),

E_c = $\frac{u^2}{C_p\, T_W}$ (Eckert Number)

The transformed boundary conditions are:

$$u = v = T = 0 \text{ at } \eta = -\frac{1}{2} \tag{20}$$

$$u = v = 0,\ T = \cos\omega t \text{ at } \eta = \frac{1}{2} \tag{21}$$

For the oscillatory internal flow, we shall assume that the fluid flows only under the influence of a non-dimensional pressure gradient oscillating in x- direction with the following form:

$$-\frac{\partial p}{\partial x} = P\cos\omega t \tag{22}$$

3. Solution of the Problem

The boundary value problem (17)-(21) is solved by using Crank-Nicholson finite difference scheme. $\eta = -\frac{1}{2}$ The scheme for an independent variable f is given by,

$$\frac{\partial f}{\partial T} = \frac{f_{i+1,j} - f_{i,j}}{\Delta T}$$

$$\frac{\partial^2 f}{\partial \eta^2} = \frac{1}{(\Delta\eta)^2}(f_{i,\,j+1} - 2f_{ij} + f_{i,\,j+1})$$

The boundary value problem is then reduced to a system of finite difference equation which is then solved numerically by an iterative scheme.

The co-efficient of skin –frictions C_f at the left plate is given by

$$C_f = \frac{2}{\rho v^2}\tau_x$$

Where, $\tau_x = \mu \frac{\partial u}{\partial \eta})_{\eta=-\frac{1}{2}}$.

The rate of heat transfer *Nu* (Nusselt number) at the left plate is

$$Nu = \left(\frac{\partial T}{\partial \eta}\right)_{\eta=-\frac{1}{2}}$$

4. Discussion

Finite difference method was applied to obtain numerical solution of the problem in order to study the effect of different parameters on velocity field, skin- friction and temperature field. The numerical values of different parameters are taken as Ec=0.1,Gr=1.00 N=1.00 Re=1.00 Pe=0.50 ω =5.00 P=1.00 M=1.00 m=1.00 K=1.00 T=0.25 unless otherwise stated.

Velocity profile against dissipation parameter Ec is plotted in Fig- 1. It is evident from the figure that the velocity decreases with the increase of dissipation parameter Ec.

Fig.- 2 to Fig.- 6 depict the variation of velocity with Grashoff number Gr, Hartman number M, Hallcurrent parameter m and radiation parameter N. It is seen that velocity decreases with increase of all these parameters.

It is seen from fig-5 that velocity slightly increased with increase of N. In the left half of the channel, the effect of N on velocity is insignificant while in the right half of the channel velocity decreases with increase of N.

From figure 2 it is seen that for increasing Grashof number the maximum of the velocity profiles shifts towards right half of the channel due to the greater buoyancy force in this part of the channel due to the presence of hotter plate. In the right half there lies hot plate at $\eta= 1/2$ and heat is transferred from the hot plate to the fluid and consequently buoyancy force enhances the flow velocity further. In the left half of the channel, the transfer of heat takes place from the fluid to the cooler plate at $\eta = -1/2$. Thus, the effect of Grashof number on the velocity is reversed i.e. velocity decreases with increasing Gr.

It is evident from the Fig- 3 that the velocity decreases with the increase of Hartmann number M. This is because of the reason that effects of a transverse magnetic field on an electrically conducting fluid gives rise to a resistive type force (called Lorentz force) similar to drag force and upon increasing the values of *M* increases the drag force which has tendency to slow down the motion of the fluid.

The temperature profile is shown in Fig- 7 to Fig- 12 against the dissipation parameter Ec, buoyancy parameter Gr, Hartman number M, Hall parameter m, radiation parameter N and rotation parameter Ω. The temperature decreases with the increase of Gr, Hartmann number M, Hall parameter m and rotation parameter Ω but it increases with radiation parameter N and the dissipation parameter Ec.

The coefficient of skin-friction C_f and the rate of heat transfer Nu at the left plate (i.e at $\eta=-\frac{1}{2}$) are also obtained and presented in Table-1 and Table-2. The skin friction C_f at the left plate decreases while heat transfer Nu increases with increase of Hartmann number M , Hall parameter m and dissipation parameter Ec. Both the skin friction and rate of heat transfer decrease with increase of buoyancy parameter Gr.

From the above analysis we may conclude that all the parameters have significant effect on the Hall current with radiation in presence of an applied magnetic field in a porous channelwith viscous dissipation and the finite difference method can be effectively used to obtain the numerical solution.

5. Conclusion

1. Rotation tends to retard primary velocity throughout the channel whereas it tends to accelerate secondary velocity.
2. Hall current, Magnetic field, radiation and dissipation have tendency to retard both the primary and secondary velocities throughout the channel.
3. Hall current as well as magnetic field have tendency to reduce the shear stress at the left plate but enhance the rate of heat transfer.
4. Dissipation to reduce the shear stress at the left plate as well as the rate of heat transfer whereas Grashoff number reduce the shear stress but enhance the heat transfer rate.
5. Radiation and dissipation enhance the temperature whereas Grashof number, magnetic field, Hall current and rotation toreduce it.
6. Viscous dissipation is to enhance the temperature but reduced the velocity.

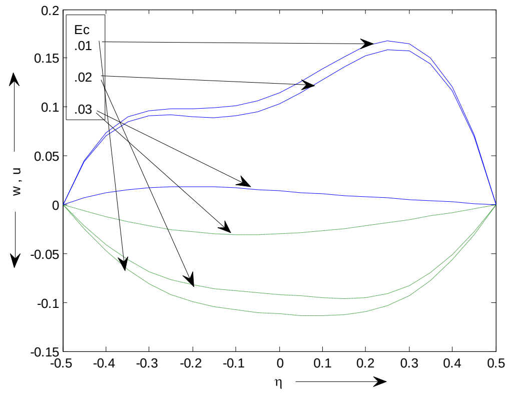

Fig- 1 *Velocity profile for different Ec*

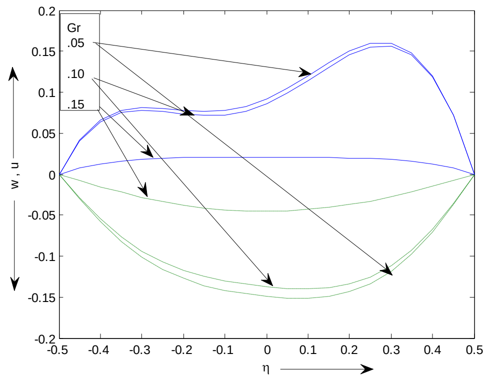

Fig- 2 *Velocity profile for different Gr*

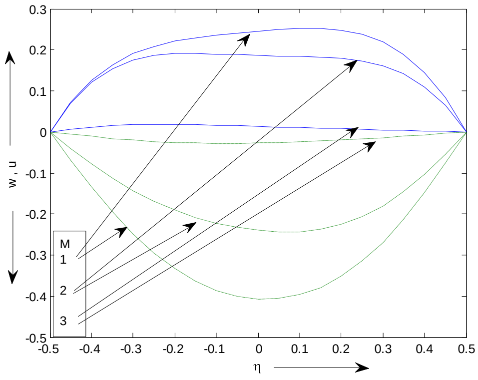

Fig- 3 *Velocity profile for different M*

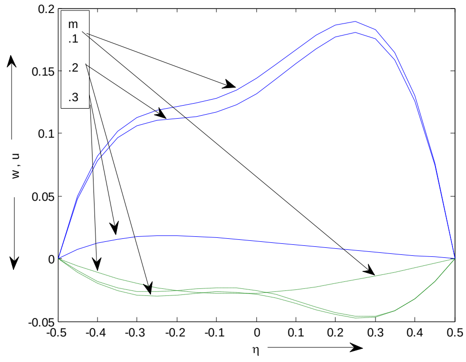

Fig- 4 *Velocity profile for different m*

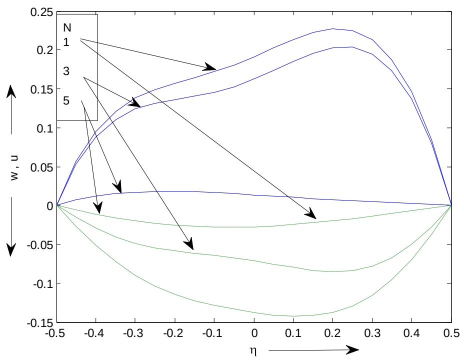

Fig- 5 *Velocity profile for different N*

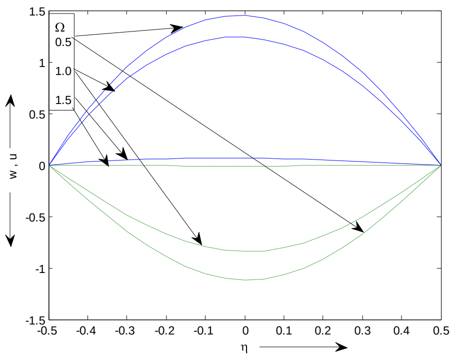

Fig- 6 *Velocity profile for different Ω*

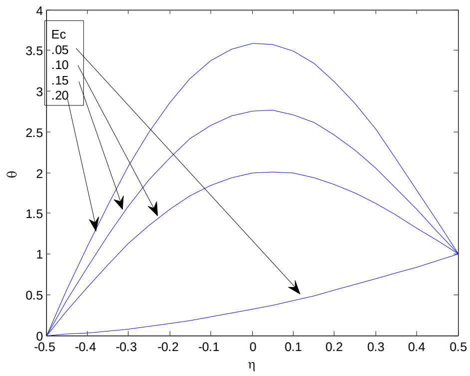

Fig- 7 *Temperature profile for different Ec*

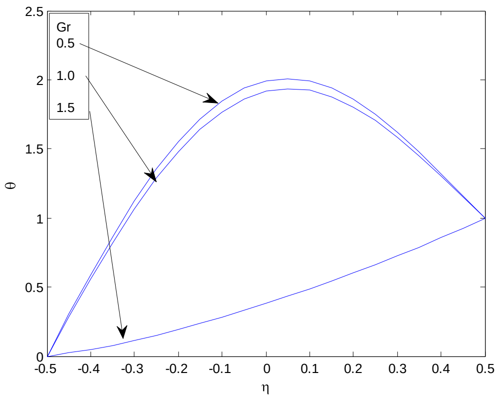

Fig- 8 *Temperature profile for Gr*

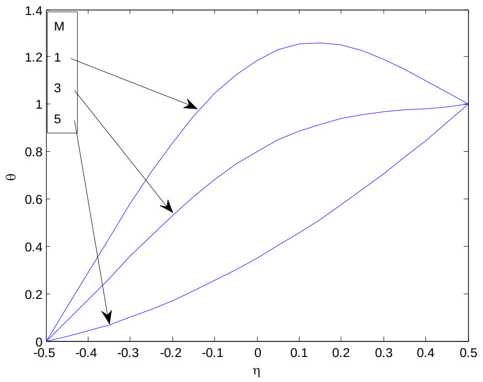

Fig- 9 *Temperature profile for different M*

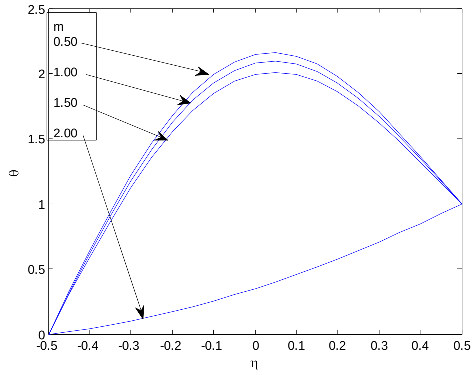

Fig- 10 *Temperature profile for different m*

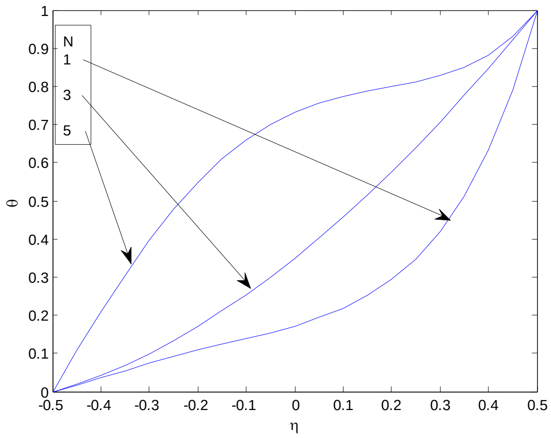

Fig- 11 *Temperature profile for small N*

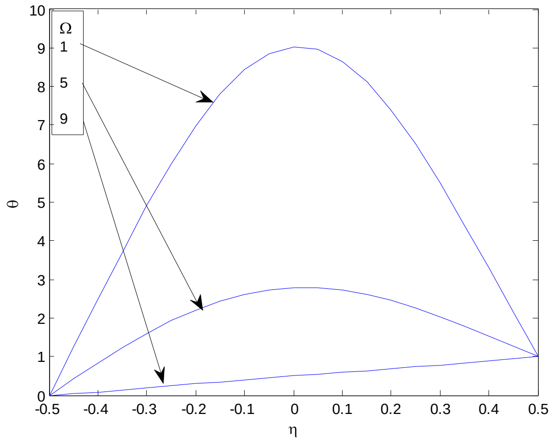

Fig- 12 *Temperature profile for different Ω*

Table 1

Gr=1.00 N=1.00 Re=1.00 Pe=0.50 Ω =10.00 ω =5.00 P=1.00 K=1.00 T=0.25

	Ec=.05		Ec=.10		Ec=.15		Ec=.20	
M	**Cf**	**Nu**	**Cf**	**Nu**	**Cf**	**Nu**	**Cf**	**Nu**
0.50	0.1003	0.3603	0.0991	0.4644	0.0984	0.5533	0.0979	0.6299
1.00	0.1008	0.3547	0.0996	0.4548	0.0989	0.5411	0.0984	0.6160
1.50	0.1009	0.3463	0.0998	0.4405	0.0990	0.5228	0.0985	0.5951
2.00	0.1002	0.3363	0.0992	0.4234	0.0983	0.5005	0.0977	0.5694
m								
0.05	0.1016	0.3541	0.1004	0.4541	0.0994	0.5403	0.0988	0.6154
1.00	0.1008	0.3547	0.0996	0.4548	0.0989	0.5411	0.0984	0.6160
1.50	0.1004	0.3560	0.0993	0.4570	0.0986	0.5437	0.0981	0.6190
2.00	0.1002	0.3571	0.0991	0.4589	0.0984	0.5461	0.0980	0.6217

Table 2

Ec=0.10 N=1.00 Re=1.00 Pe=0.50 Ω =10.00 ω =5.00 P=1.00 K=1.00 T=0.25

	Gr=.25		Gr=.50		Gr=.75		Gr=1.0		Gr=1.50	
m	**Cf**	**Nu**	**Cf**	**Nu**	**Cf**	**Nu**	**Cf**	**Nu**	**Cf**	**Nu**
0.50	0.1024	0.5848	0.1012	0.5340	0.1006	0.4908	0.1004	0.4541	0.1006	0.3970
1.00	0.1008	0.5866	0.1000	0.5353	0.0996	0.4918	0.0996	0.4548	0.1003	0.3976
1.50	0.1001	0.5908	0.0994	0.5387	0.0991	0.4944	0.0993	0.4570	0.1002	0.3991
2.00	0.0998	0.5945	0.0991	0.5416	0.0989	0.4968	0.0991	0.4589	0.1001	0.4003
M										
0.50	0.1024	0.5848	0.1012	0.5340	0.1006	0.4908	0.1004	0.4541	0.1006	0.3970
1.00	0.1008	0.5866	0.1000	0.5353	0.0996	0.4918	0.0996	0.4548	0.1003	0.3976
1.50	0.1001	0.5908	0.0994	0.5387	0.0991	0.4944	0.0993	0.4570	0.1002	0.3991
2.00	0.0998	0.5945	0.0991	0.5416	0.0989	0.4968	0.0991	0.4589	0.1001	0.4003

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REFERENCES

[1] Crammer K R & Pai S J, Magneto Fluid Dynamics for Engineers and Applied Physicists, (McGraw-Hill Book Co. New York) (1973).

[2] F Ferraro V C A & Plumpton C, An Introduction to MagnetoFluid Mechanics, (Clarendons Press, Oxford) (1966).

[3] S Shercliff J A, A Text Book of Magneto Hydrodynamics, (Pergamon Press Ltd. New York) (1965).

[4] C Chang C & Lundgren T S, ZAMP 12 (1961) 100.

[5] Y Yen T & Chang C C, ZAMP 15 (1964) 400.

[6] Ostrach S, NACATN, (1954) 3141.

[7] Jain N C & Gupta P, Journal of Zhejiang University SCIENCE A, 7(3) (2006) 340.

[8] Paul T, Singh A K & Mishra A K, J of Math Engineering in Industry, 8 (2001) 177.

[9] Sahin A, Bull Math Soc, 101 (5) (2009) 503.

[10] Attia H A & Kotb N A, Acta Mech, 117 (1996) 215.

[11] Soundalgekar V M, IEEE Transactions on Plasma Sci, PS-14 (5) (1986) 579.

[12] Mazumder B S, Gupta A S & Datta N, lru J Heat Mass Transfer, 19 (1976) 523.

[13] Mazumder B S, Gupta A S & Datta N, lnt 1 Engng Sci, 14 (1976) 285.

[14] Sivaprasad R Prasad Rao D R V & Krishna D V, Indian J Pure Appl Math, 19(7) (1988) 688.

[15] Singh K D & Rakesh Kumar, Indian J Pure & Appl Pltys, 47 (2009) 617.

[16] Ghosh S K, Beg 0 A & Narahari M, Meccanica, 44 (2009) 741.

[17] Raptis A, Int Commun Heat Mass Transfer, 25 (1998) 289.

[18] Alagoa K D, Tay G & Abbey T M, Astrophys and Space Sci,260 (1999) 455.

[19] Mebine P, Global J Pure Appl Math, 3(2) (2007) 191.

[20] Singh K D & Kumar R, J of Rajasthan Acad Phy Sci, 8(3) (2009) 295.

[21] Meyer R C,}. Aerospace sa., 25 (1958) 561.

[22] Hazarika G.C. Math. Forum, Vol 25 (2012-13) pp 23-26.

[23] Cogley A C, Vincenti W G and Gilles S E, American Institute of Aeronautics and Astronautics, 6(1968) 551.

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