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Steady Plane Couette Flow of Viscous incompressible Fluid between two Porous Parallel Plates in magnetic field

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Abstract: In this paper we have investigated the steady plane Couette flow of viscous incompressible fluid between two porous parallel plates in magnetic field. We have studied the velocity, average velocity, shearing stress, skin frictions, the volumetric flow, drag coefficients and stream lines.
Keywords: Steady Couette flow, viscous parallel plates, incompressible fluid and magnetic field.

NOMENCLATURE

u = velocity component along x – axis
v = velocity component along y – axis
t = the time
ρ = the density of fluid
P = the fluid pressure
K= the thermal conductivity of the fluid
μ = Coefficient of viscosity
υ = Kinematic viscosity
Q = the volumetric flow

INTRODUCTION

We have investigated the steady plane Couette flow of viscous incompressible fluid between two porous parallel plates in magnetic field. Attempts have been made by several researchers i.e. M.G. Blyth & A.J. Mestel [1] Steady flow in a dividing Pipel. S. Bose & D. Dutta [2] Reflection of power in a pre-stressed dissipative layered crust. O. Botella & R.B. Peyret [3] Benchmark spectral results on the lid-driven cavity flow. S. Bottin, O. Dauchot & F. Daviaud [4] Intermittency in a locally forced plane Couette flow. S. Bottin, O. Dauchot, F. Daviau, & P. Manneville [5] Experimental evidence of streamwise vortices as finite amplitude solutions in transitional plane Couette flow. S. Bottin, F. Daviaud, P. Manneville & O. Dauchot [6] Discontinuous transition to spatiotemporal intermittency in plane Couette flow. S. Bottin, F. Daviaud, P. Manneville & O. Dauchot [7] Discontinuous transition to spatiotemporal intermittency in plane Couette flow. M.Bourich & M. Hasnaoui and A. Amahmid [8] Double-diffusive natural convection in a porous enclosure partially heated from below and differentially salted. S. N.Brown [9] Singularities associated with separating boundary layers. C. H. Bruneau, C. Jouron [10] an efficient scheme for solving steady incompressible Navier-stokes equations. N.M. Bujurke, N.P. Pai & P.K. Achar [11] Computer extended series solution to viscous flow between rotating discs. A. V. Bunyakin, S. I. Chernyshenko & G.Y. Stepanov [12] in viscid Batchelor-model flow past an airfoil with a vortex trapped in a cavity. J.M. Burgers [13] application of a model system to illustrate some points of the statistical theory of free turbulence. In this paper we have investigated the velocity, average velocity, shearing stress, skin frictions, the volumetric flow, drag coefficients and stream lines.

FORMULATION OF PROBLEM

Let us consider two infinite porous plates AB & CD separated by a distance 2h. The fluid enters in y - direction. The velocity component along x – axis is a function of y only. The motion of incompressible fluid is in two dimension and is steady then

$$u = u\ (y), \quad w = 0 \ \& \ \frac{\partial}{\partial t} = 0$$

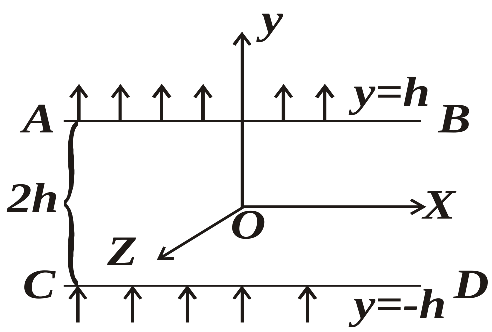
The equation of continuity for incompressible fluid

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \quad \text{and put w = 0,} \quad \frac{\partial u}{\partial x}=0 \quad \& \quad \Rightarrow \quad \frac{\partial v}{\partial y}=0$$

$\boldsymbol{v}$ is independent of $\boldsymbol{y}$ but motion along $\mathbf{y}$ – axis . So we can say v is constant velocity i.e. $\mathrm{v} = \mathrm{v}_0$

The fluid enters the flow region through one plate at the same constant velocity v_0

Also Navier - Stoke's equations for incompressible fluid in the absence of body force when flow is steady



$$v_0\frac{du}{dy}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\upsilon\frac{d^2u}{dy^2}+\frac{\sigma B_0^2\upsilon u}{\mu} \quad \text{.....} \ (1)$$

$$-\frac{1}{\rho}\frac{\partial p}{\partial y}=0 \ \text{...........} \ (2)$$

Figure-1

SOLUTION OF THE PROBLEM

Equation (2) Shows that the pressure does not depend on y hence p is a function of x only and so (1) reduces to

$$\frac{dp}{dx}=\rho\left[\upsilon\frac{d^2u}{dy^2}-v_0\frac{du}{dy}+\frac{\sigma B_0^2\upsilon u}{\mu}\right] \qquad \text{Where} \quad \frac{dp}{dx} = \text{Constant} = -\,\text{P}$$

$$\Rightarrow \frac{d^2u}{dy^2}-\frac{v_0}{\upsilon}\frac{du}{dy}+\frac{\sigma B_0^2 u}{\mu}=-\frac{P}{\mu} \qquad \Rightarrow \left(D^2-\frac{v_0}{\upsilon}D+\frac{\sigma B_0^2}{\mu}\right)u=-\frac{P}{\mu}$$

$$\text{A.E}\ \left(m^2-\frac{v_0}{\upsilon}m+\frac{\sigma B_0^2}{\mu}\right)=0 \quad \Rightarrow \quad m=\frac{\frac{v_0}{\upsilon}\pm\sqrt{\left(\frac{v_0}{\upsilon}\right)^2-\frac{4\sigma B_0^2}{\mu}}}{2} \qquad =\frac{v_0}{2\upsilon}\pm\sqrt{\left(\frac{v_0}{2\upsilon}\right)^2-\frac{\sigma B_0^2}{\mu}}$$

$$C.F.=e^{\frac{v_0}{2\upsilon}y}\left[c_1 Cosh\ Ay+c_2 Sinh\ Ay\right] \ , \quad P.I=-\frac{P}{\sigma B_0^2}$$

$$let\ A=\sqrt{\left(\frac{v_0}{2\upsilon}\right)^2-\frac{\sigma B_0^2}{\mu}} \quad and\ B=\frac{\sigma B_0^2}{\mu} \ \Rightarrow u(y)=e^{\frac{v_0}{2\upsilon}y}\left[c_1 Cosh\ Ay+c_2 Sinh\ Ay\right]-\frac{P}{B\mu}$$

Using boundary conditions: $\mathrm{u}=0$ at $\mathrm{y}=-\mathrm{h}$ and $\mathrm{u}=\mathrm{U}$ at $\mathrm{y}=\mathrm{h}$

$$e^{-\frac{v_0}{2\upsilon}h}\left[c_1 Cosh\ Ah-c_2 Sinh\ Ah\right]-\frac{P}{B\mu}=0 \ \text{.......} \ (3)$$

$$U=e^{\frac{v_0}{2\upsilon}h}\left[c_1 Cosh\ Ah+c_2 Sinh\ Ah\right]-\frac{P}{B\mu} \ \text{.......} \ (4)$$

$$\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}h}=c_1 Cosh\,Ah-c_2 Sinh\,Ah \quad \text{and} \quad \left(U+\frac{P}{B\mu}\right)e^{-\frac{v_0}{2\upsilon}h}=c_1 Cosh\,Ah+c_2 Sinh\,Ah$$

$$c_1 = \frac{1}{2Cosh\,Ah}\left[\left(U+\frac{P}{B\mu}\right)e^{-\frac{v_0}{2\upsilon}h}+\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}h}\right] \quad \& \quad c_2 = \frac{1}{2Sinh\,Ah}\left[\left(U+\frac{P}{B\mu}\right)e^{-\frac{v_0}{2\upsilon}h}-\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}h}\right]$$

$$u(y)=\frac{e^{\frac{v_0}{2\upsilon}y}Cosh\,Ay}{2Cosh\,Ah}\left\{\left(U+\frac{P}{B\mu}\right)e^{-\frac{v_0}{2\upsilon}h}+\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}h}\right\}+\frac{e^{\frac{v_0}{2\upsilon}y}Sinh\,Ay}{2Sinh\,Ah}\left\{\left(U+\frac{\rho}{B\mu}\right)e^{-\frac{v_0}{2\upsilon}h}-\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}h}\right\}-\frac{P}{B\mu}$$

$$u(y)=\left(U+\frac{P}{B\mu}\right)\frac{e^{\frac{v_0}{2\upsilon}(y-h)}Sinh\,A(y+h)}{2Sinh\,Ah\,Cosh\,Ah}-\frac{P}{B\mu}\frac{e^{\frac{v_0}{2\upsilon}(y+h)}Sinh\,A(y-h)}{2Sinh\,Ah\,Cosh\,Ah}-\frac{P}{B\mu}$$

$$u(y)=\frac{1}{Sinh\,2Ah}\left[\left(U+\frac{P}{B\mu}\right)e^{\frac{v_0}{2\upsilon}(y-h)}SinhA(y+h)-\frac{P}{B\mu}e^{\frac{v_0}{2\upsilon}(y+h)}SinhA(y-h)\right]-\frac{P}{B\mu} \quad \text{.........}(5)$$

Plane Couette flow: In this case P = 0

$$u(y)=\frac{1}{Sinh2Ah}\left[Ue^{\frac{v_0}{2\upsilon}(y-h)}SinhA(y+h)\right] \quad \text{................}(6)$$

The shearing stress at any point

$$\sigma_{xy}=\mu\frac{du}{dy}=\frac{\mu U}{Sinh2Ah}\left[\frac{v_0}{2\upsilon}e^{\frac{v_0}{2\upsilon}(y-h)}SinhA(y+h)+Ae^{\frac{v_0}{2\upsilon}(y-h)}CoshA(y+h)\right]$$

$$\sigma_{xy}=\frac{\mu Ue^{\frac{v_0}{2\upsilon}(y-h)}}{Sinh2Ah}\left[\frac{v_0}{2\upsilon}SinhA(y+h)+ACoshA(y+h)\right] \quad \text{.............}(7)$$

The skin frictions at Lower and Upper plate is given by

$$\left(\sigma_{xy}\right)_{y=h}=\frac{\mu Ue^{o}}{Sinh2Ah}\left[\frac{v_o}{2\upsilon}Sinh2Ah+ACosh2Ah\right]=\mu.U\left[\frac{v_0}{2\upsilon}+ACoth2Ah\right] \quad \text{.........}(8)$$

$$\left(\sigma_{xy}\right)_{y=-h}=\frac{\mu Ue^{-\frac{v_0}{\upsilon}h}}{Sinh2Ah}A=\frac{\mu UAe^{-\frac{v_0}{\upsilon}h}}{Sinh2Ah} \quad \text{...............}(9)$$

The average velocity distribution in plane couette flow:

$$(u)_{av}=\frac{1}{2h}\int_{-h}^{h}u(y)\,dy=\frac{1}{2h}\int_{-h}^{h}\frac{U}{Sinh2\,Ah}e^{\frac{v_0}{2\upsilon}(y-h)}SinhA(y+h)\,dy$$

$$=\frac{U}{2h\,Sinh\,2Ah}\int_{-h}^{h}e^{\frac{v_0}{2\upsilon}(y-h)}\left\{\frac{e^{A(y+h)}-e^{-A(y+h)}}{2}\right\}dy=\frac{U}{4hSinh2Ah}\int_{-h}^{h}\left\{e^{\frac{v_0}{2\upsilon}(y-h)+A(y+h)}-e^{\frac{v_0}{2\upsilon}(y-h)-A(y+h)}\right\}dy$$

$$=\frac{U}{4hSinh2Ah}\left\{\frac{e^{\frac{v_0}{2\upsilon}(y-h)+A(y+h)}}{\left(\frac{v_0}{2\upsilon}+A\right)}-\frac{e^{\frac{v_0}{2\upsilon}(y-h)-A(y+h)}}{\left(\frac{v_0}{2\upsilon}-A\right)}\right\}_{-h}^{h}=\frac{U}{4hSinh2Ah}\left[\frac{e^{2Ah}-e^{-\frac{v_0}{\upsilon}h}}{\left(\frac{v_0}{2\upsilon}+A\right)}-\frac{e^{-2Ah}-e^{-\frac{v_0}{\upsilon}h}}{\left(\frac{v_0}{2\upsilon}-A\right)}\right]$$

$$= \frac{U}{4h\,Sinh 2Ah}\left[\frac{\left(\frac{v_0}{2\upsilon} - A\right)\left[e^{2Ah} - e^{-\frac{v_0}{\upsilon}h}\right] - \left(\frac{v_0}{2\upsilon} + A\right)\left[e^{-2Ah} - e^{-\frac{v_0}{\upsilon}h}\right]}{\left\{\left(\frac{v_0}{2\upsilon}\right)^2 - A^2\right\}}\right]$$

$$Since\ \sqrt{\left(\frac{v_0}{2\upsilon}\right)^2 - \frac{\sigma B_0^2}{\mu}} = A \quad \Rightarrow \quad \left(\frac{v_0}{2\upsilon}\right)^2 - A^2 = \frac{\sigma B_0^2}{\mu} = B$$

$$(u)_{av} = \frac{U}{4Bh\ Sinh\ 2Ah}\left[\frac{v_0}{2\upsilon}\left\{e^{2Ah} - e^{-\frac{v_0}{\upsilon}h} - e^{-2Ah} + e^{-\frac{v_0}{\upsilon}h}\right\} - A\left\{e^{2Ah} - e^{\frac{v_0}{\upsilon}h} + e^{-2Ah} - e^{-\frac{v_0}{\upsilon}h}\right\}\right]$$

$$= \frac{U}{4Bh\ Sinh\ 2Ah}\left[\frac{v_0}{\upsilon} Sinh\ 2Ah - A\left\{2\ Cosh\ 2Ah - 2e^{\frac{v_0}{\upsilon}h}\right\}\right]$$

$$(u)_{av} = \frac{U}{2Bh\ Sinh\ 2Ah}\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah - A\left\{Cosh\ 2Ah - e^{-\frac{v_0}{\upsilon}h}\right\}\right] \quad \text{...........(10)}$$

The volumetric flow: $Q = 2h\ u_{av}$

$$Q = \frac{U}{B\,Sinh\ 2Ah}\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah - A\left\{Cosh\ 2Ah - e^{-\frac{v_0}{\upsilon}h}\right\}\right] \quad \text{.........(11)}$$

The drag coefficients: $C_f\ \&\ C_f^{'}\ at\ y = h\ \&\ y = -h$

$$C_f = \frac{\left(\sigma_{xy}\right)_{y=h}}{\frac{1}{2}\rho u^2{}_{av}} = \frac{\frac{\mu U}{Sinh\ 2Ah}\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah + ACosh\ 2Ah\right]}{\frac{1}{2}\rho \frac{U^2}{4B^2h^2 Sinh^2\ 2Ah}\left\{\frac{v_0}{2\upsilon} Sinh\ 2Ah - ACosh\ 2Ah + Ae^{-\frac{v_0}{\upsilon}h}\right\}^2}$$

$$C_f = \frac{8B^2h^2\mu\ Sinh\ 2Ah\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah + ACosh\ 2Ah\right]}{\rho U\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah - ACosh\ 2Ah + Ae^{-\frac{v_0}{\upsilon}h}\right]^2} \quad \text{................(12)}$$

$$C_f{'} = \frac{\left(\sigma_{xy}\right)_{y=-h}}{\frac{1}{2}\rho u^2{}_{av}} = \frac{\mu U A e^{-\frac{v_0}{\upsilon}h}}{Sinh\ 2Ah} \cdot \frac{8B^2h^2 Sinh^2\ 2Ah}{\rho U^2\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah - ACosh\ 2Ah + Ae^{-\frac{v_0}{\upsilon}h}\right]^2}$$

$$C_f{'} = \frac{8B^2\mu\ h^2 A\ e^{-\frac{v_0}{\upsilon}h}\ Sinh\ 2Ah}{\rho U\left[\frac{v_0}{2\upsilon} Sinh\ 2Ah - ACosh\ 2Ah + Ae^{\frac{v_0}{\upsilon}h}\right]^2} \quad \text{................(13)}$$

The stream line in the plane couette flow: $\dfrac{dx}{u} = \dfrac{dy}{v} = \dfrac{dz}{w}$, $\bar{q} = u\,\hat{i} + v\,\hat{j} + w\,\hat{k}$

$$\frac{dx}{\dfrac{U}{Sinh\ 2Ah} e^{\frac{v_0}{2\upsilon}(y-h)} SinhA\ (y+h)} = \frac{dy}{v_0} = \frac{dz}{o}$$

Taking first two equations

$$\frac{v_0 Sinh\ 2Ah}{U}\int dx = \int e^{\frac{v_0}{2\upsilon}(y-h)} Sinh\ A(y+h)\ dy + C_1 \Rightarrow \frac{v_0 Sinh\ 2Ah}{U} x - \int e^{\frac{v_0}{2\upsilon}(y-h)} \left\{\frac{e^{A(y+h)} - e^{-A(y+h)}}{2}\right\} dy = C_1$$

$$x\ \frac{v_0}{U}\ Sinh2\ Ah - \frac{1}{2}\int\left\{e^{\frac{v_0}{2\upsilon}(y-h)+A(y+h)} - e^{\frac{v_0}{2\upsilon}(y-h)-A(y+h)}\right\} dy = C_1$$

$$x\ \frac{v_0}{U} Sinh\ 2Ah - \frac{1}{2}\left[\frac{e^{\frac{v_0}{2\upsilon}(y-h)+A(y+h)}}{\left(\dfrac{v_0}{2\upsilon} + A\right)} - \frac{e^{\frac{v_0}{2\upsilon}(y-h)-A(y+h)}}{\left(\dfrac{v_0}{2\upsilon} - A\right)}\right] = C_1$$

$$\Rightarrow\ \frac{v_0}{U} Sinh\ 2Ah\ .\ x - \frac{1}{2B}\left[\left(\frac{v_0}{2\upsilon} - A\right)e^{\frac{v_0}{2\upsilon}(y-h)} e^{A(y+h)} - \left(\frac{v_0}{2\upsilon} + A\right)e^{\frac{v_0}{2\upsilon}(y-h)} e^{-A(y+h)}\right] = C_1$$

$$\Rightarrow\ \frac{v_0}{U} Sinh\ 2Ah\ .\ x - \frac{e^{\frac{v_0}{2\upsilon}(y-h)}}{2B}\left\{\frac{v_0}{2\upsilon}\left\{e^{A(y+h)} - e^{-A(y+h)}\right\} - A\left\{e^{A(y+h)} + e^{-A(y+h)}\right\}\right\} = C_1$$

$$\frac{v_0}{U} Sinh\ 2Ah\ .\ x - \frac{e^{\frac{v_0}{2\upsilon}(y-h)}}{2B}\left\{\frac{v_0}{\upsilon} Sinh\ A(y+h) - 2A\ Cosh\ A(y+h)\right\} = C_1$$

The first stream line of the plane couette flow:

$$\frac{v_0}{U} Sinh\ 2Ah\ .\ x - \frac{e^{\frac{v_0}{2\upsilon}(y-h)}}{B}\left\{\frac{v_0}{2\upsilon} Sinh\ A(y+h) - A\ Cosh\ A(y+h)\right\} = C_1 \quad \text{..........}(14)$$

The second stream line $\quad z = C_2 \quad$ .... (15)

Now the curl $\bar{q} = \begin{vmatrix} i & j & k \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ u & v & w \end{vmatrix} = \begin{vmatrix} i & j & k \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ \dfrac{U e^{\frac{v_0}{2\upsilon}(y-h)} Sinh\ A(y+h)}{Sinh\ 2Ah} & v_0 & o \end{vmatrix}$

$$= -\frac{U\ e^{\frac{v_0}{2\upsilon}(y-h)}}{Sinh\ 2Ah}\left[\frac{v_0}{2\upsilon} Sinh\ A(y+h) + ACosh\ A(y+h)\right]\hat{k} \neq \bar{0}$$

$\therefore$ **Motion of fluid is rotational**

Table for velocity: when **y** & **A** are vary and other are fixed

$$let \quad U=6, \quad \mu=.5, \quad \frac{v_0}{2\upsilon}=6, h=.5, \ \& \sqrt{\left(\frac{v_0}{2\upsilon}\right)^2-\frac{\sigma B_0^2}{\mu}}=A \ \ where \ \ \frac{\sigma B_0^2}{\mu}=B$$

Table-1 (for velocity)

A	y	0	0.1	0.2	0.3	0.4	0.5	0.6
1	u(y)	.132	.295	.64	1.367	2.88	6	12.42
2	u(y)	.092	.227	.52	1.184	2.67	6	13.44
3	u(y)	.063	.16	.398	.99	2.43	6	14.77
4	u(y)	.04	.11	.298	.811	2.21	6	16.31
5	u(y)	.024	.073	.221	.665	1.997	6	18.025

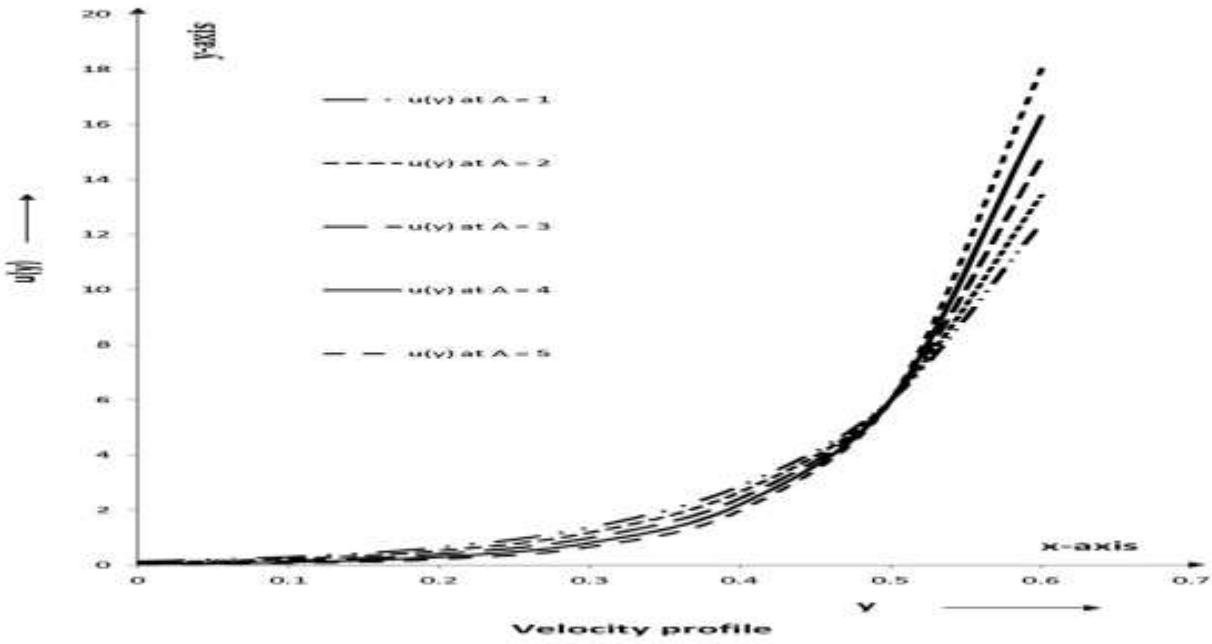


Figure-2

Table for skin friction: when **y** & **A** are vary and other are fixed

$$let \quad U=6, \quad \mu=.5, \quad \frac{v_0}{2\upsilon}=6, h=.5, \ \& \sqrt{\left(\frac{v_0}{2\upsilon}\right)^2-\frac{\sigma B_0^2}{\mu}}=A \ \ where \ \ \frac{\sigma B_0^2}{\mu}=B$$

Table-2 (for skin friction)

A	y	0	0.1	0.2	0.3	0.4	0.5	0.6
1	σ_{xy}	.541	1.159	2.45	5.125	10.64	21.94	45.04
2	σ_{xy}	.417	.95	2.15	4.835	10.84	24.22	54.08
3	σ_{xy}	.295	.733	1.81	4.46	10.99	27.04	66.54
4	σ_{xy}	.20	.549	1.49	4.06	11.04	30.01	81.57
5	σ_{xy}	.135	.405	1.22	3.66	10.98	33	99.14

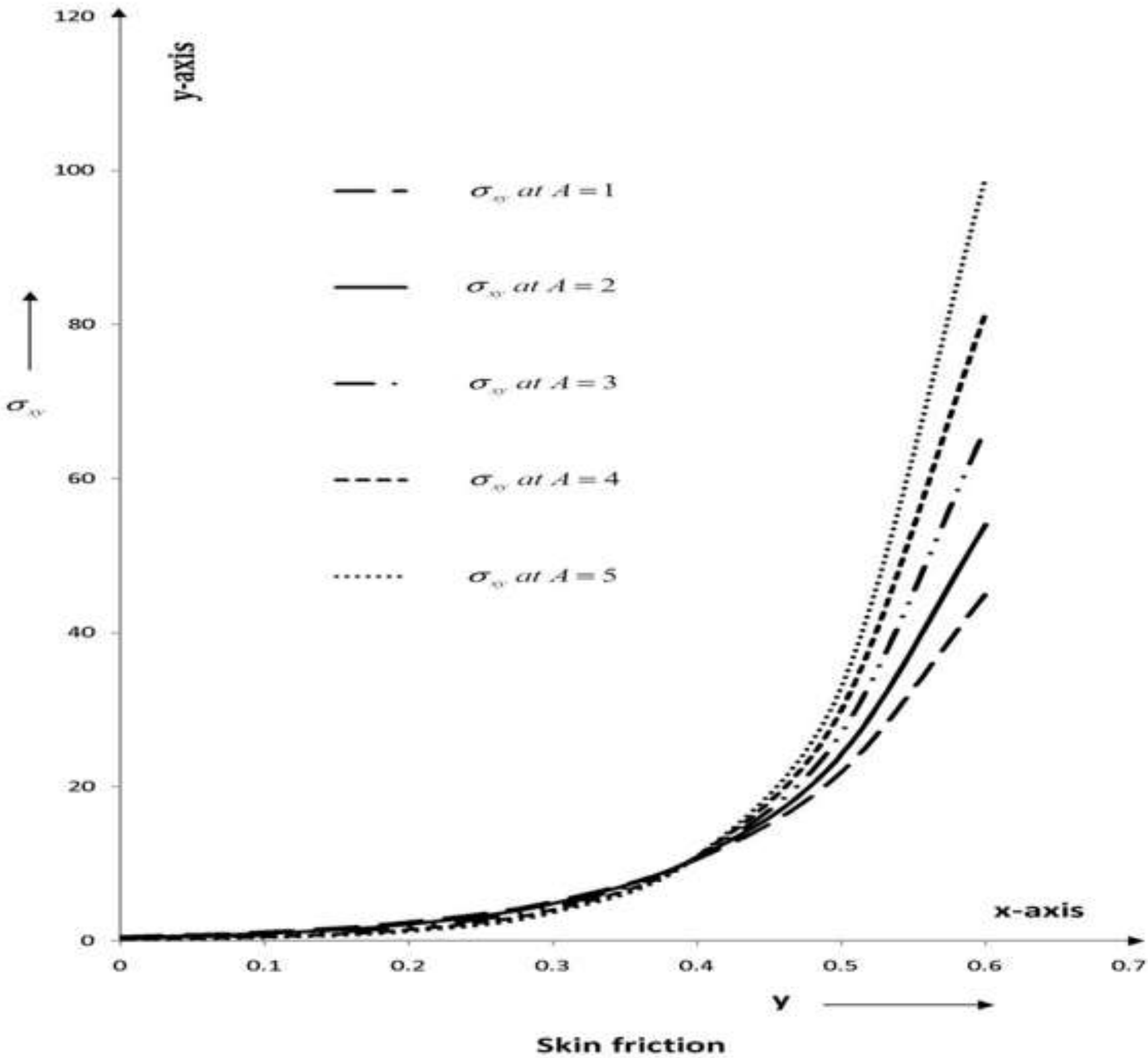


Figure-3

Case-1 $let\ \frac{1}{K}=\frac{\sigma B_0^2}{\mu}$ it is clear from chapter four and five that the graphs between porous medium and magnetic field coincide.

Case-2 when $\frac{1}{K}>\frac{\sigma B_0^2}{\mu}$ $let\ \frac{1}{K}=35\ \ i.e\ A=1\ and\ B=\frac{\sigma B_0^2}{\mu}=20\ \ i.e\ \ A=4$

Table-3 (for velocity)

	y	0	.1	.2	.3	.4	.5	.6
$\frac{1}{K}=35$ i.e A=1	u(y)	.132	.295	.64	1.367	2.88	6	12.42
$B=\frac{\sigma B_0^2}{\mu}=20\ i.e\ \ A=4$	u(y)	.04	.11	.298	.811	2.21	6	16.31

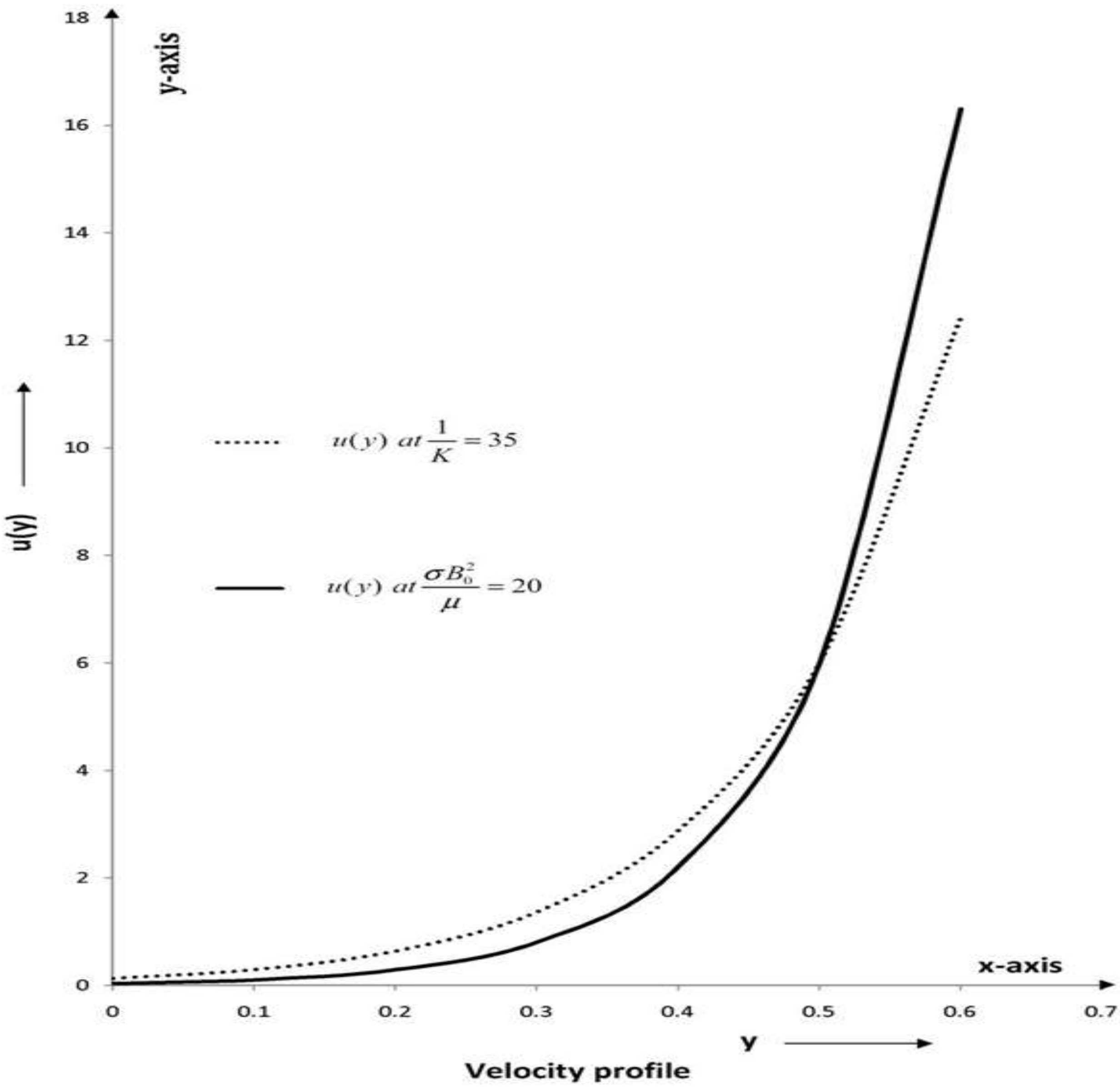


Figure-4

Case-3 when $\frac{1}{K} > \frac{\sigma B_0^2}{\mu}$ $let\ \frac{1}{K} = 35\ \ i.e\ \ A = 1\ and\ B = \frac{\sigma B_0^2}{\mu} = 20\ \ i.e\ \ A = 4$

Table -4 (for skin friction)

	y	0	.1	.2	.3	.4	.5	.6
$\frac{1}{K} = 35$ i.e A=1	σ_{xy}	**.541**	**1.159**	**2.45**	**5.125**	**10.64**	**21.94**	**45.04**
$B = \frac{\sigma B_0^2}{\mu} = 20\ i.e\ \ A = 4$	σ_{xy}	**.20**	**.549**	**1.49**	**4.06**	**11.04**	**30.01**	**81.57**

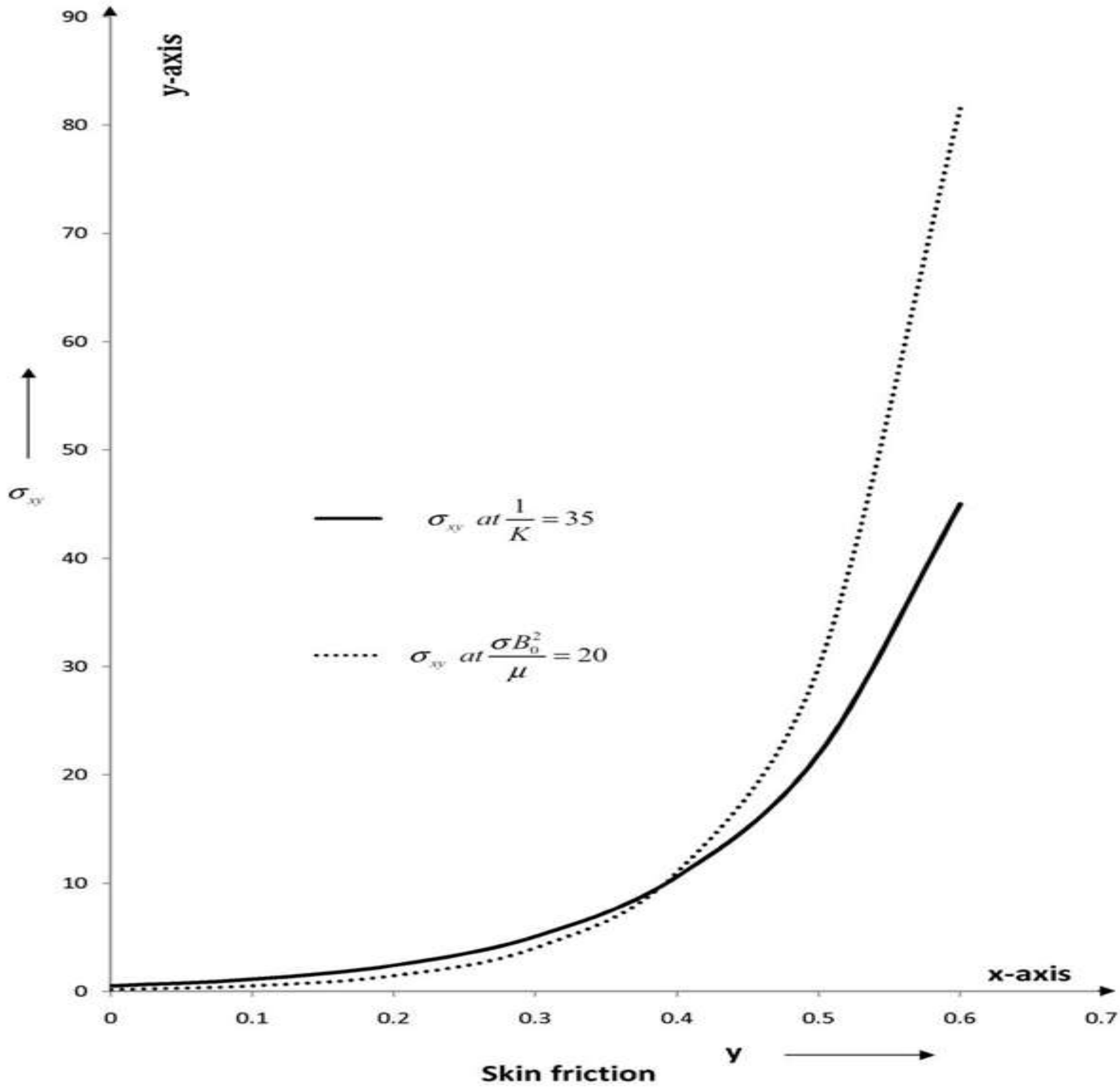


Figure-5

Table for velocity: when $\frac{1}{K} < \frac{\sigma B_0^2}{\mu}$ $let \ \frac{1}{K} = 11 \ \ i.e \ \ A = 5 \ and \ B = \frac{\sigma B_0^2}{\mu} = 32 \ \ i.e \ \ A = 2$

Table-5 (for velocity)

	y	**0**	**.1**	**.2**	**.3**	**.4**	**.5**	**.6**
$\frac{1}{K} = 11$ i.e A=5	**u(y)**	**.024**	**.073**	**.221**	**.665**	**1.997**	**6**	**18.025**
$B = \frac{\sigma B_0^2}{\mu} = 32 \ i.e \ \ A = 2$	**u(y)**	**.092**	**.227**	**.52**	**1.184**	**2.67**	**6**	**13.44**

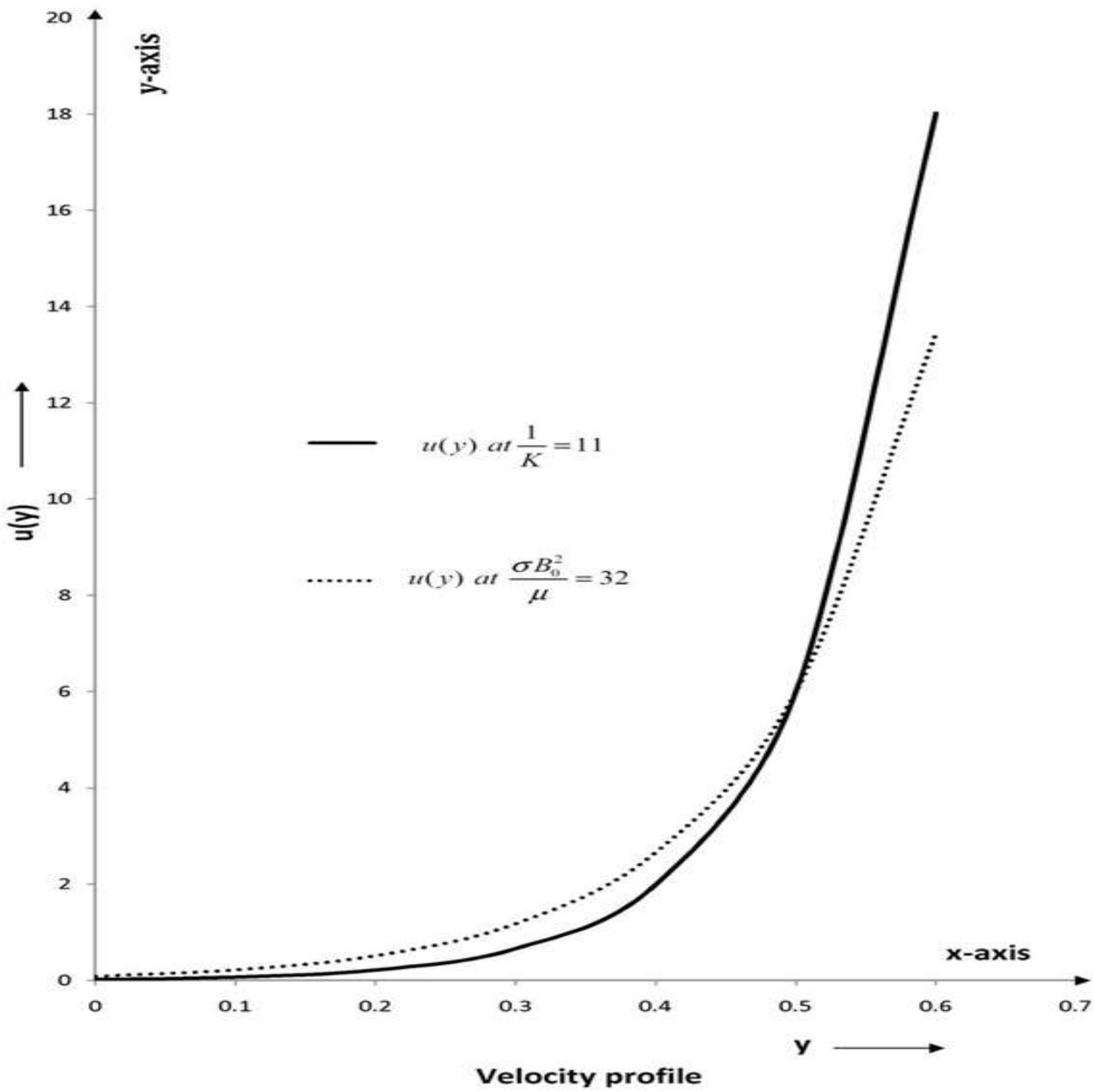


Figure-6

Table for skin friction: when $\frac{1}{K} < \frac{\sigma B_0^2}{\mu}$ let $\frac{1}{K} = 11$ i.e $A = 5$ and $B = \frac{\sigma B_0^2}{\mu} = 32$ i.e $A = 2$

Table-6 (for skin friction)

	y	0	.1	.2	.3	.4	.5	.6
$\frac{1}{K}=11$ i.e A=5	σ_{xy}	.135	.405	1.22	3.66	10.98	33	99.14
$B=\frac{\sigma B_0^2}{\mu}=32$ i.e $A=2$	σ_{xy}	.417	.95	2.15	4.835	10.84	24.22	54.08

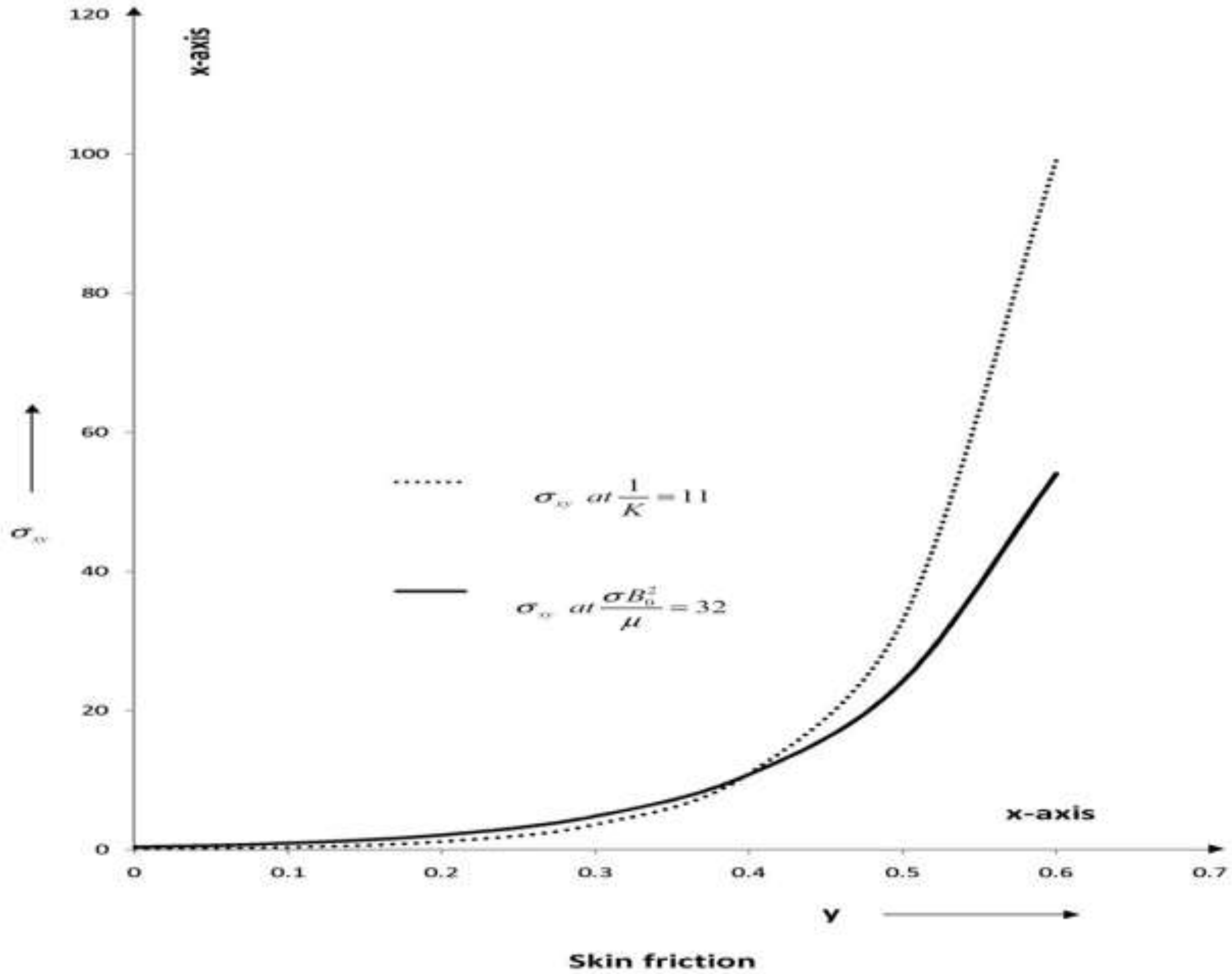


Figure-7

RESULT AND DISCUSSION

In this paper, we have investigated the velocity by the graphs of table-1 of equation (5) between velocity and distance in magnetic field. The velocity increases in the interval $0 \le y \le .6$ at each value of **h** lies between .3 to .7. Again value of velocity decreases correspondingly at each value of y between 0 to .6 when **h** increases.

Again from the table-2 the value of skin friction increases in the interval $0 \le y \le .6$ at each value of **A** increases 1 to 5 in magnetic field. Again skin friction decreases correspondingly in the interval $0 \le y \le .3$ and increases in the interval $.4 \le y \le .6$ when **A** increases from 1 to 5.

It is clear from the table-3 the value of velocity in porous medium at $\frac{1}{K} = 35$ is greater than the corresponding value of velocity in magnetic field at $\frac{\sigma B_0^2}{\mu} = 20$ in the interval $0 \le y \le .4$, the velocity is six in both mediums at $y = .5$ and the velocity in porous medium is greater than the velocity in magnetic field at $y = .6$

It is clear from the table-5 the value of velocity in porous medium at $\frac{1}{K} = 11$ is less than the corresponding value of velocity in magnetic field at $\frac{\sigma B_0^2}{\mu} = 32$ in the interval $0 \le y \le .4$, the velocity is six in both mediums at $y = .5$ and velocity in porous medium is less than the velocity in magnetic field at $y = .6$.

Again from the table-4 the value of skin friction in porous medium at $\frac{1}{K}=35$ is greater than the corresponding value of skin friction in magnetic field at $\frac{\sigma B_0^2}{\mu}=20$ in the interval $0 \le y \le .3$ and the value of skin friction in porous medium at $\frac{1}{K}=35$ is less than the corresponding values of skin friction in magnetic field at $\frac{\sigma B_0^2}{\mu}=20$ in the interval $.4 \le y \le .6$.

Again from the table-6 the skin friction in porous medium at $\frac{1}{K}=11$ is less than the corresponding value of skin friction in magnetic field at $\frac{\sigma B_0^2}{\mu}=32$ in the interval $0 \le y \le .3$ and value of skin friction in porous medium at $\frac{1}{K}=11$ is greater than the corresponding value of skin friction in magnetic field at $\frac{\sigma B_0^2}{\mu}=32$ in the interval $.4 \le y \le .6$. Also we have investigated shearing stress, the volumetric flow, drag coefficients and stream lines by the equations (7), (9), (11), (12), (13), (14) and (15) respectively.

REFERENCES

1. Blyth M.G, Mestel AJ; Steady flow in a dividing Pipe. J. Fluid Mech, 1999; 402:339-364.
2. Bose S, Dutta D; Reflection of power in a pre-stressed dissipative layered crust. Proc. Indian. Acad. Sci. (Math. Sci.), 1995;105, (3):341-351.
3. Botella O, Peyret RB; Benchmark spectral results on the lid-driven cavity flow. Computers and Fluids, 1998; 27: 421-433.
4. Bottin S, Dauchot O, Daviaud F; Intermittency in a locally forced plane Couette flow. Phys. Rev. Lett., 1997; 79: 4377–4380.
5. Bottin S, Dauchot O, Daviau F, Manneville P; Experimental evidence of streamwise vortices as finite amplitude solutions in transitional plane Couette flow. Phys. Fluids,1998; 10:2597–2607.
6. Bottin S, Daviaud F, Manneville P, Dauchot O;Discontinuous transition to spatiotemporal intermittency in plane Couette flow. Europhys. Lett, 1998; 43: 171–176.
7. Bottin S, Daviaud F, Manneville P, Dauchot O; Discontinuous transition to spatiotemporal intermittency in plane Couette flow. Europhys. Lett, 1998; 43:171–176.
8. Bourich M, Hasnaoui M, Amahmid A; Double-diffusive natural convection in a porous enclosure partially heated from below and differentially salted. Int. J. of Heat and Fluid Flow, 2004; 25(6):1034–1046.
9. Brown SN; Singularities associated with separating boundary layers. Phil. Trans. R. Soc. A, 1965;257: 409–444.
10. Bruneau CH, Jouron C; An efficient scheme for solving steady incompressible Navier-stokes equations. J. Comp. Physics; 1990; 89:389–413.
11. Bujurke NM, Pai NP, Achar PK; Computer extended series solution to viscous flow between rotating discs. Proc. Indian Acad. Sci. (Math. Sci.), 1995; 105:353-369.
12. Bunyakin AV, Chernyshenko SI, Stepanov GY; In viscid Batchelor-model flow past an airfoil with a vortex trapped in a cavity. J. Fluid Mech, 1996;323:367-376.
13. Burgers JM; Application of a model system to illustrate some points of the statistical theory of free turbulence. Proc. Acad. Sci., Amsterdam, 1940; 43(1).