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Numerical Study of the Effects of Suction and Pressure Gradient on an Unsteady MHD Fluid Flow between Two Parallel Plates in a Non-Darcy Porous Medium

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Abstract

The present problem discusses the unsteady MHD fluid flow of viscous incompressible fluid in between two parallel horizontal plates, upper being at rest and lower moving, in the presence of transverse magnetic field in a non Darcy (Darcy-Brinkman-Forchheimer) porous medium. These equations were solved numerically using explicit finite difference method. The fluid velocity with respect to the governing parameters are computed and presented graphically, and in tabular form using MATLAB.

Keywords: MHD flow; suction; Forchheimer parameter; non-Darcy porous medium.

1 Introduction

MHD fluid flow finds application in many engineering and physical science problems such as MHD generators, nuclear reactors, and plasma physics [1]. Examples of flow through porous medium are extraction of oil and natural gas from rocks (porous medium) in earth, flow of underground water through

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soil and water in side earth, various medical treatments such as tumour growth (a formation of porous medium) and their treatment such as injection (a flow through porous medium) and flow of blood and nutrients in body (bone, cartilage and muscles) [2].

Gulab et al. [3] studied an exact solution of the unsteady motion of an electrically conducting viscous incompressible fluid through porous medium in the presence of transverse magnetic field. Aydin et al. [4] studied effect of viscous dissipation and thermal buoyancy on steady MHD mixed convection flow of viscous incompressible fluid past a vertical plate.

Mahdy et al. [5] studied the effect of radiation on unsteady MHD convective flow of viscous incompressible fluid over a vertical porous plate through a porous medium in the presence of transverse magnetic field. Sengupta et al. [6] studied the effect of thermal radiation, viscous dissipation on unsteady MHD convective flow of viscous incompressible fluid over a vertical infinite porous plate in a porous medium in the presence of transverse magnetic field, chemical reaction with variable temperature and concentration and velocity slip conditions.

Das et al. [7] analysed the effect of mass transfer on unsteady hydrodynamic free convective flow of a viscous incompressible electrically conducting fluid past an infinite vertical Porous plate in the presence of constant suction and heat source. Babu et al. [1] studied unsteady two dimensional flow of viscous incompressible, electrically conducting fluid through porous medium in the presence of transverse magnetic field, chemical reaction, viscous dissipation, radiation and suction over vertical semi infinite moving permeable plate.

Singh et al [8] analysed unsteady free convective viscous incompressible flow of electrically conducting fluid with periodic heat and mass transfer past an infinite vertical plate in the slip flow regime. Bala et al. [9] studied unsteady one dimensional flow of viscous incompressible, electrically conducting fluid along a semi infinite vertical plate in the presence of transverse magnetic field, radiation, chemical reaction, and suction, having thermal and mass buoyancy effects.

Jha et al. [10] studied approximate analytical solution of steady flow of viscous incompressible fluid through porous medium between two parallel plates using Darcy-Brinkman –Forchheimer porous model. Sandeep et al. [11] studied the effects of radiation and chemical reaction on unsteady MHD free convective flow of viscous incompressible fluid on a vertical plate through porous medium in the presence of transverse magnetic field with variable temperature and concentration, and velocity slip conditions at the boundary.

Poonia et al. [12] studied the unsteady MHD free convective flow of viscous incompressible electrically conducting fluid over porous vertical plate through a porous medium in the transverse magnetic field with viscous dissipation. Chand et al. [13] studied the soret effect on unsteady MHD convective flow of viscous incompressible fluid between two vertical porous parallel plates in porous medium.

Reddy et al. [14] studied thermal and mass buoyancy effects on unsteady MHD flow of viscous incompressible fluid past an infinite vertical plate through porous medium in the presence of transverse magnetic field. Seth et al. [15] studied the effects of thermal and mass buoyancy, heat source/sink, and chemical reaction on unsteady MHD free convective flow of viscous incompressible fluid over a vertical moving plate through the porous medium in the presence of transverse magnetic field, and ramped temperature and ramped concentration.

Karthikeyan et al. [16] studied effect of heat source and radiation on unsteady MHD mixed convective flow of viscous incompressible fluid past a porous vertical moving plate through porous medium in the presence of transverse magnetic field and slip conditions. Reddy, B. Prabhakar et al. [17] studied the effect of radiation and viscous dissipation on unsteady MHD free convective flow of viscous incompressible electrically conducting fluid past a vertical plate in a porous medium with Hall current.

Uwanta et al. [18] studied the effect of radiation viscous dissipation on unsteady MHD free convective flow past a vertical plate embedded in a non -Darcy porous medium in the presence of transverse magnetic field, heat source, variable thermal conductivity and chemical reaction with variable temperature and concentration at the boundary.

Essawy et al. [19] discussed the effect of viscous dissipation on unsteady forced convective flow of a viscous incompressible fluid between two horizontal parallel plates in a non –Darcy porous medium. Olumide et al. [20] studied the effects of radiation and thermal buoyancy on unsteady MHD flow of viscous incompressible fluid between two parallel plates having porous medium under slip conditions.

Ram et al. [21] studied the effect of porosity on unsteady MHD flow of viscous incompressible fluid past a semi infinite moving vertical plate in the presence of transverse magnetic field. Ahmed et al. [22] studied the effect of radiation on unsteady MHD mixed convective flow of viscous incompressible fluid past an impulsively fixed vertical plate in the presence of transverse magnetic field.

Ibrahim et al. [23] studied the effect of radiation and chemical reaction on unsteady MHD free convective flow of viscous, incompressible fluid past a semi-infinite moving vertical porous plate in the presence of transverse magnetic field with variable temperature and concentration at the boundary. Poornima et al. [24] discussed effects of thermal radiation and chemical reaction on unsteady MHD free convective flow of viscous incompressible fluid past a semi- infinite vertical porous moving plate with constant suction.

Ali et al. [25] studied Unsteady magnetohydrodynamic oscillatory flow of viscoelastic fluids in a porous channel with heat and mass transfer. Khan, et al. [26] analysed the Effects of Hall current and mass transfer on the unsteady magnetohydrodynamic flow in a porous channel. Sheikh et al. [27] discussed MHD Flow of Micropolar Fluid over an Oscillating Vertical Plate Embedded in Porous Media with Constant Temperature and Concentration. Ali et al. [28] carried out an exact analysis of the MHD free convection flow of a Walters'-B fluid over an oscillating isothermal vertical plate embedded in a porous medium.

Above mentioned work shows following.

Table 1. Table shows the work in square bracket (referenced) with the assumptions in the cells just above them

Steady	Non-porous medium	Non Darcy porous medium	Absent Magnetic field	Presence of pressure gradient
[4] and [10]	[4,8,9,22]	[10,18,19] [25,26,27,28]	[10,19]	[2,3,6], [10,13,16,20]

Thus in the reference, the works [4,10] studied steady fluid flow and remaining works studied unsteady fluid flow. Works [4,8,9,22] do not consider no porous medium, works [10,18,19] consider non-Darcy porous medium and remaining Darcy porous medium. The works [2,3,6,10,13,16,20] consider pressure gradient, and remaining do not consider it. The works [10,19] do not consider magnetic field and while remaining others consider the magnetic field.

And from the above study it is observed that the unsteady MHD fluid flow of viscous incompressible fluid in between two parallel horizontal plates, upper being at rest and lower moving, in the presence of transverse magnetic field in a non- Darcy (Darcy-Brinkman-Forchheimer) porous medium is not discussed.

The present problem discusses the unsteady MHD fluid flow of viscous incompressible fluid in between two parallel horizontal plates, upper being at rest and lower moving, in the presence of transverse magnetic field in a non Darcy (Darcy-Brinkman-Forchheimer)porous medium.

2 Formulation of the Problem

In the formulation of the problem we consider following assumptions.

Assumptions: fluid is viscous, incompressible, electrically conducting. Flow is unsteady, two dimensional, laminar between two parallel plates, located at the $y' = 0$ and $y' = h$ planes and extend from $x' = -\infty \; to \; +\infty$ and $z' = -\infty \; to \; +\infty$ embedded in an Extended-DF (Darcy Forchheimer) porous medium where a high Reynolds number. Flow region is in the transverse magnetic field, and is having Non - Darcy (Darcy-Brinkman-Forchheimer) porous medium. strength of uniform magnetic field is B_0 and electrical conductivity of the fluid is σ . The fluid is assumed to be Newtonian with uniform properties and the porous medium is isotropic and homogeneous. The fluid flows between the two plates under the influence of a constant pressure gradient $\partial p'/\partial x'$ in the x'-direction, and a uniform suction from above and injection from below which are applied at $t' = 0$ with constant velocity v_0 in the positive y'-direction, as shown in Fig. 1.

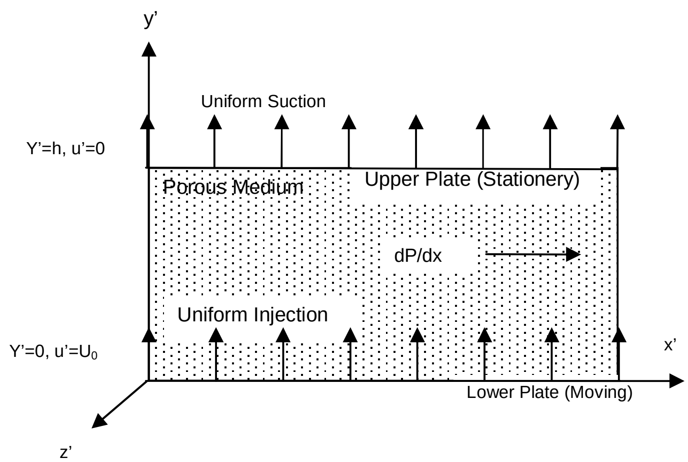

Fig. 1. The geometry of the problem (Physical problem and coordinate system)

The upper plate is kept stationary while the lower plate is moving with a constant velocity U_0 . The flow is through a porous medium and affected by another inertial effects where the non-Darcy (Darcy-Brinkman-Forchheimer) model is assumed.

From the geometry of the problem and due to infinite dimensions in the x' and z'-directions, it is evident that $\frac{\partial}{\partial x'} = \frac{\partial}{\partial z'}$ for all quantities, i.e. they are independent in the x' and z'-coordinates. pressure gradient $\partial p'/\partial x'$ is assumed constant. Thus the velocity vector of the fluid is $\overrightarrow{v'(y,t)} = u'(y,t)\,\hat{i} + v_0\,\hat{j}$, with the initial and boundary conditions $u' = 0 \; at \; t' = 0 \; for \; all \; values \; of \; y'$, and $u' = U_0 \; at \; y' = 0 \; and \; u' = 0, \; at \; y' = h \quad for \; t' > 0$. Under the above assumptions the fluid flow is governed by the following continuity and momentum equation.

The continuity equation:

$$\frac{\partial u'}{\partial x'} + \frac{\partial v'}{\partial y'} = 0 \tag{1}$$

The equation of momentum:

$$\rho \frac{\partial u'}{\partial t'} + \rho v_0 \frac{\partial u'}{\partial y'} = -\frac{\partial p'}{\partial x'} + \mu \frac{\partial^2 u'}{\partial y'^2} - \sigma B_0^2 u' - \frac{\mu}{K} u' - \frac{\rho \lambda}{\sqrt{K}} u'^2 \tag{2}$$

The first term in the right-hand side of Equation (2) is pressure gradient term, second is the Brinkman viscous term (it represents the viscous force acting on fluid due to flow through a highly porous medium), third is magnetic effect term, fourth is the Darcy and fifth is the Forchheimer term, hence the momentum transfer in the porous media, under magnetic field is governed by time dependent, extended Darcy-Brinkman-Forchheimer model.

Under these assumptions, the appropriate boundary condition for the velocity field satisfies following conditions:

$$\begin{aligned} &t' \le 0 : u' = 0 \quad for\ all \quad y'; \\ &t' \ge 0 : u' = U_{0,} \quad at \quad y' = 0; \\ &u' \to 0,\ as\ \ y' \to h. \end{aligned} \tag{3}$$

The equations above also have been transformed in dimensionless form by using the non-dimensional parameters defined as follows

$$x = \frac{x'}{h}, y = \frac{y'}{h}, z = \frac{z'}{h}, u = \frac{u'}{U_0}, t = \frac{t' U_0}{h}, p = \frac{p'}{\rho U_0^2}, \tag{4}$$

The dimensionless form of equation (2):

$$\frac{\partial u}{\partial t} + \frac{v_0}{U_0}\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \frac{\mu}{\rho h U_0}\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2 h}{\rho U_0} u - \frac{\mu}{\rho h U_0}\frac{h^2}{K} u - \frac{\lambda h}{\rho \sqrt{K}} u^2, \tag{5}$$

$$\frac{\partial u}{\partial t} + S\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \frac{1}{\mathrm{Re}}\frac{\partial^2 u}{\partial y^2} - M1u - \frac{\beta}{\mathrm{Re}} u - \gamma u^2, \tag{6}$$

Dimensionless parameters:

$$\begin{aligned} &\text{Suction parameter } S = \frac{v_0}{U_0}, \text{Prassure gradient} = -\frac{\partial p}{\partial x}, \\ &\text{Reynold number } \mathrm{Re} = \frac{\rho h U_0}{\mu}, \text{Magnetic parameter } M1 = \frac{\sigma B_0^2 h}{\rho U_0}, \\ &\text{Porosity Parameter } \beta = \frac{h^2}{K}, \text{Forchheimer Parameter } \gamma = \frac{\lambda h}{\rho \sqrt{K}}. \end{aligned} \tag{7}$$

$$\begin{aligned} &t \le 0 : u = 0 \quad for\ all \quad y; \\ &t \ge 0 : u = 1 \ \ at \ \ y = 0; \\ &u \to 0,\ as\ \ y \to 1. \end{aligned} \tag{8}$$

The numerical solution of Equation (6) using the initial and boundary conditions (9) is obtained by discretization of the momentum Equation (6) into the finite difference equation at the grid points (i,k). Here the index i refers to y (spatial coordinate) and k to t (time coordinate). Using the following in equation (6) and simplifying we get

$$\frac{\partial u}{\partial t}=\frac{\left(u_i^{k+1}-u_i^k\right)}{\Delta t},\ \frac{\partial u}{\partial y}=\frac{\left(u_{i+1}^{k}-u_i^k\right)}{\Delta y},\ \frac{\partial^2 u}{\partial y^2}=\frac{\left(u_{i+1}^{k}-2u_i^k+u_{i-1}^{k}\right)}{(\Delta y)^2}\ ,\ u=u_i^k, or\, u=u(i,k) \tag{9}$$

$$\frac{\left(u_i^{k+1}-u_i^k\right)}{\Delta t}+S\ \frac{\left(u_{i+1}^{k}-u_i^k\right)}{\Delta y}=-\frac{\partial p}{\partial x}+\frac{1}{\text{Re}}\frac{\left(u_{i+1}^{k}-2u_i^k+u_{i-1}^{k}\right)}{(\Delta y)^2}$$
$$-M1u_i^k-\frac{\beta}{\text{Re}}\,u_i^k-\gamma\left(u_i^k\right)^2, \tag{10}$$

This implies

$$u_i^{k+1}=\left(\frac{\Delta t}{\text{Re}(\Delta y)^2}-S\,\frac{\Delta t}{\Delta y}\right)u_{i+1}^k+\begin{pmatrix}1-\dfrac{2\Delta t}{\text{Re}(\Delta y)^2}+S\,\dfrac{\Delta t}{\Delta y}\\ -M\,\Delta t-\dfrac{\beta\,\Delta t}{\text{Re}}\end{pmatrix}u_i^k$$
$$+\left(\frac{\Delta t}{\text{Re}(\Delta y)^2}\right)u_{i-1}^k-\gamma\Delta t\,\left(u_i^k\right)^2-\frac{\partial p\ \Delta t}{\partial x}; \tag{11}$$

or

$$u_i^{k+1}=ru1u_{i+1}^k+ru2u_i^k+ru3u_{i-1}^k+ru4\,\left(u_i^k\right)^2+ru5; \tag{12}$$

with boundary conditions :

$$\begin{aligned}&t\le 0: u=0\ \ for\ all\ \ y;\\&t\ge 0: u=1\ \ at\ \ y=0;\\&u\to 0,\ as\ y\to 1.\end{aligned} \tag{13}$$

where

$$ru1=\left(\frac{\Delta t}{\text{Re}(\Delta y)^2}-S\,\frac{\Delta t}{\Delta y}\right),\ ru2=\begin{pmatrix}1-\dfrac{2\Delta t}{\text{Re}(\Delta y)^2}\\ +S\,\dfrac{\Delta t}{\Delta y}-M\,\Delta t-\dfrac{\beta\,\Delta t}{\text{Re}}\end{pmatrix},$$
$$ru3=\left(\frac{\Delta t}{\text{Re}(\Delta y)^2}\right),\ \ ru4=-\gamma\Delta t\ \ ,\ \ ru5=-a\ \Delta t\ where\ \ a=\frac{\partial p}{\partial x}. \tag{14}$$

Putting

$$S = \frac{v_0}{U_0} = 0, G = -\frac{\partial p}{\partial x}, M1 = \frac{\sigma B_0^2 h}{\rho U_0} = 0, Da = \frac{U_0 K}{\upsilon h}, C = \lambda\left(\sqrt{\frac{U_0 h}{\rho\mu}}\right)$$

equation (6) reduces to

$$\frac{\partial u}{\partial t} = G + \frac{1}{\mathrm{Re}}\frac{\partial^2 u}{\partial y^2} - \frac{1}{Da}u - \frac{C}{\sqrt{Da}}u^2. \quad (15)$$

Jha et al. [10]. Here G is pressure gradient, Re is Reynold number, Da is Darcy parameter, C is Forchheimer coefficient

3 Numerical Solutions of the Governing Equations

Equations (6) is solved numerically using finite differences under the initial and boundary conditions (9) to determine the velocity distribution for different values of the parameters: Magnetic parameter (M1), Porosity Parameter (beta), Forchheimer Parameter (gamma), Suction parameter (S) and pressure gradient(a). The explicit finite difference method is applied. The finite difference equations are written at the mid-point of the computational cell and the different terms are replaced by their second-order central difference approximations in the y-direction. Finally, the block tri-diagonal system is solved using Thomas algorithm. The effect of various parameters for their some values, on the fluid velocity is discussed by the help of tables annd figures ploted using MATLAB.

4 Results and Discussion

The non-dimensional linear velocity 'u' for various values of different parameters is shown in Figs. 2 to 7.

To ensure the numerical accuracy, the values of 'u' by present method are compared with the results of Jha et al. [10] in Table 2 for various values of 'y' and u(0) = 1.0, Re = 1.0, Da = 0.01, G = 0.0 , C = 0.52 and those are found in excellent agreement with the present values. Thus, we are very much confident that the present results are accurate.

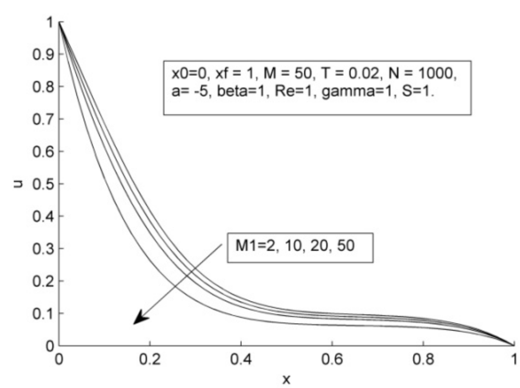

Fig. 2. Graph between x and u for some values of magnetic parameter (M1)

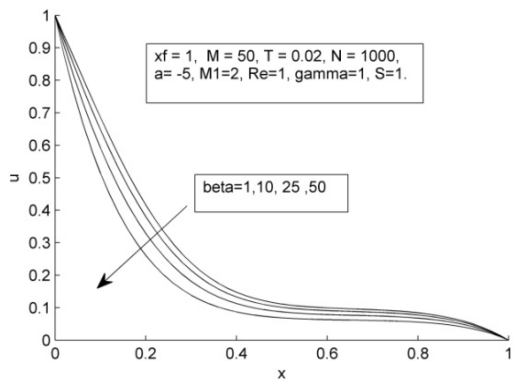

Fig. 3. Graph between x and u for some values of Porosity parameter (beta)

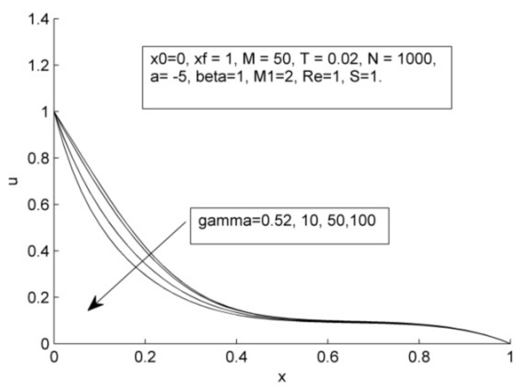

Fig. 4. Graph between x and u for some values of Forchheimer parameter (gamma)

The effect of magnetic field parameter M1 on the velocity profiles of the flow field keeping other parameters of the flow field as constant is shown in Fig. 2. The magnetic field parameter is taken in increasing order and it is found to slow down the velocity of the flow field to a considerable amount due to the magnetic pull of the Lorentz force acting on the flow field and hence thickness of velocity boundary layer decreases. This parameter shows overturn effect. The curves have point of inflection at some point of x. Thus, as M1 increases the concavity to the right of the point of inflection increases slowly.

The effect of beta parameter on the velocity profiles of the flow field keeping other parameters of the flow field as constant is shown in Fig. 3. The beta parameter is taken in increasing order and it is found to slow down the velocity of the flow field to a considerable amount and hence thickness of velocity boundary layer decreases. This parameter shows overturn effect. The curves have point of inflection at some point of x. Thus, as beta increases the concavity to the right of the point of inflection increases slowly.

The effect of gamma parameter on the velocity profiles of the flow field keeping other parameters of the flow field constant is shown in Fig. 4. It is observed that the gamma parameter decreases the velocity of the flow field at all points and hence thickness of velocity boundary layer decreases. The curves have point of inflection at some point of x. Thus, as gamma increases the concavity to the right of the point of inflection increases slowly.

The effect of S parameter on the velocity profiles of the flow field keeping other parameters of the flow field constant is shown in Fig. 5. The S parameter *is* taken in increasing order and it reveals that it has an increasing effect on velocity of the flow field and hence thickness of velocity boundary layer increases. This parameter shows reverse effect. The curves have point of inflection at some value of x. Thus, as S increases concavity to the right of the point of inflection increases slowly and to the left of the point of inflection convexity increases speedily.

The effect of Reynolds number on the velocity profiles of the flow field keeping other parameters of the flow field constant is shown in Fig. 6. The Reynolds number is taken in increasing order and it reveals that it has a decreasing effect on velocity of the flow field and hence thickness of velocity boundary layer decreases. This parameter shows reverse effect. The curves have point of inflection at some value of x. Thus as Re increases concavity to the right of the point of inflection increases slowly and to the left of the point of inflection convexity increases speedily.

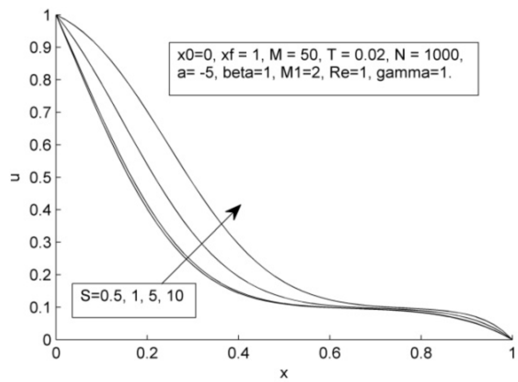

Fig. 5. Graph between x and u for some values of Suction parameter(S)

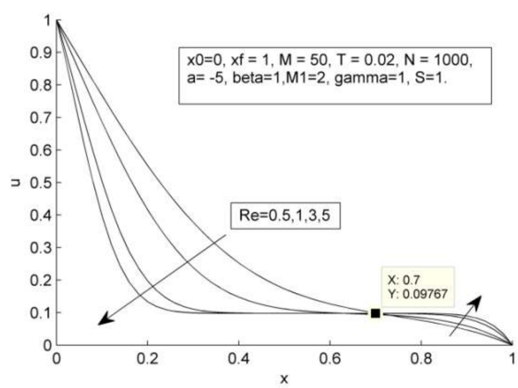

Fig. 6. Graph between x and u for some values of Re

The effect of 'a' parameter on the velocity profiles of the flow field keeping other parameters of the flow field constant is shown in Fig. 7. The 'a' parameter is taken in increasing order and it reveals that it has a decreasing effect on velocity of the flow field and hence thickness of velocity boundary layer decreases. This parameter shows reverse effect. The curves have point of inflection at some value of x. Thus as 'a' from negative to positive increases concavity to the right of the point of inflection decreases slowly and to the left of the point of inflection convexity increases. At 'a'=0 curve is having no point of inflection. As 'a' increases positively convexity of the curves increases speedily. It shows back flow of fluid.

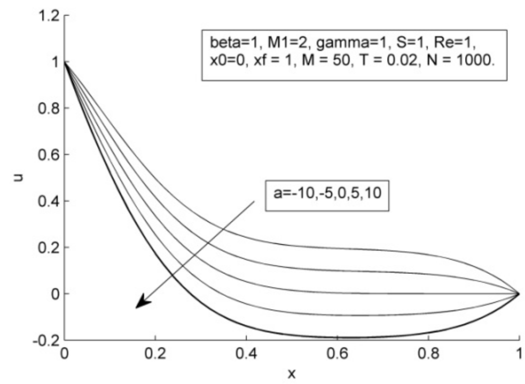

Fig. 7. Graph between x and u for some values of pressure gradient 'a'

Table 2. u(0) = 1.0, Re = 1.0, Da = 0.01, G = 0.0 , C = 0.52

Y	Jha et al. 2011 Analytical solution	Jha et al. 2011 Numerical solution(implicit finite-difference solution)	Present numerical solution (explicit finite -difference solution)
0	1.00000	1.00000	1.000000000000000
0.1	0.36443	0.36457	0.364575906033471
0.2	0.13439	0.13381	0.133816860095207
0.3	0.04959	0.04923	0.049239066609518
0.4	0.01828	0.01813	0.018134379532668
0.5	0.00673	0.00668	0.006680768585060
0.6	0.00248	0.00246	0.002460897887381
0.7	0.00091	0.00090	0.000904830462657
0.8	0.00033	0.00032	0.000328092075290
0.9	0.00011	0.00010	0.000106444781205
1.0	0.00000	0.00000	0

Table 3 shows with increase in M1 the magnetic parameter, there is decrease in skin friction.

Table 3. x0=0, xf = 1, M = 50, T = 0.02, N = 1000,a= -5, beta=1, Re=1, gamma=1, S=1

M1(Magnetic parameter)	f'(0)
2	-3.124018684816082
10	-3.695160495560013
20	-4.363598355225684
50	-6.116018310834672

Table 4 shows with increase in porosity parameter (beta) there is decrease in skin friction.

Table 4. x0=0, xf = 1, M = 50, T = 0.02, N = 1000,a= -5, M1=2, Re=1, gamma=1, S=1

beta(porosity parameter)	f'(0)
1	-3.124018684816082
10	-3.764198077816205
25	-4.742579302900640
50	-6.168829989758767

Table 5 shows with increase in Forchheimer parameter (gamma) there is decrease in skin friction.

Table 5. x0=0,xf = 1, M = 50, T = 0.02,N = 1000,a= -5,eta=1,M1=2,Re=1,S=1

Gamma (Forchheimer parameter)	f'(0)
0.52	-3.098479707521196
10	-3.584949183496505
50	-5.306871559144716
100	-6.960184422820820

Table 6 shows with increase in Suction parameter (S) there is increase in skin friction.

Table 6. x0=0, xf = 1, M = 50, T = 0.02, N = 1000,a= -5, beta=1, M1=2, Re=1, gamma=1

S (Suction parameter)	f'(0)
0.5	-3.315022949648028
1	-3.124018684816082
5	-1.806322818171507
10	-0.723288116082899

Table 7 shows with increase in Reynold number (Re) there is decrease in skin friction.

Table 7. x0=0, xf = 1, M = 50, T = 0.02,N = 1000, a= -5, beta=1,M1=2, gamma=1, S=1

Re (Reynold number)	f'(0)
0.5	-2.333979299251399
1	-3.124018684816082
3	-4.952852877483122
5	-6.095401644675269

Table 8 shows with increase in pressure gradient (a) there is decrease in skin friction.

Table 8. x0=0, xf = 1, M = 50, T = 0.02, N = 1000, beta=1, M1=2, gamma=1, Re=1, S=1

a (pressure grad.)	f'(0)
-10	-2.433187705086781
-5	-3.124018684816082
0	-3.815244127786965
5	-4.506864634166618
10	-5.198880805411488

5 Conclusions

In the present work, the numerical study of effects of magnetic field, porosity, Forchheimer, suction, and pressure- gradient parameters on an unsteady magnetohydrodynamic (MHD) fluid flow, between two horizontal parallel plates in a non–Darcy porous medium has been discussed. The fluid velocity with respect to the governing parameters are computed and presented graphically and in tabular form.

From the study, it is found that the fluid velocity decreases with increase in the value of Magnetic parameter (M1), Porosity parameter (beta), Reynold number (Re) or Pressure gradient (a).The velocity increases with increase in the value Suction(S) parameter. Skin friction decreases with increase in the value of Magnetic parameter (M1), Porosity parameter (beta), Reynold number (Re) or Pressure gradient (a). Skin friction increases with increase in the value Suction(S) parameter. The velocity boundary layer thickness decreases with increase in the value of Magnetic parameter (M1), Porosity parameter (beta), Reynold number (Re) or

Pressure gradient (a). The velocity boundary layer thickness increases with increase in the value Suction parameter (S).

Competing Interests

Author has declared that no competing interests exist.

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