INVESTIGATION OF LAMINAR FLOW OF THE VISCOUS FLUIDS IN A CHANNEL WITH A POROUS BOUNDING WALL

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Abstract:

In this study we have investigated laminar flow of viscous fluid in a channel with porous bounding wall. We have solve the non-linear differential equation by perturbation technique and obtained the solution. A numerical simulation and Matlab software are used to analyze the problem. The focus of this paper is to investigate the effects of permeability parameter on the fluid velocity and slip coefficient. The affect of small as well as large Reynolds numbers is also seen.

.**Key Words: -** permeable wall, Viscous fluid, Reynolds number, Porous medium & Slip coefficient.

Nomenclature

h	Height of the channel;
x	The axial distance from the channel entrance;
y	The coordinate axis perpendicular to the channel walls measured from the Non-porous wall;
u	Velocity component in the x-direction;
u_0	Average velocity over the channel at channel inlet;
Re	Reynolds Number for flow entering the channel, $0\ h/\nu$
v	Velocity component in the y- direction;
V	v/v_w ;

Greek Symbols

ρ	Density of the fluid;
η	Dimensionless variable in the $y-$ direction, y/h;
υ	Kinematic viscosity;
α	Surface characteristics of the membrane;
Δp	Dimensionless pressure drop, $2[p(0,\eta)-p(x,\eta)]/(\rho {u_0}^2)$;
ϕ	Slip coefficient, $\sqrt{k}/\alpha h$;
ψ	Stream Function;
σ	Electrical conductivity
K	Permeability parameter

1. Introduction

The study of the Boundary layer flow problem in the presence of porous bounding wall has considerable interest for its numerous industrial and engineering applications such as boundary layer along with a liquid film, polymer processing, and chemical engineering processes. Berman (1953) has studied the laminar flow in a channel with porous walls and solved the Nervier-Stokes equations with suitable boundary conditions. He has been found a complete description of fluid flow in a channel having a rectangular cross-section with two equally porous walls. Terrill (1965) has been investigated the flow in a uniformly porous channel with large injection. He has been obtained the inner and outer expansions and therefore includes the viscous layer. F. M. White (1991) has been written a book on the viscous flow whose name is Viscous Fluid Flow. Cox (1991) has been studied two dimensional flow of a viscous incompressible fluid through a channel with one porous bounding wall. Avramenko et al. (2005) have been investigated stability of a laminar flow in a parallel-plate channel filled with a fluid-saturated porous medium and their results indicate that both linear and quadratic drag terms increase with the critical value of the Reynolds number, which indicates that the stability of the laminar parallel plate flow increases in a porous medium.

Several engineering applications such as food processing, oil recovery, the spreading of contaminants in the environment and in the industries like material and chemical, the fluid saturating the porous matrix is non-Newtonian. Recently researcher Muthuraj and Srinivas (2009) have been studied the influence of magnetic field and wall slip conditions on the steady flow between parallel flat wall and a long wavy wall with soret effect. They have found out that the effect of increasing suction parameter suppresses the velocity while it enhances the fluid temperature. Mohamed and Abou-Zeid (2009) have been investigated the numerical treatment of heat and mass transfer of MHD flow of Carreau fluid with diffusion and chemical reaction through a non-Darcy porous medium. They have found the solution of partial differential equations by finite difference technique. The flow of petroleum through the porous ground represents an example of the motion of our fluid especially in the motion of the fluid in the earth’s core. Garg and Singh (2014) have been analyzed hydro-magnetic mixed convection flow through a porous medium in a hot vertical channel with span wise Co sinusoidal temperature and Heat Radiation. Kishan Naikoti and Meenakshi Vadithya (2014) have been studied thermal radiation effects on Magnetohydordynamic flow and heat transfer in a channel with porous walls of different permeability. Agarwal et al. (2016) have been investigated Magnetohydordynamic flow in a channel with a porous bounding wall. They have been obtained the solution of non-linear differential equation by perturbation technique and found the effects of magnetic fields and other variables such as Reynolds number slip coefficient and width of the channel on the fluid velocity.

Presently we have investigated the Bujurke et al. (2010) research paper who has been studied the analysis of laminar flow in a channel with one porous bounding wall. The objective of this investigation is to study the effect of permeability parameter, on fluid, moving in a channel surrounded by a porous wall. The effects of other parameters such as slip coefficient, Reynolds No., etc., have been shown in these results with the help of graphs.

2. Mathematical Formulation

The study of a viscous fluid in channel flow is considered in which the fluid flowing between parallel porous and rigid walls. The origin is assumed at the center of the channel and let x and y be the coordinate axes parallel and perpendicular to the channel walls. The length of the channel is assumed to be L and h is the distance between the two parallel porous and rigid wall, u and v be the velocity components in the x-direction and y directions, respectively.

Let $\eta = y/h$ be the dimensionless variable, then the continuity and momentum equation are

$$\frac{\partial u}{\partial x} + \frac{1}{h}\frac{\partial v}{\partial \eta} = 0 \qquad (1)$$

$$u\frac{\partial u}{\partial x} + \frac{v}{h}\frac{\partial u}{\partial \eta} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\left(\frac{\partial^2 u}{\partial x^2} + \frac{1}{h^2}\frac{\partial^2 u}{\partial \eta^2}\right) - \frac{\mu}{\rho\kappa}u \qquad (2)$$

$$u\frac{\partial v}{\partial x} + \frac{v}{h}\frac{\partial v}{\partial \eta} = -\frac{1}{\rho h}\frac{\partial p}{\partial \eta} + \frac{\mu}{\rho}\left(\frac{\partial^2 v}{\partial x^2} + \frac{1}{h^2}\frac{\partial^2 v}{\partial \eta^2}\right) - \frac{\mu}{\rho\kappa}u \qquad (3)$$

where, κ represents thermal conductivity, p represents Pressure, ρ represents density of fluid, μ represents the viscosity of fluids and this equation is also known as Navier Stoke's equation.

The boundary conditions are

$$u(x,0) = 0, \quad v(x,0) = 0 \qquad (4)$$

$$u(x,1) = V \quad (constant) \qquad (5)$$

$$u(x,1) = -\phi\frac{\partial u}{\partial \eta} \qquad (6)$$

We know that the stream function represented by $\psi(x,y)$ and the equation is

$$u = \frac{\partial \psi}{\partial y} \quad \& \quad v = -\frac{\partial \psi}{\partial x} \qquad (7)$$

Making the dimensionless of equation (10), by introducing the dimensionless variable $\eta = y/h$

We get

$$u = \frac{1}{h}\frac{\partial \psi}{\partial \eta} \quad \& \quad v = -\frac{\partial \psi}{\partial x} \tag{8}$$

We assume he stream function for the flow, as Terril and Shrestha (1965)

$$\psi(x,\ \eta) = (hU - V\,x)\,f'(\eta) \tag{9}$$

Where U is the average entrance velocity of viscous fluid at $x = 0$, from (9), the velocity components of u and v are given by the equation

$$u = \left[U - \frac{Vx}{h}\right] f'(\eta) \tag{10}$$

$$v = V\,f(\eta) \tag{11}$$

From Navier Stokes equation (2), (3) and eliminating p and using the equation (10) and (11), we get

$$Re[f'f'' - ff''' - r\,f''] + f^{iv} = 0$$

or

$$Re\,\frac{d}{d\lambda}[f'^2 - ff'' - r\,f'] + f^{iv} = 0 \tag{12}$$

Integrating above differential equation, we get

$$Re\,[f'^2 - ff'' - r\,f'] + f''' = A \tag{13}$$

Let $Re = \frac{V\rho h}{\mu}$ be represents the Reynolds Number of the suction, $r = h\mu/\rho\kappa$ is constant and K = r Re represents the permeability parameter of the porous medium.

The above differential equation is Non-linear differential equation and solving by using perturbation method. The boundary condition of $f(\eta)$ are

$$\left.\begin{aligned} f_n &= 0 \ \ at \ \ \eta = 0 \ \ \forall \ \ n \geq 0 \\ f_n^{'} &= 0 \ \ at \ \ \eta = 0 \ \ \forall \ \ n \geq 0 \end{aligned}\right\} \tag{14}$$

$$\left.\begin{aligned} f_0 = 1,\ f_n &= 0 \ \ at \ \ \eta = 1 \ \ \forall \ \ n \geq 1 \\ f_n^{'} + \phi f_n^{''} &= 0 \ \ at \ \ \eta = 1 \ \ \forall \ \ n \geq 0 \end{aligned}\right\} \tag{15}$$

The process of solving the differential equation (13) is given below by Perturbation method.

3. Method of Solution

In this study, we used the perturbation technique for the solution of the non-linear differential equations. The solution of the above non-linear differential equation (13) under the conditions (14) and (15) has been used. Here we choose a special case study when Re. r = K for small and Large Reynolds number Re, the approximate analytic solution can be obtained by using the perturbation technique. In this situation $f(\eta)$ may be expanded in the form

Let $f(\eta) = f_0(\eta) + \mathrm{Re} f_1(\eta) + \mathrm{Re}^2 f_2(\eta) + \cdots = \sum_{n=0}^{\infty} Re^n f_n(\eta),$ (16)

And $A = A_0 + A_1 Re^1 + A_2 Re^2 + \ \ldots \ = \sum_{n=0}^{\infty} A_n R^n$, (17)

Putting the value of $f(\lambda)$ & A in above equation (19), we get

$$Re\left[\left(f_0'(\eta) + Re^1 f_1'(\eta) + \mathrm{Re}^2 f_2'(\eta) + \cdots\right)^2 - \left(f_0(\eta) + Re^1 f_1(\eta) + \mathrm{Re}^2 f_2(\eta) + \cdots\right).\left(f_0''(\eta) + Re^1 f_1''(\eta) + \mathrm{Re}^2 f_2''(\eta) + \cdots\right) - r\left(f_0'(\eta) + Re^1 f_1'(\eta) + \mathrm{Re}^2 f_2'(\eta) + \cdots\right)\right] + f_0'''(\eta) + Re^1 f_1'''(\eta) + \mathrm{Re}^2 f_2'''(\eta) + \cdots = A_0 + A_1 Re^1 + A_2 Re^2 + \cdots \quad . \quad (18)$$

Taking the coefficient of Re^0, Re^1 and Re^2 from equation (18), we get

$$f_0''' = A_0 \quad , \quad (19)$$

$$f_1''' = A_1 + f_0 f_0'' - f_0'^2 + r f_0' \quad , \quad (20)$$

$$f_2''' = A_2 + f_0 f_1'' + f_1 f_0'' - 2 f_0' f_1' + r f_1' \ . \quad (21)$$

Solving the equation (19), (20) and (21), using the boundary condition (14) and (15), we get

$$f_1 = -\frac{2(1+\phi)}{(1+4\phi)}\eta^3 + \frac{3(1+2\phi)}{(1+4\phi)}\eta^3 \quad , \quad (22)$$

$$f_1 = -\frac{2(1+\phi)^2}{35(1+4\phi)^2}\eta^7 + \frac{(1+\phi)(1+2\phi)}{5\,(1+4\phi)^2}\eta^6 - \frac{3(1+2\phi)^2}{10\,(1+4\phi)^2}\eta^5 + \frac{(27+270\,\phi+808\,\phi^2+880\phi^3)}{70(1+4\phi)^3}\eta^3 - \frac{(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{35(1+4\phi)^3}\eta^2 + r\left[-\frac{(1+\phi)}{10\,(1+4\phi)}\eta^5 + \frac{(1+2\phi)}{4(1+4\phi)}\eta^4 - \frac{(3+21\,\phi+48\,\phi^2)}{15(1+4\phi)^2}\eta^3 + \frac{(1+8\,\phi+32\,\phi^2)}{20(1+4\phi)^2}\eta^2\right], \quad (23)$$

$$f_2 = \frac{24(1+\phi)^3}{34650(1+4\phi)^3}\,\eta^{11} - \frac{96(1+\phi)^2(1+2\phi)}{25200(1+4\phi)^3}\,\eta^{10} + \frac{24\,(1+\phi)(1+2\,\phi)^2}{5040(1+4\phi)^3}\,\eta^9 - \frac{18(1+2\phi)^3}{3360\,(1+4\phi)^3}\,\eta^8 +$$
$$\frac{6\,(1+\phi)(27+270\,\phi+808\,\phi^2+880\,\phi^3)}{7350\,(1+4\,\phi)^4}\,\eta^7 - \frac{(226+2226\,\phi+10968\,\phi^2+162208\,\phi^3+13056\,\phi^4)}{4200\,(1+4\phi)^4}\,\eta^6 +$$
$$\frac{(1+2\,\phi)(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{175\,(1+4\,\phi)^4}\eta^5 +$$
$$\frac{(925691+10148227\,\phi+56675432\,\phi^2+7425066092\,\phi^3+1337928760\,\emptyset^4+101877040\,\emptyset^5)}{323400\,(1+4\phi)^5}\eta^3 -$$
$$\frac{(1858001+20497820\,\phi+114502856\,\phi^2+14830885430\,\phi^3+2590851280\,\emptyset^4+202973760\,\emptyset^5)}{646800\,(1+4\phi)^5}\eta^2 + r\Big[-\frac{12(1+\phi)^2}{5040(1+4\phi)^2}\,\eta^9 +$$
$$\frac{36(1+\phi)(1+2\phi)}{3360\,(1+4\phi)^2}\eta^8 - \frac{18(3+24\,\phi+64\,\phi^2+48\,\phi^3)}{2100\,(1+4\,\phi)^3}\eta^7 + \frac{(29+261\,\phi+920\,\phi^2+928\,\phi^3)}{1200\,(1+4\,\phi)^3}\eta^6 + \frac{(39+390\,\phi+408\,\phi^2-48\,\phi^3)}{4200\,(1+4\,\phi)^3}\eta^5 -$$
$$\frac{(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{420\,(1+4\,\phi)^3}\eta^4 + \frac{(10280+395600\,\phi+4201904\,\phi^2+1315562\,\emptyset^3+16259097\,\emptyset^4)}{235200\,(1+4\phi)^4}\eta^3 +$$
$$\frac{(2956+386052\,\phi+4337504\,\phi^2+1615210\,\emptyset^3+16551961\,\emptyset^4)}{235200\,(1+4\phi)^4}\eta^2\Big] + r^2\Big[-\frac{5(1+\phi)}{2100(1+4\phi)}\,\eta^7 + \frac{4(1+2\,\phi)}{600(1+4\phi)}\,\eta^6 -$$
$$\frac{3(3+21\,\phi+48\,\phi^2)}{900\,(1+4\,\phi)^2}\eta^5 + \frac{(1+8\,\phi+32\,\phi^2)}{240\,(1+4\,\phi)^2}\eta^4 + \frac{(29+377\,\phi+1388\,\phi^2+1824\,\phi^3)}{4200\,(1+4\phi)^3}\eta^3 + \frac{(71+878\,\phi+2920\,\phi^2+3072\,\phi^3)}{8400\,(1+4\phi)^3}\,\eta^2\Big],$$

(24)

Now putting the value of f_0, f_1 and f_2 in equation (16) we get

$$f(\eta) = -\frac{2(1+\phi)}{1+4\phi}\,\eta^3 + \frac{3(1+2\phi)}{1+4\phi}\,\eta^2 +$$

$$Re\Big[-\frac{2(1+\phi)^2}{35(1+4\phi)^2}\,\eta^7 + \frac{(1+\phi)(1+2\phi)}{5\,(1+4\phi)^2}\,\eta^6 - \frac{3(1+2\phi)^2}{10\,(1+4\phi)^2}\,\eta^5 + \frac{(27+270\,\phi+808\,\phi^2+880\phi^3)}{70(1+4\phi)^3}\,\eta^3 -$$
$$\frac{(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{35(1+4\phi)^3}\eta^2\Big] + K\Big[-\frac{(1+\phi)}{10\,(1+4\phi)}\,\eta^5 + \frac{(1+2\phi)}{4(1+4\phi)}\,\eta^4 - \frac{(3+21\,\phi+48\,\phi^2)}{15(1+4\phi)^2}\,\eta^3 + \frac{(1+8\,\phi+32\,\phi^2)}{20(1+4\phi)^2}\eta^2\Big] +$$
$$Re^2\Big[\frac{24(1+\phi)^3}{34650(1+4\phi)^3}\,\eta^{11} - \frac{96(1+\phi)^2(1+2\phi)}{25200(1+4\phi)^3}\,\eta^{10} + \frac{24\,(1+\phi)(1+2\,\phi)^2}{5040(1+4\phi)^3}\,\eta^9 - \frac{18(1+2\phi)^3}{3360\,(1+4\phi)^3}\,\eta^8 +$$
$$\frac{6\,(1+\phi)(27+270\,\phi+808\,\phi^2+880\,\phi^3)}{7350\,(1+4\,\phi)^4}\,\eta^7 - \frac{(226+2226\,\phi+10968\,\phi^2+162208\,\phi^3+13056\,\phi^4)}{4200\,(1+4\phi)^4}\,\eta^6 +$$
$$\frac{(1+2\,\phi)(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{175\,(1+4\,\phi)^4}\eta^5 +$$
$$\frac{(925691+10148227\,\phi+56675432\,\phi^2+7425066092\,\phi^3+1337928760\,\emptyset^4+101877040\,\emptyset^5)}{323400\,(1+4\phi)^5}\eta^3 -$$
$$\frac{(1858001+20497820\,\phi+114502856\,\phi^2+14830885430\,\phi^3+2590851280\,\emptyset^4+202973760\,\emptyset^5)}{646800\,(1+4\phi)^5}\eta^2\Big] +$$
$$Re\,.\,K\Big[-\frac{12(1+\phi)^2}{5040(1+4\phi)^2}\,\eta^9 + \frac{36(1+\phi)(1+2\phi)}{3360\,(1+4\phi)^2}\eta^8 - \frac{18(3+24\,\phi+64\,\phi^2+48\,\phi^3)}{2100\,(1+4\,\phi)^3}\eta^7 + \frac{(29+261\,\phi+920\,\phi^2+928\,\phi^3)}{1200\,(1+4\,\phi)^3}\eta^6 +$$
$$\frac{(39+390\,\phi+408\,\phi^2-48\,\phi^3)}{4200\,(1+4\,\phi)^3}\eta^5 - \frac{(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{420\,(1+4\,\phi)^3}\eta^4 +$$

$$\frac{\left(10280+395600\,\phi+4201904\,\phi^2+1315562\,\emptyset^3+16259097\,\emptyset^4\right)}{235200\,(1+4\phi)^4}\eta^3+$$

$$\left.\frac{\left(2956+386052\,\phi+4337504\,\phi^2+1615210\,\emptyset^3+16551961\,\emptyset^4\right)}{235200\,(1+4\phi)^4}\eta^2\right]+K^2\left[-\frac{5(1+\phi)}{2100(1+4\phi)}\,\eta^7+\frac{4(1+2\,\phi)}{600(1+4\phi)}\,\eta^6-\right.$$

$$\left.\frac{3\left(3+21\,\phi+48\,\phi^2\right)}{900\,(1+4\,\phi)^2}\eta^5+\frac{\left(1+8\,\phi+32\,\phi^2\right)}{240\,(1+4\,\phi)^2}\eta^4+\frac{\left(29+377\,\phi+1388\,\phi^2+1824\,\phi^3\right)}{4200\,(1+4\phi)^3}\eta^3+\frac{\left(71+878\,\phi+2920\,\phi^2+3072\,\phi^3\right)}{8400\,(1+4\phi)^3}\,\eta^2\right],$$

(25)

where, $K\ = Re\,.\,r = Re.\,h\mu/\kappa$, K is called Permeability parameter

Now putting K = 0 in above equation (25), we get Bujurke et al (2010) solution

$$f(\eta)=-\frac{2(1+\phi)}{1+4\phi}\,\eta^3+\frac{3(1+2\phi)}{1+4\phi}\,\eta^2+$$

$$Re\left[-\frac{2(1+\phi)^2}{35(1+4\phi)^2}\,\eta^7+\frac{(1+\phi)(1+2\phi)}{5\,(1+4\phi)^2}\,\eta^6-\frac{3(1+2\phi)^2}{10\,(1+4\phi)^2}\,\eta^5+\frac{(27+270\,\phi+808\,\phi^2+880\phi^3)}{70(1+4\phi)^3}\,\eta^3-\right.$$

$$\left.\frac{(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{35(1+4\phi)^3}\eta^2\right]++Re^2\left[\frac{24(1+\phi)^3}{34650(1+4\phi)^3}\,\eta^{11}-\frac{96(1+\phi)^2(1+2\phi)}{25200(1+4\phi)^3}\,\eta^{10}+\frac{24\,(1+\phi)(1+2\,\phi)^2}{5040(1+4\phi)^3}\,\eta^9-\right.$$

$$\frac{18(1+2\phi)^3}{3360\,(1+4\phi)^3}\,\eta^8+\frac{6\,(1+\phi)(27+270\,\phi+808\,\phi^2+880\,\phi^3)}{7350\,(1+4\,\phi)^4}\,\eta^7-\frac{(226+2226\,\phi+10968\,\phi^2+162208\,\phi^3+13056\,\phi^4)}{4200\,(1+4\phi)^4}\,\eta^6\ +$$

$$\frac{(1+2\,\phi)(8+88\,\phi+272\,\phi^2+312\,\phi^3)}{175\,(1+4\,\phi)^4}\eta^5+$$

$$\frac{\left(925691+10148227\,\phi+56675432\,\phi^2+7425066092\,\phi^3+1337928760\,\emptyset^4+101877040\,\emptyset^5\right)}{323400\,(1+4\phi)^5}\eta^3-$$

$$\left.\frac{\left(1858001+20497820\,\phi+114502856\,\phi^2+14830885430\,\phi^3+2590851280\,\emptyset^4+202973760\,\emptyset^5\right)}{646800\,(1+4\phi)^5}\eta^2\right]+\cdots\ . \qquad (26)$$

4. Results and Discussion

The main objective of this study was to find a solution to a viscous fluid in a channel with a porous bounding wall. In this we have used the perturbation technique for the solution of the non-linear differential equation, the graphs of the velocity against dimensionless variable have been plotted using constant values of slip coefficient, Reynolds number, permeability parameter, etc. Figure 1 and 2 show the variation of permeability parameter K; it is seen that increase of permeability parameter K (0.1, 0.3, 0.5, 0.7, 0.9 & 0.0, 0.3, 0.6, 0.9), velocity of fluid decreases sharply. Figure 3, & 4 is the variation of Reynolds number which show that the velocity of the fluid decreases sharply with the increase of Reynolds number; it also increases between the range of $1 \leq \eta \leq 1.2$. Figure 5, & 6 is also the variation of Reynolds number which show that the velocity of fluid decreases with the increase of Reynolds number in the interval of $0 \leq \eta \leq 1$. Figures 7, 8 & 9 is the graph, the variation of slip coefficient ϕ which depicts the velocity of fluid enhanced sharply with the increase of slip coefficient $\phi(0 \leq \phi \leq 1.6)$. Figure 10 & 11 is the graph variation of slip coefficient ϕ in the absence of permeable wall (K = 0) which gives the velocity of fluid increases sharply with the increase of slip coefficient ϕ $(0 \leq \phi \leq 1.6)$.

Figure 12 is the graph variation of slip coefficient ϕ in the absence of permeable wall (K = 0) which gives the velocity of fluid also increases slowly with the increase of slip coefficient ϕ $(0 \leq \phi \leq 1)$. Figure 13 is the graph of the velocity of fluid against slip coefficient and variation of permeability parameter has been studied from this graph; it is seen that the increase of permeability parameter velocity of fluid forms a constant velocity. Figure 14 is the graph of the velocity of fluid against slip coefficient and variation of Reynolds number has been analyzed from this graph; it has seen that the increase of Reynolds number velocity of fluid lacks slowly. Figure 15 is the graph of the velocity of fluid against permeability parameter K and variation of Reynolds number has been done from this graph; it found that the increase of Reynolds number velocity of the fluid decreases sharply.

Figure 16 is the graph of the velocity of fluid against permeability parameter K and the variation of slip coefficient has given; it is seen that the velocity of fluid increases sharply with the enhancement of slip coefficient. Figure 17 is the graph of the velocity of fluid against Reynolds number Re and variation of slip coefficient has given from this; it is seen that the velocity of fluid increases sharply with the enhancement of slip coefficient. Figure 18 is the graph of velocity of fluid against Reynolds number Re and variation of permeability parameter K has been obtained; it is analyzed that velocity of fluid increases sharply with decrease of permeability parameter K. The overall results of our analysis matches the results described in Bujurke et al. (2010) in the absence of permeable wall or permeable parameter (K = 0).

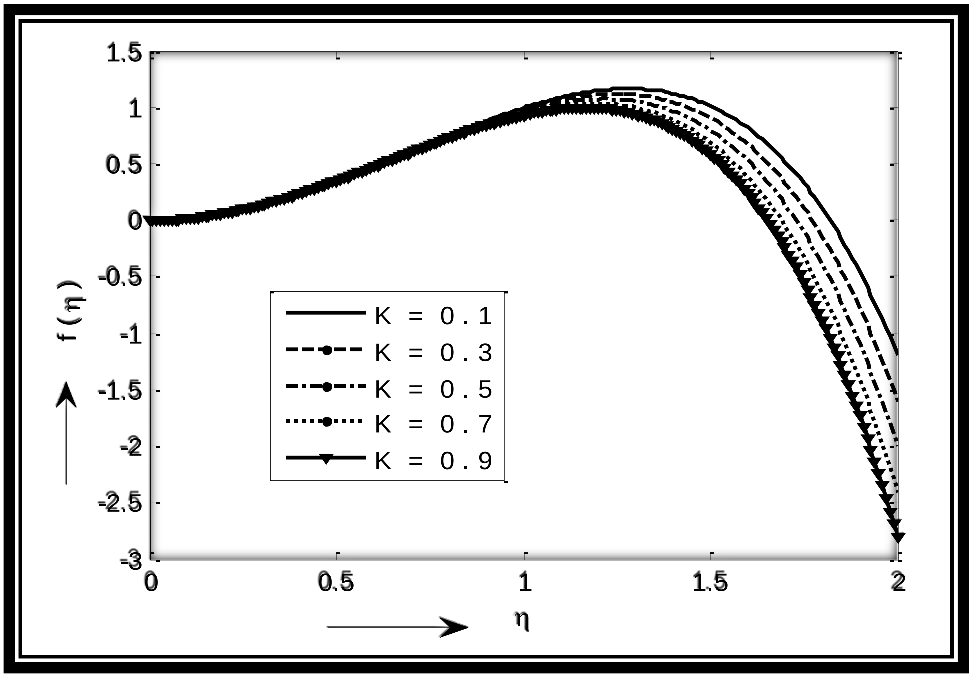

Fig 1: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (Re = 2; ϕ = 0.5) and variation of permeability parameter K (0.1, 0.3, 0.5, 0.7, 0.9)

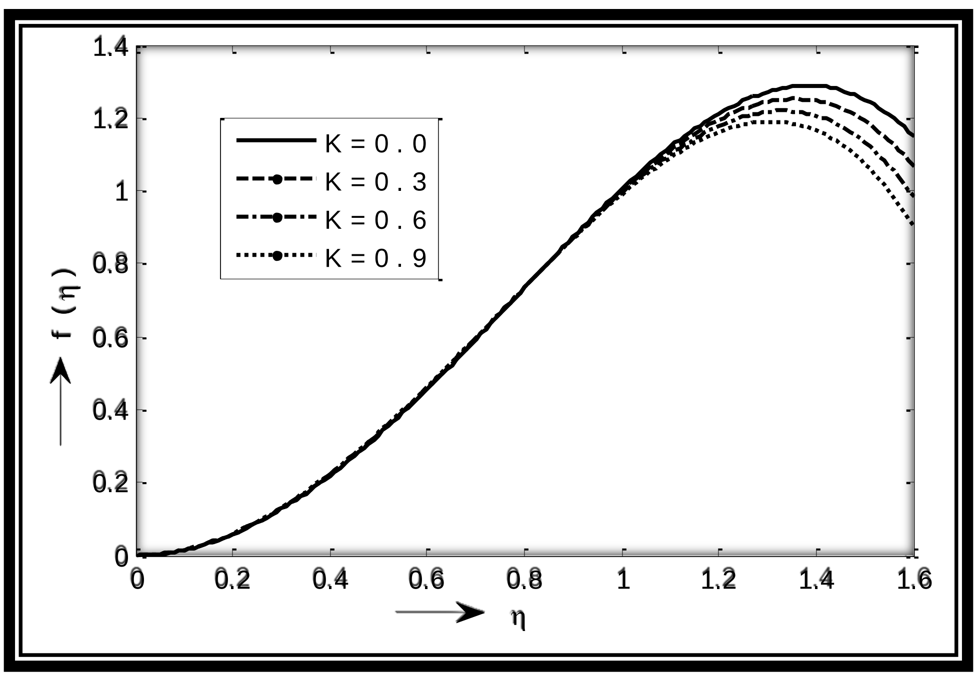

Fig 2: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (Re = 2; ϕ = 0.8) and variation of permeability parameter K (0.0, 0.3, 0.6, 0.9)

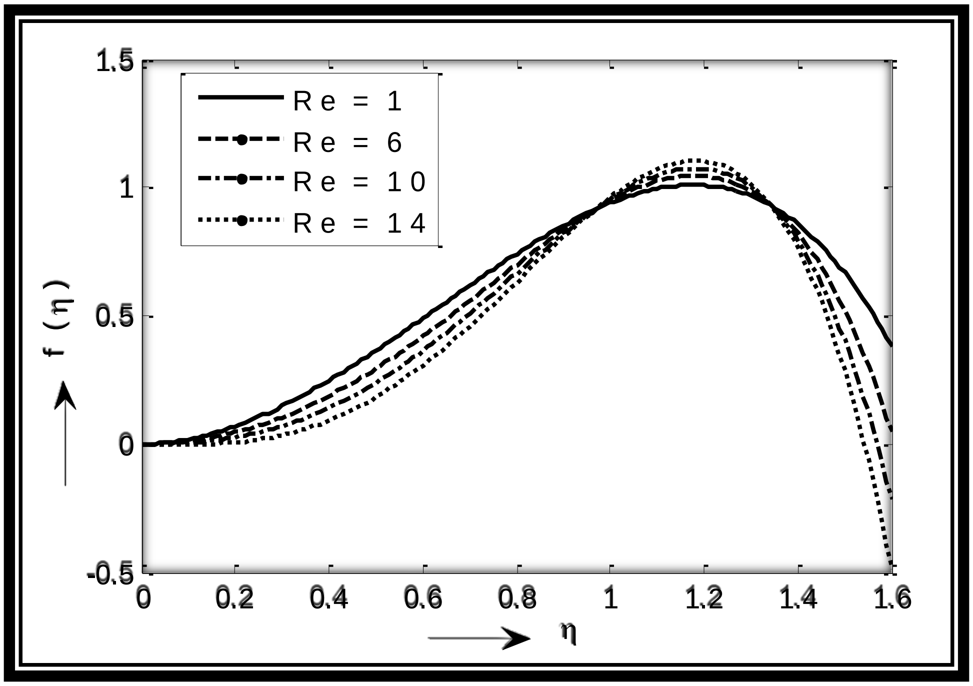

Fig 3: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; ϕ = 0.5) and variation of Reynolds number Re (1, 6, 10, 14)

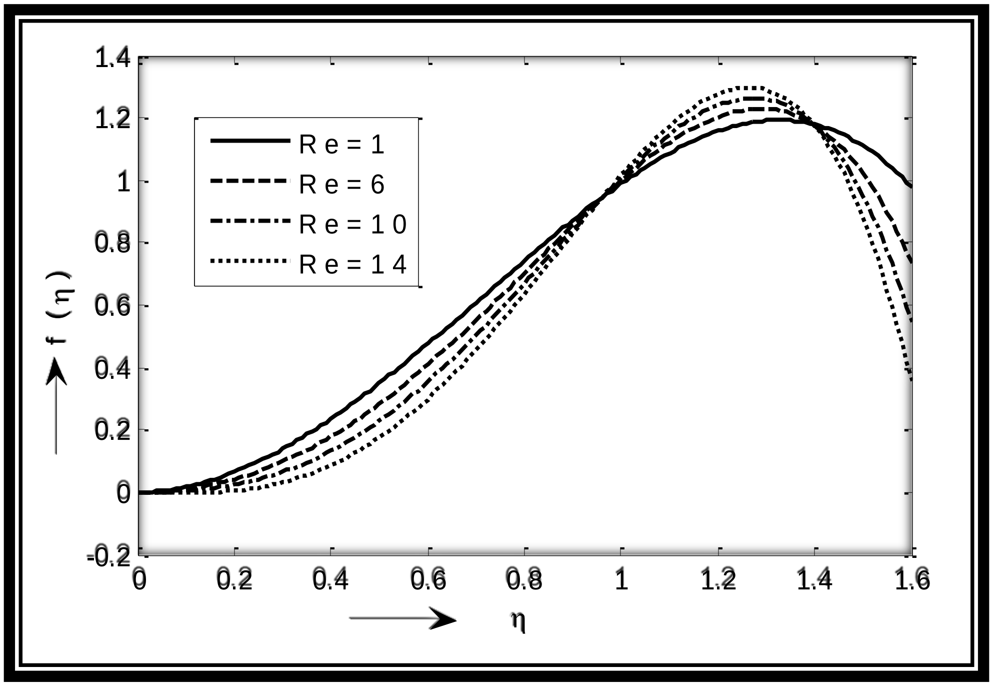

Fig 4: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; ϕ = 0.8) and variation of Reynolds number Re (1, 6, 10, 14)

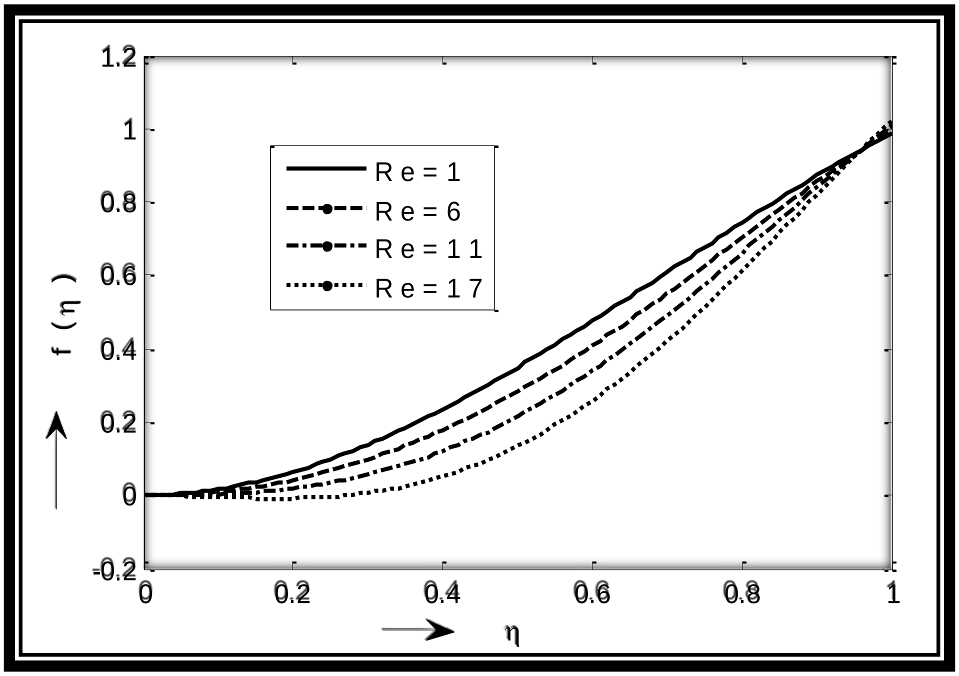

Fig 5: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; ϕ = 0.8) and variation of Reynolds number Re (1, 6, 10, 14)

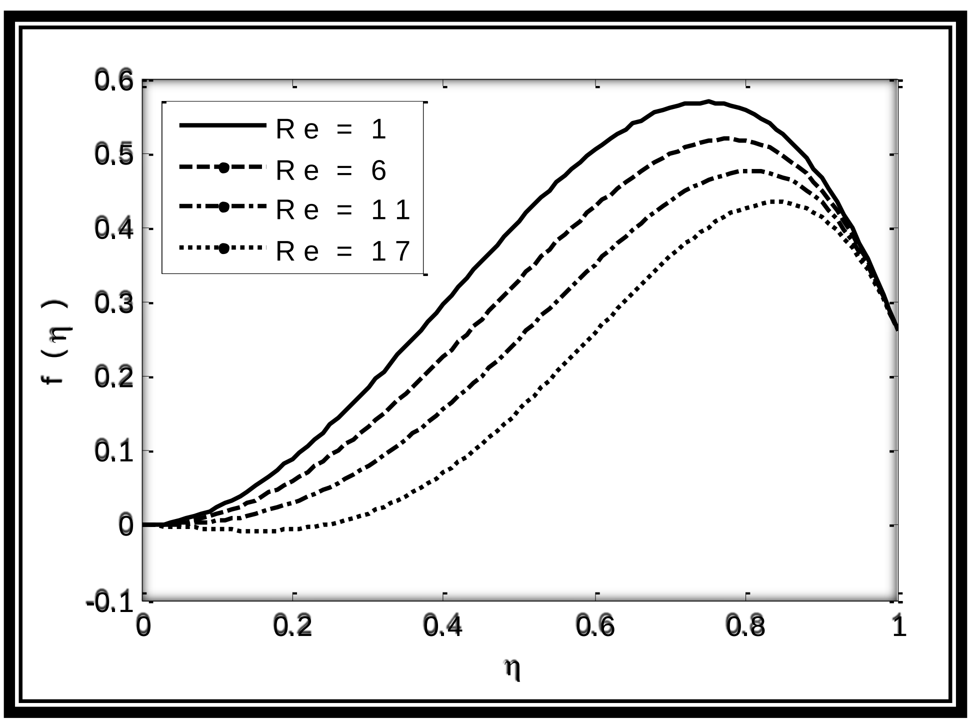

Fig 6: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; ϕ = 0.5) and variation of Reynolds number Re (1, 6, 11, 17)

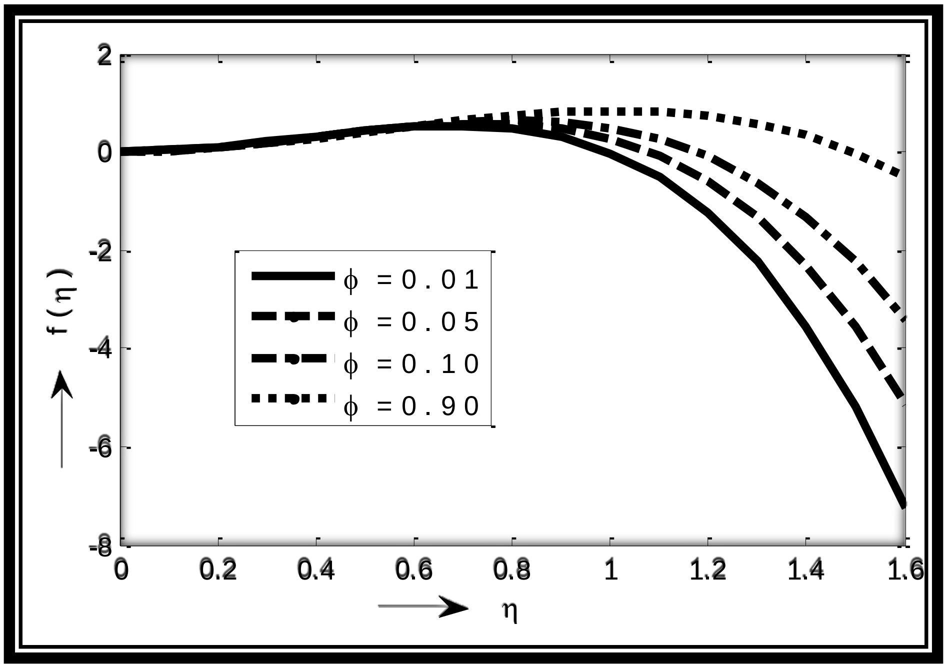

Fig 7: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.06; Re = 0.06) and variation of Slip coefficient ϕ (1, 6, 10, 14)

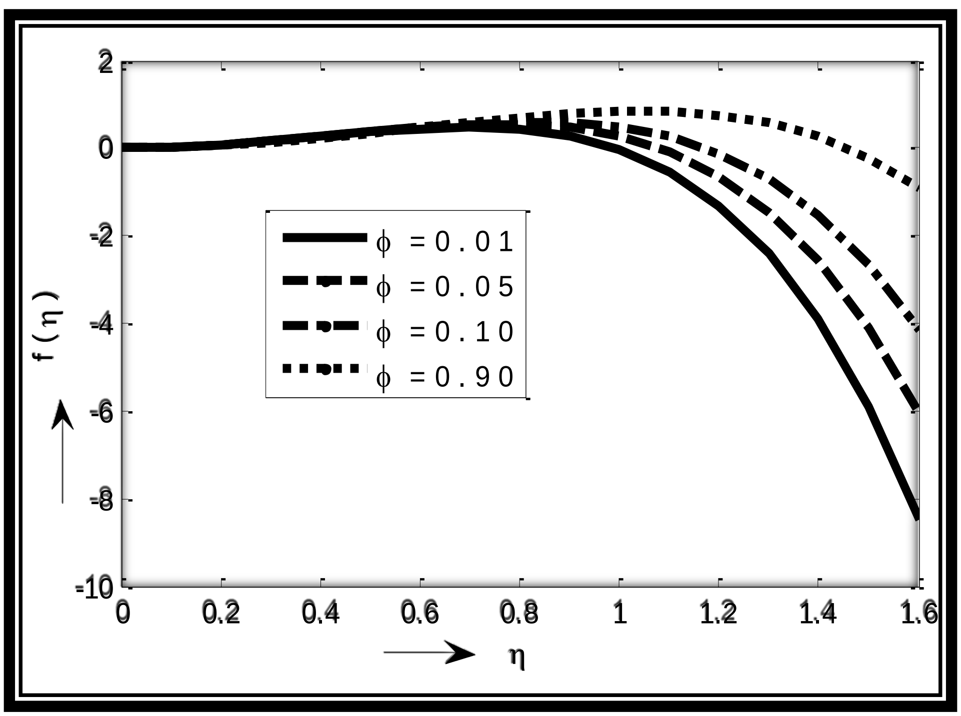

Fig 8: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; Re = 4.0) and variation of Slip coefficient ϕ (0.01, 0.05, 0.10 & 0.90)

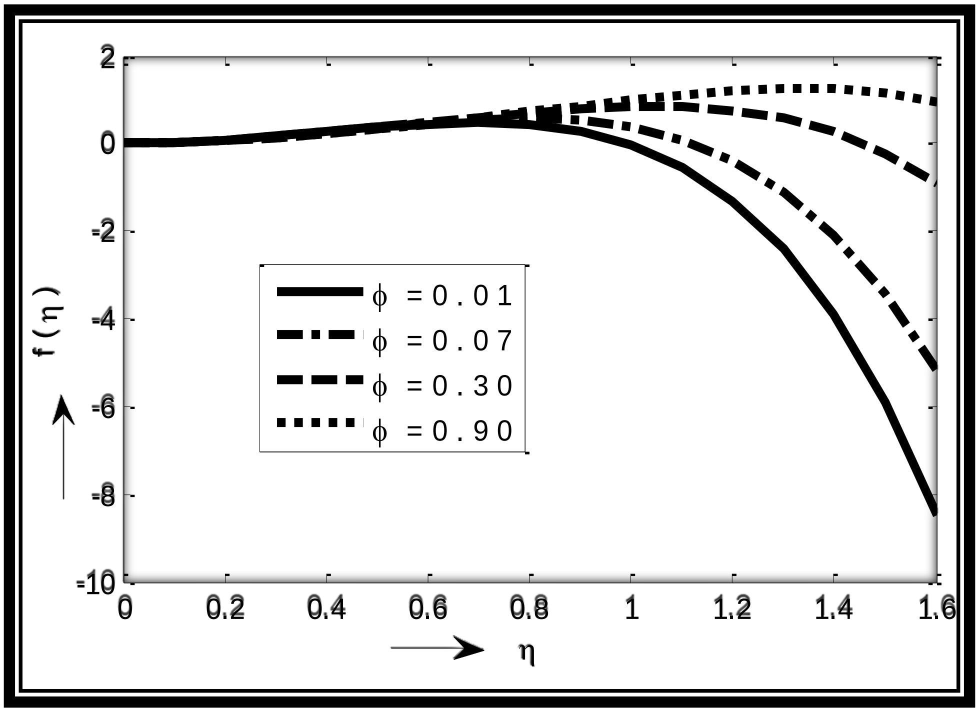

Fig 9: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.8; Re = 4.0) and variation of Slip coefficient ϕ (0.01, 0.05, 0.10 & 0.90)

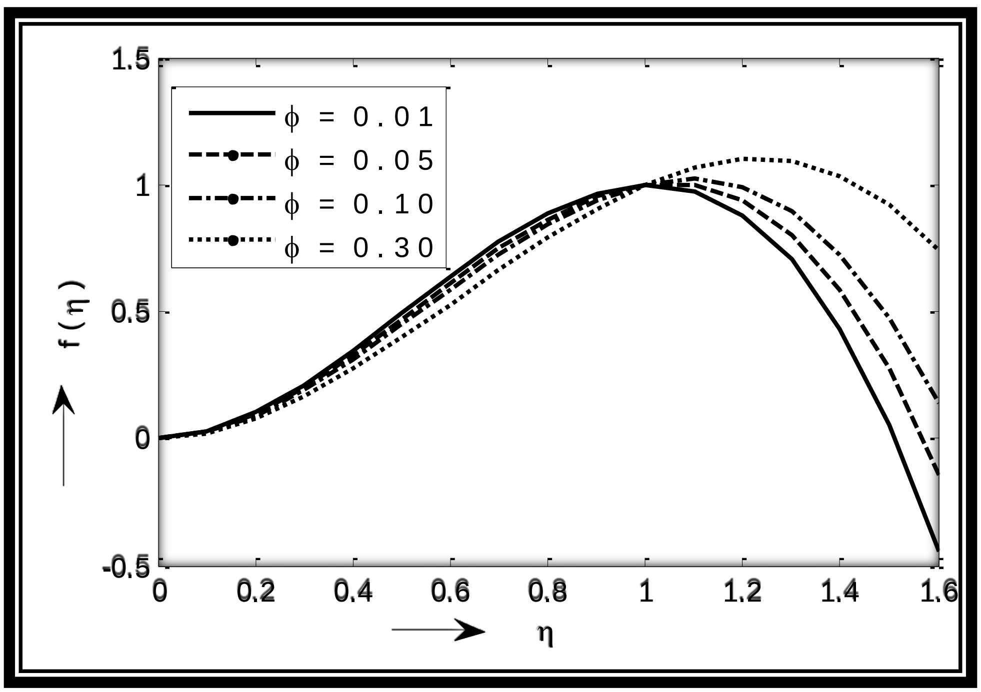

Fig 10: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.0; Re = 4.0) and variation of Slip coefficient ϕ (0.01, 0.05, 0.10 & 0.30)

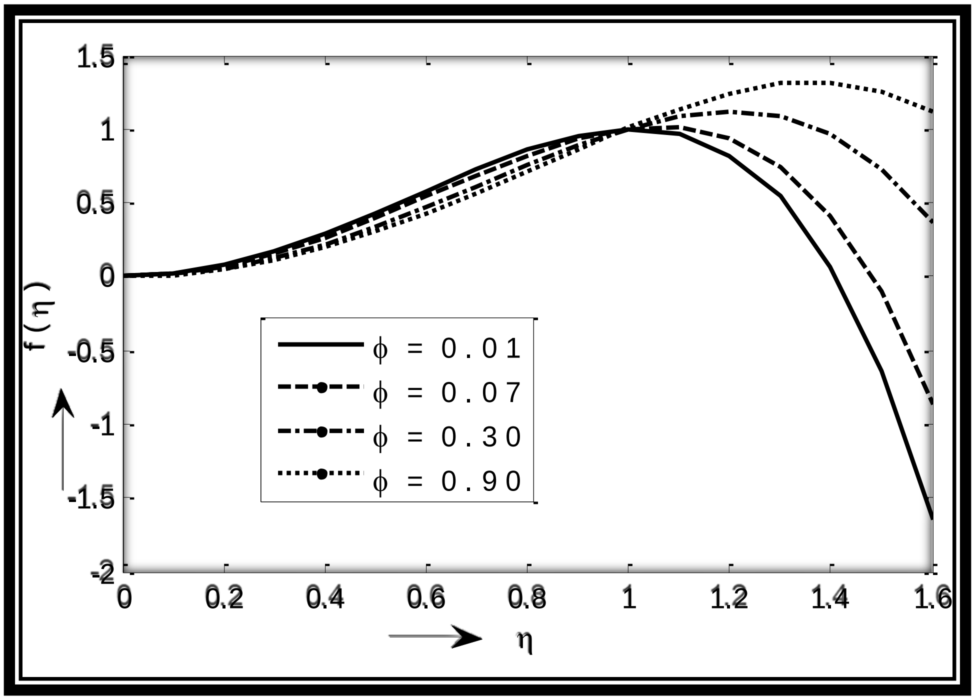

Fig 11: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.0; Re = 4.0) and variation of Slip coefficient ϕ (0.01, 0.07, 0.30 & 0.90)

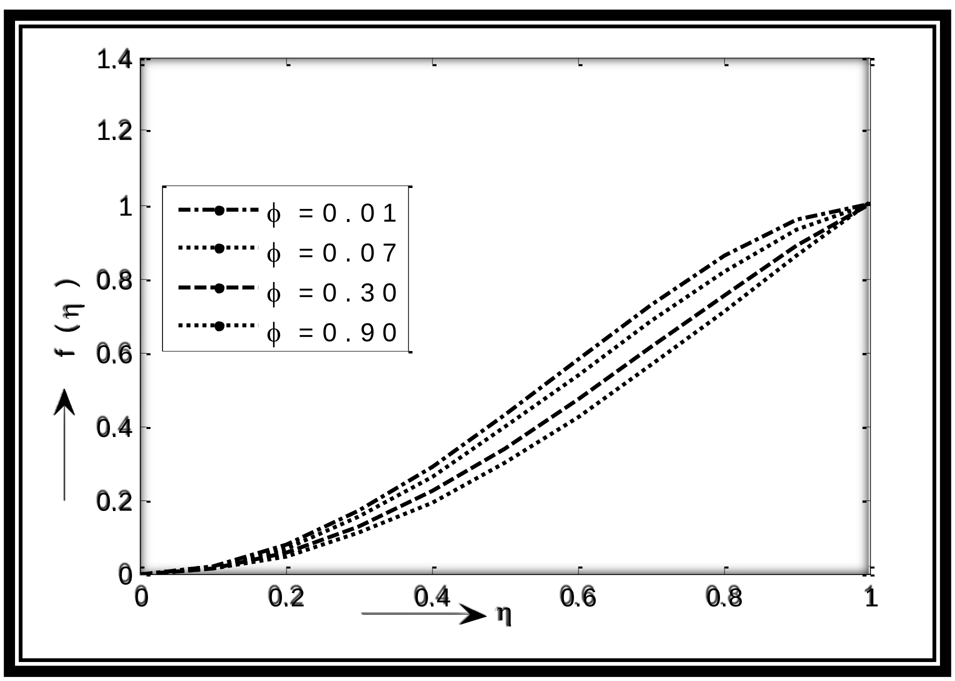

Fig 12: Velocity of fluid $f(\eta)$ against dimensionless variable η, at constant parameter (K = 0.0; Re = 4.0) and variation of Slip coefficient ϕ (0.01, 0.07, 0.30 & 0.90)

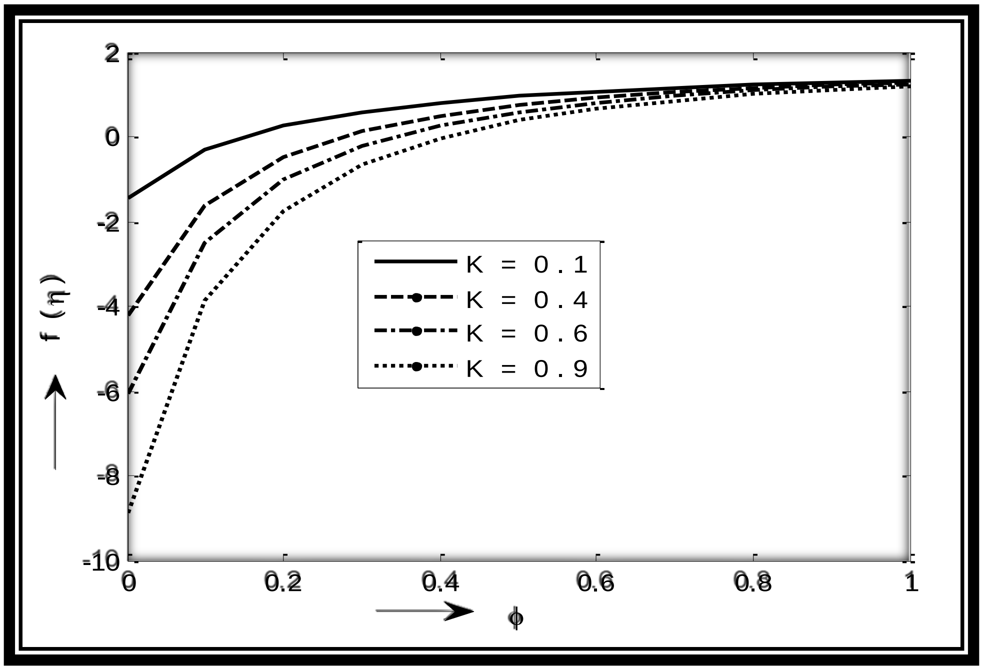

Fig 13: Velocity of fluid $f(\eta)$ against slip coefficient ϕ at constant parameter (η = 1.6; Re = 0.01) and variation of permeability coefficient K (0.1, 0.4, 0.6 & 0.9)

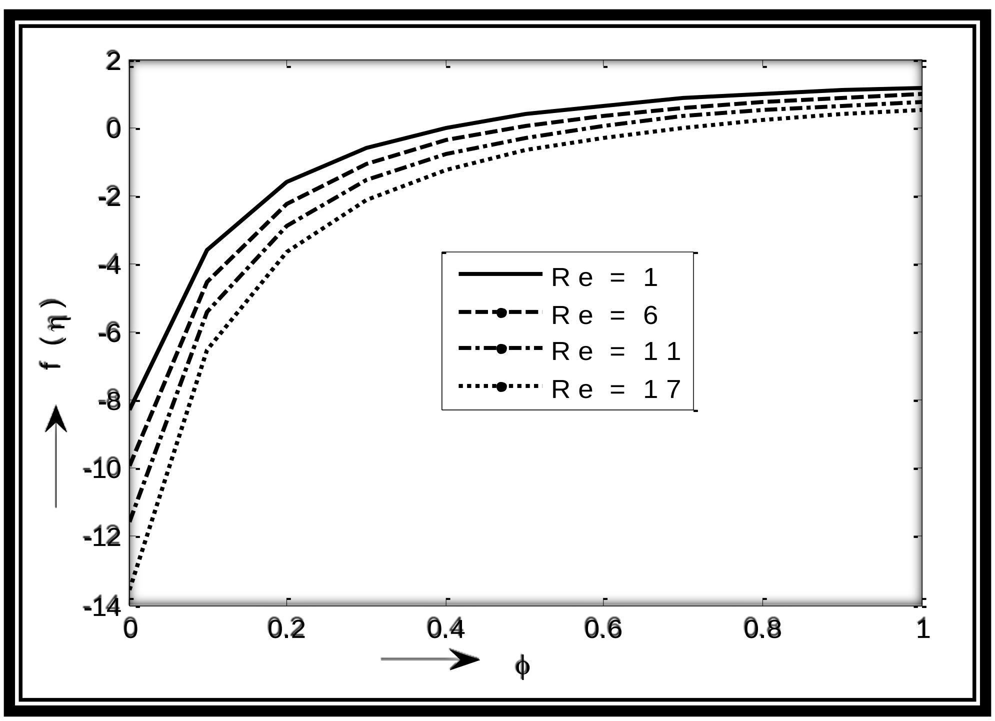

Fig 14: Velocity of fluid $f(\eta)$ against slip coefficient ϕ at constant parameter (η = 1.6; K = 0.8) and variation of Reynolds number Re (1, 6, 11, 17)

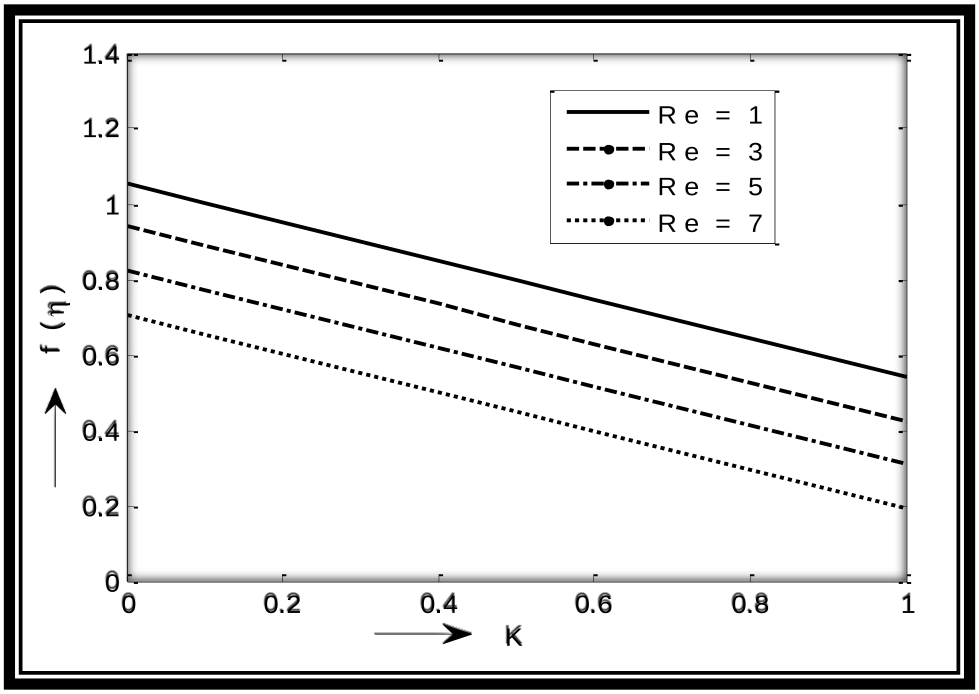

Fig 15: Velocity of fluid $f(\eta)$ against permeability parameter K at constant parameter (η = 1.6; ϕ = 0.6) and variation of Reynolds number Re (1, 3, 5, 7)

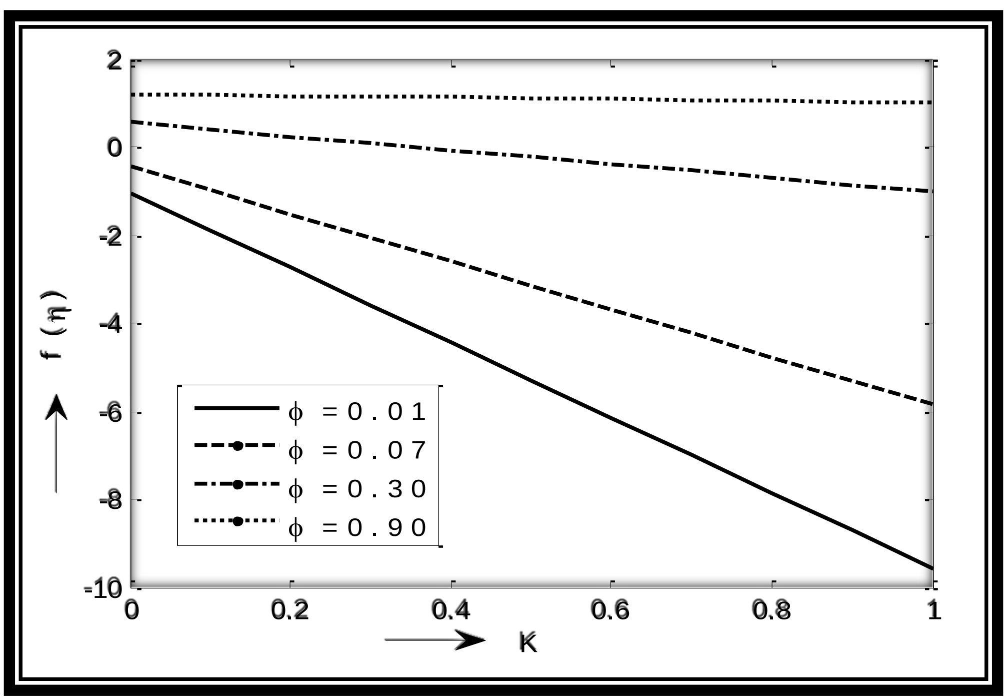

Fig 16: Velocity of fluid $f(\eta)$ against permeability parameter K at constant parameter (η = 1.6; Re= 2.0) and variation of slip coefficient ϕ (0.01, 0.07, 0.30, 0.90)

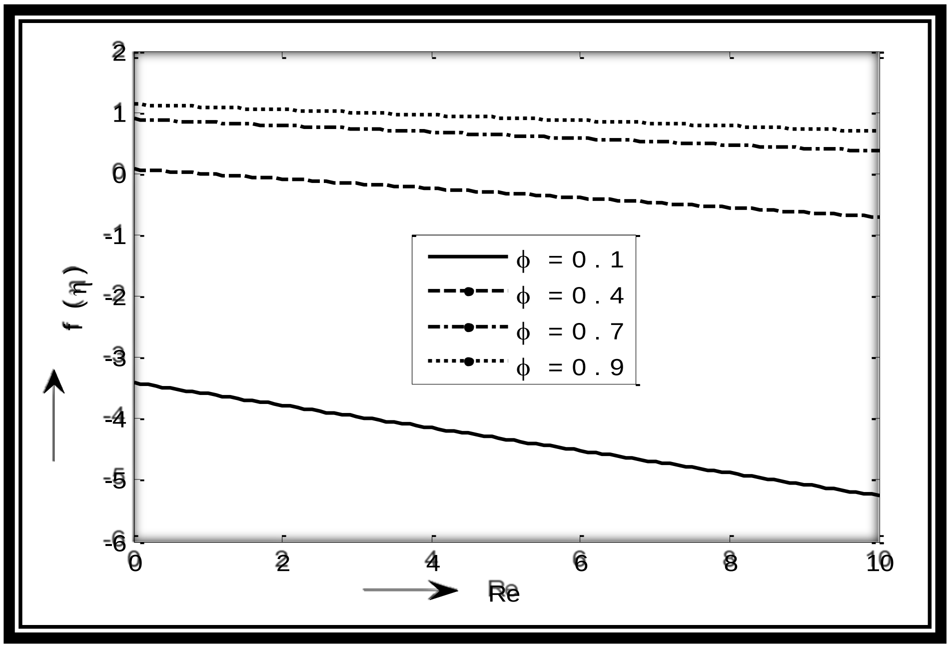

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Fig 17: Velocity of fluid $f(\eta)$ against Reynolds number Re at constant parameter (η = 1.6; K= 0.8) and variation of slip coefficient ϕ (0.1, 0.4, 0.7, 0.9)

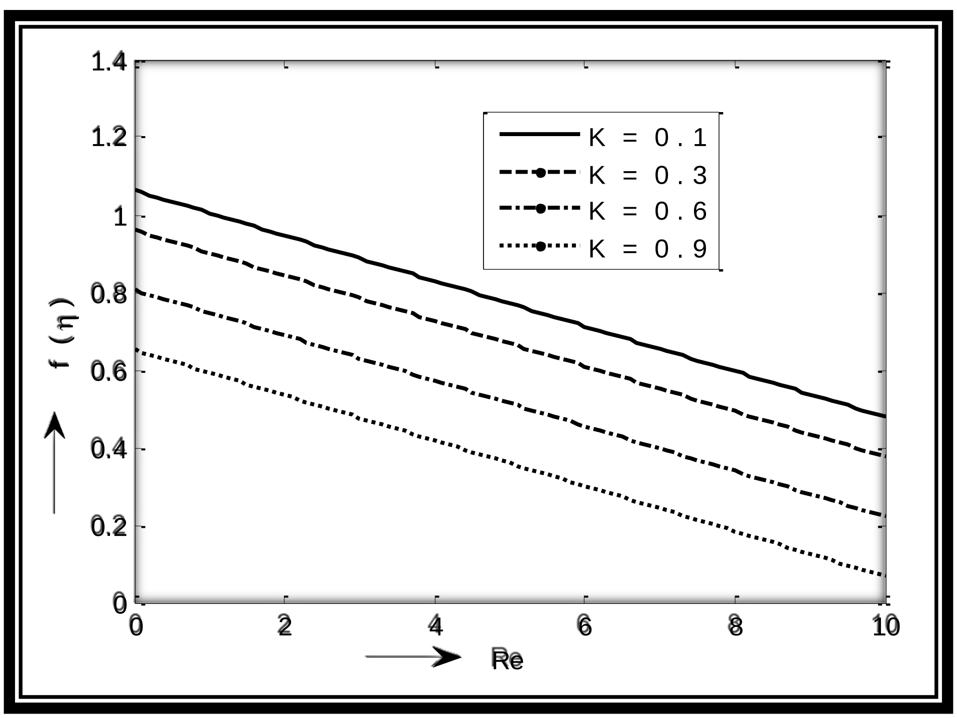

Fig 18: Velocity of fluid $f(\eta)$ against Reynolds number Re at constant parameter (η = 1.6; ϕ = 0.6) and variation of permeability parameter K(0.1, 0.4, 0.7, 0.9)

5. Conclusion

In this paper the objective is to investigate the effects of permeability parameter on the velocity of fluid with porous bounding wall and for the purpose the perturbation technique used. The enhancement of permeability parameter K velocity of fluid decreases sharply and similar effect with the increase of Reynolds number Re. it has been also seen that velocity of fluid increases sharply with increase of slip coefficient fluid. The application of incompressible viscous flow of fluid is in engineering and biological problem such as accelerators, electrostatics precipitation, electrostatic chemical filtration, petroleum industry, geothermal energy extraction and plasma studies etc

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