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Effect of Suction and Injection on Magnetohydrodynamic Three Dimensional Cauette Flow And Heat Transfer between Two Infinite Horizontal Moving Parallel Porous Plates

Divya Saxena, Vivek Kumar Sharma
Jagan Nath University, Jaipur, Rajasthan, India

Abstract: *The object of the following paper is to investigate the effect of constant suction and injection on three dimensional Couette flow of a viscous incompressible electrically conducting fluid through a porous medium between two infinite horizontal parallel porous moving flat plates in presence of a transverse magnetic field. Both the plates are in uniform motion, subjected to a transverse sinusoidal injection and uniform suction of the fluid. Due to sinusodal type of injection, the flow becomes three dimensional. The governing equations of the flow field are solved analytically and the expressions for the velocity field, the temperature field, skin friction and the rate of heat transfer in terms of Nusselt number are obtained and analyzed with the help of figures and tables. It is observed that the retardation occurs in the main flow velocity (u) due to increased magnetic parameter (M) and it accelerates the cross flow velocity (w). Also increased permeability parameter (Kp) and suction / injection parameter (Re) reverses the effect. Prandtl number and the suction / injection parameter have retarding effect on the temperature field. The increasing suction / injection parameter decreased both the components of skin friction at the wall while the permeability parameter increases the x-component and reduces the z-component of the skin friction at the wall. The effect of increasing permeability parameter is to increase the magnitude of rate of heat transfer at the wall while a growing Prandtl number (Pr) reverses the effect.*
Keywords: *MHD, couette flow, heat transfer, suction, sinusoidal injection, porous medium*

I. Introduction

The phenomena of MHD Cauette flow and heat transfer through moving plates play an important role in science and technology. Channel flows through porous media could be very practicable in many engineering and geophysical applications in the field of chemical engineering for filtration and purification processes, in agricultural engineering to study the underground water resources, in petroleum industry to study the movement of natural gas, oil and water through the oil channels and reservoirs.

In recent years several authors have studied the free convection and mass transfer flow of a viscous fluid through porous medium. Here are the some series of investigations have been made by different scholars where the porous medium is either bounded by horizontal or vertical surfaces. Singh and Verma (1995) investigated the three dimensional oscillatory flow through a porous medium with periodic permeability. Attia and Kotb (1996) discussed the MHD flow between two parallel plates with heat transfer. Chamkha (1996) analyzed the unsteady hydromagnetic natural convection in a fluid saturated porous channel.

Three dimensional free convective flows through a porous medium in presence of heat transfer was studied by Ahamed and Sharma (1997). Attia (1997) discussed the transient MHD flow and heat transfer between two parallel plates with temperature dependent viscosity. Krishna *et al*. (2004) presented the hydromagnetic oscillatory flow of a second order Rivlin-Ericksen fluid in a channel. Sharma and Yadav (2005) analyzed the heat transfer through three dimensional Couette flow between a stationary porous plate bounded by porous medium and a moving porous plate. Sharma *et al*. (2005) explained the steady laminar flow and heat transfer of a non-Newtonian fluid through a straight horizontal porous channel in the presence of heat source. Vershney and Singh (2005) presented the effect of periodic permeability on three dimensional free convective flows with heat and mass transfer through a porous medium. Jain *et al*. (2006) investigated the three dimensional couette flows with transpiration cooling through a porous medium in the slip flow regime. Recently, Das *et al*. (2008) analyzed the three dimensional couette flow and heat transfer in presence of a transverse magnetic field and Das et.al (2009) discussed the effect of suction and injuction on MHD three dimentional couette flow and heat transfer through a porous medium.

Our present paper is devoted to study the of constant suction and sinusoidal injection on three dimensional couette flow of a viscous incompressible electrically conducting fluid through a porous medium between two infinite horizontal parallel porous flat plates in presence of a transverse magnetic field. The plates in uniform motion are, respectively, subjected to a transverse sinusoidal injection and uniform suction of the fluid .This type of injection velocity distribution the flow becomes three dimensional and the governing equations of the flow field are solved by analytically using series expansion method and the expressions for the velocity field, the temperature field, skin friction and the rate of heat transfer i.e. the heat flux in terms of Nusselt number are obtained. The effects of the flow parameters on the velocity field, temperature field and skin friction and heat flux have been studied and analyzed with the help of figures and tables.

II. Mathematical Formulation And Its Solution

We consider the viscous incompressible electrically conducting fluid occupying the space between two moving infinite horizontal parallel porous plates.

The analysis of the problem is based on the following assumptions:

- The three dimensional flow considered in the presence of a uniform transverse magnetic field B_0.
- The coordinate system considered with origin at the lower horizontal plate subjected to the uniform velocity -*U* in *x**-*z** plane and the upper plane at *l* distance from it is subjected to a uniform velocity *U*. And the *y**-axis is normal to the planes (plates).
- Both the plates are at constant temperatures T_0 and T_w respectively ($T_w > T_0$).
- The upper plate is subjected to a constant suction velocity *V* and the lower plate to a transverse sinusoidal injection velocity $v^*(z^*) = V\left[1 + \epsilon \cos\left(\frac{\pi z^*}{l}\right)\right]$, $(\epsilon \ll 1)$ where ϵ is a very small positive constant quantity and l is equal to the wavelength of injection velocity. This kind of injection velocity occurs the flow three dimensional.
- All the physical quantities are independent of *x** which is the property of the laminar flow.
- The velocity components are *u**, *v**, *w** in *x**, *y**, *z** directions, respectively, and the temperature denoted by T *.

With the forgoing assumptions, the non dimensional forms of the governing equations are

$$\frac{\partial v^*}{\partial y^*} + \frac{\partial w^*}{\partial z^*} = 0 \qquad \ldots(1)$$

$$v^*\frac{\partial u^*}{\partial y^*} + w^*\frac{\partial u^*}{\partial z^*} = \upsilon\left(\frac{\partial^2 u^*}{\partial y^{*2}} + \frac{\partial^2 u^*}{\partial z^{*2}}\right) - \frac{\upsilon}{k^*}u^* - \frac{\sigma B_0^2 u^*}{\rho} \qquad \ldots(2)$$

$$v^*\frac{\partial v^*}{\partial y^*} + w^*\frac{\partial v^*}{\partial z^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial y^*} + \upsilon\left(\frac{\partial^2 v^*}{\partial y^{*2}} + \frac{\partial^2 v^*}{\partial z^{*2}}\right) - \frac{\upsilon}{k^*}v^* \qquad \ldots(3)$$

$$v^*\frac{\partial w^*}{\partial y^*} + w^*\frac{\partial w^*}{\partial z^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial z^*} + \upsilon\left(\frac{\partial^2 w^*}{\partial y^{*2}} + \frac{\partial^2 w^*}{\partial z^{*2}}\right) - \frac{\upsilon}{k^*}w^* - \frac{\sigma B_0^2 w^*}{\rho} \qquad \ldots(4)$$

$$v^*\frac{\partial T^*}{\partial y^*} + w^*\frac{\partial T^*}{\partial z^*} = \alpha\left(\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\partial^2 T^*}{\partial z^{*2}}\right) \qquad \ldots(5)$$

Where ρ is the density, υ is the kinematic viscosity, σ is the coefficient of electrical conductivity, B_0 is the coefficient of electromagnetic induction, k^* is the permeability of the porous medium, α is thermal diffusivity.

The corresponding initial and boundary conditions are

$$y^* = 0 \;:\; u^* = -U, v^* = V\left(1 + \epsilon\cos\frac{\pi z^*}{l}\right), w^* = 0, T^* = T_0^*;$$
$$y^* = l \;:\; u^* = U, v^* = V, w^* = 0, T^* = T_w^* \qquad \ldots(6)$$

Introducing the following dimensionless quantities:

$$u = \frac{u^*}{U}, v = \frac{v^*}{V}, w = \frac{w^*}{V}, y = \frac{y^*}{l}, z = \frac{z^*}{l}, T = \frac{T^* - T_0^*}{T_w^* - T_0^*}, Re = \frac{Vl}{\upsilon}, Pr = \frac{\upsilon}{\alpha}, M^2 = \frac{\sigma B_0^2 l^2}{\rho \upsilon}, K_p = \frac{K^*}{l^2} \qquad \ldots(7)$$

Where Re is Reynolds Number,Pr is Prandtl Number, M^2 is magnetic parameter and Kp is permeability parameter. Substituting the dimensionless quantities in the governing equations from and the corresponding conditions of the Couette Flow. Equation (1)-(6) reduces to the following form:

$$\frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad \ldots(8)$$

$$v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = \frac{1}{Re}\left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) - \frac{1}{ReKp}u - \frac{M^2}{Re}u \qquad \ldots(9)$$

$$v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = \frac{1}{Re}\left(\frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) - \frac{1}{ReKp}v \qquad \ldots(10)$$

$$v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = \frac{1}{Re}\left(\frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right) - \frac{1}{ReKp}w - \frac{M^2}{Re}w \qquad \ldots(11)$$

$$v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z} = \frac{1}{RePr}\left(\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) \qquad \ldots(12)$$

The corresponding boundary conditions are reduce on the form of

$$y = 0 \;:\; u = -1, v = 1 + \epsilon\cos\pi z, w = 0, T = 0;$$
$$y = 1 \;:\; u = 1, v = 1, w = 0, T = 1 \qquad \ldots(13)$$

III. Method Of Solution

To solve the problem, it is assumed that the amplitude ($\epsilon \ll 1$) of permeability variation is very small so the solution pretends as:

$$u(y,z) = u_0(y) + \epsilon u_1(y,z) + \epsilon^2 u_2(y,z) + \cdots \qquad \ldots(14)$$

$$v(y,z) = v_0(y) + \epsilon v_1(y,z) + \epsilon^2 v_2(y,z) + \cdots \quad \ldots(15)$$
$$w(y,z) = w_0(y) + \epsilon w_1(y,z) + \epsilon^2 w(y,z) + \cdots \quad \ldots(16)$$
$$T(y,z) = T_0(y) + \epsilon T_1(y,z) + \epsilon^2 T_2(y,z) + \cdots \quad \ldots(17)$$

Case I

When ϵ=0 the problem reduces to the two dimensional free convective MHD flow through a porous medium with constant permeability which is governed by following equations:

$$\frac{dv_0}{dy} = 0 \quad \ldots(18)$$
$$\frac{d^2u_0}{dy^2} - v_0 Re\frac{du_0}{dy} - \left(M^2 + \frac{1}{Kp}\right)u_0 = 0 \quad \ldots(19)$$
$$\frac{d^2T_0}{dy^2} - v_0 RePr\frac{dT_0}{dy} = 0 \quad \ldots(20)$$

The corresponding boundary conditions for eq (18) - eq (20) are as follows

$$y = 0 \ : \ u_0 = -1, v_0 = 1, T_0 = 0;$$
$$y = 1 \ : \ u_0 = 1, v_0 = 1, T_0 = 1 \quad \ldots(21)$$

Solution of the two dimensional flow under the boundary conditions (21) are given by

$$u_0 = c_1e^{m_1y} + c_2e^{m_2y} \quad \ldots(22)$$
$$T_0 = \frac{e^{RePry} - 1}{e^{RePr} - 1} \quad \ldots(23)$$
$$v_0 = 1 \quad \ldots(24)$$
$$w_0 = 0 \quad \ldots(25)$$

Here m_1, m_2, c_1 and c_2 are constants and are not mentioned here due to shake of brevity.

Case II

When ϵ≠0 substituting eq (14) – eq (17) into equations (8) – (12) with the help of equation (22) – (25) and comparing the like powers of ϵ, neglecting the higher order terms . We get the following first order equations

$$\frac{dv_1}{dy} + \frac{dw_1}{dz} = 0 \quad \ldots(26)$$
$$\frac{\partial u_1}{\partial y} + v_1\frac{\partial u_0}{\partial y} = \frac{1}{Re}\left(\frac{\partial^2 u_1}{\partial y^2} + \frac{\partial^2 u_1}{\partial z^2}\right) - \frac{1}{ReKp}u_1 - \frac{M^2}{Re}u_1 \quad \ldots(27)$$
$$\frac{\partial v_1}{\partial y} = \frac{1}{Re}\left(\frac{\partial^2 v_1}{\partial y^2} + \frac{\partial^2 v_1}{\partial z^2}\right) - \frac{1}{ReKp}v_1 \quad \ldots(28)$$
$$\frac{\partial w_1}{\partial y} = \frac{1}{Re}\left(\frac{\partial^2 w_1}{\partial y^2} + \frac{\partial^2 w_1}{\partial z^2}\right) - \frac{1}{ReKp}w_1 - \frac{M^2}{Re}w_1 \quad \ldots(29)$$
$$\frac{\partial T_1}{\partial y} + v_1\frac{\partial T_0}{\partial y} = \frac{1}{RePr}\left(\frac{\partial^2 T_1}{\partial y^2} + \frac{\partial^2 T_1}{\partial z^2}\right) \quad \ldots(30)$$

The corresponding boundary conditions are

$$y = 0 \ : \ u_1 = 0, v_1 = \cos\pi z, w_1 = 0, T_1 = 0;$$
$$y = 1 \ : \ u_1 = 0, v_1 = 0, w_1 = 0, T_1 = 0 \quad \ldots(31)$$

Some of the equations are independent of main flow component and the temperature field. Following Das et al. (2008), we assume velocity components and temperature in the following form:

$$\left.\begin{aligned} u_1(y,z) &= u_{11}(y)\cos\pi z \\ v_1(y,z) &= v_{11}(y)\cos\pi z \\ w_1(y,z) &= -\frac{1}{\pi}v_{11}'(y)\sin\pi z \\ T_1(y,z) &= T_{11}(y)\cos\pi z \end{aligned}\right\} \quad \ldots(32)$$

First substitute these assumptions in equation (28), (29)and (30) followed by the boundary conditions we have

$$u_{11}'' - Reu_{11}' - \left(M^2 + \pi^2 + \frac{1}{Kp}\right)u_{11} = Rev_{11}u_0' \quad \ldots(33)$$
$$v_{11}'' - Rev_{11}' - \left(\pi^2 + \frac{1}{Kp}\right)v_{11} = 0 \quad \ldots(34)$$
$$T_{11}'' - RePrT_{11}' - \pi^2 T_{11} = RePrv_{11}T_0' \quad \ldots(35)$$

and

$$y = 0 \ : \ u_{11} = 0, v_{11} = 1, T_{11} = 0;$$
$$y = 1 \ : \ u_{11} = 0, v_{11} = 0, T_{11} = 0 \quad \ldots(36)$$

Solution of the above equations under the boundary conditions are

$$v_1 = (c_3e^{m_3y} + c_4e^{m_4y})\cos\pi z \quad \ldots(37)$$
$$w_1 = -\frac{1}{\pi}(c_3m_3e^{m_3y} + c_4m_4e^{m_4y})\sin\pi z$$
…(38)
$$T_1 = \left(a_1e^{n_1y} + a_2e^{n_2y} + c_5e^{(m_3+RePr)y} + c_6e^{(m_4+RePr)y}\right)\cos\pi z \quad \ldots(39)$$

$$u_1 = \left(c_7 e^{m_7 y} + c_8 e^{m_8 y} + c_9 e^{(m_1+m_3)y} + c_{10} e^{(m_2+m_3)y} + c_{11} e^{(m_1+m_4)y} + c_{12} e^{(m_2+m_4)y}\right)\cos \pi z \quad \ldots(40)$$

Here constants are not mentioned here due to shake of brevity.

Substituting the values from equations (22)-(25) and equations (37)-(40) in equations (14)-(17) the solution for velocity and temperature is given by

$$u(y,z) = (c_1 e^{m_1 y} + c_2 e^{m_2 y}) + \epsilon\left(c_7 e^{m_7 y} + c_8 e^{m_8 y} + c_9 e^{(m_1+m_3)y} + c_{10} e^{(m_2+m_3)y} + c_{11} e^{(m_1+m_4)y} + c_{12} e^{(m_2+m_4)y}\right)\cos \pi z + \cdots \quad \ldots(41)$$

$$v(y,z) = 1 + \epsilon(c_3 e^{m_3 y} + c_4 e^{m_4 y})\cos \pi z + \cdots \quad \ldots(42)$$

$$w(y,z) = -\frac{\epsilon}{\pi}(c_3 m_3 e^{m_3 y} + c_4 m_4 e^{m_4 y})\sin \pi z + \cdots \quad \ldots(43)$$

$$T(y,z) = \frac{e^{RePry} - 1}{e^{RePr} - 1} + \epsilon\left(a_1 e^{n_1 y} + a_2 e^{n_2 y} + c_5 e^{(m_3+RePr)y} + c_6 e^{(m_4+RePr)y}\right)\cos \pi z + \cdots \quad \ldots(44)$$

Skin Friction Coefficient and Heat Transfer Coefficient

The quantities of physical interest are the coefficient of skin friction τ_x and τ_z as well as heat transfer coefficient (Nusselt Number) Nu are defined as

$$\tau_x = \left(\frac{du_0}{dy}\right)_{y=0} + \epsilon\left(\frac{du_1}{dy}\right)_{y=0} \quad \ldots(45)$$

$$\tau_z = \epsilon\left(\frac{dw_1}{dy}\right)_{y=0} \quad \ldots(46)$$

And $N_u = \left(\frac{dT_0}{dy}\right)_{y=0} + \epsilon\left(\frac{dT_1}{dy}\right)_{y=0}$ …(47)

IV. Result And Discussion

Here, we assigned physically realistic numerical values to the embedded parameters in the system in order to gain an insight into the flow structure with respect to velocity and temperature. The effect of the flow parameters on velocity field are studied and discussed using velocity profiles shown in fig. (1) – (8) and temperature profiles shown in fig. (9)-(10) and the effects of the pertinent parameters on the skin friction and heat flux are discussed using tables (1)-(2)

Velocity field

The main flow field as well as the cross flow field suffers a change in magnitude due to the variation in magnetic parameter (M), permeability parameter (Kp), and suction / injection parameter (Re).

As shown in fig.(1) and fig.(4) the magnetic parameter (M) influences the main velocity of the flow field. The flow velocity increases to its maximum value as we proceed from narrow area of the flow. But in case of non MHD flow (M=0) we observe that the increase in magnetic parameter retard the main flow velocity. It is because of the magnetic pull of Lorentz force which acts on the flow field.

The effects of suction / injection parameter (Re) on the flow velocity are shown in fig.(3) and fig.(6). The flow velocity decreases as suction / injection parameter increase. It is observed from the fig.(2) and fig.(5) the permeability parameter enhanced the velocity of the flow field at all the points.

Temperature field

The variation in Prandtl Number (Pr) and suction / injection parameter (Re) are the main cause of change in temperature field. In observation of fig.(9) as Prandtl Number increases the molecular motion of the fluid elements let down therefore the temperature decreases at all the points.

The temperature suffers decrement as the suction / injection parameter increases. Further in absence of suction / injection parameter the temperature profile becomes linear.

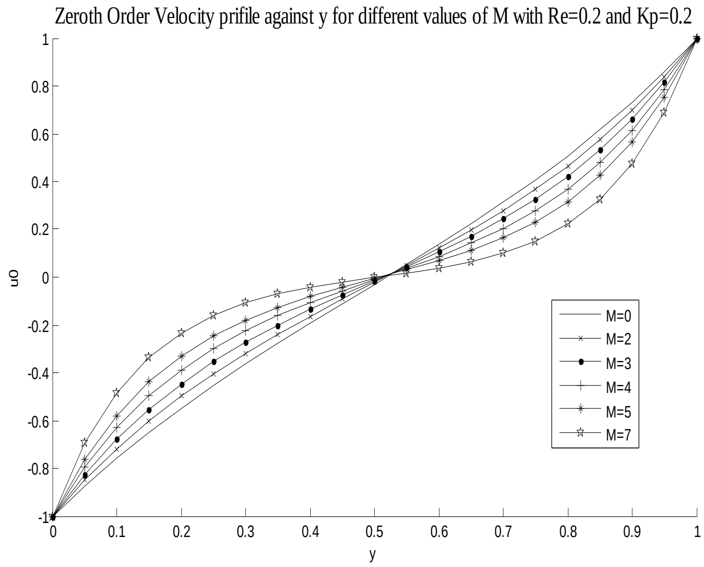
Zeroth Order Velocity prifile against y for different values of M with Re=0.2 and Kp=0.2
u0
y
M=0
M=2
M=3
M=4
M=5
M=7

Fig. (1)

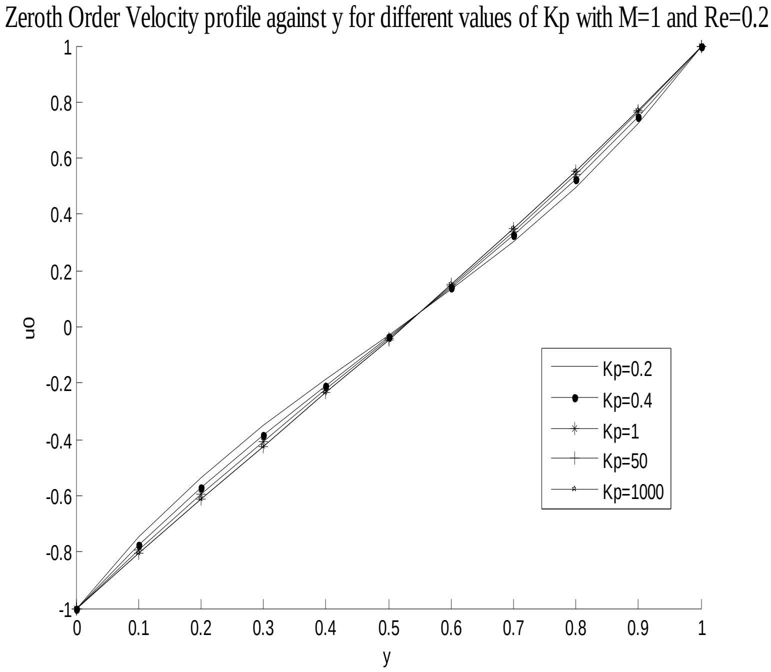
Zeroth Order Velocity profile against y for different values of Kp with M=1 and Re=0.2
u0
y
Kp=0.2
Kp=0.4
Kp=1
Kp=50
Kp=1000

Fig. (2)


Zeroth Order Velocity profile against y for different values of Re with M=1 and Kp=0.2
u0
y
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Re=0
Re=0.4
Re=1
Re=2
Re=3
Re=4

Fig. (3)

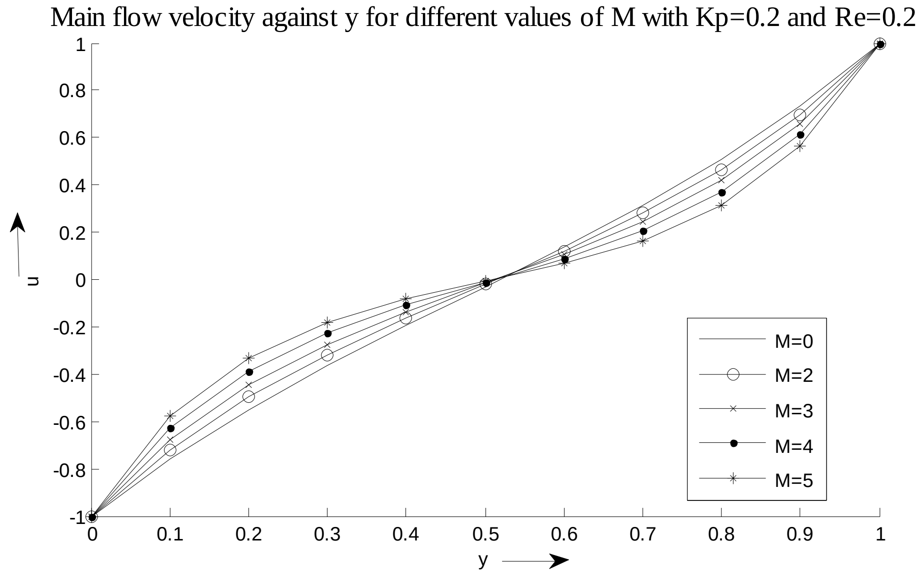
Main flow velocity against y for different values of M with Kp=0.2 and Re=0.2
u
y
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
M=0
M=2
M=3
M=4
M=5

Fig. (4)

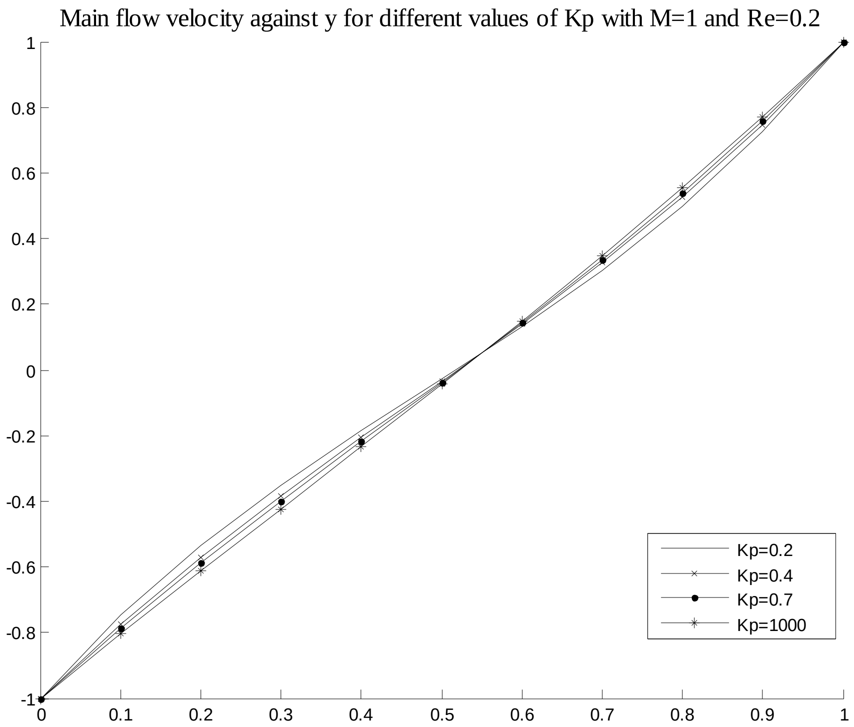
Main flow velocity against y for different values of Kp with M=1 and Re=0.2
Kp=0.2
Kp=0.4
Kp=0.7
Kp=1000
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. (5)

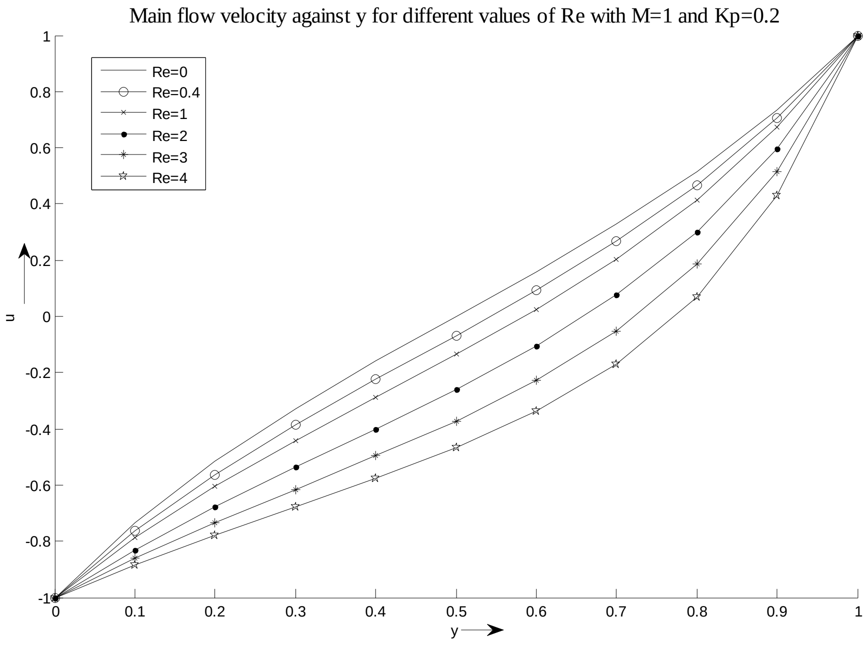
Main flow velocity against y for different values of Re with M=1 and Kp=0.2
Re=0
Re=0.4
Re=1
Re=2
Re=3
Re=4
u
y
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. (6)

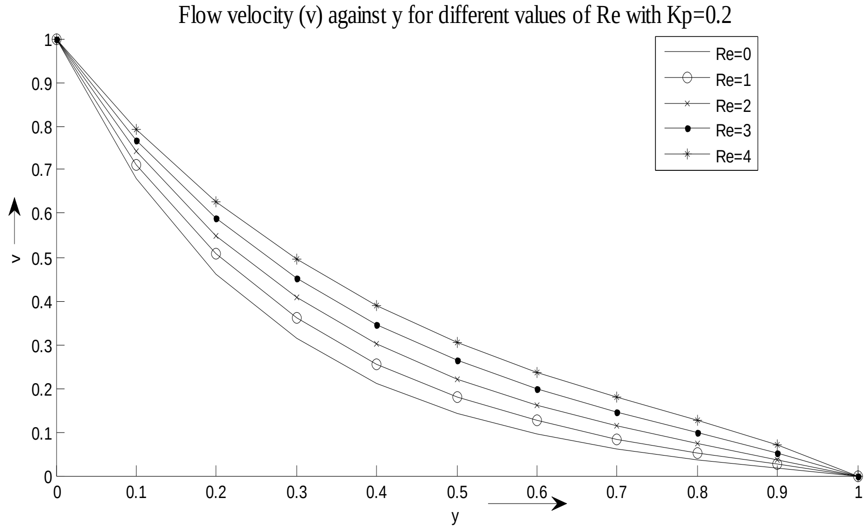
Flow velocity (v) against y for different values of Re with Kp=0.2
Re=0
Re=1
Re=2
Re=3
Re=4
v
y
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. (7)

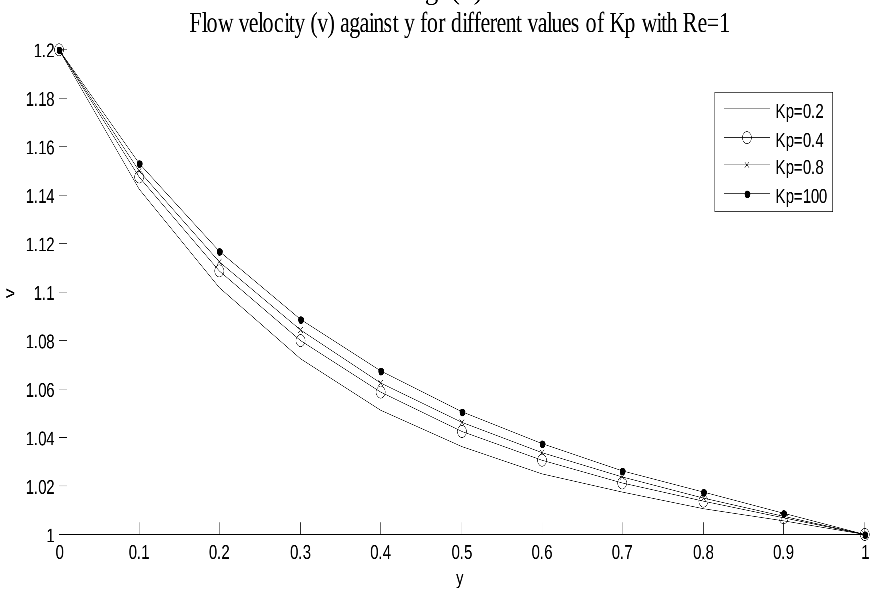
Flow velocity (v) against y for different values of Kp with Re=1
Kp=0.2
Kp=0.4
Kp=0.8
Kp=100
v
y
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. (8)

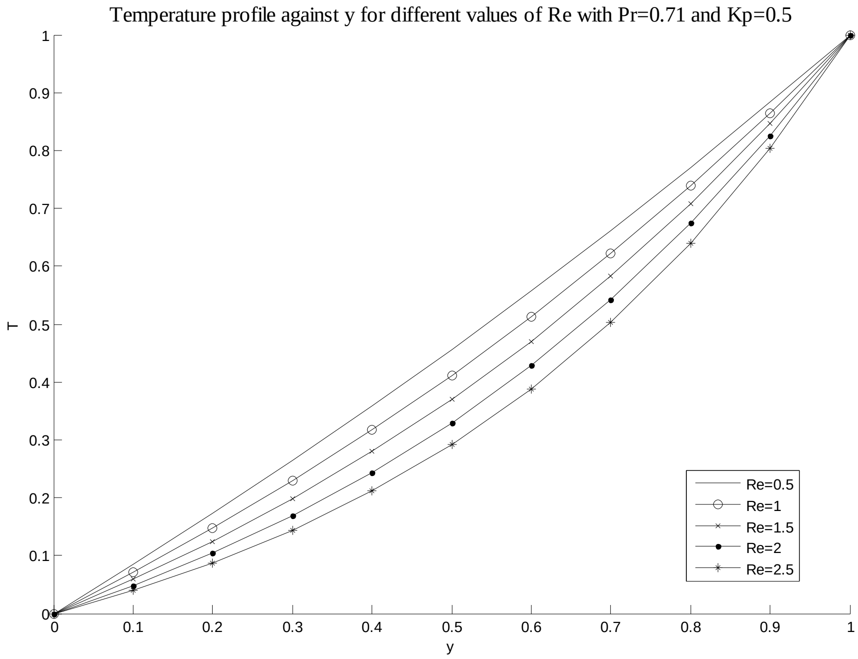

Fig. (9)

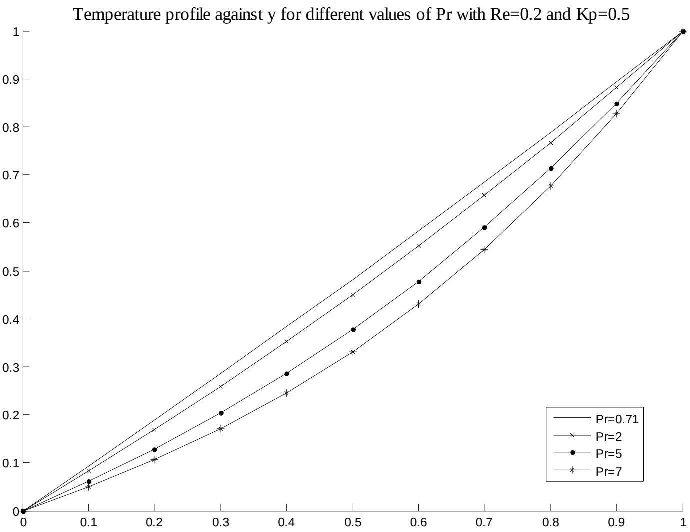

Fig. (10)

Skin friction

The skin friction at the walls for different values of magnetic parameter (M), permeability parameter (Kp), and suction / injection parameter (Re) are shown in Table (1) – (3).

It is observed from table (1) that a growing magnetic parameter (M) enhances both the components of skin friction. Also it is observed that increased permeability parameter (Kp), and suction / injection parameter (Re) reduces the x-component and z-component of the skin friction.

M	τx (z=1/4)	τz (z=1/4)	τx (z=1/3)	τz (z=1/3)
0	2.6266371	2.6504391	2.6266609	2.6504391
0.1	2.628127	2.6504391	2.6281507	2.6504391
0.2	2.6325936	2.6504391	2.6326173	2.6504391
0.3	2.6400279	2.6504391	2.6400517	2.6504391
0.4	2.6504153	2.6504391	2.6504391	2.6504391

Table (1) : Skin friction at the wall for different values of M with Kp=0.2, Re=0.2 and ϵ=0.002

Kp	**τx (z=1/4)**	**τz (z=1/4)**	**τx (z=1/3)**	**τz (z=1/3)**
0.2	2.7732325	2.6504391	2.7732565	2.6504391
0.4	2.397237	2.6504391	2.3972611	2.6504391
0.6	2.2642844	2.6504391	2.2643086	2.6504391
0.8	2.1961779	2.6504391	2.1962022	2.6504391
1	2.1547607	2.6504391	2.154785	2.6504391

Table (2) : Skin friction at the wall for different values of Kp with M=1, Re=0.2 and ϵ=0.002

Re	**τx (z=1/4)**	**τz (z=1/4)**	**τx (z=1/3)**	**τz (z=1/3)**
0	2.9124247	2.6504391	2.9124247	2.6504391
0.1	2.8419542	2.6504391	2.8419665	2.6504391
0.2	2.7732325	2.6504391	2.7732565	2.6504391
0.5	2.5773922	2.6504391	2.5774489	2.6504391
1	2.2841932	2.6504391	2.2842955	2.6504391

Table (3) : Skin friction at the wall for different values of Re with Kp=0.2, M=1 and ϵ=0.002

Rate of heat transfer (Nu)

The rate of heat flux in the terms of Nusselt Number is represents in the table below. This shows that increased parameters retards the magnitude rate of heat transfer at the wall.

Re	Nu		Pr	Nu		Kp	Nu
0.1	0.9649005		0.71	0.9306415		0.2	0.9306415
0.2	0.9306415		1	0.9032787		0.4	0.9306397
0.5	0.8328915		2	0.8132022		0.6	0.930639
0.7	0.7718822		5	0.5817986		0.8	0.9306386
1	0.6865048		7	0.4580339		1	0.9306384
Pr=0.71 and Kp=0.2			Re=0.2 and Kp=0.2			Re=0.2 and Pr=0.71	

Table (4) : Rate of heat flux

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