ORIGINAL PAPER

STABILITY OF MAGNETOHYDRODYNAMIC FLOW OF VISCOUS FLUID IN A HORIZONTAL CHANNEL OCCUPIED BY A POROUS MEDIUM

P.M. BALAGONDAR[1], M. S. BASAVARAJ[2], RAGHAWENDRA MISHRA[3]

Manuscript received: 05.08.2014; Accepted paper: 06.09.2014;

Published online: 30.09.2014.

Abstract. *A study is made of the influence of a coplanar magnetic field on the linear stability of a electrically conducting fluid flowing between two infinite parallel fixed plates in a porous media using the energy method. The sufficient condition for stability is obtained using the nature of growth rate,* c_i *as well as sufficiently small values of the Reynolds number,* R_e*. From this condition we found that the strengthening or weakening of the stability criterion is dictated by the strength of the magnetic field and porous parameter. In particular, we found that the interaction of magnetic field with porous parameter is more effective in stabilizing the electrically conducting fluid in a porous medium compared to that of ordinary Newtonian viscous fluid.*

Keywords: *Linear Stability, porous media, Magnetohydrodynamic and growth rate.*

1. INTRODUCTION

The instability of a hydro magnetic shear flow, in which the additional influence of a magnetic field is taken into account, has received considerable attention owing, to its importance in a number of astrophysical contexts (see for example, Michael 1953, Hunt 1966). The effect of a magnetic field on the stability of laminar flows of an electrically conducting fluid has been found theoretically in a number of cases: it is known to be generally of a stabilizing nature, and this has confirmed qualitatively by experiment. In particular, they have shown that even in the nonlinear region the diffusive processes are very important throughout the fluid region. Using this assumption Stuart (1954), Velikhov (1959) and Tarasov (1960) examined the stability of plane poiseuille flow with a parallel magnetic field. Drazin (1960) has examined some general aspects of the stabilizing influence of a parallel magnetic field on a plane parallel flow, also considering only two-dimensional disturbances. Wooler (1961) has examined the stability of a plane parallel flow for small magnetic Reynolds number, when the magnetic field lies in the plane of the flow but is not parallel to it. He has also shown that three dimensional disturbances can be the most unstable.

Magnetohydrodynamic shear instability of a field aligned shear flow could be responsible for the generation and maintenance of turbulence. The situation is modeled locally

[1] Bangalore University, Deapartment of Mathematics, 560001 Bangalore, India. E-mail: drp_mb@yahoo.com.
[2] M. S. Ramaiah Institute of Technology, Department of Mathematics, 560054 Bangalore, India.
E-mail: basavarajms@msrit.edu.
[3] Govt.P.G College, Department of Mathematics, 263645 Uttarkhand, India.
E-mail: raghavendramisra@yahoo.in

by a linear shear profile, and stability with respect to three dimensional disturbances is studied in the presence of both viscous and ohmic dissipation. In this local formulation the boundaries are absent, and there is no inflection- point instability. The effect of a uniform coplanar magnetic field on the stability of parabolic flow of a conducting fluid between parallel walls has been investigated and the stability equations were first given by Micheal (1953) who showed that Squire's theorem is applicable only to two-dimensional magnetohydrodynamic flows.

Because of the complicated form of the stability equations, Stuart (1954) simplified the equations by assuming the magnetic Reynolds number R_m as small. The fluid dynamic and electrodynamic equations are uncoupled because the induced magnetic field is of second order. He claimed the closure of the curve could not be verified because the assumption of small R_m and higher values of the Reynolds number R_e. In a discussion of Stuart's paper, Cowling (1957) said the existence of a region of stability for large values of R_e "hardly seems reasonable". Rossow (1959) solved the problem again and obtained stability curves for constant values of the magnetic interaction parameter *N*. The curves shift towards higher R_e with increased *N* but do not form closed loops. As the stability diagrams were of limited value, the stability equation for small R_m has been resolved by a numerical method.

Hains (1965) investigated the same problem to study the influence of a coplanar magnetic field on the stability of a conducting fluid flowing between parallel planes. Four sets of stability diagrams were presented so that each stability curve will represent the effect of a given applied magnetic field, as only one of the four quantities in the Reynolds number, is changed. The flow is always stable for initial disturbances of the field produced by passage of a pulsating current through walls of finite conductivity.

In this era of modernization and globalization considerable interest has been evinced in the study of flow through porous media because of its natural occurrence and of its importance in industrial, geophysical, biomedical applications. In chemical industries involving different types of chemicals which are freely suspended in fluid saturated porous media have been used to achieve the effective mixing process (see De Wiest, 1969). In petroleum industries, porous medium is used for oil recovery, filtration and cleaning of oil spills. In nuclear industries, porous medium is used for effective insulation and for emergency cooling of nuclear reactors (Masuoka, 1974). Study of flow through a porous medium is also of immense use in geothermal studies (Cheng ,1978., Rudraiah and Srimani, 1980) and in biomedical engineering problems to understand the transport processes in lungs, kidneys, cartilages in synovial joints and so on.

In this paper we investigate the stability of two dimensional incompressible electrically conducting viscous fluids through a porous channel. The stability equation and the stability criteria are obtained using the energy method. In section 2, we set up the governing equations for two-dimentional incompressible electrically conducting fluid through porous media with aligned magnetic field $\vec{B}$. In section 3.1 the basic velocity $\bar{u}(y)$ and in section 3.2 linear perturbation equations are obtained. Finally using the linear stability analysis the stability equation in the form similar to Orr-Sommerfield equation is derived. And in section 4, the expression for growth rate c_i using energy method is obtained as a function of porous parameter σ_p, Reynolds number R_e, ratio of viscosity β, magnetic interaction parameter N and magnetic Reynolds number R_m. In section 5, detailed investigation of stability of flow under investigation is carried out. Finally the graphs and conclusions are presented in section 6.

NOMENCLATURE:

$\vec{q}$	velocity vector (u,v)	c_r	phase velocity
ρ	Density	σ	electrical conductivity
μ	coefficient of viscosity	β	ratio of viscosity
υ	kinematic viscosity	$\bar{u}$	basic velocity
μ_p	viscosity of porous media	σ_p	porous parameter
(x,y)	space co-ordinates	c	velocity of perturbed quantities
U_0	mean velocity	$\vec{B}$	magnetic field
$\vec{J}$	current density	α	horizontal wave number
P	Pressure	t	Time
R_e	Reynolds number	R_m	magnetic Reynolds number
c_i	growth rate	N	magnetic interaction parameter

2. MATHEMATICAL FORMULATION

We consider a steady flow of an electrically conducting fluid in the presence of a coplanar magnetic field between two infinite parallel plates *y=h* and *y=-h.* We take the origin O midway between the plates and use rectangular coordinates x and y, with the x-axis in the direction of the flow and the y-axis perpendicular to the plates. The plates at *y=h* and *y=-h* are assumed to be electrically non-conducting. The fluid layer is permeated by a uniform external magnetic field and flow through porous media as shown in fig.1 is considered.

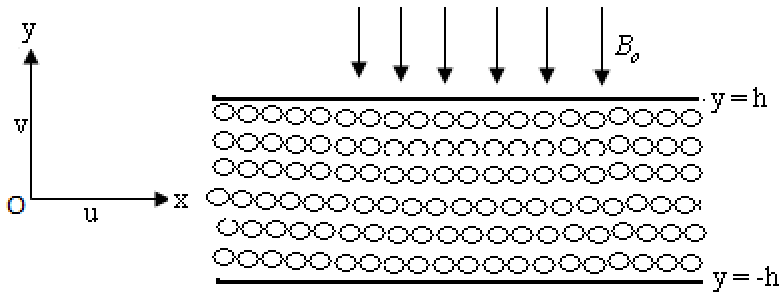

Fig. 1. Physical configuration

The magnetohydrodynamic flow equations for viscous incompressible electrically conducting fluid through a porous media are the following:
The continuity equation:

$$\nabla \cdot \vec{q} = 0 \tag{1}$$

Momentum equation:

$$\rho\left[\frac{\partial \vec{q}}{\partial t} + (\vec{q}\cdot\nabla)\vec{q}\right] = -\nabla p + \mu\nabla^2\vec{q} + \vec{J}\times\vec{B} - \frac{\mu_p}{k}\vec{q} \tag{2}$$

Ohm’s law:

$$\vec{J} = \sigma \left(\vec{E} + \vec{q} \times \vec{B}\right) \tag{3}$$

Faraday's law

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{4}$$

Ampere's law:

$$\vec{J} = \nabla \times \vec{B} \tag{5}$$

Magnetic continuity:

$$\nabla \cdot \vec{B} = 0 \tag{6}$$

where $\vec{q} = (u, v)$ is the velocity, ρ is the density, p is the pressure, μ is the viscosity co-efficient, σ is the electrical conductivity, t is the time and $\vec{E}$ is the electric field. Elimination of $\vec{E}$ from eqn.(3) and eqn.(4) with the aid of eqn.(1), eqn.(5) and eqn.(6) yields

$$\rho\left[\frac{\partial \vec{q}}{\partial t} + (\vec{q} \cdot \nabla)\vec{q}\right] = -\nabla p + \mu \nabla^2 \vec{q} + \left(\vec{B} \cdot \nabla\right)\vec{B} - \nabla B^2 - \frac{\mu_p}{k}\vec{q} \tag{7}$$

$$\frac{\partial \vec{B}}{\partial t} + (\vec{q} \cdot \nabla)\vec{B} = \left(\vec{B} \cdot \nabla\right)\vec{q} + \frac{1}{\sigma}\nabla^2 \vec{B} \tag{8}$$

where the components of the magnetic field and velocity are, respectively

$$\vec{B} = B_x\,\hat{i} + B_y\,\hat{j} \tag{9}$$

$$\vec{q} = u\,\hat{i} + v\,\hat{j}\ . \tag{10}$$

2.1. THE LINEAR STABILITY EQUATIOS

For a two dimensional flow of incompressible homogeneous fluid in the presence of coplanar magnetic field through a saturated porous media equations (7) and (8) written in component wise form using (9) and (10). Then by defining the following nondimensional variables

$$\bar{u}^* = \frac{\bar{u}}{u_o},\quad u^* = \frac{u}{u_o},\quad v^* = \frac{v}{u_o},\quad p^* = \frac{p}{\rho u_o^2},\quad y^* = \frac{y}{h},\quad x^* = \frac{x}{h},$$
$$t^* = \frac{t}{\left(\frac{h}{u_o}\right)},\quad \left(B_x^*, B_y^*\right) = \frac{\left(B_{x,}B_y\right)}{B_o} \tag{11}$$

where u_o is the average velocity and h is the channel half width and substituting them into these equations after neglecting the asterisk (*), we get the following equations (12) to (17) in nondimensional form

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{12}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{\partial p}{\partial x}+\frac{1}{\mathrm{Re}}\nabla^2 u-\frac{N}{R_m}\nabla B^2+\frac{N}{R_m}\left(B_x\frac{\partial B_x}{\partial x}+B_y\frac{\partial B_x}{\partial y}\right)-\frac{\beta\,\sigma_p{}^2}{R_e}u \tag{13}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{\partial p}{\partial y}+\frac{1}{Re}\nabla^2 u-\frac{N}{R_m}\nabla B^2+\frac{N}{R_m}\left(B_x\frac{\partial B_y}{\partial x}+B_y\frac{\partial B_y}{\partial y}\right)-\frac{\beta\,\sigma_p{}^2}{R_e}v \tag{14}$$

$$\frac{\partial B_x}{\partial x}+\frac{\partial B_y}{\partial y}=0 \tag{15}$$

$$\frac{\partial B_x}{\partial t}+u\frac{\partial B_x}{\partial x}+v\frac{\partial B_x}{\partial y}=\left(B_x\frac{\partial u}{\partial x}+B_y\frac{\partial u}{\partial y}\right)+\frac{1}{R_m}\nabla^2 B_x \tag{16}$$

$$\frac{\partial B_y}{\partial t}+u\frac{\partial B_y}{\partial x}+v\frac{\partial B_y}{\partial y}=\left(B_x\frac{\partial v}{\partial x}+B_y\frac{\partial v}{\partial y}\right)+\frac{1}{R_m}\nabla^2 B_y \tag{17}$$

where $Re=\frac{u_o\,h}{\nu}$ is the Reynolds number; $R_m=\sigma\,u_o\,h$ is the magnetic Reynolds number; $\sigma_p=\frac{h}{\sqrt{k}}$ is the porous parameter; $\beta=\frac{\mu_p}{\mu}$ is the ratio of viscosity and $N=\frac{\sigma\,B_0^2\,h}{\rho\,u_0}$ is the is the magnetic field interaction parameter.

2.2. BASIC FLOW

We consider a basic flow of two dimensional incompressible electrically conducting viscous fluid through a porous channel and assuming it to be fully developed and unidirectional parallel to the plates driven by a constant pressure gradient $\frac{\partial p_b}{\partial x}$.The basic flow, $\bar{u}(y)$, parallel to the boundaries in the x-direction, satisfies the momentum equation

$$0=-\frac{\partial p_b}{\partial x}+\frac{1}{R_e}\frac{d^2\bar{u}}{dy^2}-\frac{\beta\,\sigma_p^2}{R_e}\bar{u} \tag{18}$$

$$0=\frac{\partial p_b}{\partial y} \tag{19}$$

where the suffix *b* represents the basic state quantity and $P=\frac{\partial p_b}{\partial x}$ is constant pressure gradient. The no-slip boundary conditions

$$\bar{u}=0 \quad \text{at} \quad y=\pm 1 \tag{20}$$

where the parameters Re, R_m σ_p and β are defined below of equation (17)

Solving equation (18) and using the boundary conditions (20), we get

$$\bar{u} = c_1 e^{(\beta\sigma_p)y} + c_2 e^{-(\beta\sigma_p)y} - \frac{R_e P}{\beta\sigma_p} \tag{21}$$

where $c_1 = c_2 = \dfrac{R_e P\ e^{\sqrt{\beta\sigma_p}}}{\left(1+e^{2\sqrt{\beta\sigma_p}}\right)\beta\sigma_p}$

2.3. DERIVATION OF STABILITY EQUATION

Equations (12) to (17) are linearized by assuming small perturbations in the dependant variables of the form

$$u = \bar{u}(y) + \varepsilon\ \frac{\partial\phi'}{\partial y}(x,y,t)$$

$$v = -\varepsilon\ \frac{\partial\phi'}{\partial x}(x,y,t)$$

$$p = p_b(x,y) + \varepsilon\ p'(x,y,t) \tag{22}$$

$$B_x = 1 + \varepsilon\frac{\partial\psi'}{\partial y}(x,y,t)$$

$$B_y = -\varepsilon\ \frac{\partial\psi'}{\partial x}(x,y,t)$$

where ε is a small quantity. These relations automatically satisfie the continuity equations (12) and (15). Substituting equation (22) into equations (12) to (17), equating the coefficients at $O(\varepsilon)$, we obtain

$$\phi'_{ty} + \bar{u}(y)\phi'_{xy} - \bar{u}'(y)\phi'_x = -\frac{\partial p'}{\partial x} - \frac{N}{R_m}\psi'_{xy} + \frac{1}{R_e}\left(\phi'_{yxx} + \phi'_{yyy}\right) - \frac{\beta\ \sigma_p^{\ 2}}{R_e}\phi'_y \tag{23}$$

$$\phi'_{tx} + \bar{u}(y)\phi'_{xx} = \frac{\partial p'}{\partial y} + \frac{N}{R_m}\left(\psi'_{xx} + 2\psi'_{yy}\right) + \frac{1}{R_e}\left(\phi'_{xxx} + \phi'_{yyx}\right) + \frac{\beta\ \sigma_p^{\ 2}}{R_e}\phi'_x \tag{24}$$

$$\psi'_{tx} + \bar{u}(y)\ \psi'_{xx} = \psi'_{xx} + \frac{1}{R_m}\left(\psi'_{xxx} + \psi'_{yyx}\right) \tag{25}$$

$$\psi'_{ty} + \bar{u}(y)\ \psi'_{xy} = \phi'_{xy} - \bar{u}'(y)\ \psi'_x + \frac{1}{R_m}\left(\psi'_{xxy} + \psi'_{yyy}\right)\ . \tag{26}$$

Assuming solutions of equations in the separable form

$$\phi'(x,y,t)=\phi(y)\ e^{i\alpha(x-ct)}$$

$$\psi'(x,y,t)=\psi(y)\ e^{i\alpha(x-ct)} \tag{27}$$

where $c=c_r+i\,c_i$ is the velocity of the disturbance, c_r is called the phase velocity and c_i is called the growth rate and α is the horizontal wave number. When $c_i>0$, the system is unstable and $c_i<0$, the system is stable. Substituting equation (27) into equations (23)-(26), and eliminating the pressure term , we get the following stability equations

$$\begin{aligned}(\bar{u}-c)\left(D^2-\alpha^2\right)\phi-\left(D^2\bar{u}\right)\phi+\frac{i}{\alpha R_e}\left(D^2-\alpha^2\right)^2\phi-\frac{i\beta\sigma_p^2}{\alpha R_e}\left(D^2-\alpha^2\right)\phi=\\ i\alpha N\left[\left((\bar{u}-c)\psi-\phi\right)\right]\end{aligned} \tag{28}$$

$$\frac{i}{\alpha R_m}\left(D^2-\alpha^2\right)\psi=\phi-(\bar{u}-c)\psi\ . \tag{29}$$

The boundary conditions of the above problem now reduce to the following

$$\phi=D\phi=0,\ \psi=0\ \text{at}\ \ y=\pm 1. \tag{30}$$

From equations (28) and (29), we obtain the following stability equation

$$\begin{aligned}(\bar{u}-c)\left(D^2-\alpha^2\right)\phi-\left(D^2\bar{u}\right)\phi+\frac{i}{\alpha R_e}\left(D^2-\alpha^2\right)^2\phi-\frac{i\beta\sigma_p^2}{\alpha R_e}\left(D^2-\alpha^2\right)\phi-\\ \frac{N}{R_m}\left(D^2-\alpha^2\right)\psi=0\end{aligned} \tag{31}$$

2.4. STABILITY ANALYSIS

Following Drazin and Ried (2004) we find the conditions for stability or instability of the basic flow using the energy method. For this multiply equation (31) by $\bar{\phi}$ the complex conjugate of ϕ and integrating the resulting equation with respect to y from -1 to +1 using the boundary conditions (30), we get the following equation

$$\begin{aligned}\left(I_2^2+2\alpha^2 I_1^2+\alpha^4 I_0^2\right)+\beta\sigma_p^2\frac{\Lambda}{a^2}\left(\ I_1^2+\alpha^2 I_0^2\right)+M^2 I_1^2=-i\alpha\,ReQ\\ +i\,c\,\alpha\,Re\left(I_1^2+\alpha^2 I_0^2\right)\end{aligned} \tag{32}$$

where $$I_n^2 = \int_{-1}^{1} \left| D^n \phi \right|^2 dy \qquad (n = 0 \text{ to } 2) \tag{33}$$

$$\begin{aligned} Q &= \int_{-1}^{1} \left[\overline{u} \, |D\phi|^2 + \left(D^2 \overline{u} + \alpha^2 \overline{u} \right) |\phi|^2 \right] dy + \int_{-1}^{1} \overline{\phi} \, (D\overline{u})(D\phi) \, dy - \frac{N}{R_m} \int_{-1}^{1} \left(D^2 - \alpha^2 \right) \psi \, \overline{\phi} \, dy \\ &= Q_r + i Q_i \end{aligned} \tag{34}$$

$$Q_r = \mathrm{Re}(Q) = \int_{-1}^{1} \left[\overline{u} \, |D\phi|^2 + \left(D^2 + \alpha^2 \right) \overline{u} \right] |\phi|^2 \, dy - \frac{N}{R_m} \int_{-1}^{1} \left(D^2 - \alpha^2 \right) \left(\phi_r \psi_r + \phi_i \psi_i \right) dy \tag{35}$$

$$Q_i = \mathrm{Im}(Q) = \int_{-1}^{1} \left(\phi_r \, D\phi_i - \phi_i \, D\phi_r \right) D\overline{u} \; dy - \frac{N}{R_m} \int_{-1}^{1} \left(D^2 - \alpha^2 \right) \left(\phi_i \psi_r + \phi_r \psi_i \right) dy \; . \tag{36}$$

The second term on the left-hand side of equation (32) is the contribution of the porous media and the term involving N and R_m on the right hand side of equation (32) are due to the presence of magnetic field.

Equating real and imaginary parts of equation (32) to zero respectively, we get

$$c_r = \frac{Q_r}{\left(I_1^2 + \alpha^2 I_0^2 \right)} \tag{37}$$

$$c_i = \frac{1}{\left(I_1^2 + \alpha^2 I_0^2 \right)} \left[Q_i - \frac{1}{\alpha R_e} \left\{ I_2^2 + \left(2\alpha^2 + \beta \sigma_p^2 \right) I_1^2 + \left(\alpha^4 + \beta \sigma_p^2 \alpha^2 \right) I_0^2 \right\} \right] \tag{38}$$

Equation (38) is simply called the energy equation for two dimensional disturbances propagating in the direction of the basic flow. We write Eq. (36) in the form

$$\mathrm{Im}(Q) = \frac{i}{2} \int_{-1}^{1} \left(\phi \; D\overline{\phi} - \overline{\phi} \; D\phi \right) D\overline{u} dy - \frac{N}{R_m} \int_{-1}^{1} \left(D^2 - \alpha^2 \right) \left(\phi_i \psi_r + \phi_r \psi_i \right) dy \; . \tag{39}$$

From eq. (39) it follows that

$$\left| \mathrm{Im}(Q) \right| \le \int_{-1}^{1} |\phi| \; |D\phi| \; |D\overline{u}| dy - \frac{N}{R_m} \left| \int_{-1}^{1} \left(D^2 - \alpha^2 \right) \left(\phi_i \psi_r + \phi_r \psi_i \right) \right| dy$$

and using Schwarz's inequality, we get

$$\left| Im(Q) \right| \le I_1 \, I_0 \, q - B_1$$

where $q = \max\limits_{-1 < y < 1} \left| Du_b \right|$ and

$$B_1 \le \frac{N}{R_m}\left|\int_{-1}^{1}\left(D^2-\alpha^2\right)\left(\phi_i\,\psi_r+\phi_r\,\psi_i\right)\right|dy\ .$$

This gives the upper bound for c_i of the form

$$c_i \le \frac{\left(I_1\,I_0\,q-B_1\right)-\dfrac{1}{\alpha\,R_e}\left\{I_2^2+\left(2\alpha^2+\beta\,\sigma_p^2\right)I_1^2+\left(\alpha^4+\beta\,\sigma_p^2\,\alpha^2\right)I_0^2\right\}}{\left(I_1^2+\alpha^2 I_0^2\right)}\ . \tag{40}$$

From Eq.(40) it follows, that a sufficient condition for stability is

$$R_e < \frac{1}{\alpha\left(I_1\,I_0\,q-B_1\right)}\left[I_2^2+\left(2\alpha^2+\beta\,\sigma_p^2\right)I_1^2+\left(\alpha^4+\beta\,\sigma_p^2\,\alpha^2\right)I_0^2\right]. \tag{41}$$

3. RESULTS AND DISCUSSION

The sufficient condition for stability (c_i <0) is obtained from equation (38) in terms of the Reynolds number R_e and various other parameters involved in the problem which is given by equation (41). The growth rate given by equation (38) is computed numerically using single term Galerkin expansion and the results are depicted graphically.

Fig. 2 show the influence of σ_p on the basic velocity U_b, this figure indicate that velocity profiles are symmetric about $y=0$ with maximum value along the centerline and minimum at the wall. However, for increasing values of σ_p, the fluid velocity decreases and flattens out. From this figure it is clear that as porous parameter, σ_p increases from 1, 4, 8 to 10 the basic velocity profile turned form parabolic to linear. This is because of the resistance offered by porous media on the flow.

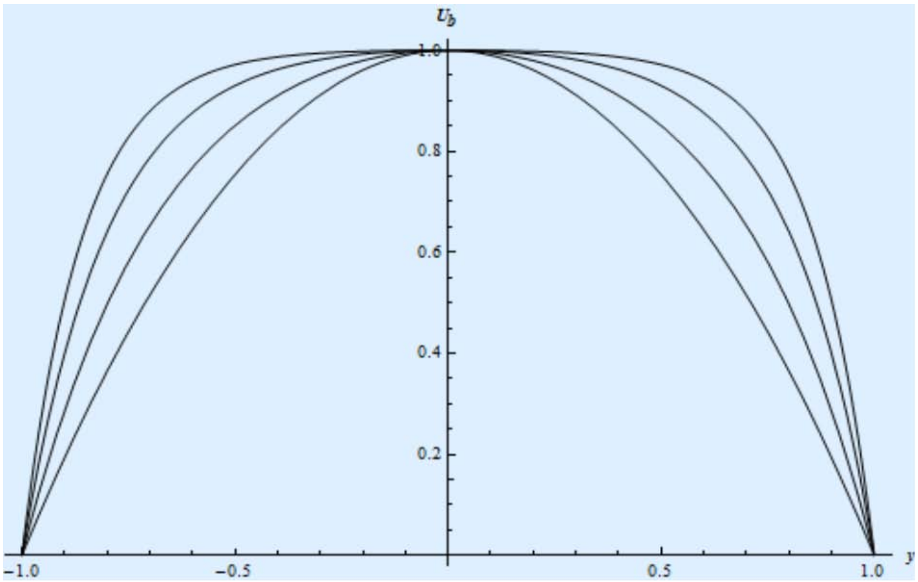

Fig.2. Basic velocity profile for different values of porous parameter $\sigma_p = 1, 4, 8$ *and* 10.

Fig.3 shows that the plot of growth rate c_i as a function of horizontal wave number α for different values of the porous parameter, σ_p for fixed values of interaction parameter $N = 0.5$, Reynolds number, $R_e = 10$ and magnetic Reynolds number, $R_m = 2$.

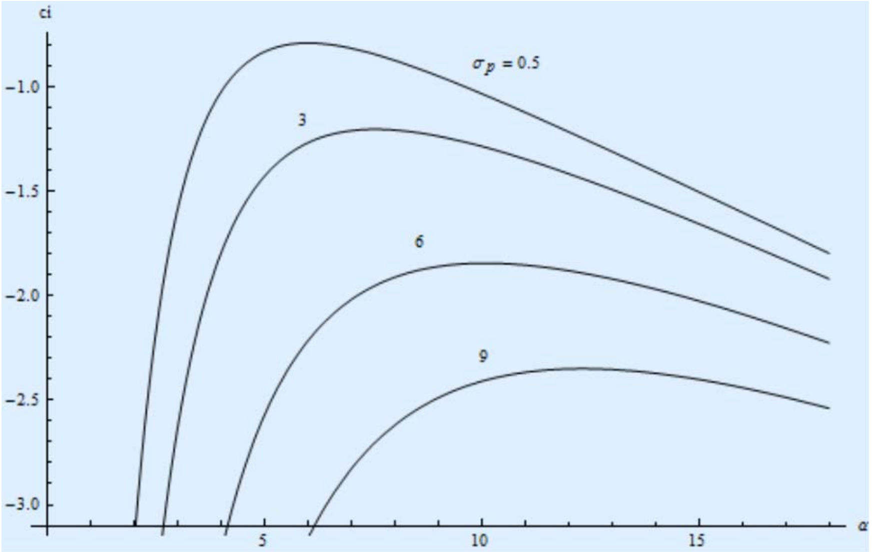

Fig.3. Plot of growth rate c_i versus wave number α for different values of $\sigma_p\ (\beta = 2,\ R_m = 2,\ R_e = 10,\ N = 0.5)$

From Fig.3, it is clear that an increase in the value of σ_p is to decrease the value of growth rate, which makes the system more stable. The reason for this is that the decrease in growth rate is due to the resistance offered by the solid particles in the porous media to the fluid. Fig.4 shows the variation in the growth rate of the most unstable mode against the wave number α for different values of β with $\sigma_p = 1.5, N = 0.5,\ R_m = 2$ and $R_e = 10.$ It is observed that increasing the value of β is to suppress the disturbances and thus its effect is to eliminate the growth of small disturbances in the flow.

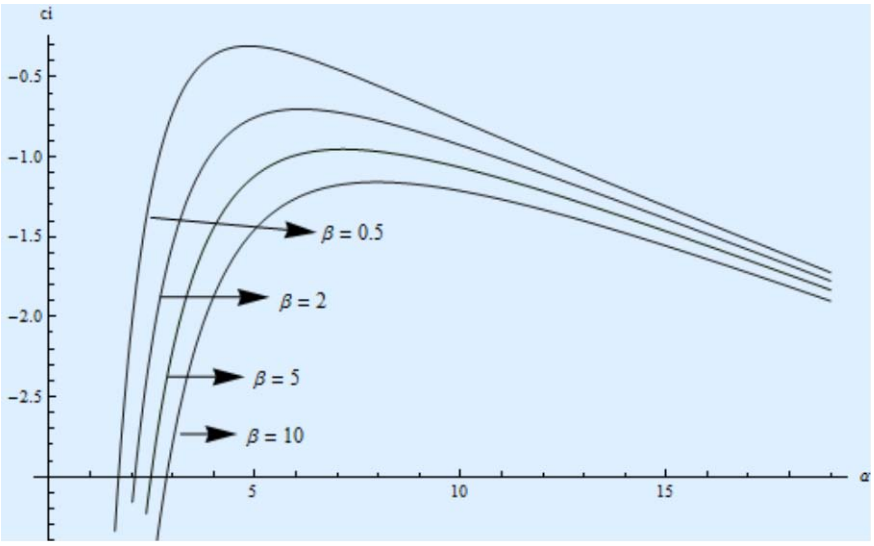

Fig.4. Plot of growth rate c_i versus wave number α for different values of β $(N = 0.5,\ R_m = 2,\ R_e = 10,\ \sigma_p = 1.5)$

Fig.5 shows that the plot of c_i with α for different values of magnetic interaction parameter N for fixed values of $\beta = 2,\ R_m = 0.4,\ \sigma_p = 1$ and $R_e = 8$. From Fig.4, it may be inferred that for an increase in the value of N increases the value of c_i, and thus make the system more unstable.

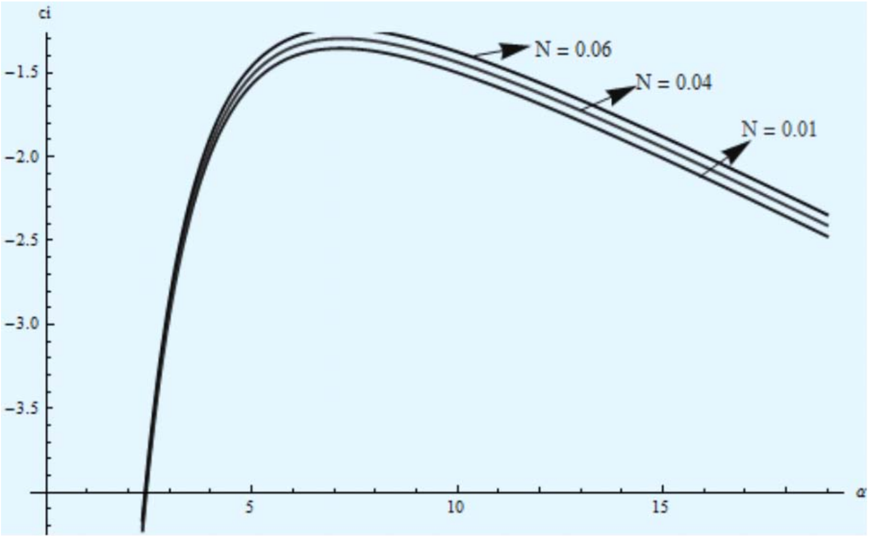

Fig.5. Plot of growth rate c_i versus wave number α for different values of N
$(\beta = 2,\ R_m = 0.5,\ R_e = 8,\ \sigma_p = 1)$

Fig.6 shows that the plot of c_i with α for different values of Magnetic Reynolds number R_m for fixed values of $\beta = 2,\ N = 0.5,\ \sigma_p = 1.5$ and $R_e = 10$. The reason being that an increase in R_m is to decrease the kinetic energy and hence, make the system more stable.

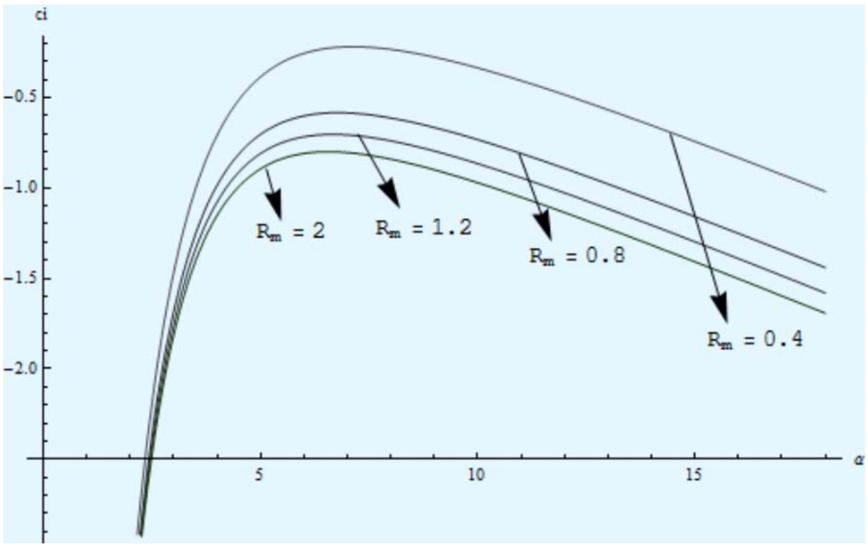

Fig.6. Plot of growth rate c_i versus wave number α for different values of R_m
$(\beta = 2,\ \sigma_p = 1.5,\ R_e = 10,\ N = 0.5)$

4. CONCLUSIONS

It is known that the stability of classical poiseuille flow, a sufficient condition for stability is the existence of point of inflexion. This stability of poiseuille flow was extended to magnetohydrodynamic stability of an inviscid poorly conducting parallel fluid flow in a porous media and in the presence of the magnetic field was investigated by several authors. They have shown that the stability is determined in terms of Reynolds number rather than the point of inflexion of the basic velocity profile. Recently Rudraiah et.al. have found a sufficient condition for stability of electrohydrodynamic stability of couple stress fluid flow in a channel. In the present paper, a sufficient condition for stability is obtained using the nature of the growth rate c_i as well as sufficiently small values of Reynolds number, R_e. From this we found that strengthening or weakening of a sufficient condition for stability depends on the Magnetic interaction parameter N, porous parameter σ_p, Magnetic Reynolds number R_m and ratio of viscosities β. From these, we conclude that the interaction of the magnetic field in the presence of porous media is more effective in stabilizing an electically conducting fluid compared with that of ordinary Newtonian viscous fluid.

Acknowledgment: The author Basavaraj M.S. would like to acknowledge the support and encouragement given by the management, Director and the Principal of M.S. Ramaiah Institute of Technology, Bangalore, India.

REFERENCES

[1] Drazin, P. G., *Introduction to hydrodynamic stability*, Cambridge University Press, 2002.
[2] Drazin, P.G., Reid, W. H., *Hydrodynamic Stability*, Cambridge University Press, 2004.
[3] De Wiest, R.J.M., *Flow through porous media*, Academic Press, Newyork, 1969.
[4] Hains, F. D., *The physics of fluids*, **8**, 11, 1965.
[5] Howard, L.N., Gupta, A.S., *J. Fluid Mech.*, **14**, 463, 1962.
[6] Hunt, J.C.R., *Proc. R. Soc. London*, **A293**, 342, 1966.
[7] Joseph, D.D., *J. Fluid Mech.*, **33**, 617, 1968.
[8] Stuart, J.T., *Proc. R. Soc. London*, Ser. **A221,** 189, 1954.
[9] Lin, C.C., *The theory of hydrodynamic stability*, Cambridge University Press, 1955.
[10] Masuoka, T., *Bulletin of the JSME*, **17**, 225, 1974.
[11] Micheal, D.H., *Proc. Comb. Phil. Soc.*, **49**, 166, 1953.
[12] Miles, J.W., *J. Fluid Mech.*, **10**, 496, 1961.
[13] Rudraiah, N., *Appl. Sci. Res., Sect. B*, **11,** 118, 1963.
[14] Rudraiah, N., Shankar, B.M., Ng, C.O., *Special topics and reviews in porous media- An international Journal*, **2**, 11, 2011.
[15] Rudraiah, N., Narayana, C.L., *Acta Mech.*, **14**, 229, 1972.
[16] Stokes, V.K., *Phys. Fluids*, **11**, 1131, 1968.
[17] Rossow, V.J., *NACA Rep.*, **1958**, 20, 1959.
[18] Tarasov, Y.A., *Sovieth physics JETP*, **10**, 1209, 1960.
[19] Velikov, E.P., *Zh. Eksp.Teor. Fiz.*, **36**(4), 1192, 1959.
[20] Wooler, P.T., *Phys. Fluids*, **4**, 24, 1961.