Chemical reaction Effects on Oscillatory flow through Porous Channel with Mass Transfer

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ABSTRACT

We investigate the effect on the unsteady oscillatory flow through a vertical channel with non-uniform wall temperature. The fluid is subjected to the chemical reaction with mass transfer and the velocity slip through the porous medium is taken into consideration. Exact solutions,governing the fluid flow of the dimensionless equations are obtained and the effects of the flow parameters with chemical reactions and mass transfer ontemperature, velocity profiles, skin friction and rate of heat transfer are discussed and shown graphically. It is observed that skin friction increases on both channel platesasinjectionincreasesontheheat source.

KEYWORDS: Porous Medium, Chemical Reaction, Oscillatory flow, Mass Transfer, Heat Source

1. INTRODUCTION:

The Fluid flows with chemical reaction on oscillatory flowhave attracted the attention of engineers and scientists. Various researchers studied the concepts ofoscillatory flows have special relevance in vibrating media withapplicationsinoil-drilling,manufacturing,processingoffoods and paper, oil exploration, cosmetic products, polymer industries,flow in a desert cooler, energy transfer in a wet cooling tower,chemical industry, petroleum industry. understanding of fluid dynamics of porous media with heat and mass transfer flows emerge in various innovative applications such as oil and gas industryand underground porous rocks.Thereisalways a molecular diffusion of species in the presence of chemical reaction within or at the boundary during several practical diffusive operations.There are two types of reactions,namely, homogeneous and heterogeneous. A homogeneous reaction takes place uniformly in the entire given phase whereas a heterogeneous reaction exists in are stricted region or within the boundary of a phase.These formations is an important example representing a first-order homogeneous chemical reaction.Severalresearchersinviewofsuchfactsareengaged in the discussion of oscillatory flow.The study of mass and heat transfer problems combined with chemical reaction in the presence of heat source through porous medium has importance in many practical applications in the areas of science and technology.

Many authors have discussed the fluid flow through porous medium with heat and mass transfer in oscillatory fluid problems. To mention just a few, Faladeetal [1] investigated the effect of suction/injection on the unsteady oscillatory flow through a vertical channel with non-uniform wall temperature.Makinde and Mhone [2] discussed the MHD oscillatory forced convective fluid flow through a porous channel.Mohammad Al Zubi[3] analyzed the Heat and mass transfer of an oscillatory flow in two-dimensional over an infinite vertical permeable moving plate through porous medium with chemical reaction. Ramaiah etal [4] presented the influence of chemical reaction and effects on free convective heat and mass transfer flow of fluid through porous medium bounded by an oscillating porous plate in the presence of heat sources. Vidhya etal [5] reported the effect of heat and mass transfer on MHD oscillatory flow through porous mediumwith chemical reaction in an asymmetric channel in the presence of heat source. Saleh Alharbietal [6] examined the convective mass and heat transfer characteristics of an oscillatory flow in a porous medium with chemical reaction.M.Vidhyaand SundaramalKesavan[7] investigated Laminar convection through porous medium between two vertical parallel plates with heat source. K.D. Singh [8] discussed the Exact solution of an oscillatory MHD flow in a channel filled with porous medium. Sasikumar and Govindarajan [9] analyzed the effect of magnetic field on oscillatory flow through vertical parallel flat plates in a porous channel with heat source and chemical reaction.

2. MATHEMATICAL ANALYSIS

Consider the unsteady laminar flow of an incompressible viscous electrically conducting fluid through a channel with slip at the cold plate. An external magnetic field is placed across the normal to the channel. It is assumed that the fluid has small electrical conductivity and the electro-magnetic forceproduced isalsoverysmall.Theflowissubjectedtosuctionatthecold wall and injection at the heated wall. We choose a Cartesian coordinatesystem$x^{\prime}$;$y^{\prime}$where$x^{\prime}$liesalongthecentreofthe channel,and$y^{\prime}$isthedistancemeasuredinthenormalsection suchthat$y^{\prime}$¼$a$isthechannel’shalfwidthasshowninFig.1 below

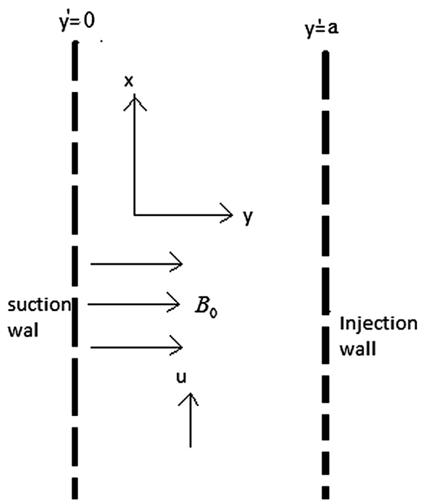

Figure 1 Physical model of the problem

The governing equations of the flow are as follows:

$$\frac{\partial U'}{\partial t'} - v_0 \frac{\partial U'}{\partial y'} = \frac{-1}{\rho}\frac{\partial P'}{\partial x'} + v\frac{\partial^2 U'}{\partial y'} + g\beta(T' - T_0) + g\beta'(C' - C_0) - \frac{v}{K}U' - \sigma\frac{B_0^2 U}{\rho} \quad (1)$$

$$\frac{\partial T'}{\partial t'} - v_0 \frac{\partial T'}{\partial y'} = \frac{4\alpha^2}{\rho C_p}(T - T_0) + \frac{K_f}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} + Q(T' - T_0) \quad (2)$$

$$\frac{\partial C'}{\partial t'} - v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - K_f(C' - C_0) \quad (3)$$

With boundary conditions $T = T_1$

$$u' \frac{\sqrt{K}}{\alpha_s}\frac{du\prime}{dv\prime}, \quad T = T_0 \quad \text{on } y' = 0 \quad (4)$$

$$u' = 0, \; T' = T_1 \quad \text{on } y' = a \quad (5)$$

Where t' – time, u'-axial velocity, v_0 – constant horizontal velocity, ρ-fluid density, P'-fluid pressure, v-kinematic viscosity, K-porous permeability, $\sigma -$ electrical conductivity, B_0– magnetic field intensity, g-gravitational acceleration, β – volumetric expansion, C_p – is the specific heat at constant pressure, α is the term due to thermal radiation, K represents the thermal conductivity, T' – fluid temperature, T_0 – fluid temperature.

Introducing the dimensionless quantities as follows:

$$(x,y) = \frac{(x',y')}{h}, \; u = \frac{hu\prime}{v}, \; t = \frac{vt'}{h^2}, \; p = \frac{h^2 p'}{\rho v^2}, \; Gr = \frac{g\beta(T_1 - T_0)h^3}{v^2},$$

$$Pr = \frac{\rho C_p v}{k}, \; \theta = \frac{T - T_0}{T_1 - T_0}, \; \delta = \frac{4\alpha^2 h^2}{\rho C_p v}, \; \gamma = \frac{\sqrt{K}}{\alpha_s h},$$

$$Ha^2 = \frac{\sigma_e B_0^2 h^2}{\rho v}, \; Da = \frac{K}{h^2}, \; s = \frac{v_0 h}{v} \quad (6)$$

we obtain the dimensionless Equations as follows:

$$\frac{\partial U}{\partial t} - s\frac{\partial U}{\partial y} = -\frac{\partial P}{\partial x} + \frac{\partial^2 U}{\partial y^2} - \left(H_a^2 + \frac{1}{D_a}\right)U + G_r\theta + G_c\varphi \quad (7)$$

$$\frac{\partial \theta}{\partial t} - s\frac{\partial \theta}{\partial y} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial y^2} + \delta\theta + S_0\theta \quad (8)$$

$$\frac{\partial C}{\partial t} - \frac{1}{S_c}\frac{\partial C}{\partial y} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} - K_c C \quad (9)$$

The boundary conditions are (10) and (11)

$$U = \frac{\partial U}{\partial y}, \; \theta = 0, \; \phi = 0 \quad \text{on } y=0 \quad (10)$$

$$U = 0, \; \theta = 1, \; \phi = 1 \quad \text{on } y=1 \quad (11)$$

In equations (7) to (11)

Da- Darcy parameter, S-suction/injection parameter, H_a^2 – Hartmann's number, Gr- Grashof number, Pr- Prandtl number, δ – thermal radiation parameter, γ–Navier slip parameter.

3. Method of Solution

In order to solve equations (7) to (9)

Let $-\frac{\partial P}{\partial x} = \lambda\, e^{i\omega t}$, $U(y,t) = U_0(y)e^{i\omega t}$, $\theta_0(y,t) = \theta_0(y)e^{i\omega t}$,

$$\phi_0(y,t) = \phi_0(y)e^{i\omega t} \tag{12}$$

Substitute the boundary conditions (10) and (11) and the expressions in (12) into equations (7) to (9) we obtain the following

$$U_0'' + SU_0' - \left\{H_a^2 + \frac{1}{D_a} + i\omega\right\}U_0 = -\lambda - G_r\theta_0 + G_c\phi_0 \tag{13}$$

$$\theta_0'' + SP_r\theta_0' + \{\delta - i\omega + S_0\}P_r\theta_0 = 0 \tag{14}$$

$$\phi_0'' + S_c\phi_0' + S_c\gamma\phi_0 = 0 \tag{15}$$

The exact solutions of (15), (14) and (13) are respectively as follows

$$\phi_0 = F_1(e^{X_1 y} - e^{X_2 y}) \tag{16}$$

$$\theta_0 = F_2(e^{m_1 y} - e^{m_2 y}) \tag{17}$$

$$U_0 = \frac{Z_{10}}{Z_9}e^{l_1 y} + \frac{Z_{11}}{Z_9}e^{l_2 y} + \frac{\lambda}{Q_1} + \frac{Z_1}{Z_3}e^{m_2 y} - \frac{Z_1}{Z_4}e^{m_1 y} + \frac{Z_2}{Z_5}e^{X_2 y} - \frac{Z_2}{Z_6}e^{X_1 y} \tag{18}$$

The rate of heat transfer is given by

$$Nu = F_2[m_1 e^{m_1 y} - m_2 e^{m_2 y}] \tag{19}$$

The Skin friction is given by

$$Sf = \frac{Z_{10}}{Z_9}l_1 e^{l_1 y} + \frac{Z_{11}}{Z_9}l_2 e^{l_2 y} + \frac{Z_1}{Z_3}m_2 e^{m_2 y} - \frac{Z_1}{Z_4}m_1 e^{m_1 y} + \frac{Z_2}{Z_5}X_2 e^{X_2 y} - \frac{Z_2}{Z_6}X_1 e^{X_1 y} \tag{20}$$

All the constant terms are defined in Appendix A.

4. Results and Discussion

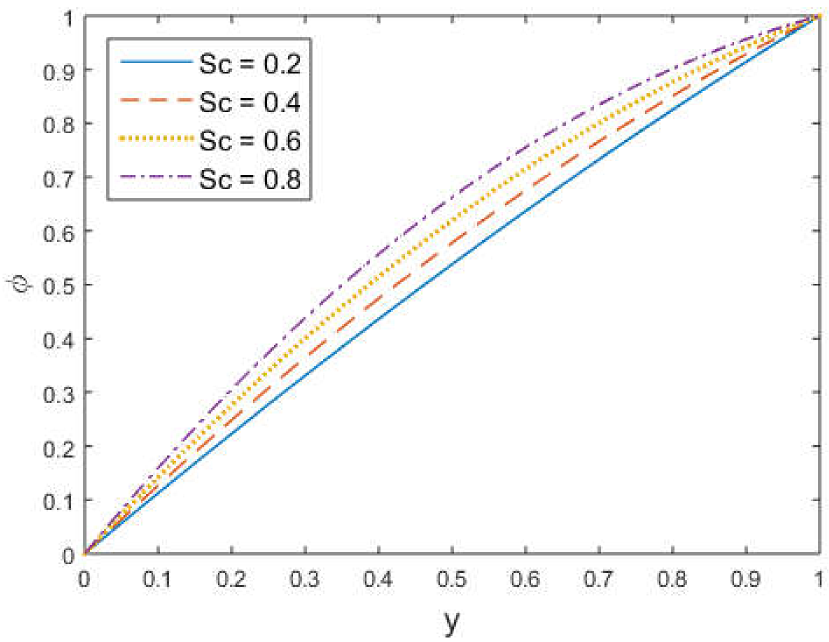

Figure 2: Velocity Profile of the fluid

In this paper, the oscillatory fluid flow through a permeable channel filled with a porous medium is studied. The flow is due to free convection and increasing pressure gradient through a vertical channel.

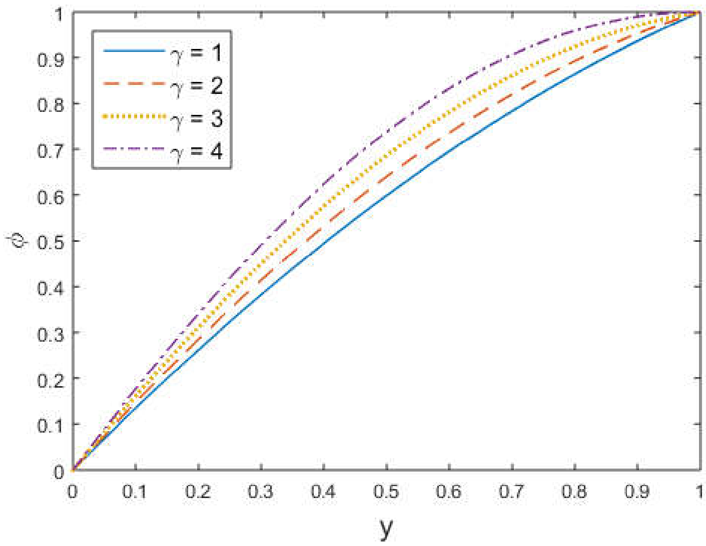

Figure 3 : Temperature Profile of the fluid

As shown in Fig. 3, as the radiation parameter increases, and the fluid temperature is seen to be increasing. This is due to the heat transfer from the heated wall to the fluid since the fluid absorbs its own radiations.

5. Conclusion

In this paper, the effect of chemical reaction on oscillatory flow through a porous medium with heat source and mass transfer in the thermal radiation limit.

The obtained result reduced to that presented in [2]when s 0. Additionally, we conclude that an increase in the suction/injection parameter:

Appendix A

$$X_1 = \frac{-Sc + \sqrt{Sc^2 - 4Sc\gamma}}{2}$$

$$X_2 = \frac{-Sc - \sqrt{Sc^2 - 4Sc\gamma}}{2}$$

A = $\frac{1}{e^{X_1} - e^{X_2}}$ B = $\frac{-1}{e^{X_1} - e^{X_2}}$

$$\mathrm{F}_1 = \frac{1}{e^{X_1} - e^{X_2}}$$

$$m_1 = -\frac{\mathrm{SP_r} + \sqrt{S^2 P_r^2 - 4(\delta - \mathrm{i}\omega + \mathrm{S_0})\mathrm{P_r}}}{2}$$

$$m_2 = -\frac{\mathrm{SP_r} - \sqrt{S^2 P_r^2 - 4(\delta - \mathrm{i}\omega + \mathrm{S_0})\mathrm{P_r}}}{2}$$

$\mathrm{A}_1 = \frac{1}{e^{m_1} - e^{m_2}}$ $\mathrm{A}_2 = \frac{-1}{e^{m_1} - e^{m_2}}$

$\mathrm{F}_2 = \frac{1}{e^{m_1} - e^{m_2}}$

$l_1 = \frac{-S + \sqrt{S^2 + 4Q_1}}{2}$ $l_2 = \frac{-S - \sqrt{S^2 + 4Q_1}}{2}$

$Q_1 = \mathrm{H_a^2} + \frac{1}{\mathrm{D_a}} + \mathrm{i}\omega$ $Z_1 = GrF_2$

$Z_2 = GcF_1$ $Z_3 = m_2^2 + Sm_2 - Q_1$

$Z_3 = m_2^2 + Sm_2 - Q_1$ $Z_4 = m_1^2 + Sm_1 - Q_1$

$Z_5 = X_1^2 + SX_2 - Q_1$ $Z_6 = X_1^2 + SX_1 - Q_1$

$$Z_7 = \frac{Z_1}{Z_3}(\gamma m_2 - 1) - \frac{Z_1}{Z_4}(\gamma m_1 - 1) + \frac{Z_2}{Z_5}(\gamma X_2 - 1) - \frac{Z_2}{Z_6}(\gamma X_1 - 1)$$

$$Z_8 = \frac{\lambda}{Q_1} + \frac{Z_1}{Z_3} e^{m_2} - \frac{Z_1}{Z_4} e^{m_1} + \frac{Z_2}{Z_5} e^{X_2} - \frac{Z_2}{Z_6} e^{X_1}$$

$Z_9 = e^{l_2}(\gamma l_1 - 1) - e^{l_1}(\gamma l_2 - 1)$ $\quad$ $Z_{10} = e^{l_2} Z_7 - (\gamma l_2 - 1) Z_8$

$Z_{11} = Z_8(\gamma l_1 - 1) - Z_7 e^{l_1}$

$B_1 = \frac{Z_7 e^{l_2} - Z_8(\gamma l_2 - 1)}{Z_9}$ $\quad$ $B_2 = \frac{Z_8(\gamma l_1 - 1) - Z_7 e^{l_1}}{Z_9}$

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