J. KSIAM Vol.19, No.1, 57–68, 2015 http://dx.doi.org/10.12941/jksiam.2015.19.057

COUETTE FLOW OF TWO IMMISCIBLE LIQUIDS BETWEEN TWO PARALLEL POROUS PLATES IN A ROTATING CHANNEL

CH. BABY RANI

DEPARTMENT OF MATHEMATICS, V. R. SIDDHARTHA ENGINEERING COLLEGE, KANURU, KRISHNA (DIST), ANDHRA PRADESH , INDIA, PIN 520007, INDIA.
E-mail address: ranicbr@gmail.com

ABSTRACT. When a straight channel formed by two parallel porous plates, through which two immiscible liquids occupying different heights are flowing a secondary motion is set up. The motion is caused by moving the upper plate with a uniform velocity about an axis perpendicular to the plates. The solutions are exact solutions. Here we discuss the effect of suction parameter and the position of interface on the flow phenomena in case of Couette flow. The velocity distributions for the primary and secondary flows have been discussed and presented graphically. The skin-friction amplitude at the upper and lower plates has been discussed for various physical parameters.

1. INTRODUCTION

The fluid flow between porous boundaries is of practical interest in hydrology and petroleum industry. The problem of water coming is usually encountered in the oil industry when a layer of water underlies a layer of water forming a system of immiscible fluids. The effect of suction is to supply an adverse pressure gradient to the fluid which intern causes back flow near the stationary plate. The velocity profile due to the flow of two incompressible immiscible fluids between two parallel plates and occupying equal heights was obtained by Bird *et al* [1]. The problem was extended by Kapur and Sukla [2] to the case of the flow of a number of incompressible immiscible fluids occupying different heights. Vidyanidhi and Nigam[3] who have studied the secondary flow when a straight channel, formed by two parallel plates through which fluid is flowing under a constant pressure gradient, is rotated about an axis perpendicular to the plates. This problem was later extended by Vidyanidhi [4] in the frame work of hydromagnetics and by Vidyanidhi, BalaPrasad and RamanaRao [5] to include the effects of uniform suction and injection. The later analysis has been made use of by RamanaRao and Balaprasad [6] in studying the temperature distribution

Received by the editors October 18 2014; Revised December 30 2015; Accepted in revised form January 28 2015; Published online March 18 2015.
2010 *Mathematics Subject Classification.* 35Q35, 76S05.
Key words and phrases. Porous Parallel plates, Reynolds number, Suction Reynolds number, Primary velocity, Secondary velocity, skin-friction.

Jana and Datta [7] have considered the Couette flow and the heat transfer of a various incompressible fluids between two infinite parallel plates which rotate with a uniform angular velocity about an axis perpendicular to the plates.

V.V.RamanaRao and Narayana [8] extended the work of Jana and Datta [7] on the flow of two incompressible immiscible fluids occupying equal heights between two parallel plates. Ch.BabyRani [9] extended the work of V. V. RamanaRao and N. V. Narayana[10] on the flow of two immiscible liquids occupying different heights between two parallel porous plates for Poiseuille flow. Ch.Baby Rani [11] studied the heat transfer characteristics for the two liquids occupying different heights in a rotating channel for poiseuille flow. Ch. Baby Rani [12] considered the combined effect of the pressure gradient and motion of the upper plate and studied the velocity distributions for the liquids occupying different heights between two parallel porous plates. Ch. Baby Rani [13] studied the heat transfer characteristics for Generalized Couette flow of two immiscible liquids occupying different heights between two parallel plates in a rotating channel.

Here we consider the two liquids occupying different heights between two parallel porous plates in a rotating system for Couette flow and I discussed the primary flow and the secondary flow for the two immiscible liquids to obtain the effects uniform suction and injection at the plates. Olive oil and water can be taken as two immiscible liquids to test the theoretical conclusions of this work for setting up an experiment as suggested by Vidyanidhi and Nigam [3].

2. Mathematical formulation and its solution

The equations of motion and continuity for the steady state in a rotating frame of reference $O'X'Y'Z'$ as considered by Squire (1956) for two immiscible liquids as shown in Fig.1, with negligible modified pressure, are

$$\left(\overrightarrow{U_m^1}.\overrightarrow{\nabla^1}\right)\overrightarrow{U_m^1} + 2\overrightarrow{\Omega} \times \overrightarrow{U_m^1} = v_m \overrightarrow{\nabla'^2}\overrightarrow{U_m^1} \tag{2.1}$$

$$\overrightarrow{\nabla^1}.\overrightarrow{U_m^1} = 0\,(m = 1, 2) \tag{2.2}$$

Here the subscripts 1 and 2 refer to the upper and lower liquids in the ranges $\epsilon^1 \leq z^1 \leq L$(zone-I) and $-L \leq Z^1 \leq \epsilon^1$(zone-II) respectively. $\overrightarrow{U_1^1}, \overrightarrow{U_2^1}, \overrightarrow{\Omega^1}$ and $\overrightarrow{r^1}$ are the velocities of the upper liquid, lower liquid, angular velocity and position vector respectively.

We choose a right handed Cartesian system such that Z^1-axis is perpendicular to the motion of the liquids along the X^1-axis between two infinite parallel plates $Z^1 = \pm L$(stationary relative to $O'X'Y'Z'$).

The motion is caused when the upper plate moves with uniform velocity U_0 along the X^1-axis.

The velocities of the two fluids are then represented by

$$\overrightarrow{U_1^1} = \left[u_1^1\left(z^1\right), v_1^1\left(z^1\right), -W_o\right], \quad \overrightarrow{U_2^1} = \left[u_2^1\left(z^1\right), v_2^1\left(z^1\right), -W_o\right] \tag{2.3}$$

And $\Omega^1 = \left(0, 0, \Omega^1\right)$

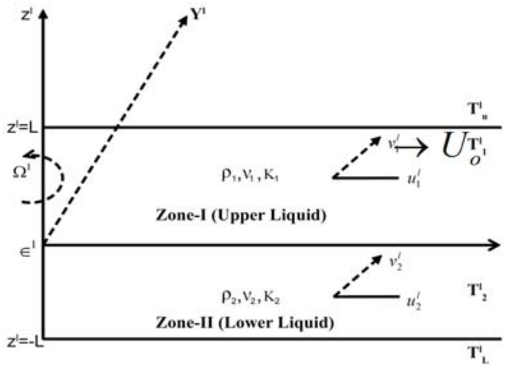


FIGURE 1. Schematic diagram

Introducing, the non-dimensional quantities

$$x^1 = xL,\ \ y^1 = yL,\ \ z^1 = zL,\ \ u_1^1 = u_1U_0,\ \ v_1^1 = v_1U_0,$$
$$u_2^1 = u_2U_0,\ \ v_2^1 = v_2U_0,\ \ \rho_2 = \lambda\rho_1,\ \ v_2 = \mu^2 v_1,$$

$\Omega^1 = \alpha^2 v_2/L^2$ (Taylor number for the lower liquid)

$$\beta_m = \frac{L\Omega_m^1}{\nu_m} \text{ (Suction Reynolds number)} \tag{2.4}$$

$\Omega_1^1\nu_2 = \Omega_2^1\nu_1$ then $\beta_1 = \beta_2 = \beta$ implying that the normal velocity at the plate z$^1 = -L$ is a porous plate through which liquid is forced into the channel with a uniform velocity and the rate of injection at the lower plate is equal to the suction rate at the upper plate.

Equation (2.1) reduces to

The equations in zone-I ($\epsilon \le z \le L$) are

$$\frac{d^2u_1}{dz^2} - \beta\frac{du_1}{dz} = -2\alpha^2\mu^2 v_1,\quad \frac{d^2v_1}{dz^2} - \beta\frac{dv_1}{dz} = 2\alpha^2\mu^2 u_1 \tag{2.5}$$

The equations in zone-II are $(-L \le z \le \epsilon)$are

$$\frac{d^2u_2}{dz^2} - \beta\frac{du_2}{dz} = -2\alpha^2 v_2,\ \ \frac{d^2v_2}{dz^2} - \beta\frac{dv_2}{dz} = 2\alpha^2 u_2 \tag{2.6}$$

We seek the solutions of equations (2.6) and (2.7) subject to the boundary conditions.

$$u_1 = 1,\ v_1 = 0 \,\text{at}\, z = 1$$

$$u_2 = v_2 = 0 \,\text{at}\, z = -1 \tag{2.7}$$

Interface conditions are

$$u_1 = u_2,\ v_1 = v_2 \text{ at } z = \epsilon$$

$$\frac{du_1}{dz} = \lambda\mu^2\frac{du_2}{dz} \text{ at } z = \epsilon, \quad \frac{dv_1}{dz} = \lambda\mu^2\frac{dv_2}{dz} \text{ at } z = \epsilon$$

In terms of complex notation $q_1 = u_1 + iv_1,\ q_2 = u_2 + iv_2$

In zone-I

$$\frac{d^2q_1}{dz^2} - \beta\frac{dq_1}{dz} - 2i\mu^2\alpha^2 q_1 = 0 \tag{2.8}$$

In zone-II

$$\frac{d^2q_2}{dz^2} - \beta\frac{dq_2}{dz} - 2i\alpha^2 q_2 = 0 \tag{2.9}$$

Subject to the boundary conditions

$$q_1 = 1 \text{ at } z = 1,$$

Interface condition

$$\begin{aligned} q_1 &= q_2 \text{ at } z = \epsilon, (-1 < \epsilon < 1) \\ \frac{dq_1}{dz} &= \lambda\mu^2\frac{dq_2}{dz}\ at\ z = \ \epsilon, \\ q_2 &= 0 \text{ at } z = -1 \end{aligned} \tag{2.10}$$

Let

$$m_1 = \left[\frac{\sqrt{\beta^4 + 64\alpha^4\mu^4} + \beta^2}{2}\right]^{\frac{1}{2}}, \quad n_1 = \left[\frac{\sqrt{\beta^4 + 64\alpha^4\mu^4} - \beta^2}{2}\right]^{\frac{1}{2}} \tag{2.11}$$

$$m_2 = \left[\frac{\sqrt{\beta^4 + 64\alpha^4} + \beta^2}{2}\right]^{\frac{1}{2}}, \quad n_2 = \left[\frac{\sqrt{\beta^4 + 64\alpha^4} - \beta^2}{2}\right]^{\frac{1}{2}} \tag{2.12}$$

We get

$$q_1 = e^{\frac{\beta z}{2}}\left[A\ Sh\left(\frac{m_1}{2} + i\frac{n_1}{2}\right)z\ +\ B\ Ch\left(\frac{m_1}{2} + i\frac{n_1}{2}\right)z\right] \tag{2.13}$$

$$q_2 = e^{\frac{\beta z}{2}}\left[C\ Sh\left(\frac{m_2}{2} + i\frac{n_2}{2}\right)z\ +\ D\ Ch\left(\frac{m_2}{2} + i\frac{n_2}{2}\right)z\ \right] \tag{2.14}$$

$$\begin{aligned} q_1 = e^{\frac{\beta z}{2}}\Bigg[\frac{1}{a_1^2 + b_1^2}\left\{e^{-\frac{\beta}{2}}(a_1 - ib_1) - \frac{H_1G_2 - H_2G_1}{F_1G_2 - F_2G_1}\{(a_1e_1 + b_1f_1) + i(a_1f_1 - b_1e_1)\}\right\} \\ Sh\left(\frac{m_1z}{2} + i\frac{n_1z}{2}\right) + \frac{H_1G_2 - H_2G_1}{F_1G_2 - F_2G_1}Ch\left(\frac{m_1z}{2} + i\frac{n_1z}{2}\right)\Bigg] \end{aligned} \tag{2.15}$$

$$\begin{aligned} q_2 = e^{\frac{\beta z}{2}}\Bigg[\frac{1}{a_2^2 + b_2^2}\left\{\frac{H_2F_1 - H_1F_2}{F_1G_2 - F_2G_1}\{(a_2e_2 + b_2f_2) + i(a_2f_2 - b_2e_2)\}\right\}Sh\left(\frac{m_2z}{2} + i\frac{n_2z}{2}\right) \\ + \frac{H_2F_1 - H_1F_2}{F_1G_2 - F_2G_1}Ch\left(\frac{m_2z}{2} + i\frac{n_2z}{2}\right)\Bigg] \end{aligned} \tag{2.16}$$

Separating the real and imaginary parts

$$U_1 = \frac{e^{\frac{\beta z}{2}}}{\left(a_1^2+b_1^2\right)\left(\lambda_1^2+\lambda_3^2\right)}\Big[e^{-\frac{\beta}{2}}\left(\lambda_1^2+\lambda_3^2\right)\Big(a_1 Sh\frac{m_1 z}{2}\cos\frac{n_1 z}{2} + b_1 Ch\frac{m_1 z}{2}\sin\frac{n_1 z}{2}\Big)$$
$$+\left\{(\lambda_1\lambda_2+\lambda_3\lambda_4)(a_1e_1+b_1f_1)-(\lambda_1\lambda_4-\lambda_2\lambda_3)(a_1f_1-b_1e_1)\right\}Sh\frac{m_1 z}{2}\cos\frac{n_1 z}{2}$$
$$-\left\{(\lambda_1\lambda_2+\lambda_3\lambda_4)(a_1f_1-b_1e_1)+(\lambda_1\lambda_4-\lambda_2\lambda_3)(a_1e_1+b_1f_1)\right\}Ch\frac{m_1 z}{2}\sin\frac{n_1 z}{2}$$
$$+\left(a_1^2+b_1^2\right)\Big\{(\lambda_1\lambda_4-\lambda_2\lambda_3)Sh\frac{m_1 z}{2}\sin\frac{n_1 z}{2}-(\lambda_1\lambda_2+\lambda_3\lambda_4)Ch\frac{m_1 z}{2}\cos\frac{n_1 z}{2}\Big\}\Big] \quad (2.17)$$

$$V_1 = \frac{e^{\frac{\beta z}{2}}}{\left(a_1^2+b_1^2\right)\left(\lambda_1^2+\lambda_3^2\right)}\Big[e^{-\frac{\beta}{2}}\left(\lambda_1^2+\lambda_3^2\right)\Big(a_1 Ch\frac{m_1 z}{2}\sin\frac{n_1 z}{2} - b_1 Sh\frac{m_1 z}{2}\cos\frac{n_1 z}{2}\Big)$$
$$+\left\{(\lambda_1\lambda_2+\lambda_3\lambda_4)(a_1e_1+b_1f_1)-(\lambda_1\lambda_4-\lambda_2\lambda_3)(a_1f_1-b_1e_1)\right\}Ch\frac{m_1 z}{2}\sin\frac{n_1 z}{2}$$
$$+\left\{(\lambda_1\lambda_2+\lambda_3\lambda_4)(a_1f_1-b_1e_1)+(\lambda_1\lambda_4-\lambda_2\lambda_3)(a_1e_1+b_1f_1)\right\}Sh\frac{m_1 z}{2}\cos\frac{n_1 z}{2}$$
$$-\left(a_1^2+b_1^2\right)\Big\{(\lambda_1\lambda_4-\lambda_2\lambda_3)Ch\frac{m_1 z}{2}\cos\frac{n_1 z}{2}+(\lambda_1\lambda_2+\lambda_3\lambda_4)Sh\frac{m_1 z}{2}\sin\frac{n_1 z}{2}\Big\}\Big] \quad (2.18)$$

$$U_2 = \frac{-e^{\frac{\beta z}{2}}}{\left(a_2^2+b_2^2\right)\left(\lambda_1^2+\lambda_3^2\right)}\left[\left\{(\lambda_1\lambda_5+\lambda_3\lambda_6)(a_2e_2+b_2f_2)\right.\right.$$
$$\left.-(\lambda_1\lambda_6-\lambda_3\lambda_5)(a_2f_2-b_2e_2)\right\}Sh\tfrac{m_2 z}{2}\cos\tfrac{n_2 z}{2}$$
$$-\left\{(\lambda_1\lambda_5+\lambda_3\lambda_6)(a_2f_2-b_2e_2)+(\lambda_1\lambda_6-\lambda_3\lambda_5)(a_2e_2+b_2f_2)\right\}Ch\frac{m_2 z}{2}\sin\frac{n_2 z}{2}$$
$$+\left(a_2^2+b_2^2\right)\Big\{(\lambda_1\lambda_5+\lambda_3\lambda_6)Ch\frac{m_2 z}{2}\cos\frac{n_2 z}{2}-(\lambda_1\lambda_6-\lambda_3\lambda_5)Sh\frac{m_2 z}{2}\sin\frac{n_2 z}{2}\Big\}\Big] \quad (2.19)$$

$$V_2 = \frac{-e^{\frac{\beta z}{2}}}{\left(a_2^2+b_2^2\right)\left(\lambda_1^2+\lambda_3^2\right)}\left[\left\{(\lambda_1\lambda_5+\lambda_3\lambda_6)(a_2e_2+b_2f_2)\right.\right.$$
$$\left.-(\lambda_1\lambda_6-\lambda_3\lambda_5)(a_2f_2-b_2e_2)\right\}Ch\tfrac{m_2 z}{2}\sin\tfrac{n_2 z}{2}$$
$$+\left\{(\lambda_1\lambda_5+\lambda_3\lambda_6)(a_2f_2-b_2e_2)+(\lambda_1\lambda_6-\lambda_3\lambda_5)(a_2e_2+b_2f_2)\right\}Sh\frac{m_2 z}{2}\cos\frac{n_2 z}{2}$$
$$+\left(a_2^2+b_2^2\right)\Big\{(\lambda_1\lambda_6-\lambda_3\lambda_5)Ch\frac{m_2 z}{2}\cos\frac{n_2 z}{2}+(\lambda_1\lambda_5+\lambda_3\lambda_6)Sh\frac{m_2 z}{2}\sin\frac{n_2 z}{2}\Big\}\Big] \quad (2.20)$$

The skin-friction at the upper plate is given by $\tau_U = \left.\frac{dU_1}{dz}\right|_{z=1}$

$$\tau_U = \frac{e^{\frac{\beta}{2}}}{2\left(a_1^2+b_1^2\right)\left(\lambda_1^2+\lambda_3^2\right)}\left[(\beta T_1+T_3n_1-T_4m_1)a_1+(-\beta T_4+T_1m_1+T_2n_1)e_1\right.$$
$$\left.+(\beta T_3+T_2m_1-T_1n_1)f_1+(\beta T_2+T_3m_1+T_4n_1)b_1\right] \quad (2.21)$$

Where

$$T_1 = a_1e^{-\frac{\beta}{2}}\left(\lambda_1^2+\lambda_3^2\right)+(\lambda_1\lambda_2+\lambda_3\lambda_4)(a_1e_1+b_1f_1)-(\lambda_1\lambda_4-\lambda_2\lambda_3)(a_1f_1-b_1e_1) \quad (2.22)$$

$$T_2 = b_1 e^{-\frac{\beta}{2}} \left(\lambda_1^2 + \lambda_3^2\right) - (\lambda_1\lambda_2 + \lambda_3\lambda_4)(a_1 f_1 - b_1 e_1) - (\lambda_1\lambda_4 - \lambda_2\lambda_3)(a_1 e_1 + b_1 f_1) \tag{2.23}$$

$$T_3 = \left(a_1^2 + b_1^2\right)(\lambda_1\lambda_4 - \lambda_2\lambda_3) \tag{2.24}$$

$$T_4 = \left(a_1^2 + b_1^2\right)(\lambda_1\lambda_2 + \lambda_3\lambda_4) \tag{2.25}$$

The skin-friction at the lower plate is given by $\tau_L = \left.\frac{dU_2}{dz}\right|_{z=-1}$

$$\tau_L = \frac{e^{-\frac{\beta}{2}}}{2\left(a_2^2 + b_2^2\right)\left(\lambda_1^2 + \lambda_3^2\right)} \left[(-\beta S_2 + S_3 n_2 + S_4 m_2)\, a_2 + (-\beta S_4 + S_1 n_2 + S_2 m_2)\, e_2 + (\beta S_3 + S_1 m_2 - S_2 n_2)\, f_2 - (\beta S_1 + S_3 m_2 + S_4 n_2)\, b_2\right] \tag{2.26}$$

Where

$$S_1 = \{(\lambda_1\lambda_5 + \lambda_3\lambda_6)(a_2 f_2 - b_2 e_2) + (\lambda_1\lambda_6 - \lambda_3\lambda_5)(a_2 e_2 + b_2 f_2)\} \tag{2.27}$$

$$S_2 = \{(\lambda_1\lambda_6 - \lambda_3\lambda_5)(a_2 f_2 - b_2 e_2) - (\lambda_1\lambda_5 + \lambda_3\lambda_6)(a_2 e_2 + b_2 f_2)\} \tag{2.28}$$

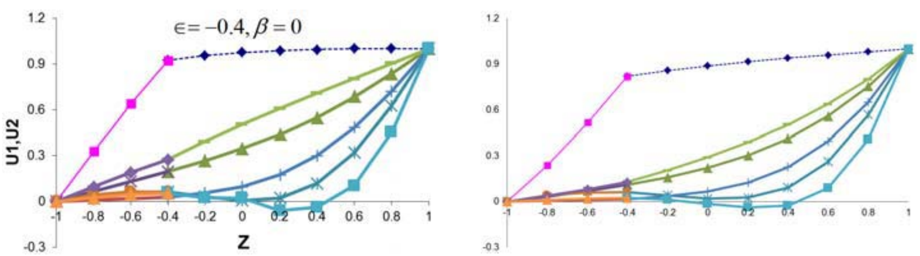
$$S_3 = \left(a_2^2 + b_2^2\right)(\lambda_1\lambda_6 - \lambda_3\lambda_5) \tag{2.29}$$

$$S_4 = \left(a_2^2 + b_2^2\right)(\lambda_1\lambda_5 + \lambda_3\lambda_6) \tag{2.30}$$

3. RESULTS & DISCUSSION

The velocity distributions for the primary and secondary flows have been shown in figures (3.1) to (3.14) illustrate the effect of the parameters α, λ and μ corresponding to both the liquids occupying different heights for both porous and non-porous cases.

The velocity distribution for the primary flow have been shown in Figs. 2(a) and (b) to illustrate the effect of the parameters α, μ and λ for $\epsilon = -0.4$ when β =0 and 1. As α increase the primary flow decreases at point of the channel irrespective of the existence of the porosity. With increase of λ and μ the primary flow depreciates irrespective of the existence of the porosity. The significance of β is marginal.



(a) (b)

FIGURE 2. (a) and (b) are velocity profiles for the primary flow.

Figures 3(a) and (b) show the primary flow at $\epsilon = 0$ for $\beta = 0$ and 1. With increase of α, μ and λ the primary flow decreases in both cases. The results are in agreement with RamanaRao and Narayana (1980) for $\beta = 0$ and $\epsilon = 0$.

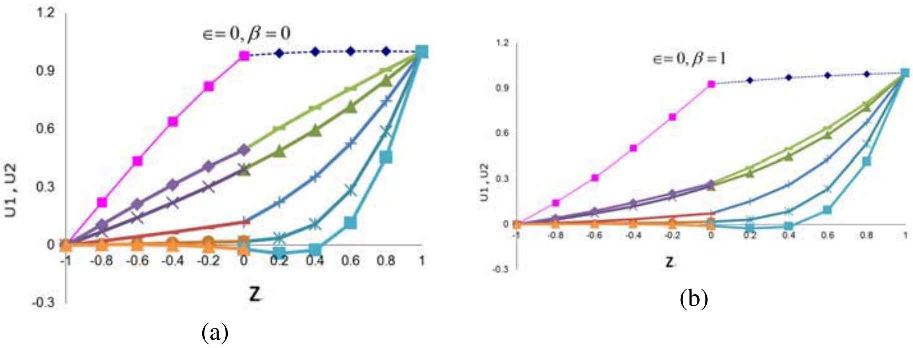


FIGURE 3. (a) and (b) are velocity profiles for the primary flow.

Figures 4(a) and (b) represent the primary flow at $\epsilon = 0.6$ for $\beta = 0$ and 1. With increase of α, μ and λ the primary flow decreases, for large values of α and μ the primary flow changes from negative to positive as we move from zone-II to zone-I irrespective of the existence of the porosity.

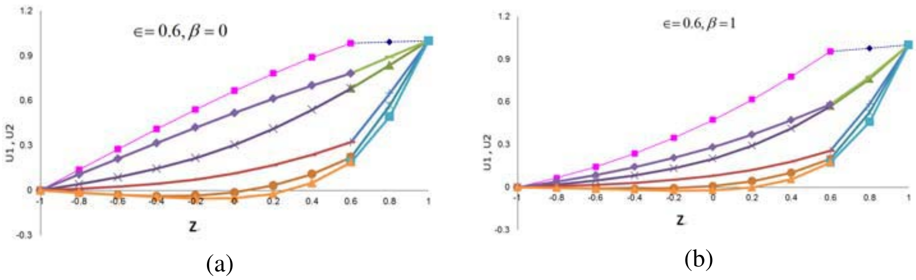
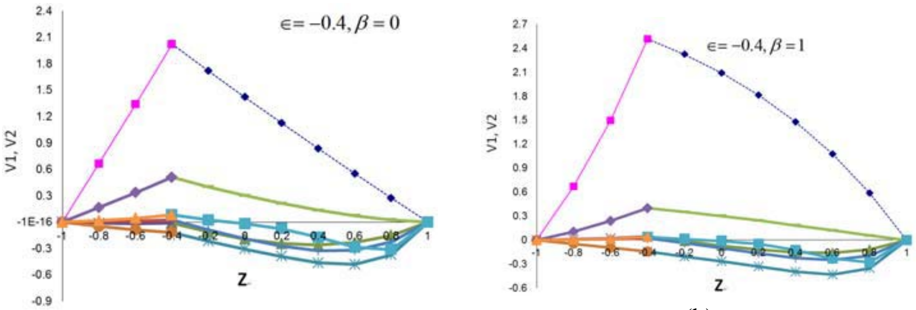


FIGURE 4. (a) and (b) are velocity profiles for the primary flow.

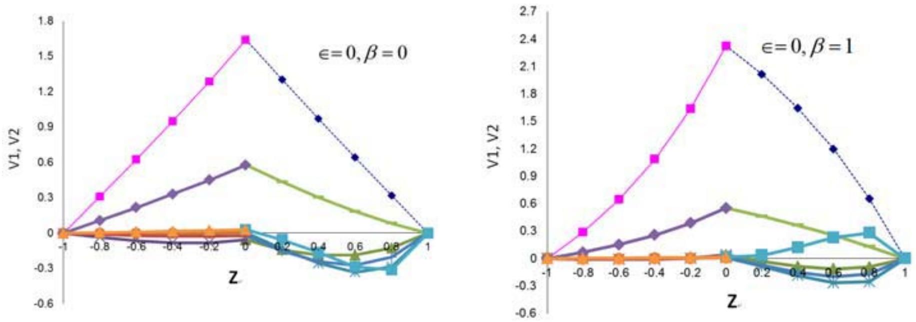
The velocity distribution for secondary flow have been shown in Figs. 5(a) and (b) for $\epsilon = -0.4$when $\beta = 0$ and 1. The secondary flow depreciates with increase of α, μ and λ for $\beta = 0$ and 1. The secondary velocity changes from positive to negative as we move from zone-II to zone-I for large values of α, μ and λ.



(a) (b)

FIGURE 5. (a) and (b) are velocity profiles for the secondary flow.

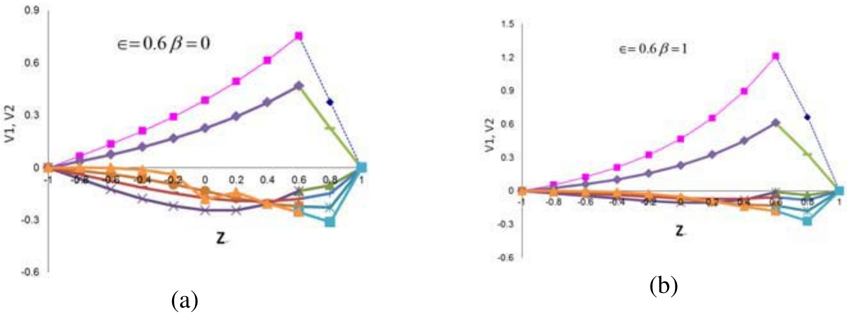
Figures 6(a) and (b) show the secondary flow for $\beta = 0$ and 1 when $\epsilon = 0$. It is concluded that the secondary flow depreciates with increase in any one of the parameters irrespective of the existence of the porosity. Similar results were found by RamanaRao & Narayana (1980) for $\epsilon = 0$ and $\beta = 0$.



(a) (b)

FIGURE 6. (a) and (b) are velocity profiles for the secondary flow.

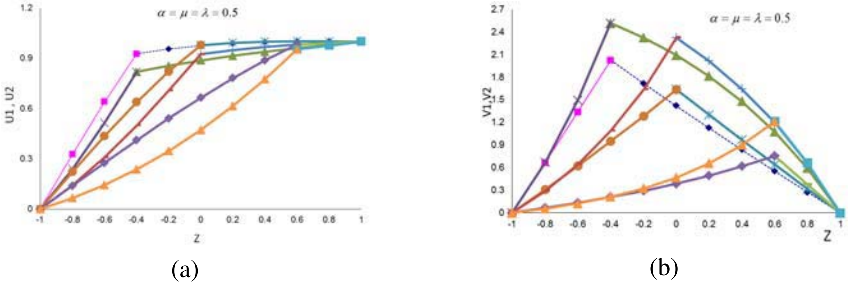
Figures 7(a) and (b) show the secondary flow for $\epsilon = 0.6$ for $\beta = 0$ and 1. The secondary flow depreciates with increase in any one of the parameters irrespective of the existence of the porosity.



(a) (b)

FIGURE 7. (a) and (b) are velocity profiles for the secondary flow.

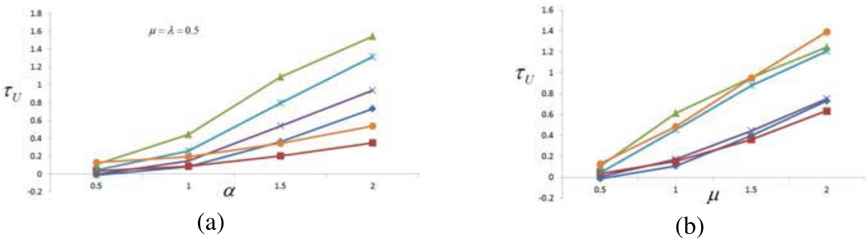
With the increase of the interface the primary flow enhances for $\beta = 0$ and 1 (in Fig. 8(a)), the secondary flow depreciates for $\beta = 0$ and 1 (in Fig. 8(b)).



(a) (b)

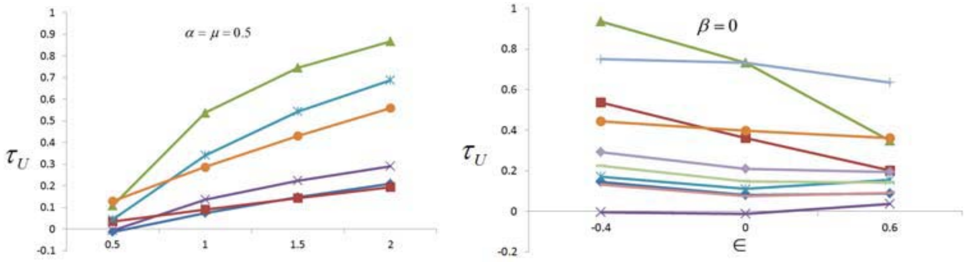
FIGURE 8. (a) and (b) are velocity profiles for the secondary flow.

The skin-friction amplitude at the upper and lower plates has been shown in Fig. 9 to Fig. 13 for various parameters. The skin-friction at the lower plate is greater than that of the upper plate.



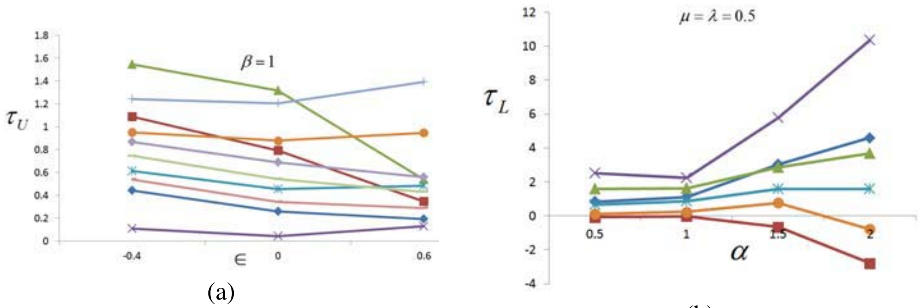
(a) (b)

FIGURE 9. (a) and (b) are skin-friction amplitude at the upper plate.



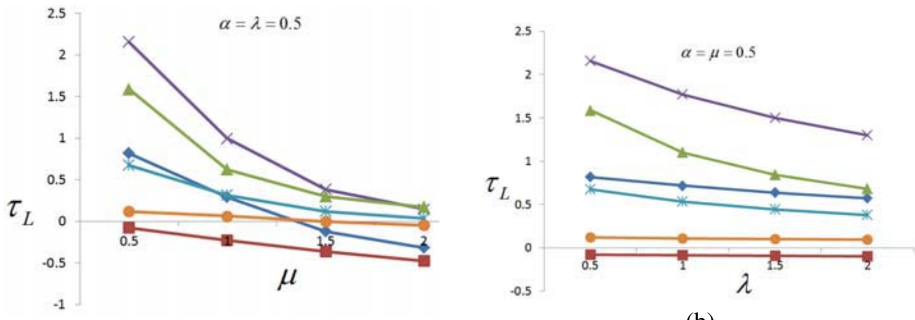
(a) (b)

FIGURE 10. (a) and (b) are skin-friction amplitude at the upper plate.



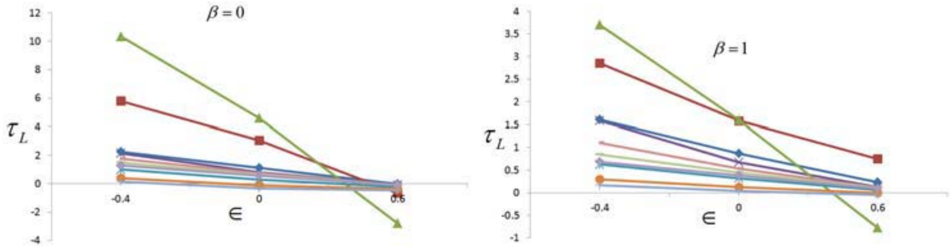
(a) (b)

FIGURE 11. (a) and (b) are skin-friction amplitude at the lower plate.



(a) (b)

FIGURE 12. (a) and (b) are skin-friction amplitude at the lower plate.



(a) (b)

FIGURE 13. (a) and (b) are skin-friction amplitude at the lower plate.

The skin-friction amplitude is found to increase at the upper plate with increase of α while λ and μ are fixed for $\epsilon = -0.4,\ 0$ and 0.6 irrespective of the existence of the porosity. As λ and μ increases the skin-friction amplitude at the upper plate increases, the remaining values being fixed for $\epsilon = -0.4,\ 0$ and 0.6 irrespective of the existence of the porosity.

As ϵ value increases the skin-friction at the upper plate decreases for large values of α and slightly increases for the remaining parameters being fixed whether there is porosity or not.

The skin-friction amplitude is found to be increase at the lower plate with increase of α the remaining values being fixed for $\epsilon = -0.4$ and 0 irrespective of the existence of the porosity.The skin-friction at the lower plate decreases at α =2, when $\epsilon = 0.6$ for both porous and non-porous cases, while $\mu$and λ being fixed. As μincreases the skin-friction amplitude at the lower plate decreases for $\epsilon = -0.4,\ 0$ and 0.6 irrespective of the existence of the porosity, while α and λ being fixed.

As λ increases the skin-friction at the lower plate decreases for $\epsilon = -0.4$ and 0, it remains constant for $\epsilon = 0.6$, while α and μ being fixed. This result holds for both porous and non-porous cases. As ϵincreases from -0.4 to 0.6 the skin-friction amplitude at the lower plate decreases for various parameters whether there is porosity or not.

4. CONCLUSION

The primary flow of the upper liquid increases to 1, from its value at $z = \epsilon$, where as that of the lower liquid increases from zero to its value at $z = \epsilon$, both the values at $z = \epsilon$ being the same. The secondary flow of the upper liquid decreases to zero from its value at $z = \epsilon$ whereas that of the lower liquid increases from zero to its value at $z = \epsilon$, both the values at $z = \epsilon$ being the same. This results valid for small values of α, μ and λ. For large values of α, μ and λ, the secondary flow of the upper liquid increases to zero from its value at $z = \epsilon$ whereas that of the lower liquid decreases from zero to its value at $z = \epsilon$, both the values at $z = \epsilon$ being the same.

In this analysis we discuss the effect of suction parameter β and position of the interface on the flow phenomena in the case of Couette flow. It is found that the variation in ϵ leads to an enhancement in the primary flow and depreciation in the secondary flow irrespective of β.

In the absence of porosity (β =0), the secondary velocity changes from positive to negative as we move from zone-II to zone-I. The region of transition from positive to negative enlarges with increase in the interface ϵ, while for $\beta \neq 0$ the transition zone depreciates in zone-II and enlarges in zone-I for $\epsilon = 0.6$ the transition zone enlarge marginally in both the zones.

REFERENCES

[1] R.B. Bird, W.E. Stewart and E. N. Lightfoot: *Transport Phenomena,* John Wiley & Sons, 1960.

[2] J. N. Kapur and J. B. Shukla**:***The flow of incompressible immiscible fluids between two plates,* Applied Scientific Research, **13**(1964),pp. 55–60.

[3] V. Vidyanidhi and S. D. Nigam: *Couette Flow between Rotating Parallel Plates under Constant Pressure Gradient*, Journal of Mathematical Physics, **1**(1967), pp. 85–98.

[4] V. Vidyanidhi: *Secondary flow of a conducting liquid in a roatating channel*, Journal of Maths. Phy. Sci. **3**(1969), pp. 193–199.

[5] V. Vidyanidhi, V. Bala Prasad and V. V. RamanaRao: *Secondary Flow between Two Parallel Porous Walls in a Rotating System*, J. Phys. Soc. Jpn. **39**(1975), pp. 1077–1081.

[6] V. V. RamanaRao and V. Bala Prasad:*Heat transfer in a rotating channel with porous walls*,Acta Physics Academic ScientiaremHungaricae,**42**(1977), pp. 143–149.

[7] R. N. Jana and N. Dutta: *Couette Flow and Heat Transfer in a Rotating System*, ActaMechanica, **26**(1977), pp. 301–306.

[8] V. V. RamanaRao and N. V. Narayana: Indian J. Technology, **18**(1980).

[9] Ch. Baby Rani*: Poiseuille flow of two immiscible liquids occupying different heights in a rotating Channel*, International Journal of Mathematical Sciences, **34**(2014), pp. 1458–1471.

[10] V. V. RamanaRao and N. V. Narayana:*Secondary flow and heat transfer of two incompressible lmrniscible fluids between two parallel plates in a rotating system,*Defence Science Journal, **31**(1981), No.3, pp. 181–198.

[11] Ch. Baby Rani: *Heat transfer of Poiseuille flow of two immiscible liquids in a roatating system,*J. Pure and Apply Physics, **23**(2011), pp. 47–57.

[12] Ch. Baby Rani: *Generalized couette flow of two immiscible liquids occupying different heights in a rotating system*, Proc. Of .ICMS-2014, published by Elsevier, pp. 363–366, 2014.

[13] Ch. Baby Rani: *Heat transfer of Generalizedcouette flow of two immiscible liquids in a roatating system*, Ultra Scientist of Physical Sciences, Vol. 25(2013),pp. 253–264.

[14] H. B. Squire: *Survey's in Mechanics*, Cambridge University Press, Londan, Vol. 139, 1956.