

Hydromagnetic Oscillatory Flow Of Dusty Fluid In A Rotating Porous Channel Through A Porous Medium

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Abstract

MHD oscillatory flow of dusty fluid in a rotating porous channel through a porous medium is studied under the influence of periodic pressure gradient. The lower porous plate is subjected to a uniform injection and the upper porous plate to a uniform suction. A magnetic field of uniform strength is applied perpendicular to the plates. The Reynolds number is assumed to be small enough so that the induced magnetic field is negligible. The whole system rotates about the axis normal to the plates. Analytical solutions for the velocities of the fluid and the dust particles are obtained. The effect of the various parameters on the fluid velocity and the dust velocity has been numerically evaluated.

KeyWords: Hydromagnetic dusty fluid, Oscillatory flow, Porous channel, Porous medium.

1.INTRODUCTION

The study of the flow of dusty gases, which has gained increased attention recently, has wide applications in environmental sciences, wastewater treatment, power plant piping, purification of the crude oils, combustion and petroleum transport. Particularly, the flow and heat transfer of electrically conducting fluids in channels under the effect of a transverse magnetic field occur in MHD accelerators, pumps and generators.

Saffman[1] gave the governing equations for the dust laden gas by making certain assumptions on the dust particles. Using Saffman model several authors have given exact solutions of various dusty gas problems, Michael and Norey[2], Rao[3], Verma and Mathur[4], Singh[5], Rukmangadachari[6], and Mitra[7] studied the problem of circular cylinders under various conditions. Gupta[8] considered the unsteady flow of a dusty gas in a channel whose cross-section is an annular sector regarding the plate

problems. Liu[9], Michael and Miller [10], Liu[11] and Vimal [12] studied the problems of infinite flat plate under various conditions. Mitra[13] has studied the flow of a dusty gas induced by the motion of a semi-infinite flat plate moving with velocity decreasing exponentially with time. Singh[14] has studied MHD flow of a dusty gas through a porous medium induced by the motion of a semi-infinite flat plate moving with velocity decreasing exponentially with time. Singh et al.[15] studied a periodic solution of oscillatory Couette flow through a porous medium in a rotating frame. Singh and Gupta[16] have discussed MHD free convective flow of a dusty gas through a porous medium induced by the motion of a semi-infinite flat plate moving with velocity decreasing exponentially with time.

Nag and Jana[17] have studied unsteady Couette flow of a dusty gas between two infinite parallel plates, when one plate of the channel is kept stationary and other plate moves uniformly in its own plane. Dalal[18] analysed the generalized Couette flow of dusty gas due to an impulsive pressure gradient as well as due to impulsive start of the lower plate. Singh and Singh [19] studied the laminar convective flow of an incompressible, conducting viscous fluid embedded with non-conducting dust particles through a vertical parallel plate channel in the presence of uniform magnetic field and constant pressure gradient taking volume fraction of the particles into consideration when one plate of the channel is fixed and the other is oscillating in time and in magnitude about a non-zero mean.

Attia[20] studied the effects of variable viscosity on the unsteady flow of an electrically conducting, viscous, incompressible dusty fluid and heat transfer between parallel non-conducting porous plates when a uniform magnetic field is applied perpendicular to the plates. Attia[21], investigated the time varying Couette flow with heat transfer of a dusty viscous incompressible, electrically conducting fluid under the influence of constant

pressure gradient without neglecting the hall current. The governing equations are solved numerically using the finite differences to yield the velocity and the temperature distribution for both the fluid and the dust particles. Venkatesh and Prasanna Kumara [22] studied the impulsive flow of an MHD dusty fluid between non-torsional oscillating plate and a long wavy wall. Gireesha et al. [23] studied the pulsatile flow of an unsteady dusty fluid through a rectangular channel. Salini et al. [24] studied unsteady flow of dusty conducting fluid through porous medium between parallel porous plates with temperature dependent viscosity and heat source. Debnath et al. [25] studied the Hydrodynamic flow of a dusty viscoelastic fluid between two infinite parallel plates.

The aim of the present paper is to study the influence of rotation and the periodic pressure gradient on the flow of an unsteady, viscous, incompressible and electrically conducting fluid embedded with non-conducting dust particles in a horizontal porous channel through porous medium rotating with constant angular velocity when a uniform magnetic field is applied perpendicular to the plates.

2. NOMENCLATURE

x, y, z	coordinates
q and q^*	fluid and dust particle velocities
u, v, w	fluid velocity component along x, y, z directions respectively
u^*, v^*, w^*	dust particle velocity component along x, y, z directions respectively
\bar{J}	Current density
\bar{B}	Magnetic flux density
ρ	fluid density
P	Pressure distribution
ν	kinematic viscosity
N	number density of dust particles per unit volume
K	Stokes resistance coefficient (for spherical particle of radius ϵ it is $6\pi\mu a$)
a	average radius of the dust particles,
μ	fluid viscosity
m^*	average mass of the dust particles.
G	Particle mass parameter
A	Pressure gradient
R	Particle concentration parameter

$$M = \sqrt{\frac{B_0^2 b^2 \sigma}{\rho \nu}}$$

Hartmann number

T

time

λ

suction parameter

Ω

Constant angular velocity of the channel

ω

Frequency of oscillation

F and

Complex velocity of fluid and dust particles

F^*

3. FORMULATION OF THE PROBLEM

Consider the flow of a dusty fluid between two infinite horizontal plates through porous media located at

$z = \pm \frac{d}{2}$ planes, as shown in the Fig.1.

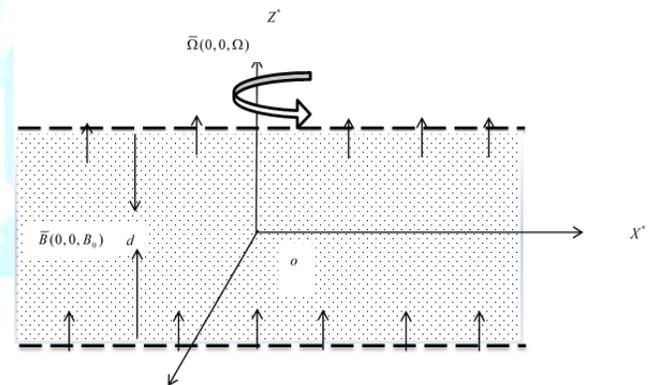


Figure1. Physical Model

The fluid is injected with constant velocity w_0 through the lower porous plate and is sucked out in to the upper porous plate with the same velocity. Thus the z component of the velocity of the fluid is constant and is denoted by w_0 . A uniform magnetic field of strength B_0 is applied in z-direction perpendicular to the plates. The basic equations for this study are based on the conservation of mass, linear momentum for both fluid and dust particles phases. The governing equations are written based on the following assumptions:

- (i) The dust particles are assumed to be electrically non-conducting, spherical in shape and uniformly distributed in the flow region.
- (ii) The fluid is incompressible and number density of dust particles is constant.
- (iii) The interactions between the particles, chemical reaction and radiation between the particles and fluid are not considered. This is necessary in order to avoid multiple equations.

(iv) The buoyancy force, induced magnetic field and Hall effects have been neglected.

(vi) The dust concentration is so small so that it is not disturbing the continuity and hydromagnetic effects.

(vii) A periodic pressure gradient varying with time is applied in x-direction.

(viii) The whole system is rotating with constant angular velocity about the z-axis. It is required to obtain the time varying velocity distribution for both the fluid and the dust particles. Since the plates are infinite in x and y directions, all the physical quantities for this fully developed flow depend only on z-coordinate except the pressure.

Let (u, v, w) and (u^*, v^*, w^*) be the fluid and dust velocities respectively. The magnetic field and angular velocities for the present problem are $(0, 0, B_0)$ and $(0, 0, \Omega_0)$ respectively.

The equations of conservation of mass

$$\text{For fluid } \nabla \cdot \bar{q} = 0 \quad (1)$$

$$\text{For dust } \nabla \cdot \bar{q}^* = 0 \quad (2)$$

The equations of momentum equation

The flow of the fluid is governed by the following momentum equation

$$\frac{\partial \bar{q}}{\partial t} + (\bar{q} \cdot \nabla) \bar{q} + 2\Omega \times \bar{q} = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \bar{q} + \frac{KN}{\rho} (\bar{q}^* - \bar{q}) + \frac{1}{\rho} \bar{j} \times \bar{B} \quad (3)$$

The flow of the dust is governed by second law of Newton's and is given by

$$m^* \left[\frac{\partial \bar{q}^*}{\partial t} + (\bar{q}^* \cdot \nabla) \bar{q}^* + 2\Omega \times \bar{q}^* \right] = K' (\bar{q} - \bar{q}^*) \quad (4)$$

The momentum equation (3) for the fluid velocity in its component form is given

$$\text{by } \frac{\partial u}{\partial t} + w_0 \frac{\partial u}{\partial z} - 2\Omega_0 v = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \frac{\partial^2 u}{\partial z^2} + \frac{KN}{\rho} (u^* - u) - \frac{\sigma B_0^2 u}{\rho} - \frac{\mu}{\rho k} u \quad (5)$$

$$\frac{\partial v}{\partial t} + w_0 \frac{\partial v}{\partial z} + 2\Omega_0 u = -\frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \frac{\partial^2 v}{\partial z^2} + \frac{KN}{\rho} (v^* - v) - \frac{\sigma B_0^2 v}{\rho} - \frac{\mu}{\rho k} v \quad (6)$$

$$0 = -\frac{1}{\rho} \frac{\partial p}{\partial z} \quad (7)$$

The momentum equation (4) for the dust velocity in its component form is given by

$$m^* \left(\frac{\partial u^*}{\partial t} - 2\Omega_0 v^* \right) = KN(u - u^*) \quad (8)$$

$$m^* \left[\frac{\partial v^*}{\partial t} + 2\Omega_0 u^* \right] = KN(v - v^*) \quad (9)$$

Boundary conditions relevant to this problem are given by

$$u = v = u^* = v^* = 0 \quad \text{at } Z = \frac{d}{2} \quad (10)$$

$$u = v = u^* = v^* = 0 \quad \text{at } Z = -\frac{d}{2} \quad (11)$$

4. NON-DIMENSIONALISATION OF THE FLOW QUANTITIES

The following non-dimensional quantities are introduced to make the basic equations and the boundary conditions dimensionless:

$$\bar{x}, \bar{y}, \bar{z} = \frac{(x, y, z)}{d}, \bar{u}, \bar{v} = \frac{(u, v)}{w_0}, (\bar{u}^*, \bar{v}^*) = \frac{(u^*, v^*)}{w_0}, \bar{w} = \frac{wd}{w_0}, \bar{t} = \frac{tw_0}{d}, \bar{\Omega} = \frac{d^2 \Omega_0}{\nu}, \bar{\lambda} = \frac{w_0 d}{\nu}, \bar{p} = \frac{p}{\rho w_0^2}, \quad (12)$$

$$Da = \frac{k}{d^2}, M = B_0 d \sqrt{\frac{\sigma}{\mu}}, R = \frac{KNd^2}{\mu}, G = \frac{m^* \nu}{KNd^2}$$

where G =Particle mass parameter, R =Particle concentration parameter, ω =Frequency of oscillation, M =Magnetic field parameter, λ =Suction parameter.

In view of the above dimensionless quantities, Eqs.(5), (6), (8) and (9) take the following non-dimensional form (bars are neglected):

$$\frac{\partial u}{\partial t} + \frac{\partial u}{\partial z} - \frac{2\Omega}{\lambda} v = -\frac{\partial p}{\partial x} + \frac{1}{\lambda} \frac{\partial^2 u}{\partial z^2} + \frac{R}{\lambda} (u^* - u) - (M^2 + \frac{1}{Da}) \frac{1}{\lambda} u \quad (13)$$

$$\frac{\partial v}{\partial t} + \frac{\partial v}{\partial z} + \frac{2\Omega}{\lambda} u = -\frac{\partial p}{\partial y} + \frac{1}{\lambda} \frac{\partial^2 v}{\partial z^2} + \frac{R}{\lambda} (v^* - v) - (M^2 + \frac{1}{Da}) \frac{1}{\lambda} v \quad (14)$$

$$\frac{\partial u^*}{\partial t} - \frac{2\Omega}{\lambda} v^* = \frac{1}{G\lambda} (u - u^*) \quad (15)$$

$$\frac{\partial v^*}{\partial t} + \frac{2\Omega}{\lambda} u^* = \frac{1}{G\lambda} (v - v^*) \quad (16)$$

The boundary conditions become

$$u = v = u^* = v^* = 0 \quad \text{at } z = -\frac{1}{2} \quad (17)$$

$$u = v = u^* = v^* = 0 \quad \text{at } z = \frac{1}{2}$$

Continuity equations are identically satisfied and $-\frac{1}{\rho} \frac{\partial p}{\partial z} = 0$,

shows the constant fluid pressure along the z-axis, the axis of rotation. We assume that the fluid flows only under the pressure gradient along the x-axis and, varies with time.

Then it follows that $-\frac{\partial p}{\partial x} = A e^{i\omega t}$ and $\frac{\partial p}{\partial y} = 0$ (18)

Denoting, $F = u + iv$, $F^* = u^* + iv^*$, then the equations (14) – (17) can be written as

$$\frac{\partial F}{\partial t} + \frac{\partial F}{\partial z} + \frac{i2\Omega}{\lambda} F = -\frac{\partial p}{\partial x} + \frac{1}{\lambda} \frac{\partial^2 F}{\partial z^2} + \frac{R}{\lambda} (F^* - F) - (M^2 + \frac{1}{Da}) \frac{1}{\lambda} F \quad (19)$$

$$\frac{\partial F^*}{\partial t} + \frac{2i\Omega}{\lambda} F^* = \frac{1}{G\lambda} (F - F^*) \quad (20)$$

The corresponding boundary conditions are

$$F = F^* = 0 \quad \text{at} \quad z = -\frac{1}{2} \quad (21)$$

$$F = F^* = 0 \quad \text{at} \quad z = \frac{1}{2}$$

5. SOLUTION OF THE PROBLEM

To solve the equations (19) and (20), we assume in complex form the solution of problem as :

$$F(Z, t) = \phi(z)e^{i\omega t}, \quad F^*(Z, t) = \psi(z)e^{i\omega t}, \quad -\frac{\partial p}{\partial x} = A e^{i\omega t}$$

(22) Substituting (22) in the equations (19) and (20), we obtain the following equations for the fluid and dust particle velocities

$$\phi^{11}(z) - \lambda\phi^1(z) - a^2\phi(z) = -A\lambda \quad (23)$$

$$\psi(z) = \frac{1}{Gi(\lambda\omega + 2\Omega) + 1} \phi(z) \quad (24)$$

These equations are solved under the following boundary conditions

$$\phi(z) = \psi(z) = 0 \quad \text{at} \quad z = -\frac{1}{2} \quad (25)$$

$$\phi(z) = \psi(z) = 0 \quad \text{at} \quad z = \frac{1}{2}$$

then we get the fluid and dust velocities as follows:

$$\phi(z) = C_1 e^{m_1 z} + C_2 e^{m_2 z} + \frac{A\lambda}{a^2} \quad (26)$$

where

$$a^2 = R + \left(M^2 + \frac{1}{Da}\right) + i(2\Omega + \lambda\omega) - \frac{R}{1 + Gi(\lambda\omega + 2\Omega)}, \quad m_1 = \frac{\lambda + \sqrt{\lambda^2 + 4a^2}}{2},$$

$$C_1 = \frac{A\lambda}{a^2} \frac{\sinh\left(\frac{m_2}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad C_2 = \frac{-A\lambda}{a^2} \frac{\sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad m_2 = \frac{\lambda - \sqrt{\lambda^2 + 4a^2}}{2}$$

The expressions for the fluid and the dust particle velocities are obtained in the following form:

$$F = e^{i\omega t} \phi(z) = e^{i\omega t} \frac{A\lambda}{a^2} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (27)$$

$$F^*(z, t) = e^{i\omega t} \psi(z) = e^{i\omega t} \frac{1}{Gi(\lambda\omega + 2\Omega) + 1} \phi(z) = \frac{e^{i\omega t} A\lambda}{a^2 (1 + iG(\lambda\omega + 2\Omega))} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (28)$$

6. DEDUCTIONS

1. Taking the Darcy number tend to infinity i.e. $(1/Da) = 0$ in Eqs. (27) and (28) we obtain the fluid and dust velocity fields as follows:

$$F = e^{i\omega t} \phi(z) = e^{i\omega t} \frac{A\lambda}{a^2} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (29)$$

$$F^*(z, t) = e^{i\omega t} \psi(z) = \frac{e^{i\omega t} A\lambda}{a^2 (1 + iG(\lambda\omega + 2\Omega))} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (30)$$

where

$$a^2 = R + M^2 + i(2\Omega + \lambda\omega) - \frac{R}{1 + Gi(\lambda\omega + 2\Omega)}, \quad m_1 = \frac{\lambda + \sqrt{\lambda^2 + 4a^2}}{2},$$

$$C_1 = \frac{A\lambda}{a^2} \frac{\sinh\left(\frac{m_2}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad C_2 = \frac{-A\lambda}{a^2} \frac{\sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad m_2 = \frac{\lambda - \sqrt{\lambda^2 + 4a^2}}{2}$$

2. When magnetic parameter (M) tend to zero and $(1/Da) = 0$ in (27) and (28) we obtain the fluid and dust velocity fields as follows:

$$F = e^{i\omega t} \phi(z) = e^{i\omega t} \frac{A\lambda}{a^2} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (31)$$

$$F^*(z, t) = e^{i\omega t} \psi(z) = \frac{e^{i\omega t} A\lambda}{a^2 (1 + iG(\lambda\omega + 2\Omega))} \left(1 + \frac{e^{m_1 z} \sinh\left(\frac{m_2}{2}\right) - e^{m_2 z} \sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (32)$$

where

$$a^2 = R + i(2\Omega + \lambda\omega) - \frac{R}{1 + Gi(\lambda\omega + 2\Omega)}, \quad m_1 = \frac{\lambda + \sqrt{\lambda^2 + 4a^2}}{2},$$

$$C_1 = \frac{A\lambda}{a^2} \frac{\sinh\left(\frac{m_2}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad C_2 = \frac{-A\lambda}{a^2} \frac{\sinh\left(\frac{m_1}{2}\right)}{\sinh\left(\frac{m_1 - m_2}{2}\right)}, \quad m_2 = \frac{\lambda - \sqrt{\lambda^2 + 4a^2}}{2}$$

3. The instantaneous volume flux Q is given

$$Q(z, t) = \left[\int_{-(1/2)}^{(1/2)} f(z) dz \right] e^{i\omega t}$$

by

$$= e^{i\omega t} \frac{A\lambda}{a^2} \left(1 + \frac{2 \operatorname{Sinh}\left(\frac{m_1}{2}\right) \operatorname{Sinh}\left(\frac{m_2}{2}\right) \left(\frac{1}{m_1} - \frac{1}{m_2}\right)}{\operatorname{Sinh}\left(\frac{m_1 - m_2}{2}\right)} \right) \quad (33)$$

From (33) we have

$$\frac{dp}{dx} = - \frac{Qa^2 m_1 m_2 \text{Sinh}\left(\frac{m_1 - m_2}{2}\right)}{\lambda \left(m_1 m_2 \text{Sinh}\left(\frac{m_1 - m_2}{2}\right) + 2 \text{Sinh}\left(\frac{m_1}{2}\right) \text{Sinh}\left(\frac{m_2}{2}\right) (m_2 - m_1) \right)} \quad (34)$$

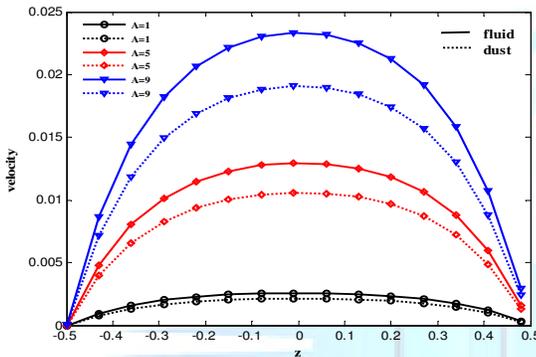


Fig.2 The variation of velocity with z for different A with $R=0.2, \omega = 2, M=1, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

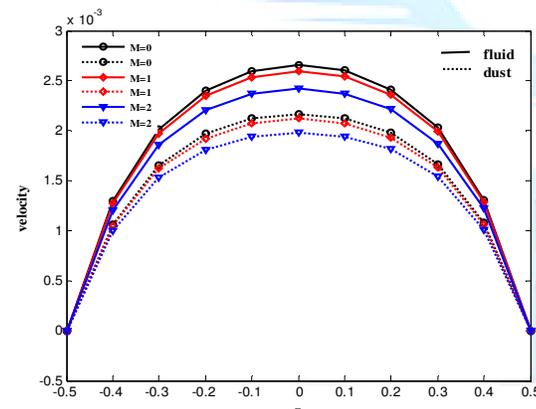


Fig.3 The variation of velocity with z for different M with $A=1, R=0.2, \omega = 2, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

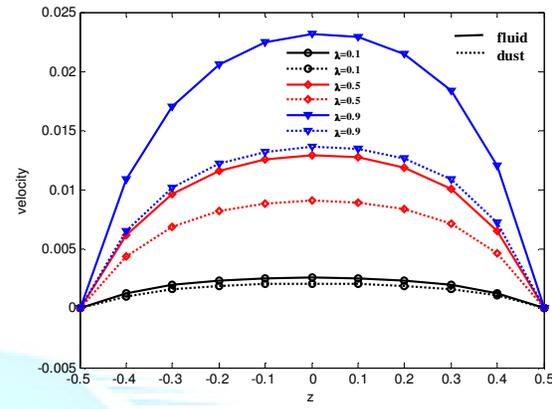


Fig.4 The variation of velocity with z for Different λ with $R=0.2, \omega = 2, A=1, t=0, G=0.2, Da=0.03, \Omega = 1$ and $M=1$

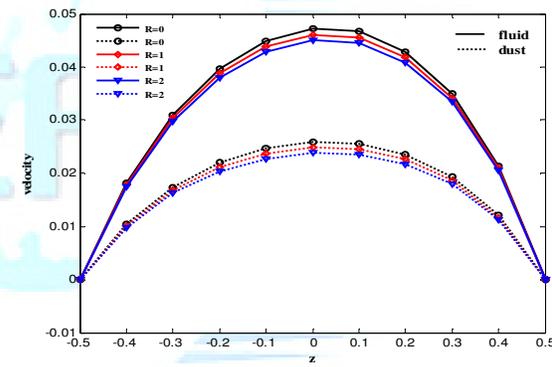


Fig.5 The variation of velocity with z for different R with $M=1, \omega = 2, A=1, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

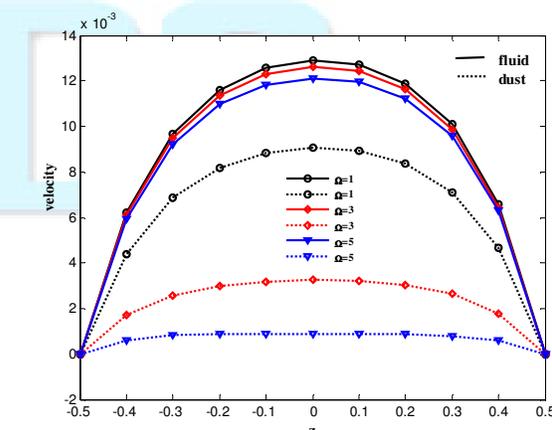


Fig.6 The variation of velocity with z for different Ω with $M=1, \omega = 2, A=1, t=0, G=0.2, Da=0.03, R = 0.2$ and $\lambda = 0.5$

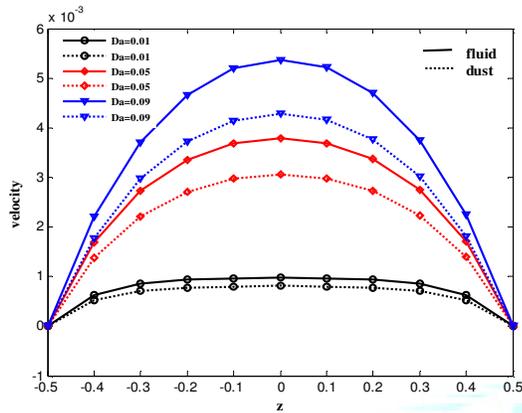


Fig.7 The variation of velocity with z for different Da with $M=1, \omega = 2, A=1, t=0, G=0.2, R=0.2, \Omega = 1$ and $\lambda = 0.5$

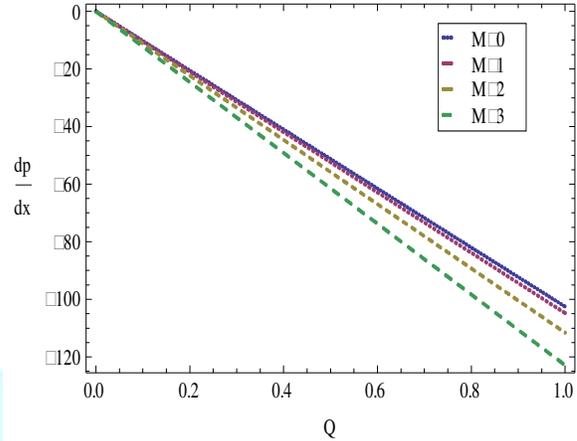


Fig.10 The variation of $\frac{dp}{dx}$ with Q for different M with $R=0.2, \omega = 2, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

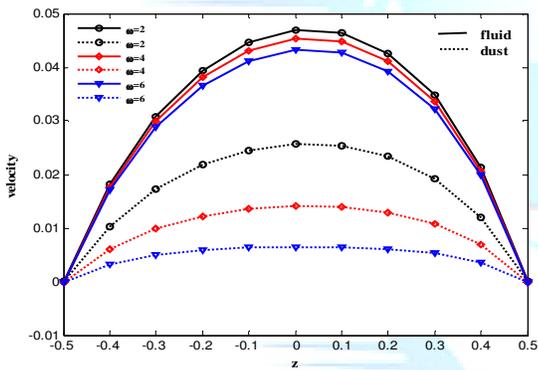


Fig.8 The variation of velocity with z for different ω with $M=1, R=0.2, A=1, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

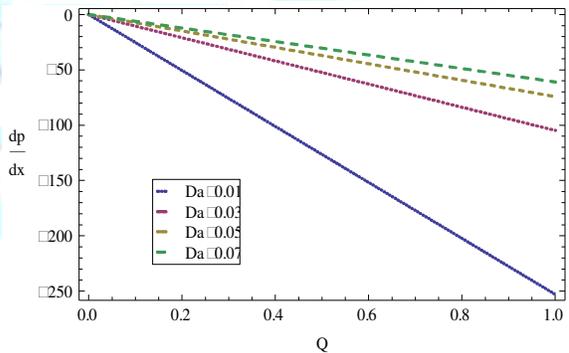


Fig.11 The variation of $\frac{dp}{dx}$ with Q for different Da with $R=0.2, \omega = 2, t=0, G=0.2, M=1, \Omega = 1$ and $\lambda = 0.5$

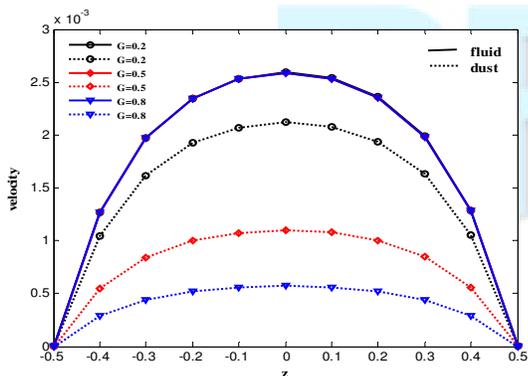


Fig.9 The variation of velocity with z for different R with $M=1, \omega = 2, A=1, t=0, G=0.2, Da=0.03, \Omega = 1$ and $\lambda = 0.5$

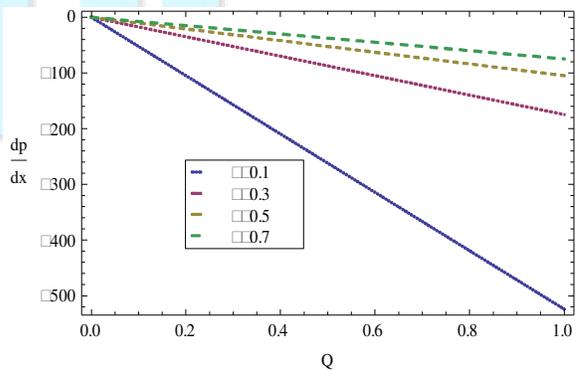


Fig.12 The variation of $\frac{dp}{dx}$ with Q for different λ with $R=0.2, \omega = 2, t=0, G=0.2, Da=0.03, \Omega = 1$ and $M=1$

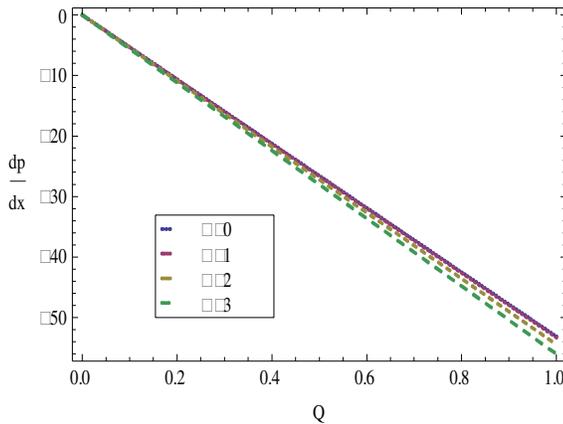


Fig.13 The variation of $\frac{dp}{dx}$ with Q for different Ω with $R=0.2, \omega = 2, t=0, G=0.2, Da=0.05, \lambda = 0.5$ and $M=1$

7. RESULTS AND DISCUSSION

The solutions for both fluid and dust velocities are obtained. The graphs for velocity distribution, such as both fluid and dust velocity distributions are shown in figures 2 to 9. The following discussion brings out the effects of some pertinent parameters such as the particle concentration parameter (R), the magnetic field parameter (M), the suction parameter (λ), the frequency of oscillation (ω), the amplitude of the pressure gradient (A), Darcy number (Da) and the particle mass parameter (G) on the fluid and dust particles velocity. The results have been graphically expressed for both the fluid and dust particles velocity.

The variation in fluid and dust velocities are shown in Fig.2 for different values of the amplitude of the pressure gradient (A), and for fixed $R=0.2, \omega = 2, M=1, G=0.2, t=0, Da=0.03, \Omega = 1$ and $\lambda = 0.1$. It is noticed that for both fluid and dust velocities increase with the increase in the amplitude of the pressure gradient A .

The variation in fluid and dust velocities are shown in Fig.3 for different values of Hartmann number M and for fixed $R=0.2, \omega = 2, A=1, G=0.2, t=0, Da=0.03, \Omega = 1$ and $\lambda = 0.1$. It is noticed that for both fluid and dust velocities decrease with the increase in the Hartmann number M . This is because the increase in the magnetic field gives rise to reduction in velocity in the channel.

The variation in fluid and dust velocities are shown in Fig.4 for different values of the suction parameter (λ) and for fixed $R=0.2, \omega = 2, A=1, G=0.2, t=0, Da=0.03, \Omega = 1$ and $M=1$. It is noticed that for both fluid

and dust velocities increase with the increase in the suction parameter λ .

The variation in fluid and dust velocities are shown in Fig.5 for different values of the particle concentration parameter (R) and for fixed $\lambda = 0.9, \omega = 2, A=1, t=0, G=0.2, Da=0.09, \Omega = 1$ and $M=1$. It is noticed that for both fluid and dust velocities decrease with the increase in the particle concentration parameter R .

The variation in fluid and dust velocities are shown in Fig.6 for different values of the rotation parameter (Ω) and for fixed $\lambda = 0.9, \omega = 2, A=1, t=0, G=0.2, Da=0.09, \Omega = 1$ and $M=1$. It is noticed that for both fluid and dust velocities decrease with the increase in the rotation parameter (Ω).

The variation in fluid and dust velocities are shown in Fig.7 for different values of the Darcy number (Da) and for fixed $\lambda = 0.9, \omega = 2, A=1, t=0, G=0.2, Da=0.09, \Omega = 1$ and $M=1$. It is noticed that for both fluid and dust velocities increase with the increase in the Darcy number Da .

The variation in fluid and dust velocities are shown in Fig.8 for different values of the frequency of oscillation (ω), and for fixed $\lambda = 0.9, \omega = 2, A=1, t=0, G=0.2, Da=0.09, \Omega = 1$ and $M=1$. It is noticed that for both fluid and dust velocities decrease with the increase in the frequency of oscillation ω .

The variation in fluid and dust velocities are shown in Fig.9 for different values of the particle mass parameter (G) and for fixed $\lambda = 0.9, \omega = 2, A=1, t=0, G=0.2, Da=0.09, \Omega = 1$ and $M=1$. It is noticed that for both fluid and dust velocities decrease with the increase in the particle mass parameter G .

The variation of pressure gradient with instantaneous volume flux Q are shown in figures 10 to 13 for different values of Magnetic parameter M , Darcy number (Da), suction parameter (λ) and rotation parameter (Ω). It is noticed that the Magnetic parameter (M), the rotation parameter (Ω) decrease the $\frac{dp}{dx}$, which is clear from figures 10 and 13 and the Darcy number (Da), the suction parameter (λ) increase the $\frac{dp}{dx}$, which is clear from figures 11 and 12.

8. CONCLUSION

- The fluid and dust particle velocity is significantly enhanced by the amplitude of the pressure gradient, Darcy number and suction parameter

- All other parameters (M, R and G) diminish the fluid and the dust particle velocity.
- The fluid and the dust particle have both decrease and increase velocity with the increase in the rotation parameter and the frequency of the oscillation (ω).
- Fluid and dust particle velocity are maximum along the centre of the channel.
- The magnetic parameter (M), the rotation parameter (Ω) significantly diminish the $\frac{d\psi}{dx}$ and the Darcy number (Da), the suction parameter (λ) significantly enhance the $\frac{d\psi}{dx}$.
- The instantaneous Volume flux Q decreases with increase in $\frac{d\psi}{dx}$.

REFERENCES

- [1] P.G.Saffman, "On the stability of laminar flow of a dusty gas", *Journal of Fluid Mechanics.*, **13** (1962) 120
- [2] D.H Michael and P.W.Norey, "The laminar flow of a dusty gas between two rotating cylinders", *Quarterly Journal of Mechanics and Applied Mathematics.*, **21**(3) (1968) 375
- [3] S.S.Rao, "Unsteady flow of dust viscous liquid through circular cylinder", *Def. Sci. Jour.*, **19** (1969) 135
- [4] P.D.Verma and A.K. Mathur, "A numerical solution of the flow of a dusty viscous liquid through of a circular cylinder", *Indian Journal of Pure and Applied Mathematics.*, **4** (1977) 133
- [5] D.Sing, "Flow of a dusty gas through a channel arbitrary time varying pressure gradient", *Indian Journal of Physics.*, **47** (1972) 341
- [6] E.Rukmangadachari, "Dusty viscous flow through a cylinder rectangular cross-section under time dependent pressure gradient", *Indian Journal of Pure and Applied Mathematics.*, **9** (1978) 8
- [7] P. J. Mitra, "Flow of a dusty gas through a channel arbitrary time varying pressure gradient ...", *Math. Phys. Sci.*, **13**(1979) 4.
- [8] S.C.Gupta, "Unsteady MHD flow in a circular pipe under transverse magnetic field", *Indian Journal of Pure and Applied Mathematics.*, **19** (1979) 6.
- [9] J.T.C.Liu, "Flow of a dusty gas through a channel arbitrary time varying pressure gradient", *Astronautica Acta.*, **17** (1972) 851
- [10] D.H.Michael and D.A.Miller, "Oscillatory of a plate in a binary mixture of incompressible Newtonian fluid", *Mathematika.*, **13** (1966) 197
- [11] J.T.C.Liu, "Flow induced by an oscillating infinite flat plate in a dusty gas", *Physics of Fluids.*, **9** (1966) 1716
- [12] C.S.Vimala "Flow of dusty gas between two Oscillating plates", *Def.Sci.J.*, **22** (1972) 231.
- [13] P.Mitra, "Flow of non-Newtonian fluid", *Acta Ciencia Indica.*, **6**(3) (1980) 144
- [14] K..P.Singh, "Unsteady flow of a stratified viscous fluid through a porous medium between two parallel plates with variable magnetic induction", *Acta Ciencia India*, **25** (1999) 4
- [15] K.D.Singh, Rakesh Sharma and Khem Chand, "A periodic solution of oscillatory couette through porous medium in a rotating frame", *Indian.J.Pure Appl. Math.*, **24** (2005) 185
- [16] P.Singh and C.B.Gupta, "Hall currents effects on MHD free convection flow with heat and mass transfer in the presence of radiation and heat source", *Jour PAS*, **8** (2002) 193
- [17] S. K. Nag, N. Datta, R. N. Jana, "Couette flow of a dusty gas", *Acta Mechanica*, **33**(1978) 179
- [18] D.Dalal, "Generalized couette flow of a dusty gas", *Ind. Journal of Tech.*, **30** (1992) 260.
- [19] N.P.Singh and A.K.Singh, "MHD effects on convective flow of dusty viscous fluid with volume fraction", *Bulletin of the institute of Mathematics Academia Sinica.*, **30** (2002) 141
- [20] Hazem Ali Attia, "Unsteady MHD Couette flow and heat transfer of dusty fluid with variable physical properties", *Applied Mathematics and Computation.*, **177**(1) (2006) 308.
- [21] H.A.Attia, "Unsteady flow of a Dusty conducting fluid between parallel porous plates with temperature dependent viscosity", *Turk J Phys*, **29**(2005) 257.
- [22] P.Venkatesh and B.C.Prasanna Kumara, "Impulsive flow of an MHD dusty fluid between non-torsional oscillating plate and a long wavy wall", *International journal of physical and mathematical sciences.*, **14** (2013) 358.
- [23] B.J.Gireesha, C.S.Bagewadi and B.C.Prasanna Kumara, "Pulsatile flow of an unsteady dusty fluid through rectangular channel", *comm. Non. Sci.and Num.Sim.*, **14** (2009) 2103.
- [24] Salini, M.S.Saroa, Rajeev Jha, "Unsteady flow of dusty conducting fluid through porous medium between porous plates with temperature dependent viscosity and heat source", *International Journal of Scientific Research Engineering and Technology.*, **1**(3) (2012) 13
- [25] Debnath, L., Ghosh, B.C. and Ghosh, N.C, "The Hydrodynamic flow of a dusty viscoelastic fluid between two infinite parallel plates", *Computers and Mathematics with Applications*, **39** (2000) 103