AN ANALYTICAL APPROACH TO MHD PLASMA BEHAVIOR OF A ROTATING ENVIRONMENT IN THE PRESENCE OF AN INCLINED MAGNETIC FIELD AS COMPARED TO EXCITATION FREQUENCY

S.K. GHOSH*
Department of Mathematics, Narajole Raj College
P.O.: Narajole, Dist.: Midnapore (West)
Pin Code: 721 211 (West Bengal), INDIA
e-mail: g_swapan2002@yahoo.com

I. POP
Faculty of Mathematics, University of Cluj
R-3400 Cluj. CP 253, ROMANIA
e-mail: popi@math.ubbcluj.ro

We have examined the MHD plasma behavior of a rotating environment in the presence of an inclined magnetic field with the positive direction of the axis of rotation. The interplay of a hydromagnetic force and Coriolis force exerts its influence of a dynamo mechanism with reference to the solar and terrestrial context when the Hall current is taken into account. It is stated that the electrical discharge of the solar corona in the presence of a traveling magnetic field experiences an irregular fluctuation at the resonant level to produce thermonuclear fusion reaction of the Sun with regard to excitation frequency. On the other hand, the thermonuclear fusion reaction of the Sun stops when the excitation frequency is switched off and the MHD plasma flow tends to an equilibrium position with regard to a neutral plasma stability parameter.

Key words: neutral plasma stability parameter, forced oscillation, resonance, excitation frequency, angular frequency of oscillation.

1. Introduction

The high frequency MHD plasma flow of a rotating environment leads to the dissociation of ions and electrons when the kinetic energy is transformed into heat as studied by Ghosh (1996) under frequency domain. The magnetohydrodynamic (MHD) plasma behavior of a rotating environment in the presence of an inclined magnetic field has received wide attention in literature as it is applied in space science. An oscillating behavior of the universe leads to a resonant response when a forced oscillation is applied to the Sun. The situation of a rotating environment is an illustration of excitation frequency of an oscillating field with regard to an interesting mathematical condition $G^2 = \left(16K^4 - \mathrm{M}^4 \sin^4 \theta\right)^{1/2}$; a resonant response to an oscillating field occurs when the excitation frequency $\omega > \frac{1}{2} \cos \omega T \ \left(16K^4 - \mathrm{M}^4 \sin^4 \theta\right)^{1/2}$ (see Ghosh, 1997; 2001). In response to the solar and terrestrial context, the stars go faster and faster from the Interstellar medium due to an irregular change of galaxies and the position of the planets becomes irregular. It is important to note that the thermonuclear fusion reaction of the Sun exerts its influence of excitation frequency whereas thermonuclear fusion reaction stops if the excitation frequency is switched off. Since irregular fluctuation builds up rapidly with a driving force the laser radiation is so intense at the transition if the excitation frequency is $\omega > \frac{1}{2} \cos \omega T \ \left(16K^4 - \mathrm{M}^4 \sin^4 \theta\right)^{1/2}$. This situation reveals that the laser

---
* To whom correspondence should be addressed

radiation is so intense that many photons can be simultaneously involved in a transition when the kinetic energy is transformed into heat. It is stated that the induced laser radiation experiences a multiphoton process to produce a bright blue flash and a loud bang, and ultraviolet radiation and the binary *X*-ray are emitted with a driving force in the presence of a radio frequency accelerator (see Ghosh and Pop, 2004). The binary *X*-ray is produced due to a fluctuation of the magnetic field when a forced oscillation is applied to the Sun. In the light of our present investigation, it is stated that the Earth may be put into the vacuum with strong ionizing radiation in the atmosphere and the binary *X*-ray is produced due to a fluctuation of the magnetic field when a forced oscillation is applied to the Sun.

2. Basic equations and its solutions

The basic equations of magnetohydrodynamics in a rotating frame of reference:

The MHD momentum equation in a rotating frame of reference

$$(\boldsymbol{q}\cdot\nabla)\boldsymbol{q}+2\Omega\hat{K}\times\boldsymbol{q}=-\frac{1}{\rho}\nabla p+\nu\nabla^{2}\boldsymbol{q}+\frac{1}{\rho}\boldsymbol{J}\times\boldsymbol{\beta}\,. \tag{2.1a}$$

The equation of continuity

$$\vec{\nabla}\cdot\boldsymbol{q}=0\,. \tag{2.1b}$$

Ohm's law for a moving conductor taking Hall current into account

$$\boldsymbol{J}+\frac{\omega_e\tau_e}{B_o}(\boldsymbol{J}\times\boldsymbol{B})=\sigma[\boldsymbol{E}+\boldsymbol{q}\times\boldsymbol{B}]. \tag{2.2}$$

Maxwell's equations are

$$\vec{\nabla}\times\boldsymbol{B}=\mu_e\boldsymbol{J}\,,$$

$$\vec{\nabla}\times\boldsymbol{E}=-\frac{\partial\boldsymbol{B}}{\partial t},$$

$$\vec{\nabla}\cdot\boldsymbol{J}\neq 0\,, \tag{2.3}$$

$$\vec{\nabla}\cdot\boldsymbol{D}=\rho_e\,,$$

$$\vec{\nabla}\cdot\boldsymbol{B}=0 \quad \text{(solenoidal relation)}.$$

Since the flow becomes steady, $\vec{\nabla}\times\boldsymbol{E}=\boldsymbol{0}$. In a continuous media, the assumption $\vec{\nabla}\cdot\boldsymbol{J}\neq 0$ is justified for a discharge channel when the applied magnetic field is inclined with the axis of rotation. Since charge density is negligible it turns into $\vec{\nabla}\cdot\boldsymbol{D}=0$.

$\boldsymbol{q}, \boldsymbol{B}, \boldsymbol{E}, \boldsymbol{J}$ and $\boldsymbol{D}$ are, respectively, the velocity vector, the magnetic field vector, the electric field vector, the current density vector and the displacement vector. σ, ν, μ_e, ρ, $\hat{\kappa}$, ρ_e, B_o, ω_e, τ_e and θ are, respectively, the electrical conductivity, kinematic coefficient of viscosity, magnetic permeability, fluid density, unit-vector along z-axis, charge density, magnetic flux density, cyclotron frequency, electron collision time and the angle of inclination of a magnetic field with the positive direction of the axis of rotation.

The authors have studied the steady hydromagnetic flow of a viscous incompressible electrically conducting fluid confined between a parallel plate channel $z = \pm L$, rotating with a uniform angular velocity Ω about an axis perpendicular to the plane of flow under the influence of a constant pressure gradient in such a way that the plates and channel rotate in unison with the same constant angular velocity Ω and the applied uniform magnetic field is inclined with the positive direction of the axis of rotation. The frictional shearing stress becomes important to study the MHD plasma flow at the boundary. Since Hall current induces a secondary flow as given by Sato (1961), the problem is no longer one-dimensional. It is a two dimensional motion. Since the plates are infinite along x and y directions, all physical quantities except pressure will be functions of z only.

We have examined that the thermonuclear fusion reaction of the Sun leads to a discharge channel subject to an excitation frequency at the resonant level when a forced oscillation is taken into account. Our present problem is true for the physical interpretation, specially for a magnetohydrodynamic flow that the displacement current is neglected in the case of a fluid motion whose velocity is small as compared to the velocity of light. Also, for fluids, which are almost neutral; its charge density is negligible. The flow becomes unstable in the Earth's liquid core when a forced oscillation is applied to the Sun. An analytical approach is based on Ghosh (1997; 2001), which is comparable with Einstein theory of relativity where the time dimension is closely resemblance to the angular frequency of oscillation in a rotating environment.

To incorporate the study of Ghosh and Pop (2002) together with the fundamental equations of magnetohydrodynamics in a rotating frame of reference, the following assumptions are used which are compatible with the fundamental equations of magnetohydrodynamics

$$\begin{aligned} &\boldsymbol{q} = (u', v', 0), \qquad \boldsymbol{B} = (B_x + B_o \sin\theta, B_y, B_o \cos\theta), \\ &\boldsymbol{E} = (E_x, E_y, E_z), \qquad \boldsymbol{J} = (J_x, J_y, J_z). \end{aligned} \tag{2.4}$$

Under the assumptions (2.4), the following equations are compatible with the fundamental equations of magnetohydrodynamics in a rotating frame of reference become

$$-2\Omega v' = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu \frac{\partial^2 u'}{\partial z^2} + \frac{B_o}{\rho} J_y \cos\theta, \tag{2.5}$$

$$2\Omega u' = \nu \frac{\partial^2 v'}{\partial z^2} + \frac{B_o}{\rho}(J_z \sin\theta - J_x \cos\theta), \tag{2.6}$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial z} - \frac{B_o}{\rho} J_y \sin\theta. \tag{2.7}$$

Equations (2.5) to (2.7) in the dimensionless form are

$$-2K^2 v = R + \frac{d^2 u}{d\eta^2} + \frac{\mathrm{M}^2 \cos\theta}{1+m^2}(mv - u\cos\theta), \tag{2.8}$$

$$2K^2 u = \frac{d^2 v}{d\eta^2} - \frac{M^2}{1+m^2}\left(v + mu\cos\theta\right) \tag{2.9}$$

where $\eta = Z/L$, $u' = \frac{u\nu}{L}$, $v' = \frac{v\nu}{L}$, $R = \frac{L^3}{\rho v^2}\left(-\frac{\partial p}{\partial x}\right)$ is the dimensionless pressure gradient, $K^2 = \frac{\Omega L^2}{\nu}$ is the rotation parameter, which is the reciprocal of the Ekman number, $M = B_0 L(\sigma/\rho v)^{1/2}$ is the Hartmann number and $m = \omega_e \tau_e$ is the Hall current parameter. Ω is the angular velocity of the system referred to a fixed inertial frame and $p = p' - \frac{1}{2}\rho|\Omega \times r|^2$, p' and r denote fluid pressure and position vector from the axis of rotation.

The boundary condition (no – slip) become

$$u = v = 0 \qquad \text{at} \qquad \eta = \pm 1. \tag{2.10}$$

Equations (2.8) and (2.9) together with the boundary condition (2.10) can be solved and the solutions can be expressed in an elegant form such as

$$\begin{aligned} u(\eta) = {} & R\frac{\frac{1}{2}\frac{M^2}{1+m^2}\left(\frac{M^2\sin^2\theta}{1+m^2} + iG^2\right) - \left(2K^2 + \frac{mM^2\cos\theta}{1+m^2}\right)^2}{iG^2\left(\alpha^2+\beta^2\right)^2}\left[1 - \frac{\cosh(\alpha - i\beta)\eta}{\cosh(\alpha - i\beta)}\right] + \\ & - R\frac{\frac{1}{2}\frac{M^2}{1+m^2}\left(\frac{M^2\sin^2\theta}{1+m^2} - iG^2\right) - \left(2K^2 + \frac{mM^2\cos\theta}{1+m^2}\right)^2}{iG^2\left(\alpha^2+\beta^2\right)^2}\left[1 - \frac{\cosh(\alpha + i\beta)\eta}{\cosh(\alpha + i\beta)}\right], \end{aligned} \tag{2.11}$$

$$v(\eta) = iR\frac{\left(2K^2 + \frac{mM^2\cos\theta}{1+m^2}\right)}{G^2}\left[\frac{1}{(\alpha - i\beta)^2}\left\{1 - \frac{\cosh(\alpha - i\beta)\eta}{\cosh(\alpha - i\beta)}\right\} - \frac{1}{(\alpha + i\beta)^2}\left\{1 - \frac{\cosh(\alpha + i\beta)\eta}{\cosh(\alpha + i\beta))}\right\}\right] \tag{2.12}$$

where

$$\alpha, \beta = \frac{1}{2}\left[\left\{\frac{\left(1+\cos^2\theta\right)^2 M^4}{\left(1+m^2\right)^2} + G^4\right\}^{1/2} \pm \frac{\left(1+\cos^2\theta\right)M^2}{1+m^2}\right]^{1/2}, \tag{2.13}$$

and

$$G^2 = \left[\left(4K^2 + \frac{2mM^2\cos\theta}{1+m^2}\right)^2 - \frac{M^4\sin^4\theta}{\left(1+m^2\right)^2}\right]^{1/2} > 0\,. \tag{2.14}$$

In the absence of Hall current $(m=0)$, the solutions (2.11) and (2.12) reduce to

$$u(\eta)=R\frac{\left(\mathrm{M}^2\sin^2\theta+iG^2\right)\mathrm{M}^2-8K^4}{2iG^2\left(\alpha^2+\beta^2\right)^2}\left\{1-\frac{\cosh(\alpha-i\beta)\eta}{\cosh(\alpha-i\beta)}\right\}+ \\ -\frac{\left(\mathrm{M}^2\sin^2\theta-iG^2\right)\mathrm{M}^2-8K^4}{2iG^2\left(\alpha^2+\beta^2\right)^2}\left\{1-\frac{\cosh(\alpha+i\beta)\eta}{\cosh(\alpha+i\beta)}\right\}, \tag{2.15}$$

$$v(\eta)=iR\frac{2K^2}{G^2}\left[\frac{1}{(\alpha-i\beta)^2}\left\{1-\frac{\cosh(\alpha-i\beta)\eta}{\cosh(\alpha-i\beta)}\right\}-\frac{1}{(\alpha+i\beta)^2}\left\{1-\frac{\cosh(\alpha+i\beta)\eta}{\cosh(\alpha+i\beta)}\right\}\right] \tag{2.16}$$

where

$$\alpha,\beta=\frac{1}{2}\left[\left\{\left(1+\cos^2\theta\right)^2\mathrm{M}^4+G^4\right\}^{1/2}\pm\mathrm{M}^2\left(1+\cos^2\theta\right)\right]^{1/2}, \tag{2.17}$$

and

$$G^2=\left(16K^4-\mathrm{M}^4\sin^4\theta\right)^{1/2}, \tag{2.18}$$

which is in agreement with Ghosh and Pop (2002).

3. Frictional shearing stresses at the plate $\eta=\pm 1$

The frictional shearing stresses $\left.\frac{du}{d\eta}\right|_{\eta=\pm 1}$ and $\left.\frac{dv}{d\eta}\right|_{\eta=\pm 1}$ at the upper and lower plates can be obtained from the solutions (2.11) and (2.12).

Remarks:

The maintenance of a magnetic field with the positive direction of the axis of rotation plays an important role of a dynamo mechanism of the Earth's liquid core. The interplay of the hydromagnetic force and Coriolis force leads to a stability parameter $G^2=\left(16K^4-\mathrm{M}^4\sin^4\theta\right)^{1/2}>0$. It is numerically verified that the frictional shearing stresses at the upper and lower plate are equal in magnitude for an arbitrary value of either K^2 or $\theta(O\le\theta\le 2\pi)$ taking any arbitrary value of M^2 (supposed to be strong magnetic field $\mathrm{M}^2=10$) and the Hall current parameter $m=0$.

The following conditions are satisfied

$$\frac{du}{d\eta}\Big/\eta=1=\frac{du}{d\eta}\Big/\eta=-1 \quad \text{and} \quad \frac{dv}{d\eta}\Big/\eta=1=\frac{dv}{d\eta}\Big/\eta=-1. \tag{3.1}$$

The above conditions (2.19) can be expressed as a condition of equilibrium. Thus, the flow becomes stable. In a stable region there must be a critical point.

4. Determination of validity of an argument in comparison with excitation frequency

The investigation is based on the MHD plasma behavior at the resonant level when a forced oscillation is taken into account (see Ghosh, 1997; 2001). The solutions (1a) and (1b) in Ghosh (2001) can be expressed as the velocity distributions by applying $u(\eta, T) = u_0(\eta)\cos\omega T$ and $v(\eta, T) = v_0(\eta)\cos\omega T$ in the following way.

$$u(\eta, T) = \frac{\left(M^2\sin^2\theta + iG^2\right)R_1 - 2P}{2iG^2}\left\{1 - \frac{\cosh(\alpha - i\beta)\eta}{\cosh(\alpha - i\beta)}\right\} + \\ - \frac{\left(M^2\sin^2\theta - iG^2\right)R_1 - 2P}{2iG^2}\left\{1 - \frac{\cosh(\alpha + i\beta)\eta}{\cosh(\alpha + i\beta)}\right\}, \tag{4.1}$$

$$v(\eta, T) = \frac{2P\left(M^2\sin^2\theta - iG^2\right) - \left(M^4\sin^4\theta + G^4\right)R_1}{8iK^2G^2}\left\{1 - \frac{\cosh(\alpha - i\beta)\eta}{\cosh(\alpha - i\beta)}\right\} + \\ - \frac{2P\left(M^2\sin^2\theta + iG^2\right) - \left(M^4\sin^4\theta + G^4\right)R_1}{8iK^2G^2}\left\{1 - \frac{\cosh(\alpha + i\beta)\eta}{\cosh(\alpha + i\beta)}\right\} \tag{4.2}$$

where

$$R_1 = \frac{RM^2}{\left(\alpha^2 + \beta^2\right)^2}, \tag{4.3a}$$

$$P = R\left[1 - \frac{M^2\left(M^2\cos^2\theta - \omega\tan\omega T\right)}{\left(\alpha^2 + \beta^2\right)^2}\right], \tag{4.3b}$$

and

$$\alpha, \beta = \frac{1}{2}\left\{\left[\left\{\left(1 + \cos^2\theta\right)M^2 - 2\omega\tan\omega T\right\}^2 + G^4\right]^{1/2} \pm \left\{\left(1 + \cos^2\theta\right)M^2 - 2\omega\tan\omega T\right\}\right\}^{1/2}, \tag{4.3c}$$

with

$$G^2 = \left(16K^4 - M^4\sin^4\theta - 4\omega^2\tan^2\omega T - 4\omega^2\right)^{1/2}. \tag{4.3d}$$

Case I:

When the angular frequency of oscillation is switched off i.e., $\omega T = 0$, the velocity distributions (4.1) and (4.2) can be explained in two ways; the excitation frequency may be either $\omega < \frac{1}{2}\left(16K^4 - M^4\sin^4\theta\right)^{1/2}$ or $\omega > \frac{1}{2}\left(16K^4 - M^4\sin^4\theta\right)^{1/2}$. The condition $\omega < \frac{1}{2}\left(16K^4 - M^4\sin^4\theta\right)^{1/2}$ is valid for low frequency of oscillation in response to a dynamo mechanism of solar and terrestrial context.

Another condition $\omega > \frac{1}{2}\left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$ leads to a resonant response subject to the high frequency of oscillation. Thus, the resonant condition $G^2 = \left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$ can be written in the form $\omega - \frac{1}{2}\left(16K^4 - M^4 \sin^4\theta\right)^{1/2} > 0$.

Case II:

When the excitation frequency is switched off i.e., $\omega = 0$, the solutions (4.1) and (4.2) reduce to the solutions (2.15) and (2.16) together with (2.17) and (2.18) which are in agreement with Ghosh and Pop (2002).

It is stated that the thermonuclear fusion reaction of the Sun stops when the excitation frequency is switched off, i.e., $\omega = 0$ and the MHD plasma flow tends to an equilibrium position subject to an interplay of the hydromagnetic force and Coriolis force with regard to the neutral plasma stability parameter $G^2 = (16K^4 - M^4 \sin^4\theta)^{1/2}$.

Case III:

It is observed from the solutions (4.1) and (4.2) that the irregular fluctuations build up rapidly with a driving force when $\omega T = \pi/2$. The growing magnetic field can, at an appropriate level, release the constraint at the resonant level and the binary *x*-ray is produced due to the fluctuation of a magnetic field. This leads to a resonant condition $\omega > 1/2 \cos\omega T\left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$ (see condition (4.3d). On the other hand, the condition (4.3d) comes to a justification of $\omega < 1/2 \cos\omega T\left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$ which can be explained as an oscillatory dynamo with regard to solar and terrestrial context.

5. Conclusion

The electrical discharge of a solar corona in the presence of a traveling magnetic field experiences an irregular fluctuation at the resonant level to produce a thermonuclear fusion reaction of the Sun with regard to excitation frequency. The frictional layer at the boundary of the solar corona breaks down and the proliferation of a supercritical state emerges the situation of a thermonuclear fusion reaction of the Sun. It is noticed that the hydrogen bomb blasting on the surface of the Sun leads to a continuous process due to a chain reaction. Since an irregular fluctuation builds up rapidly with a driving force the resonant condition $\omega > \frac{1}{2}\cos\omega T\left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$ exerts its influence of the growing magnetic field at the resonant level and the binary *X*-ray is produced due to a fluctuation of the magnetic field. This situation reveals that the universe is expanding with an irregular space-time interval. This leads to an irregular change of galaxies with regard to Hot Big Bang model in the universe. It is stated that the controlled thermonuclear fusion reaction of the Sun stops when the excitation frequency is switched off $(\omega = 0)$ and the MHD plasma flow tends to an equilibrium position with regard to the fully ionized neutral plasma stability parameter $G^2 = \left(16K^4 - M^4 \sin^4\theta\right)^{1/2}$.

6. Discussion of results

The MHD plasma flow tends to an equilibrium state in order to stop thermonuclear fusion reaction when the excitation frequency is switched off and the velocity distributions are in agreement with the solutions (2.15) and (2.16) under steady state condition (See Ghosh and Pop, 2002). The authors have obtained the numerical results of the solutions (2.11) and (2.12), which are depicted graphically versus η for various values of K^2, m and θ, taking M^2 as fixed. Figures 1 and 2 show that, for an arbitrary value of K^2, the velocity profiles increase with an increase in $\theta(0 \le \theta \le 2\pi)$ for $M^2 = 10$, $K^2 = 4$ and $m = 0$. It is examined that the velocity distributions due to primary flow are identical when $\theta = n\pi$ and $(2n+1)\frac{\pi}{2}$. It is numerically verified that in the presence of Hall current, the velocity profiles due to primary and secondary flows, increase with an increase in θ for $M^2 = 10$ and $K^2 = 4$. Also, the velocity distributions are identical when $\theta = n\pi$ and $(2n+1)\frac{\pi}{2}$. It is noticed that the fully ionized neutral plasma flow behavior exerts its influence of Hall current. It experiences a dynamo mechanism of the Earth's liquid core with regard to a traveling magnetic field when Hall current is taken into account. This corresponds to the author's investigation (Ghosh, 1999a; b) implying thereby the Hall current plays an important role in determining the stabilizing pattern of flow when the excitation frequency is switched off and the solutions for the velocity distributions $u(\eta,T) = u_o(\eta)\cos\omega T$ and $v(\eta,T) = v_o(\eta)\cos\omega T$ (see solutions (2.6) and (2.7) in Ghosh (1999b)) reduce to the solutions (2.11) and (2.12).

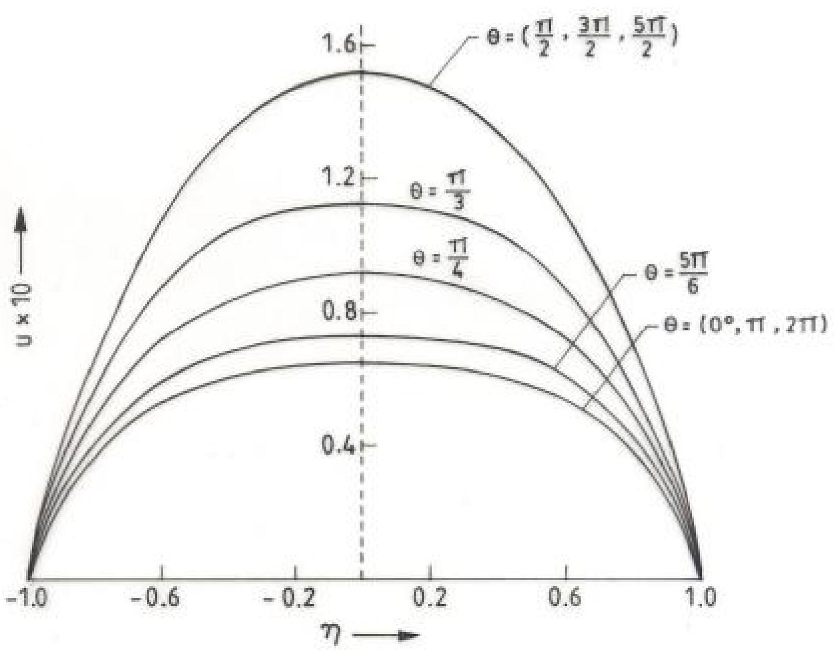

Fig.1. Velocity distribution (u) in the primary flow for $M^2 = 10$, $K^2 = 4$, and $m = 0$.

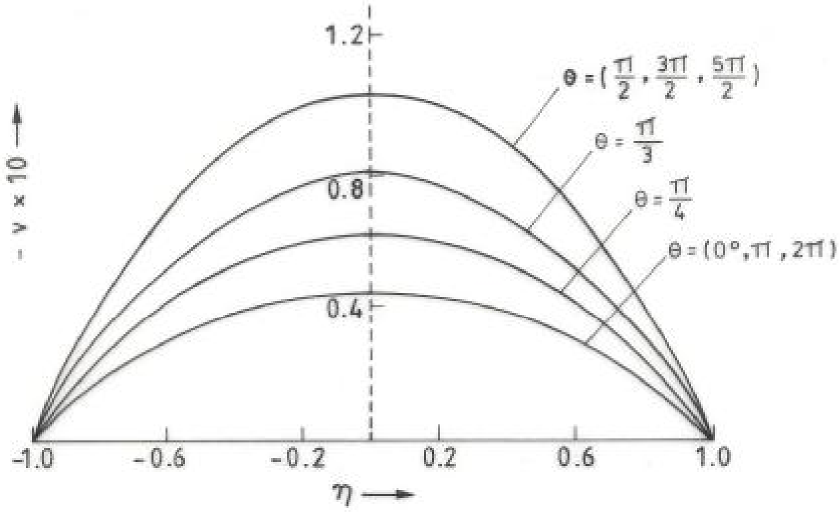

Fig.2. Velocity distribution (v) in the secondary flow for $\mathrm{M}^2 = 10$, $K^2 = 4$, and $m = 0$.

Figures 3 and 4 demonstrate that in the presence of Hall current, the velocity distribution due to primary flow behaves in an oscillatory manner with the increase in M^2 for $K^2 = 4$, $\theta = \dfrac{\pi}{4}$ and $m = 0.5$ while the velocity distribution in the secondary flow decreases with the increase in M^2 for $K^2 = 4$, $\theta = \dfrac{\pi}{4}$ and $m = 0.5$. Figures 5 and 6 reveal that the velocity distribution in the primary flow decreases with the increase in the Hall current parameter *m* while the velocity distribution in the secondary flow increases with the increase in the Hall parameter *m* for $\mathrm{M}^2 = 10$ for $K^2 = 4$, $\theta = \dfrac{\pi}{4}$ (taking any arbitrary value).

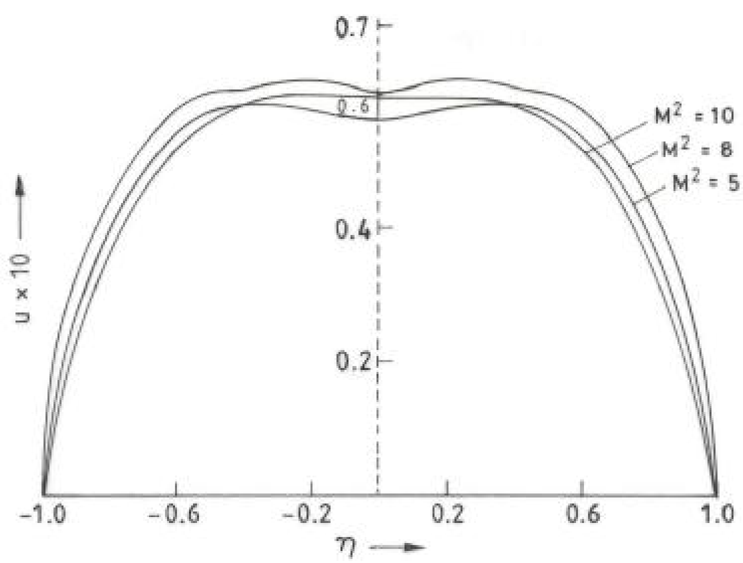

Fig.3. Velocity distribution (u) in the primary flow for $K^2 = 4$, $\theta = \pi/4$ and $m = 0.5$.

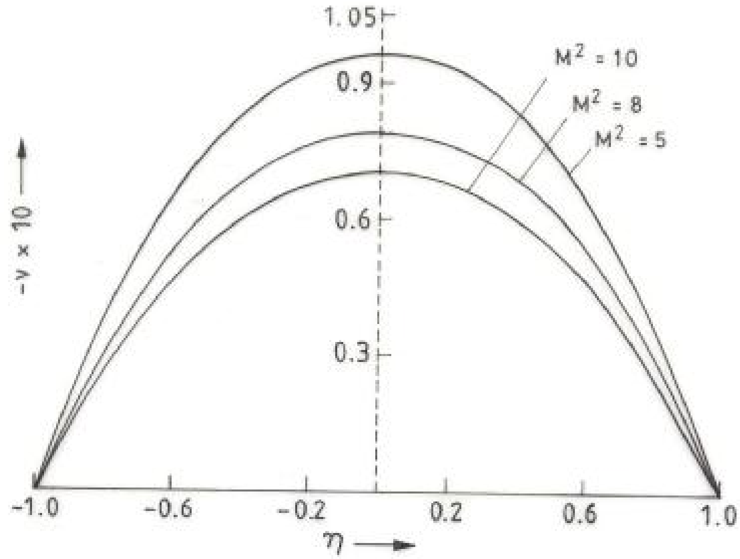

Fig.4. Velocity distribution (v) in the secondary flow for $K^2 = 4$, $\theta = \pi/4$ and $m = 0.5$.

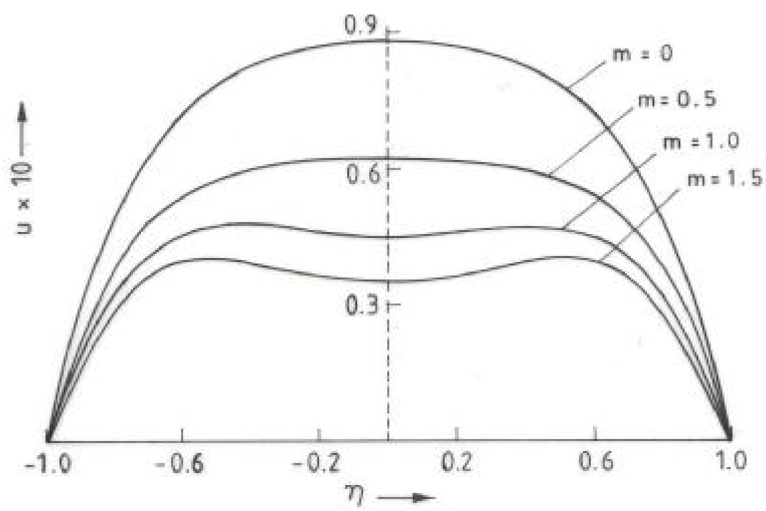

Fig.5. Velocity distribution (u) in the primary flow for $M^2 = 10$, $K^2 = 4$, and $\theta = \pi/4$.

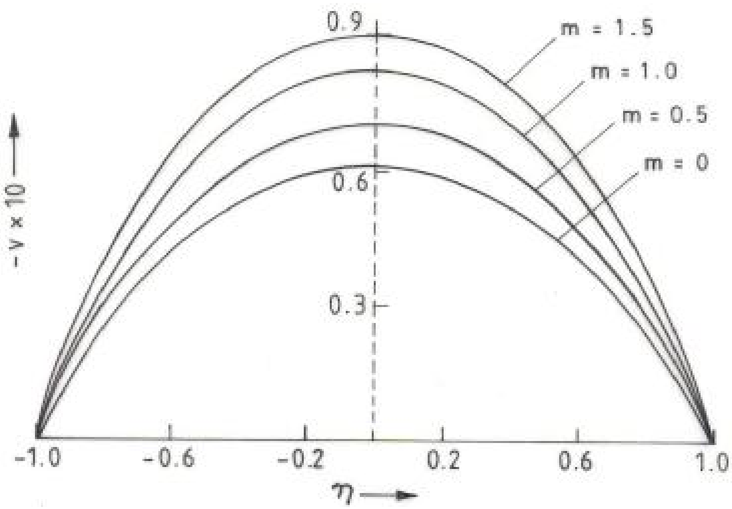

Fig.6. Velocity distribution (v) in the secondary flow for $M^2 = 10$, $K^2 = 4$, and $\theta = \pi/4$.

Acknowledgment

One of the author (S.K. GHOSH) wishes to express his sincere thanks to University Grants Commission in pursusing the work under the scheme "Minor Research Project".

Nomenclature

$\boldsymbol{B}$ – magnetic field vector
B_0 – magnetic flux density
$\boldsymbol{D}$ – displacement vector
$\boldsymbol{E}$ – electric field vector
$\boldsymbol{J}$ – current density vector
K^2 – rotation parameter which is the reciprocal of the Ekman number
L – characteristic length
m – Hall current parameter
M – Hartmann number
p – modified pressure including centrifugal force
R – non-dimensional pressure gradient
q – velocity vector
v – kinematic coefficient of viscosity
η – width of the channel
θ – angle of inclination of a magnetic field with the positive direction of the axis of rotation
$\hat{\kappa}$ – unit vector along Z – axis
μ_e – magnetic permeability
ρ – fluid density
ρ_e – charge density
σ – electrical conductivity
τ_e – electron collision time
ω – excitation frequency
ωT – angular frequency of oscillation
ω_e – cyclotron frequency
Ω – angular velocity

References

Ghosh S.K. (1996): *Hydromagnetic flow in a rotating channel permeated by an inclined magnetic field in the presence of an oscillator*. – Czechoslovak Journal of Physics, vol.46, No.1, pp.85-95.

Ghosh S.K. (1997): *A note on unsteady hydromagnetic flow in a rotating channel permeated by an inclined magnetic field in the presence of an oscillator*. – Czechoslovak Journal of Physics, vol.47, No.8, pp.787-792.

Ghosh S.K. (1999a): *Hall effect on unsteady hydromagnetic flow in a rotating channel permeated by an inclined magnetic field in the presence of an oscillator*. – Czechoslovak Journal of Physics, vol.49, No.4, pp.465-472.

Ghosh S.K. (1999b): *Hall effect on unsteady hydromagnetic flow in a rotating channel permeated by an inclined magnetic field in the presence of an oscillator* (Erratum). – Czechoslovak Journal of Physics, vol.49, No.12, pp.1751.

Ghosh S.K. (2001): *A note on unsteady hydromagnetic flow in a rotating channel permeated by an inclined magnetic field in the presence of an oscillator*. – Czechoslovak Journal Physics, vol.51, No.8, pp.799-804.

Ghosh S.K. and Pop I. (2002): *A note on a hydromagnetic flow in a slowly rotating system in the presence of an inclined magnetic field*. – Magnetohydrodynamics, vol.38, No.4, pp.377-384.

Ghosh S.K. and Pop I. (2004): *Comments on MHD plasma flow in a rotating environment in the presence of an inclined magnetic field*. – International Journal of Applied Mechanics and Engineering, vol.9, No.4, pp.821-826.

Sato H. (1961): *The Hall effects in the viscous flow of ionized gas between parallel plates under transverse magnetic field*. – Journal of Physical Society of Japan, vol.16, No.7, pp.1427-1433.

Received: May 5, 2005

Revised: October 23, 2005