Mixed convective flow with the external magnetic field effect of a continuous movement over a permeable wall

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Abstract: *The continuous flow of an incompressible viscoelastic and viscous fluid passes through an infinite oscillating length of a vertical permeable plate with a magnetic field effect. Formulated differential equations are simplified by finite difference method for this problem. The profiles of concentration, temperature and velocity are graphically evaluated by the impact of numerous flow parameters.*

Keywords: *MHD flow, Viscoelastic fluid, Porous plate, Unsteady flow.*

2010 Mathematics Subject Classification: 92C10.

1. Introduction:

Chemical reaction is a very important phenomenon in the field of chemical and hydrometallurgical industries. In the effect of inclined applied magnetic field, Kane et al. (2020) depicts the unpredictable fluid flow through two oscillating parallel permeable plates. In the impact of uniform temperature, thermal radiation and general diffusion, Raju et al. (2019) depicted the flow of visco-elastic fluid passes through an infinitely long vertical permeable layer. The effects of mixed convection and Navier slip on a chemically reactive heat and mass transfer magneto hydrodynamics fluid flow over a permeable surface with convective boundary conditions have been investigated by Fenuga et al. (2018). The MHD flow of Viscoelastic Fluid shown by Sharmin and Alam (2017) passes through an Infinite Oscillating Porous Plate with Thermal Diffusion and Heat Source.

Raghunath et al. (2016) examined the visco-elastic fluid in the slip flow regime of unsteady MHD flow past an infinite oscillating porous plate. Reddy et al. (2015) investigated the free flow for convective fluid through a semi-infinite vertical porous plate with chemical reaction and heat absorption through Magneto hydrodynamics. The MHD Flow through oscillatory porous plate is explained by Moniem and Hassanin (2013).

Ahmad and Das (2013) explain the thermal radiation and chemical reaction of MHD heat flow and mass transfer passes through an embedded porous plate. In the presence of external electrical and magnetic fields, Gedik et al. (2012) showed the 2-phase fluid of unsteady MHD flow past in circular pipes. Uwanta et al. (2011) studied the flow of viscoelastic fluid with heat dissipation through an infinite vertical plate.

The turbulent free convection flow of viscoelastic and viscous incompressible fluid passes through the continuous moving vertical porous plate with the effect of first-order chemical reaction was studied by Damseh and Sannak (2010). Kumar et al. (2010) studied reliable steady flow magnetohydrodynamics through permeable boundaries for channels and solved the governing equation by the technique for Finite difference.

Kumar et al. (2010) examined that technique of perturbation through a planer channel to unsteady MHD periodic viscous fluid flow. In a channel filled with porous medium, Makinde and Mhone (2005) examined oscillatory MHD flow and heat transfer. An unstable MHD channel via porous media was investigated by Ram and Mishra (1977).

2. Formulation of the problem:

Consider the MHD flow passing through an oscillating infinite vertical porous plate of viscoelastic and viscous fluid flow. Let u*, v* and w* be the components for velocity along the axis for x*, y* and z*.

$$\frac{\partial w^*}{\partial z^*} = 0 \tag{1}$$

$$\frac{\partial u^*}{\partial t^*} + w^* \frac{\partial u^*}{\partial z^*} = \nu \frac{\partial^2 u^*}{\partial z^{*2}} - \frac{K_0}{\rho}\left(\frac{\partial^3 u^*}{\partial z^{*2}\partial t} + w^* \frac{\partial^3 u^*}{\partial z^{*3}}\right) - \frac{\sigma B_0^2}{\rho} u^* - \frac{\nu}{k} u^*$$

$$+g\beta(T^* - T_\infty^*) + g\beta^*(C^* - C_\infty^*) \tag{2}$$

$$\frac{\partial v^*}{\partial t^*} + w^* \frac{\partial v^*}{\partial z^*} = \nu \frac{\partial^2 v^*}{\partial z^{*2}} - \frac{K_0}{\rho}\left(\frac{\partial^3 v^*}{\partial z^{*2}\partial t} + w^* \frac{\partial^3 v^*}{\partial z^{*3}}\right) - \frac{\sigma B_0^2}{\rho} v^* - \frac{\nu}{k} v^* \tag{3}$$

$$\frac{\partial T^*}{\partial t^*} + w^* \frac{\partial T^*}{\partial z^*} = -S(T^* - T_\infty^*) + \alpha \frac{\partial^2 T^*}{\partial z^{*2}} \tag{4}$$

$$\frac{\partial C^*}{\partial t^*} + w^* \frac{\partial C^*}{\partial z^*} = -K_1(C^* - C_\infty^*) + D \frac{\partial^2 C^*}{\partial z^{*2}} \tag{5}$$

From (1)

$$w^* = -w_0 \tag{6}$$

Where the w 0 constant is positive. As the suction is along the permeable plate, the negative input is received.

By the operation (2)+ i(3), taking $q^* = u^* + iv^*$

$$\frac{\partial q^*}{\partial t^*} - w_0 \frac{\partial q^*}{\partial z^*} = \nu \frac{\partial^2 q^*}{\partial z^{*2}} - \frac{K_0}{\rho}\left(\frac{\partial^3 q^*}{\partial z^{*2}\partial t} - w_0 \frac{\partial^3 q^*}{\partial z^{*3}}\right) - \frac{\sigma B_0^2}{\rho} q^* - \frac{\nu}{k} q^* + + g\beta^*(C^* - C_\infty^*) + g\beta(T^* - T_\infty^*) \tag{7}$$

The boundary conditions are

$$\left.\begin{array}{l} q^* = U_0 e^{i\omega t} + L_1 \frac{\partial q^*}{\partial z^*}, \ T^* = T_w^*, C^* = C_w^*, z^* = o \\ q^* \to 0, \ T^* \to T_\infty^*, C^* \to C_\infty^*, \ z^* \to \infty \end{array}\right\} \tag{8}$$

$L_1 = (2 - m_1)(L/m_1)$ *is the* Mean free path, *where* $L = \mu(\pi/2p\rho)^{1/2}$ and m_1*is* coefficient of Maxwell's reflection.

Considering the following dimensionless quantities as:

$$u = \frac{u^*}{U_0}, v = \frac{v^*}{U_0}, t = \frac{t^* U_0^2}{\nu}, \quad z = \frac{z^* U_0}{\nu}, w = \frac{\nu w^*}{U_0^2},$$

$$w_0 = \frac{W_0^*}{U_0}, \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*},$$

$$C. = \frac{C.^* - C_\infty^*}{C_w^* - C_\infty^*}$$

The governing equations reduce to the following equations;

$$\frac{\partial q}{\partial t} - w_0 \frac{\partial q}{\partial z} = \frac{\partial^2 q}{\partial z^2} - R_c\left(\frac{\partial^3 q}{\partial z^2 \partial t} + w_0 \frac{\partial^3 q}{\partial z^3}\right) - \begin{pmatrix} m^2 \\ + \frac{1}{K} \end{pmatrix} q + 2G_r\theta + 2G_m\theta \qquad (9)$$

$$P_r 1\left(\frac{\partial\theta}{\partial t} - w_0 \frac{\partial\theta}{\partial z}\right) = \frac{\partial^2\theta}{\partial z^2} - P_r * S * \theta \qquad (10)$$

$$\left(\frac{\partial C}{\partial t} - w_0 \frac{\partial C}{\partial z}\right) 1S_c = \frac{\partial^2 C}{\partial z^2} - S_C * K_C * C \qquad (11)$$

3. Solution of the problem

Solve, by applying the finite difference technique, non-linear partial differential equations (9)-(11) under conditions (8). The reliability is increased by increasing the linearization points at some given points. The following equations can be described as equations (9)-(11). $q' = \frac{2q_{i+1,j} - 2q_{i,j}}{2\Delta t}$,

$$u' = \frac{2u_{i-1,j} - 2u_{i,j}}{2\Delta y},$$

$$u'' = \frac{2u_{i-1,j} - 4u_{i,j} + 2u_{i+1,j}}{2(\Delta y)^2}.$$

4. Results

The effect of the various parameters such as Prandtl number (Pr), Modified Grashof number (Gm), Grashof number (Gr), Chemical reaction variable (Kc), Schmidt number (Sc), Elastic parameter (Rc), Porosity parameter (K) were examined.

Figure 1-8 demonstrates that with the increasing value of Pr, K, Rc and Kc, the velocity profiles u and v decrease while increasing the value of M and Gm. As the value of Gr and Sc decreases, the velocity elements U decrease and v increase.

Figure 9 to 11 reveals that the temperature profile increases by raising the value of w-0 and Pr. Figures (12) to (13) reveal that as Kc and Rc increase in value, the concentration profile can decreases.

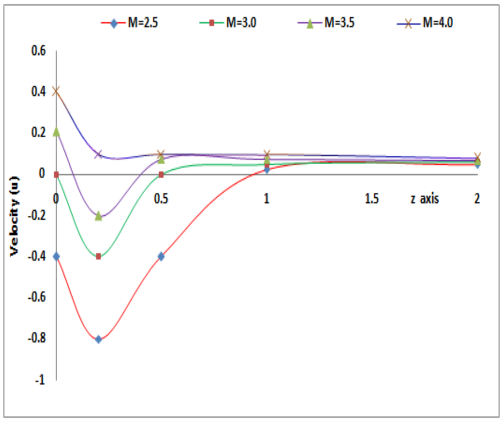


Figure 1: The effect of Magnetic parameter (M) on the velocity Profile.

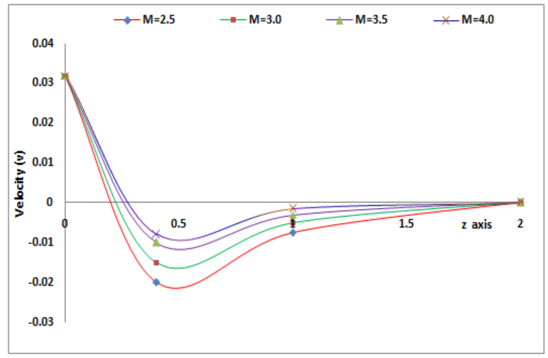


Figure 4: The effect of Elastic parameter (Rc) on the velocity Profile.

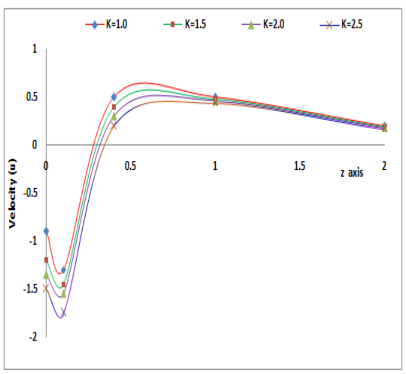


Figure 2: The effect of porosity parameter (K) on the velocity Profile.

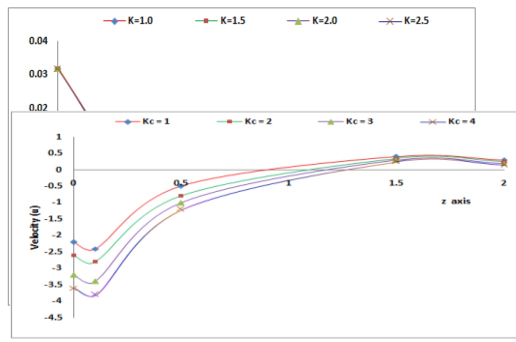
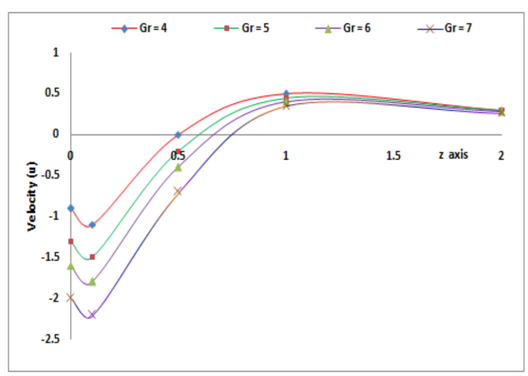


Figure 5: The effect of Chemical reaction parameter (Kc) on the velocity Profile.



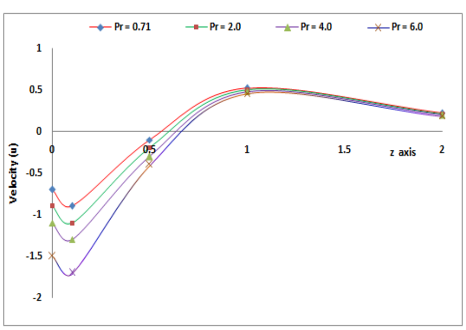


Figure 3: The effect of Prandtl number (Pr) on the velocity Profile.

Figure 6: The effect of Grashof number (Gr) on the velocity Profile.

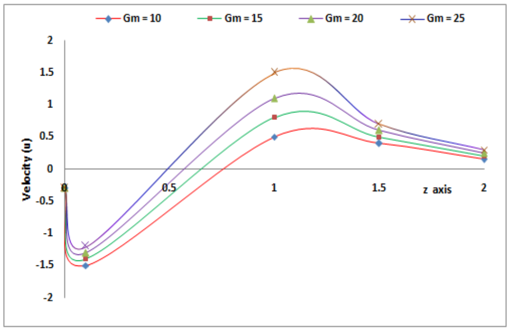


Figure 7: The effect of Grashof Number (Gm) on the velocity Profile.

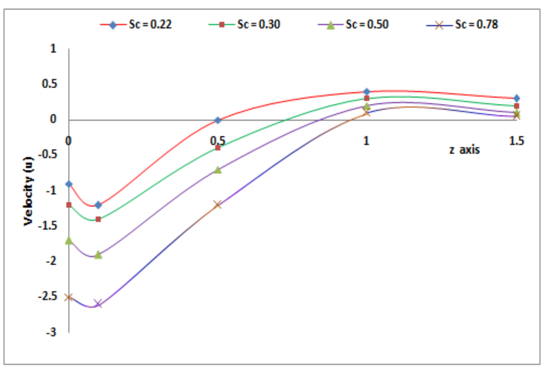


Figure 8: The effect of Schmidt number (Sc) on the velocity Profile.

5. Conclusion:

The current research has investigated the impact of flow parameters on unstable MHD flow. With the increasing value of K, Pr, Rc, Kc, the velocity profile decreases, while the increasing value of the Magnetic parameter (M) and Schmidt number increases with the increasing value of K, Pr, Rc, Kc (Sc). With an increased value of S, Pr and w, the temperature profile has been decreased. With the increasing Schmidt number (Sc) and chemical reaction parameter (Kc) values, the concentration profile decreased.

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