Influence of Heat Generation and Radiation on MHD Flow of Natural Convection

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Abstract: This article explains an influence of heat generation on MHD natural flow convective a vertical permeable surface with radiation. By using perturbation technique the equations of governing are converted to a system of non-linear O.D.E’S and are explained mathematically. Numerous physical limitations like M, F, Pr and some other parameters are studied through diagrams and tabular values. As conclusion of this investigation, decreasing in velocity profile as numerical standards increased in major cases except few effects like absorption radiation parameter R, Schmidt number Sc over velocity flow. The same effects are investigated for temperature profile as well as concentration profile.

Index terms: Radiation, Heat Generation, MHD, Vertical Plate.

I. INTRODUCTION

In Science and Engineering the flow role of natural hydro viscous incompressible involving heat and mass transfer plays a commanding role. These impacts of mentioned can be observe in petrochemical manufacturing, in power systems, organic vapour testimony on exteriors, in chilling of nuclear reactors, dynamics and geophysics as well as in MHD compeers systems. Ali Chamkha [1], in his investigation he identified the heat effect in an unsteady natural convective past a semi-infinite moving permeable surface for different parameters. The presentation of a heat generation viscous stream through a leaky medium was in [2], observed the influences of MHD, diffusion on mutual natural convective flow. In [3] authors used numerical method Galerkin’s F.E.M solving the principal eq’s as a result they detected a mass transfer properties with heat generation/absorption on transient MHD natural convective fluid surrounded in a permeable medium. Thermal radiation effect was examined in [4], on mixed flow through vertical convective surfaces in saturated permeable medium. In [5] the possessions of head generation/absorption was calculated when the fluid was considered as free convective flow and surrounded electrically conducted on a vertical wavy surface. A transient double diffusive MHD natural flow convective of kuvshinski fluid was studied in [7] by means of radiation, chemical reaction and absorption on moving leaky surface surrounded in a leaky medium with heat generation. An influences of heat transfer on MHD with hall current, natural convective flow with a vertical porous plate studied in [12].

Srilatha and Balamurugan[10] analysed the properties on MHD natural convective over a vertical permeable dish in the presence of radiation absorption by using perturbation procedure. Properties of hall current, chemical response and radiation on flow natural convective through a spongy medium bounded was studied by [6, 11]. It motivated to explore the impact of thermal radiation on convective flow on a vertical permeable plate. Using trail procedure the leading eq’s are determined accurately by reducing structure of non-linear O.D.E’s.

II. PROBLEM FORMATION

Problematic of unsteady 2 - dimensional natural flow convective of an non-compressible permeable viscous fluid past vertical plate. On the plate \( v' = -U_0 \) is considered perpendicularly. In this experiment temperature maintained constant on the plane. \( O (x', y', z') \) is a system of rectangular coordinates with \( y' = 0, z' \) as a leading edge on axis. In this experiment except the influence of the density variation, the remaining all properties consider as it is for the fluid. Variations in density, expansion coefficient with respect to momentum and temperature are tiny. The set of following equations formed by usual approximation of Boussinesq’s.

\[
\begin{align*}
\frac{\partial u_1}{\partial t} + v_1 \frac{\partial u_1}{\partial y} &= g \beta (T_1 - T_{dw}) + g \beta (C_1 - C_{in}) + v \frac{\partial^2 u_1}{\partial y^2} - \frac{\sigma \beta \gamma}{\rho (1 + \alpha t^2)} + \frac{v}{k_1} u_1 \quad (1) \\
\frac{\partial T_1}{\partial t} + v_1 \frac{\partial T_1}{\partial y} &= \alpha \frac{\partial^2 T_1}{\partial y^2} + \frac{R^*}{\delta_c p_c} (C_1 - C_{in}) - \frac{1}{\rho_c p} \frac{\partial v_1}{\partial y} + \frac{Q_1}{\rho_c p} (T_1 - T_{dw}) \quad (2) \\
\frac{\partial C_1}{\partial t} + v_1 \frac{\partial C_1}{\partial y} &= D \frac{\partial^2 C_1}{\partial y^2} + k (C_1 - C_{in}) \quad (3)
\end{align*}
\]

Where, \( u_1, v_1 \) are the constituents of velocity, constituents of temperature and concentration are \( T_1, C_1 \). \( \alpha, D, m, K \) and \( R^* \) are the thermal conductivity, concentration diffusivity, hall currents parameter, chemical reaction rate constant, coefficient of proportionality for absorption radiation respectively.

Corresponding boundary circumstances:

\[
\begin{align*}
&u_1 = 0, \quad T_1 = T_{dw}, \quad C_1 = C_{in}, \quad \text{at} \quad y' = 0 \\
&u_1 = 0, \quad T_1 = T_{in}, \quad C_1 = C_{in}, \quad \text{at} \quad y' \to \infty
\end{align*}
\] (5)

Non-dimensional variables are make known to as

\[
\begin{align*}
u &= \frac{u_1}{U_0}, \quad t = \frac{t_1 u_0^2}{v}, \quad y = \frac{y_1 U_0}{v}, \quad T = \frac{T_1 - T_{in}}{T_{dw} - T_{in}}, \quad C = \frac{C_1 - C_{in}}{C_{in} - C_{in}}
\end{align*}
\]


\[ k = \frac{\nabla^2}{a^2}, \quad P_r = \frac{v}{\nu}, \quad S_c = \frac{v}{D}, \quad M = \frac{\alpha B^2 v}{\mu u^2}, \quad M_1 = \frac{M}{1 + m^2}, \quad R = \frac{v \sigma \tau (c_0^2 - c_2^2)}{\rho u^2}, \]

\[ N = \frac{\beta (c_0^2 - c_2^2)}{\beta (c_0^2 - c_2^2)}, \quad K_r = \frac{\nu \beta \tau (c_0^2 - c_2^2)}{u_0}, \quad F = \frac{4 \alpha v}{\rho u^2}. \]

(6)

Parameters \( P_r, G_r, N, S_c, M, K, \beta, \beta^1 K_r, R \), are in [7]. \( F \)-thermal radiation, \( P \)-heat generation parameters respectively.

From (2)-(4), represents the non-dimensional equation forms obtained by introducing the non-dimensional quantities.

Non-dimensional form of equations (2)-(4) as in the bellow which are obtained with the help of the above non-dimensional quantities.

\[ \frac{\partial u}{\partial t} - \frac{\nu \partial^2 u}{\partial y^2} = G_r(T + N C) + \frac{\beta^2 u}{\partial y^2} - \left[ M_1 + \frac{1}{K_0} \right] u \]

(7)

\[ \frac{\partial T}{\partial t} - \frac{\nu \partial^2 T}{\partial y^2} = \frac{1}{\nu} \frac{\partial^2 T}{\partial y^2} + R C - F T + P T \]

(8)

\[ \frac{\partial C}{\partial t} - \frac{\nu \partial^2 C}{\partial y^2} = \frac{1}{\nu} \frac{\partial^2 C}{\partial y^2} + K_r C \]

(9)

The analogous boundary conditions are

\[ u = 0, \quad T = 1, \quad C = 1, \quad \text{at} \quad y = 0, \]

(10)

\[ u = 0, \quad T = 0, \quad C = 0, \quad \text{as} \quad y \to \infty \]

III. SOLUTION OF THE PROBLEM

Partial Differential equations in the above are reduced as ordinary DE’s for velocity, temperature, and concentrations in the nbd of porous plate are considered as follows.

\[ u(y, t) = u_0(y_0) e^{-\nu t}, \]

\[ T(y, t) = T_0(y_0) e^{-\nu t}, \]

\[ C(y, t) = C_0(y_0) e^{-\nu t}. \]

(11)

Substituting equation (11) in equations (7) to (9) we obtain

\[ u_0^1 + u_0^3 + \left[ n - (M_1 + \frac{1}{K}) \right] u_0 = -G_r T_0 + G_r N C_0 \]

(12)

\[ T_0^1 + P_r T_0 - P_r(F - G - n)T_0 = -P_r R C_0 \]

(13)

\[ C_0^1 + S_r C_0 + (n + K_r)S_r C_0 = 0 \]

(14)

\[ u_0 = 0, \quad T_0 = 1, \quad C_0 = 1, \quad \text{at} \quad y = 0, \]

(15)

\[ u_0 = 0, \quad T_0 = 0, \quad C_0 = 0, \quad \text{as} \quad y \to \infty \]

(16)

is the boundary conditions for the (12)-(14). (12)-(14) are solved by using (15) gives solutions as

\[ u_0 = (-S_2 - S_3) e^{-a_2 y} + S_2 e^{-a_3 y} + S_3 e^{-a_4 y} \]

(16)

\[ T_0 = e^{-a_2 y} + S_1(e^{-a_2 y} - e^{-a_3 y}) \]

(17)

\[ C_0 = e^{-a_2 y} \]

(18)

IV. RESULT AND DISCUSSION

In terms of the physical parameters \( P_r, S_c, M, K, R, K_r \) and \( m \), equations (12)-(14) are solved and got the physical awareness on Concentration \( C \), velocity \( u \) and temperature \( T \). We have chosen \( P_r = 0.71 \) (air), \( S_c = 1.5 \), \( n = 0.1 \), \( t = 0.1 \). For other non-dimensional parameters we consider different values. The effect of \( M \) (magnetic parameter) can be witnessed from Figure 1. It is discerned that growing the magnetic parameter the flow of viscosity slows down. This is for the reason that, damping effect on the velocity profile which due to drag force opposes the fluid motion as \( M \) increased. Effect of constraint \( R \) on the velocity profile is plotted in Fig. 2. It can be notice from Figure 3, effect of permeability limit \( K \) over the velocity profile. As this parameter increase the velocity flow is going slow down. In the observation of the chemical reaction, the parameter \( K_r \) over the velocity increases the flow rate is decreasing. The computational values of this parameter computed and plotted in Figure 4. Figure 5, is the computational diagram for the numerical values of thermal radiation (\( F \)) effect over the velocity. We can observe, when the numerical \( F \) values increases the profile of velocity decreases. In the velocity profile, the influence of the constraint \( G_r \) also slowdowns the flow rate with an increase of the numerical values for it. Figure-6 indicates the effect of Grasshof number. Figure-7 denotes the effect of buoyancy parameter \( N \) over the velocity profile. From that it can be observe that this parameter is also decreases or slowdowns the flow rate as the values of the parameter increases. The effect of heat generation parameter can be observe for different computational values in Figure-8. From that we can observe the flow rate decreases as the parameter values increases. Figure-9, is the computational diagram of the absorption constraint \( R \) over the velocity profile. Form this computation it can be observe that as the parameter values increases the effect of \( R \) also increases. The effect of \( S_c \) over the velocity which shown in figure 10. In the interval [0, 2] as the numerical value of \( S_c \) increased the velocity of flow increased and after a particular value of \( y \) in that interval velocity flow starts decreasing. From Figure 1 to 10 the velocity flow profile decreases or increases as the corresponding parameters increases. Effects of Prandtl number, thermal radiation parameter, buoyancy ratio, radiation limit, Schmidt number with numerical computation over temperature are presented from Figure.11-14. From all these diagrams we observed that as the parameters increased the temperature profile decreases except absorption of radiation parameter \( R \). The influence of Prandtl quantity \( P_r \) on the profile of temperature distribution shown in Figure 11. It is because, the smaller numerical values of \( P_r \) increases the thermal conductivity. So the heated surface differ away rapidly than for higher values of \( P_r \). Therefore, rate of heat transfer reduced due to thick layer of boundary. This figure shows that the temperature declines with the growth of Prandtl numeral \( P_r \). Figure.14 is diagram for distinct numerical values of the absorption of radiation parameter \( R \). It can be notice, in the interval [0, 2.8] temperature profile increased and after that interval flow decreased with an increase of the numerical values for \( R \). Figures.17 and Figure.18 are the effects of \( S_c \) and \( K_r \) over the concentration respectively. As the corresponding numerical values increased the flow profile decreased in the situation of \( S_c \) parameter and increased in the case of \( K_r \) respectively. The computational tables are also presented for Sherwood number, Nusslet number and skin-friction.
number for different flow quantities.

Figure 1: Profiles of velocity due to Magnetic parameter \( M \)

Figure 2: Profiles of velocity due to \( m \)

Figure 3: Profiles of velocity due to permeability parameter \( K \)

Figure 4: Profiles of velocity due to \( k_r \)

Figure 5: Profiles of velocity due to thermal radiation parameter \( F \)

Figure 6: Profiles of velocity due to Gr.

Figure 7: Profiles of velocity due to buoyancy ratio \( N \).

Figure 8: Profiles of velocity due to heat generation parameter \( P \).

Figure 9: Profiles of velocity due to absorption radiation parameter \( R \).

Figure 10: Profiles of velocity due to Schmidt number \( S_c \).

Figure 11: Profiles of temperature due to Prandtl number \( Pr \).
Influence of Heat Generation and Radiation on MHD Flow of Natural Convection

Figure 1.2 Profiles of temperature due to constraint \( Kr \).

Figure 1.3 Profiles of temperature due to thermal radiation \( F \).

Figure 1.4 Profiles of temperature due to buoyancy ratio \( N \).

Figure 1.5 Profiles of temperature due to absorption of radiation \( R \).

Figure 1.6 Profiles of temperature due to \( Sc \).

Figure 1.7 Profiles of concentration due to Schmidt number \( Sc \).

Figure 1.8 Profiles of concentration due to Chemical reaction \( Kr \).

Computational values for Sherwood number for dissimilar flow measures:

| \( Sc \) | \( Kr \) | \( Sk \) |
|---------|---------|---------|
| 1.5     | 1.3170  |         |
| 2.5     | 2.3164  |         |
| 3.5     | 3.3097  |         |
| 4.5     | 4.3014  |         |

| \( Kr \) | \( F \) | \( N \) | \( R \) | \( Nu \) |
|---------|---------|---------|---------|---------|
| 1.5     | 0.0624  |         |         |         |
| 2.5     | 0.5074  |         |         |         |
| 3.5     | 0.9798  |         |         |         |
| 4.5     | 1.8108  |         |         |         |

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| 3.5     | 0.9798  |         |         |         |         |         |
| 4.5     | 1.8108  |         |         |         |         |         |

The following are the Nusslet number for different flow quantities.

| \( Sc \) | \( Kr \) | \( Pr \) | \( F \) | \( N \) | \( R \) | \( Nu \) |
|---------|---------|---------|---------|---------|---------|---------|
| 1.5     | 0.0624  |         |         |         |         |         |
| 2.5     | 0.5074  |         |         |         |         |         |
| 3.5     | 0.9798  |         |         |         |         |         |
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|---------|---------|---------|---------|---------|---------|---------|
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| 2.5     | 0.5074  |         |         |         |         |         |
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| 3.5     | 0.9798  |         |         |         |         |         |
| 4.5     | 1.8108  |         |         |         |         |         |

The following are the Nusslet number for different flow quantities.
The following are the values for skin friction number $\tau$ for different flow quantities.

| Sc  | Kr  | Pr  | F  | N  | R  | M  | m  | K  | P  | Gr  | $\tau$ |
|-----|-----|-----|----|----|----|----|----|----|----|-----|-------|
| 1.5 |     |     |    |    |    |    |    |    |    |     | 2.3296 |
| 2.5 |     |     |    |    |    |    |    |    |    |     | 1.9868 |
| 3.5 |     |     |    |    |    |    |    |    |    |     | 1.7523 |
| 4.5 |     |     |    |    |    |    |    |    |    |     | 1.6524 |
| 0.6 |     |     |    |    |    |    |    |    |    |     | 2.2917 |
| 1.0 |     |     |    |    |    |    |    |    |    |     | 2.0742 |
| 1.5 |     |     |    |    |    |    |    |    |    |     | 1.8605 |
| 2.0 |     |     |    |    |    |    |    |    |    |     | 1.7398 |
| 0.6 |     |     |    |    |    |    |    |    |    |     | 2.2534 |
| 0.8 |     |     |    |    |    |    |    |    |    |     | 2.1070 |
| 1.0 |     |     |    |    |    |    |    |    |    |     | 1.9686 |
| 1.2 |     |     |    |    |    |    |    |    |    |     | 1.8388 |
| 0.6 |     |     |    |    |    |    |    |    |    |     | 2.2648 |
| 0.7 |     |     |    |    |    |    |    |    |    |     | 2.2133 |
| 0.8 |     |     |    |    |    |    |    |    |    |     | 2.1711 |
| 0.9 |     |     |    |    |    |    |    |    |    |     | 2.1359 |
| 0.3 |     |     |    |    |    |    |    |    |    |     | 2.4156 |
| 0.4 |     |     |    |    |    |    |    |    |    |     | 2.5410 |
| 0.5 |     |     |    |    |    |    |    |    |    |     | 2.7913 |
| 0.6 |     |     |    |    |    |    |    |    |    |     | 2.7389 |
| 3.0 |     |     |    |    |    |    |    |    |    |     | 2.5236 |
| 4.0 |     |     |    |    |    |    |    |    |    |     | 2.7176 |
| 5.0 |     |     |    |    |    |    |    |    |    |     | 2.9116 |
| 6.0 |     |     |    |    |    |    |    |    |    |     | 3.1057 |
| 1.5 |     |     |    |    |    |    |    |    |    |     | 2.1786 |
| 2.0 |     |     |    |    |    |    |    |    |    |     | 2.0534 |
| 2.5 |     |     |    |    |    |    |    |    |    |     | 1.9472 |
| 3.0 |     |     |    |    |    |    |    |    |    |     | 1.8559 |
| 2.0 |     |     |    |    |    |    |    |    |    |     | 2.5596 |
| 3.0 |     |     |    |    |    |    |    |    |    |     | 2.6526 |
| 5.0 |     |     |    |    |    |    |    |    |    |     | 2.7151 |
| 7.0 |     |     |    |    |    |    |    |    |    |     | 2.7347 |
| 1.5 |     |     |    |    |    |    |    |    |    |     | 2.5895 |
| 2.0 |     |     |    |    |    |    |    |    |    |     | 2.7564 |
| 2.5 |     |     |    |    |    |    |    |    |    |     | 2.8734 |
| 3.0 |     |     |    |    |    |    |    |    |    |     | 2.9601 |
| 0.6 |     |     |    |    |    |    |    |    |    |     | 2.4425 |
| 0.7 |     |     |    |    |    |    |    |    |    |     | 2.5554 |
| 0.8 |     |     |    |    |    |    |    |    |    |     | 2.6682 |
| 0.9 |     |     |    |    |    |    |    |    |    |     | 2.7811 |
| 3.0 |     |     |    |    |    |    |    |    |    |     | 3.4945 |
| 4.0 |     |     |    |    |    |    |    |    |    |     | 4.6593 |
| 5.0 |     |     |    |    |    |    |    |    |    |     | 5.8241 |
| 6.0 |     |     |    |    |    |    |    |    |    |     | 6.9889 |
V. CONCLUSIONS

From this entire study, properties of thermal radiation on MHD free convection flow with heat generation was observed. By this investigation the following points makes our conclusions.

1. The velocity profile of flow decreases as the parameters magnetic, hall current, permeability, chemical reaction, thermal radiation parameter, Grashof, buoyancy, heat generation absorption radiation. It is witnessed that when Schmidt number increased the effect of velocity profile increased up to some numerical values for Sc and then started decreasing with the increasing the values for Sc.

2. Temperature goes down with increase of the prandtl parameter, chemical reaction parameter, and thermal radiation parameter but there is a inverse effect in buoyancy ratio over the temperature.

3. The outcome of absorption of radiation parameter R over the temperature has increased initially and then after decreased with an increase of the numerical values for R.

4. Sherwood numeral rises with an growth in Schmidt numeral and declines through increase of chemical reaction parameter.

5. Nusselt number decreases with growth of Schmidt numeral, buoyancy ration, absorption radiation parameter. It declines with a rise of chemical response constraint, prandtl number, and thermal radiation parameter.

6. Skin friction parameter decreases in the case of increase the numerical values for different parameters and in some cases in reverse.

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