[Volume 3 issue 2 February 2015]
Page No.861-870 ISSN :2320-7167

INTERNATIONAL JOURNAL OF MATHEMATICS AND COMPUTER RESEARCH

Steady Motion of Viscous Liquid Due To a Slowly Rotating Sphere through Porous Medium with Magnetic Field

Dr. Anand Swrup Sharma
Associate Professor, Dept. of Applied Sciences, Ideal Institute of Technology, Ghaziabad (U.P.)
Email: sharma.as09@gmail.com

ABSTRACT
In this paper we have investigated the steady motion of viscous liquid due to a slowly rotating sphere through porous medium with magnetic field. We have investigated the angular velocity, couple and rate of dissipation of energy.

KEY WORDS: Steady poiseuille flow, viscous parallel plates, incompressible fluid, through porous medium and magnetic field.

NOMENCLATURE:

u =Velocity component along x–axis
v = Velocity component along y–axis
w= Velocity component along z–axis
t = the time
ρ = The density of fluid
P = the fluid pressure
K= the thermal conductivity of the fluid
μ = Coefficient of viscosity
υ = Kinematic viscosity
Q= the volumetric flow
r = Radius of sphere
N=Couple

INTRODUCTION:

We have investigated the steady motion of viscous liquid due to a slowly rotating sphere through porous medium with magnetic field. Attempts have been made by several researchers i.e. Q. Jian & R. K. N. D. Rajapakse [1] on coupled heat-moisture transfer in deformable porous media. Z. Joaqu´ın, E. Pablo, G. Enrique, L. M. Joe's & A. B. Osman [2] an electrical network for the numerical solution of transient MHD couette flow of a dusty fluid: Effects of variable properties and hall current. R. Jordan [3] a statistical equilibrium model of coherent structures in magnetohydrodynamics. D. D. Joseph, D. A. Field & G. Papanicolaou [4] nonlinear equation governing flow in a saturated porous media. I. Jun, O. Masaaki, K. Shinichi & H. S. Mesasu [5] bubble behaviour in magnetic fluid under a non uniform magnetic field. G. Juncu [6] a numerical study of steady viscous flow past a fluid spheres. F. Junichiro, N. Yoshhiykki, I. Masashi & E. Hirochito [7] unsteady fluid forces on a blade in a cross flow Turbine. R. Jyosna & S. P. Vanka [8] Multi grid calculation of steady, viscous flow in a triangular cavity. Kang-Hoon KO & N. K. Anand [9] use of porous baffles to enhance heat transfer in a rectangular channel. U. Kazuyuki [10] inertia effects on two dimensional magneto hydrodynamic channel flow under travelling sine wave magnetic field. J. L. Kerrebrock [11] Magnetohydrodynamic Generators with Nonequilibrium Ionization. A. R. A. Khaled & K. Vafai [12] the role of porous media in modeling flow and heat transfer in biological tissues. In this paper we have investigated the angular velocity, Couple on the sphere and rate of dissipation of energy
.

FORMULATION OF THE PROBLEM:

Let $\bar{q} = q(u,v,w)$ *Where* $w = 0$, $u = -\omega y$ & $v = \omega x$............(1)

So that $\frac{\partial u}{\partial x} = 0$ $\frac{\partial v}{\partial y} = 0$ & $\frac{\partial w}{\partial z} = 0$ $\Rightarrow \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$

$\therefore$ The equation of continuity is satisfied where ω is the angular velocity s.t $\omega = \omega(r)$ *Where* $r^2 = x^2 + y^2 + z^2$

Navier – stokes equation in the absence of body Forces

$$\frac{d\bar{q}}{dt} = \frac{\partial \bar{q}}{\partial t} + (\bar{q}.\nabla)\bar{q} = -\frac{1}{\rho}\nabla p + \upsilon \nabla^2 \bar{q} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\upsilon \bar{q}$$

Since motion is steady $\Rightarrow \frac{\partial \bar{q}}{\partial t} = 0$ but $\bar{q}$ very small and hence neglecting square of velocities

$(\bar{q}.\nabla)\bar{q} = 0$ With these values (i) becomes $-\frac{1}{\rho}\nabla p + \frac{\mu}{\rho}\nabla^2 \bar{q} + \left(\frac{1}{\rho K} + \frac{\sigma B_0^2}{\rho \mu}\right)\mu \bar{q} = 0$

$$\Rightarrow \mu\left\{\nabla^2 \bar{q} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\bar{q}\right\} = \nabla p \text{ but } \nabla^2 q^2 = \nabla^2 u\hat{i} + \nabla^2 v\hat{j} + \nabla^2 w\hat{k}$$

$$\mu(\nabla^2 ui + \nabla^2 vj) + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\mu(ui + vj) = \frac{\partial p}{\partial x}i + \frac{\partial p}{\partial y}j + \frac{\partial p}{\partial z}k$$

Comparing $\mu\left\{\nabla^2 u + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)u\right\} = \frac{\partial p}{\partial x}$.............(2)

$$\mu\left\{\nabla^2 v + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)v\right\} = \frac{\partial p}{\partial y}............(3)$$

and $\frac{\partial p}{\partial z}$=0........(4)

SOLUTION OF THE PROBLEM:

$$u = -\omega y \Rightarrow \frac{\partial^2 u}{\partial x^2} = -y\frac{\partial^2 \omega}{\partial x^2}, \quad \frac{\partial^2 u}{\partial z^2} = -y\frac{\partial^2 \omega}{\partial z^2}, \quad \frac{\partial u}{\partial y} = -\omega - y\frac{\partial \omega}{\partial y} \quad \Rightarrow \frac{\partial^2 u}{\partial y^2} = -\frac{\partial \omega}{\partial y} - \frac{\partial \omega}{\partial y} - y\frac{\partial^2 \omega}{\partial y^2}$$

$$\therefore \nabla^2 u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = -y\frac{\partial^2 \omega}{\partial x^2} - 2y\frac{\partial \omega}{\partial y} - y\frac{\partial^2 \omega}{\partial y^2} - y\frac{\partial^2 \omega}{\partial z^2} = -y\nabla^2 \omega - 2\frac{\partial \omega}{\partial y} = -y\left[\nabla^2 \omega + \frac{2}{y}\frac{\partial \omega}{\partial y}\right]$$

Similarly $\nabla^2 v = x\left\{\nabla^2 \omega + \frac{2}{x}\frac{\partial \omega}{\partial x}\right\}$ But $r^2 = x^2 + y^2 + z^2$

$$\frac{\partial r}{\partial x} = \frac{x}{r}, \quad \frac{\partial r}{\partial y} = \frac{y}{r} \;\&\; \frac{\partial r}{\partial z} = \frac{z}{r} \;\&\; \frac{\partial \omega}{\partial x} = \frac{\partial \omega}{\partial r}.\frac{\partial r}{\partial x} = \frac{x}{r}\frac{\partial \omega}{\partial r}$$

$$\frac{\partial^2 \omega}{\partial x^2} = \frac{1}{r}\frac{\partial \omega}{\partial r} + \frac{x}{r}\left[\frac{\partial^2 \omega}{\partial r^2}\right]\frac{\partial r}{\partial x} + \left(-\frac{x}{r^2}\right)\left(\frac{x}{r}\right)\frac{\partial \omega}{\partial r} = \frac{1}{r}\frac{\partial \omega}{\partial r} + \frac{x^2}{r^2}\frac{\partial^2 \omega}{\partial r^2} - \frac{x^2}{r^3}\frac{\partial \omega}{\partial r}$$

$$\Sigma\frac{\partial^2 \omega}{\partial x^2} = \frac{1}{r}\frac{\partial \omega}{\partial r}\Sigma 1 - \frac{1}{r^3}\frac{\partial \omega}{\partial r}\Sigma x^2 + \frac{1}{r^2}\frac{\partial^2 \omega}{\partial r^2}\Sigma x^2$$

$$\nabla^2\omega = \frac{3}{r}\frac{\partial\omega}{\partial r} - \frac{1}{r}\frac{\partial\omega}{\partial r} + \frac{\partial^2\omega}{\partial r^2} = \frac{2}{r}\frac{d\omega}{dr} + \frac{d^2\omega}{dr^2} \quad \text{Also} \quad \frac{2}{x}\frac{\partial\omega}{\partial x} = \frac{2}{r}\frac{\partial\omega}{\partial r}, \quad \frac{2}{y}\frac{\partial\omega}{\partial y} = \frac{2}{r}\frac{\partial\omega}{\partial r}$$

Now (ii), (iii), (iv) reduces to $-\mu y\left[\nabla^2\omega + \frac{2}{y}\frac{\partial\omega}{\partial y} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\omega\right] = \frac{\partial p}{\partial x}$

$$-\mu x\left[\nabla^2\omega + \frac{2}{x}\frac{\partial\omega}{\partial x} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\omega\right] = \frac{\partial p}{\partial y} \quad \& \quad \frac{\partial p}{\partial z} = 0$$

$$Or \quad -\mu y\left[\frac{d^2\omega}{dr^2} + \frac{4}{r}\frac{d\omega}{dr} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\omega\right] = \frac{\partial p}{\partial x} \quad \& \quad \mu x\left[\frac{d^2\omega}{dr^2} + \frac{4}{r}\frac{d\omega}{dr} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\omega\right] = \frac{\partial p}{\partial y} \quad \& \quad \frac{\partial p}{\partial z} = 0$$

These are satisfied by p = constant, so $\frac{d^2\omega}{dr^2} + \frac{4}{r}\frac{d\omega}{dr} + \left(\frac{1}{K} + \frac{\sigma B_0^2}{\mu}\right)\omega = 0 \quad let \quad \frac{1}{K} + \frac{\sigma B_0^2}{\mu} = B^2$

$$r\omega''(r) + 4\omega'(r) + rB^2\omega(r) = 0$$

Taking Laplace Transform

$$L\{r\omega''(r)\} + 4L\{\omega'(r)\} + B^2L\{r\omega(r)\} = 0$$

$$-\frac{d}{dp}\left[p^2L\{\omega(r)\} - p\omega(0) - \omega'(0)\right] + 4\{pL\{\omega(r)\} - \omega(0)\} - B^2\frac{d}{dp}L\{\omega(r)\} = 0$$

$$-2pL\{\omega(r)\} - p^2\frac{d}{dp}L\{\omega(r)\} + A + 4pL[\omega(r)] - 4A - B^2\frac{d}{dp}L\{\omega(r)\} = 0$$

$$-(p^2+B^2)\frac{d\bar{\omega}}{dp} + 2p\bar{w} = 3A \quad let \quad \bar{\omega} = L\{\omega(r)\} \quad \therefore \frac{d\bar{\omega}}{dp} - \frac{2p}{(p^2+B^2)}\bar{\omega} = -3A.\frac{1}{(p^2+B^2)}$$

$$I.F. = e^{-\int\frac{2p}{(p^2+B^2)}dp} = e^{-\log(p^2+B^2)} = \frac{1}{(p^2+B^2)}$$

$$\Rightarrow \bar{\omega}.\frac{1}{(p^2+B^2)} = -3A\int\frac{dp}{(p^2+B^2)}\frac{1}{(p^2+B^2)} + C = -3A\int\frac{1}{(p^2+B^2)^2}dp + C$$

$$= -3A\int\frac{\sec^2\theta d\theta}{B\sec^4\theta} + C \quad On\ putting \quad p = B\tan\theta \quad \Rightarrow dp = B\sec^2\theta\, d\theta$$

$$\Rightarrow \bar{\omega}\frac{1}{(p^2+B^2)} = -\frac{3A}{B^3}\int\cos^2\theta\, d\theta + C = -\frac{3A}{2B^3}.\int(1+\cos 2\theta)\, d\theta + C$$

$$= -\frac{3A}{2B^3}.\left(\theta + \frac{\sin 2\theta}{2}\right) + C = -\frac{3A}{2B^3}\left[\tan^{-1}\frac{p}{B} + \frac{p}{\sqrt{B^2+p^2}}.\frac{B}{\sqrt{B^2+p^2}}\right] + C = -\frac{3A}{2B^3}\left[\tan^{-1}\frac{p}{B} + .\frac{Bp}{(p^2+B^2)}\right] + C$$

$$\bar{\omega} = -\frac{3A}{2B^3}\left\{(p^2+B^2)\tan^{-1}\frac{p}{B} + Bp\right\} + C(p^2+B^2)$$

$$\therefore \omega(r) = -\frac{3A}{2B^3}\left[L^{-1}\left\{(p^2+B^2)\tan^{-1}\frac{p}{B} + BL^{-1}\{p\}\right\}\right] + CL^{-1}\{p^2+B^2\}$$

$$= -\frac{3A}{2B^3}L^{-1}\left\{(p^2+B^2)\tan^{-1}\frac{p}{B}\right\} \quad \because L^{-1}[p^n] = 0 \quad \text{Since n is a positive Integer}$$

Now $f(p)=\tan^{-1}\frac{p}{B} \Rightarrow f^{'}(p)=\frac{B}{B^2+p^2} \therefore L^{-1}\left[f^{'}(p)\right]=B\,L^{-1}\left[\frac{1}{\left(p^2+B^2\right)}\right] = Sin\ r\,B$

$\Rightarrow -r\,L^{-1}[f(p)]=Sin\ r\,B \Rightarrow L^{-1}[\tan^{-1}\frac{p}{B}]=-\frac{1}{r}Sin\ r\,B=f(r)$

Now $\frac{d}{dr}\left[\frac{1}{r}Sin\ r\,B\right]=-\frac{1}{r^2}Sin\ r\,B+\frac{B}{r}Cos\ r\,B$

$$\frac{d^2}{dr^2}\left[\frac{1}{r}Sin\ r\,B\right]=\frac{2}{r^3}Sin\ r\,B-\frac{B}{r^2}Cos\ r\,B.-\frac{B}{r^2}.Cos\ r\,B-\frac{B^2}{r}.Sin\ r\,B = \frac{2}{r^3}Sin\ r\,B-.\frac{2B}{r^2}Cos\ r\,B-\frac{B^2}{r}Sin\ r\,B$$

$$\therefore \omega(r)=\frac{3A}{2B^3}\left[\frac{2}{r^3}Sin\ r\,B-\frac{2B}{r^2}Cos\ r\,B-\frac{B^2}{r}Sin\ r\,B+\frac{B^2}{r}Sin\ r\,B\right]$$

$$\omega(r)=\frac{3A}{B^3}\left[\frac{1}{r^3}Sin\ r\,B-\frac{B}{r^2}Cos\ r\,B\right] = \frac{3A}{B^2r^3}\left[\frac{1}{B}\ Sin\ r\,B-r\ Cos\ r\,B\right]$$

Let the motion be produced by a solid sphere of radius a rotating with angular velocity ω' in a liquid at rest at infinity so that $\omega=0$ at $r=\infty$ and $\omega=\omega'$ at $r=a$

$$\omega^{'}=\frac{3A}{a^3B^2}\left[\frac{1}{B}\ Sin\ a\,B-a\ Cos\ a\,B\right] \Rightarrow A=\frac{\omega^{'}a^3B^2}{3\left[\frac{1}{B}\ Sin\ a\,B-a\ Cos\ a\,B\right]}$$

$$\therefore\ \omega(r)=\frac{a^3\omega^{'}}{r^3}\ \frac{[Sin\ r\,B-r\,B\ Cos\ r\,B]}{[Sin\ a\,B-a\,B\ Cos\ a\,B]}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Again if there exists an external fixed concentric spherical boundary of radius b i.e. (i) $\omega=0$ at r = b (ii) $\omega=\omega'$ at $r=a$

$$\frac{3A}{b^3B^2}\left[\frac{1}{B}Sin\ b\,B-b\ Cos\ b\,B\right]=0 \quad \& \quad \omega'=\frac{3A}{a^3B^2}\left[\frac{1}{B}Sin\ a\,B-a\ Cos\ a\,B\right]$$

Adding both $\omega'=\frac{3A}{B^2}\left[\frac{1}{b^3B}\ Sin\ b\,B-\frac{1}{b^2}\ Cos\ b\,B+\frac{1}{a^3B}\ Sin\ a\,B-\frac{1}{a^2}\ Cos\ a\,B\right]$

$$A=\frac{\omega'B^2}{3\left[\frac{1}{b^3B}Sin\ b\,B-\frac{1}{b^2}Cos\ b\,B+\frac{1}{a^3B}Sin\ a\,B-\frac{1}{a^2}Cos\ a\,B\right]}$$

$$\therefore \omega(r)=\frac{\omega'\left[\frac{1}{B}Sin\ r\,B-r\ Cos\ r\,B\right]}{r^3\left[\frac{1}{b^3B}Sin\ b\,B-\frac{1}{b^2}\ Cos\ b\,B+\frac{1}{a^3B}\ Sin\ a\,B-\frac{1}{a^2}Cos\ a\,B\right]}\ \ldots\ldots\ldots\ldots\ldots(6)$$

Here $q_r=0,\quad q_\theta=0,\quad q_\phi=\omega r\ Sin\ \theta$

$$\frac{d\omega}{dr}=\frac{\omega'\left[\frac{-3}{B}\ Sin\ r\,B+3r\ Cos\ r\,B+B\,r^2Sin\ r\,B\right]}{r^4\left[\frac{1}{b^3B}\ Sin\ b\,B-\frac{1}{b^2}Cos\ b\,B+\frac{1}{a^3B}\ Sin\ a\,B-\frac{1}{a^2}\ Cos\ a\,B\right]}$$

$$\left(\frac{d\omega}{dr}\right)_{r=a} = \frac{\omega'\left[\frac{-3}{B} Sin\ a B + 3a\ Cos\ a B + B a^2\ Sin\ a B\right]}{a^4\left[\frac{1}{b^3 B}\ Sin\ b B - \frac{1}{b^2} Cos\ b B + \frac{1}{a^3 B}\ Sin\ a B - \frac{1}{a^2}\ Cos\ a B\right]}$$

The moment of p_ϕ is $p_\phi\ r\ Sin\theta$ where $p_\phi = \mu\ r\ Sin\theta \frac{d\omega}{dr}$ is the only non vanishing component of p. If N is the couple on the sphere of radius a, then

$$N = \int_0^\pi \left(P_\phi\ r\ Sin\theta\right)_{r=a} ds = \int_0^\pi \mu\ a^2\ Sin^2\theta \left(\frac{d\omega}{dr}\right)_{r=a} .\ 2\pi a\ Sin\theta\ a\ .\ d\theta$$

$$N = 2\pi\ \mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} \int_0^\pi Sin^3\theta\ d\theta = 4\pi\ \mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} \int_0^{\pi/2} Sin^3\theta\ d\theta$$

$$= 4\pi\mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} \frac{\Gamma 2\ \Gamma 1/2}{2\,\Gamma 5/2} = 2\pi\mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} \frac{\sqrt{\pi}}{\frac{3}{2}\cdot\frac{1}{2}\sqrt{\pi}} = \frac{8}{3}\ \pi\mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} \quad ....(7)$$

But the rate dissipation of energy $= N\omega' = \frac{8}{3}\pi\mu\ a^4 \left(\frac{d\omega}{dr}\right)_{r=a} .\omega'$

$$= \frac{8\pi\mu\ \omega'^2\left[\frac{-3}{B} Sin\ a B + 3a\ Cos\ a B + B a^2\ Sin\ a B\right]}{3\left[\frac{1}{b^3 B}\ Sin\ b B - \frac{1}{b^2}\ Cos\ b B + \frac{1}{a^3 B}\ Sin\ a B - \frac{1}{a^2}\ Cos\ a B\right]}$$

$$\lim_{b\to\infty} N = \frac{8\pi\mu\omega'\left[\frac{-3}{B}\ Sin\ a B + 3a\ Cos\ a B + a^2 B\ Sin\ a B\right]}{3\left[\frac{1}{a^3 B} Sin\ a B - \frac{1}{a^2} Cos\ a B\right]} = \frac{8\pi\mu a^3\omega'\left[\frac{-3}{B}\ Sin\ a B + 3a\ Cos\ a B + a^2 B\ Sin\, a B\right]}{3\left[\frac{1}{B} Sin\ a B - a\ Cos\ a B\right]}$$

$$= -8\pi\ \mu\ a^3\omega' + \frac{8\pi\ \mu\ a^5\omega' B}{3}\left[\frac{Sin\ a B}{\frac{1}{B} Sin\ a B - a\ Cos\ a B}\right]$$

For an infinite liquid outside a sphere of radius a, rate of dissipation of energy is

$$8\pi\ \mu\ a^3\omega'^2 - \frac{8\pi\ \mu\ a^5\omega' B}{3}\left[\frac{Sin\ a B}{\frac{1}{B} Sin\ a B - a\ Cos\ a B}\right] \quad ....(8)$$

Tables for Velocity:

$Let\ \ \omega' = 4,\ \ a = 60\ \ and\ \ \sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = B\ \ again\ let\ \sqrt{\frac{1}{K}} = \sqrt{\frac{\sigma B_0^2}{\mu}} = \frac{1}{\sqrt{6}} \ \Rightarrow\ \sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = B = \frac{1}{\sqrt{3}}$

Table-1 (for angular velocity)

	r	10	20	30	40	50	60	70
$\frac{1}{\sqrt{K}}=\frac{1}{\sqrt{6}}$	$\omega(r)$	**158.02**	**39.2**	**17.198**	**9.498**	**5.934**	**4**	**2.835**
$\sqrt{\frac{\sigma B_0^2}{\mu}}=\frac{1}{\sqrt{6}}$	$\omega(r)$	**158.02**	**39.2**	**17.198**	**9.498**	**5.934**	**4**	**2.835**
$\sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=\frac{1}{\sqrt{3}}$	$\omega(r)$	**174.57**	**35.959**	**18.60**	**10.078**	**6.136**	**4**	**2.716**

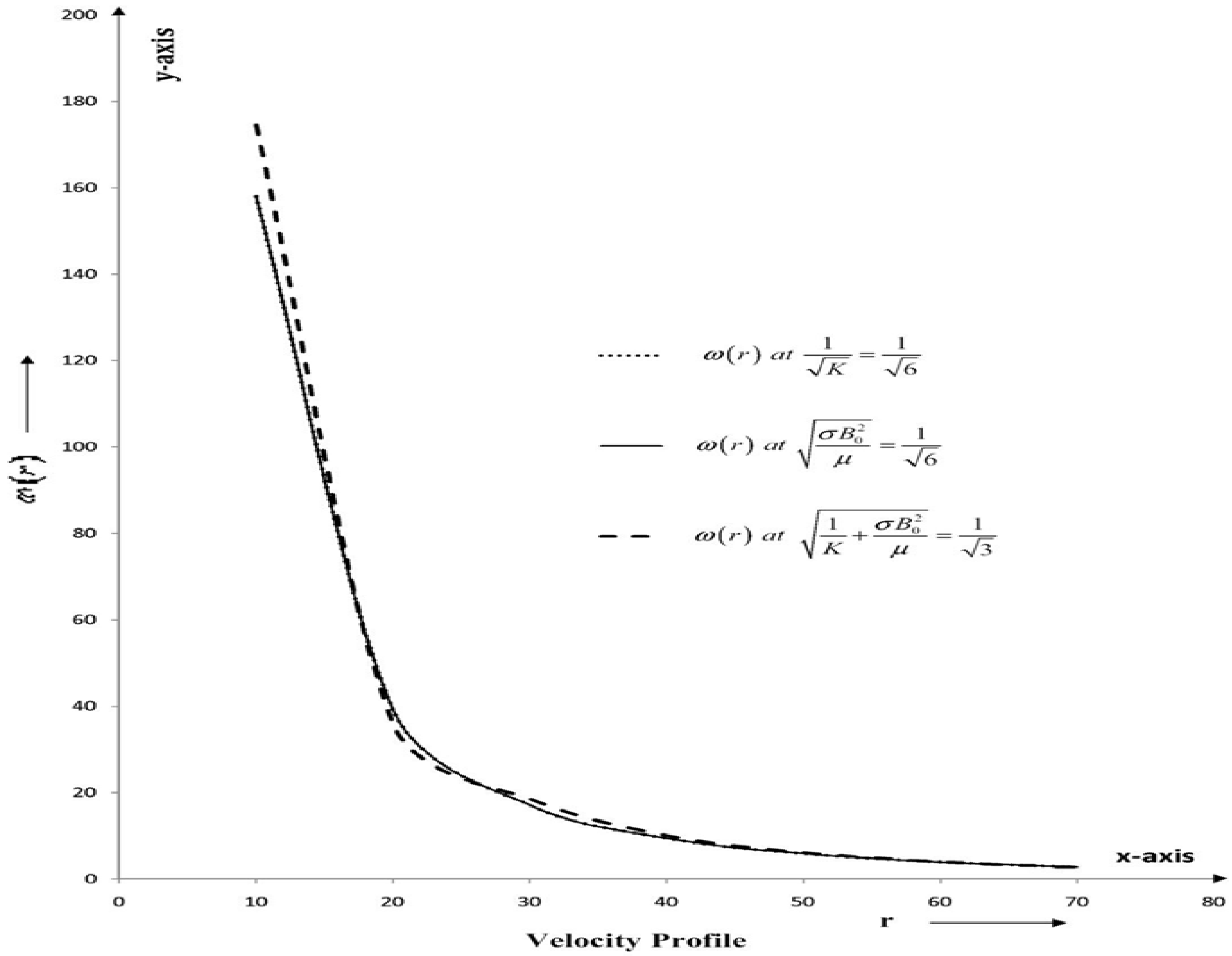

Figure-1

Case (ii):

Let $\omega'=4,\ \ a=60\ \ and\ \ \sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=B\ \ again\ let\ \ \frac{1}{\sqrt{K}}\prec\sqrt{\frac{\sigma B_0^2}{\mu}},\ \ \frac{1}{\sqrt{K}}=\frac{1}{2},\ \ \sqrt{\frac{\sigma B_0^2}{\mu}}=1\Rightarrow\ \sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=\frac{\sqrt{5}}{2}$

Table-2 (for angular velocity)

	r	10	20	30	40	50	60	70
$\frac{1}{\sqrt{K}}=\frac{1}{2}$	$\omega(r)$	**165.93**	**41**	**17.87**	**9.776**	**6.03**	**4**	**2.778**
$\sqrt{\frac{\sigma B_0^2}{\mu}}=1$	$\omega(r)$	**286.9**	**68.40**	**27.99**	**13.9**	**7.44**	**4**	**1.989**
$\sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=\frac{\sqrt{5}}{2}$	$\omega(r)$	**369.38**	**86.989**	**34.796**	**16.645**	**8.368**	**4**	**1.493**

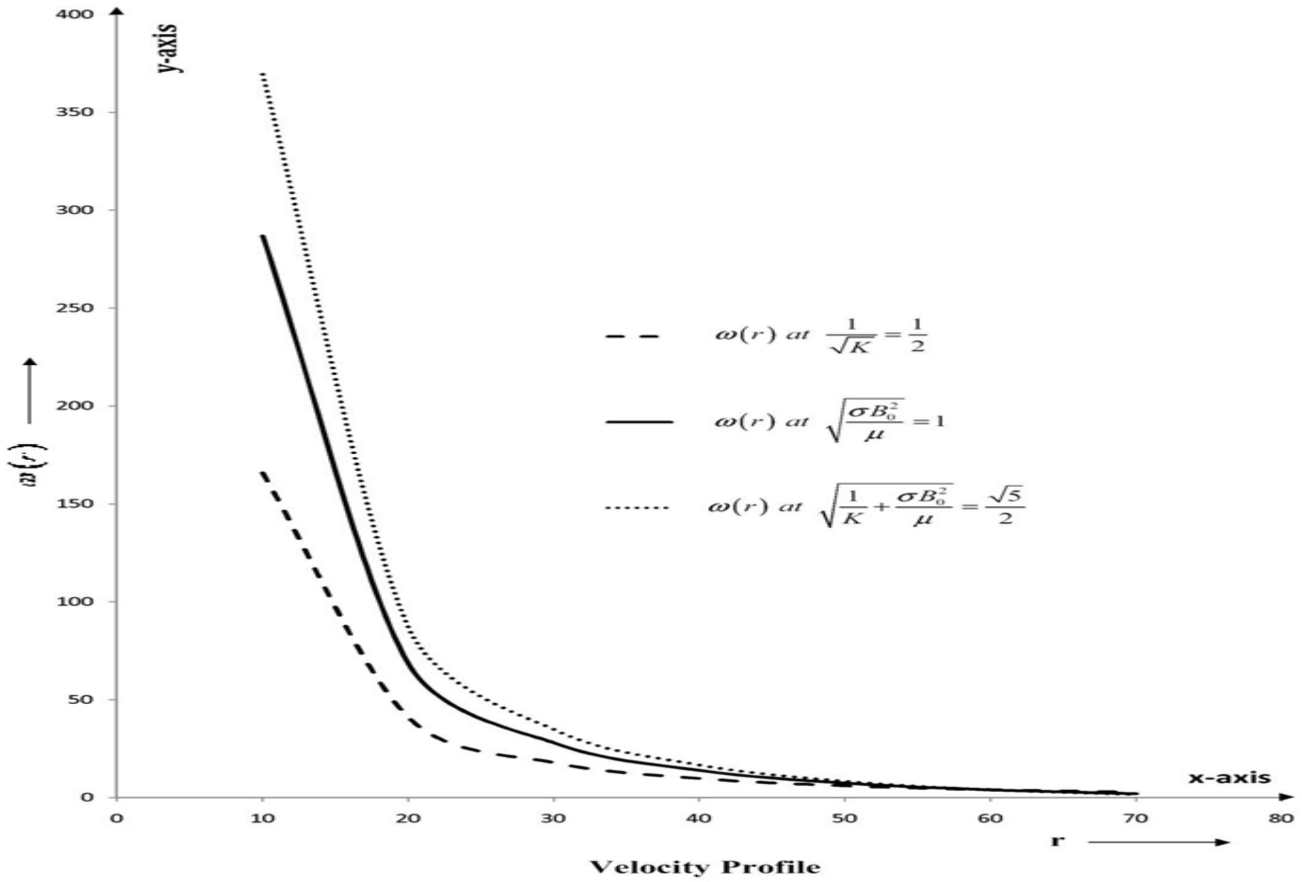

Figure-2

Case (iii):

Let $\omega'=4,\ \ a=60\ \ and\ \ \sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=B\ \ again\ let\ \ \frac{1}{\sqrt{K}}\succ\sqrt{\frac{\sigma B_0^2}{\mu}},\ \ \frac{1}{\sqrt{K}}=1,\ \ \sqrt{\frac{\sigma B_0^2}{\mu}}=\frac{1}{2}\ \ \Rightarrow\ \sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=\frac{\sqrt{5}}{2}$

Table-3 (for angular velocity)

	r	10	20	30	40	50	60	70
$\frac{1}{\sqrt{K}}=1$	$\omega(r)$	**286.9**	**68.40**	**27.99**	**13.9**	**7.44**	**4**	**1.989**
$\sqrt{\frac{\sigma B_0^2}{\mu}}=\frac{1}{2}$	$\omega(r)$	**165.93**	**41**	**17.87**	**9.776**	**6.03**	**4**	**2.778**
$\sqrt{\frac{1}{K}+\frac{\sigma B_0^2}{\mu}}=\frac{\sqrt{5}}{2}$	$\omega(r)$	**369.38**	**86.989**	**34.796**	**16.645**	**8.368**	**4**	**1.493**

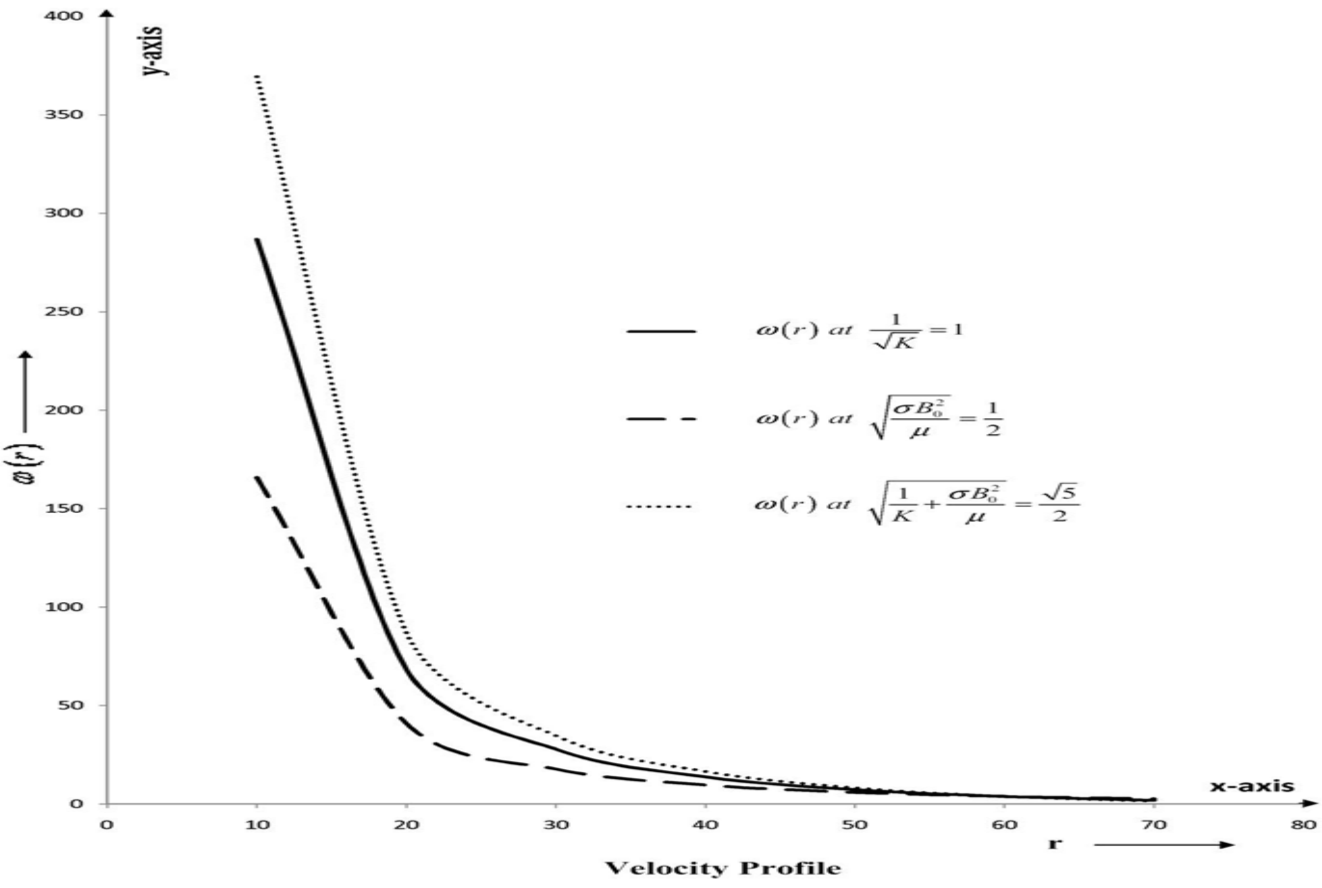

Figure-3

CONCLUSION AND DISCUSSION:

In this paper, we have investigated the angular velocity by the graph and table (1) in equation (5) between angular velocity and radius, it is clear that the angular velocity is equal in porous medium and magnetic field at $\frac{1}{\sqrt{K}} = \sqrt{\frac{\sigma B_0^2}{\mu}} = \frac{1}{\sqrt{6}}$ and less than the corresponding value of angular velocity in porous with magnetic field at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{1}{\sqrt{3}}$ in the interval $10 \le r \prec 60$, but value of angular velocity is equal in all mediums at $r = 60$, but the angular velocity at $\frac{1}{\sqrt{K}} = \sqrt{\frac{\sigma B_0^2}{\mu}} = \frac{1}{\sqrt{6}}$ is greater than the corresponding value of angular velocity at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{1}{\sqrt{3}}$ in the interval $60 \prec r \le 70$.

Again, from table (2) the angular velocity in porous medium at $\frac{1}{\sqrt{K}} = \frac{1}{2}$ is less than corresponding value in magnetic field at $\sqrt{\frac{\sigma B_0^2}{\mu}} = 1$ and is also less than the corresponding value of angular velocity in porous with magnetic field at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{\sqrt{5}}{2}$ in the interval $10 \le r \prec 60$, the value of angular velocity is equal in all mediums at $r = 60$,but the angular velocity in porous medium at $\frac{1}{\sqrt{K}} = \frac{1}{2}$ is greater than the corresponding value of angular velocity in magnetic field at $\sqrt{\frac{\sigma B_0^2}{\mu}} = 1$ and is also greater than porous with magnetic field at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{\sqrt{5}}{2}$ in the interval $60 \prec r \le 70$.

Again, from table (3) the angular velocity in magnetic field at $\sqrt{\frac{\sigma B_0^2}{\mu}} = 1$ is less than corresponding value of angular velocity in porous medium at $\frac{1}{\sqrt{K}} = \frac{1}{2}$ and is also less than the corresponding value of angular velocity in porous with magnetic field at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{\sqrt{5}}{2}$ in the interval $10 \le r \prec 60$, the value of angular velocity is equal in all mediums at $r = 60$,but the angular velocity in magnetic field at $\sqrt{\frac{\sigma B_0^2}{\mu}} = 1$ is greater than the corresponding value of angular velocity in porous medium at $\frac{1}{\sqrt{K}} = \frac{1}{2}$ and is also greater than the angular velocity in porous with magnetic field at $\sqrt{\frac{1}{K} + \frac{\sigma B_0^2}{\mu}} = \frac{\sqrt{5}}{2}$ in the interval $60 \prec r \le 70$. Also we have investigated the angular velocity by equation (6), couple on the sphere and rate of dissipation of energy by equations (7) & (8)

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