Chemical Reaction, Thermal Stratification Effects on MHD Flow Over A Vertical Stretching Surface With Heat Source

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ABSTRACT: In this study, the fluid which is viscous and incompressible are studying nonlinear Magnetohydrodynamics (MHD) flow using transfer of mass and heat specifications. Considering flow as electrical conducting and has Boussinesq in nature. While considering the chemical reactions and heat stratification investigation carried out on a vertically stretching surface where magnetic field occurs transverse to the flow direction. To solve the flow problem, governing equations in numerical methods considered. Using similarity transformations, non-linear PDEs converted into non-linear ODE. Numerical solution is obtained using values of dimensionless specifications in MATLAB bvp4c package. Results show the existence of magnetic fields, chemical reactions and thermal stratification effects flow field which is presented through graphs.

Keywords: Thermal stratification, Heat source, chemical reaction, magnetic field, bvp4c.

1. INTRODUCTION

When hot fluid ejected in the closed section, Thermal stratification is a natural phenomenon in which litter fluid present top of the fluid and denser fluid present bottom of the fluid. During extrusion process, this process deeply studied in which polymer cooled below the certain temperature using fluid. The rate of cooling shows the impact on the object of final outcome. To determine the trends of the reaction, the mathematical models are developing in the recent trends. This study helps great impact on the hydrometallurgical sectors. Study of Thermal stratification impact in the nonlinear MHD stream with mass and heat move with thermal stratification and chemical reaction over a vertically extending surfaces. Mabood et.al [3] contemplated the impact of the chemical reaction on MHD turning fluid on a vertical plate, which is porous with a heat source. The effect of the chemical reaction over moving plate investigated by the Tripathy [4]. Srinivasacharya and Ram Reddy [5] examined mixed convection in a micro polar fluid with twofold stratification. The fluid likewise represents the impact of the radiation on a vertical plate inserted in a permeable medium by Paland and Mondal [6]. Makinde and Ogulu [7] considered the thermal radiation impact on the mass exchange and the heat move of a variable thickness fluid pervaded by a transverse magnetic field. B. Rout et al. [8] examined the MHD mass and heat impact through a vertical moving plate with convective limit conditions. Contemplated the impact of the chemical reaction and thermal radiation impact on the flimsy MHD free convectional stream of vertical moving permeable plate with heat source and sink by Ibrahim et al[9]. Shankar Goud et al[10] researched the influence of the thermal radiation on the limit stream within the sight of viscous dissipation over an exponentially extending sheet. Bal Reddy et.al [11] deliberated the impact of the free convectional boundary layer flow on a permeable medium filled with nanofluid through a inclined flat plate. Kandasamy et.al [12] presented heat & mass stream through a vertical extending surface with thermal stratification and heat source
impact concentrated Venkateshwarlu et.al [13] explored the semi-infinite vertical plate with exponential power law fluid having variable thermal conductivity under the induced magnetic field. Sever researchers are investigated are different aspects in different fields [14-24].

In the current paper, Chemical reaction, heat transfer and mass transfer over vertical extending surface with thermal stratification and heat source impacts are examined. Governing equation are transformed to nonlinear deformed equation using similarity transformation. Solution are obtained using bvp4c MATLAB in built solver

2. MATHEMATICAL FORMULATION

Fluid with 2-dimensional consistent nonlinear MHD boundary layer flow stream of anviscous, incompressible, electrically conducting, and Boussinesq in nature. Fluid stream over a vertical extending surface with uniform magnetic field impacts considered. The fluid expected to have the behaviour of the chemical reaction and the thermal stratification. In the facilitate framework, x – axis considered as corresponding to the vertical surface and Y-hub as the opposite to the vertical surface and strength of transverse magnetic field applied parallely. Expected factors like an initiated magnetic field, and the electric field not considered because of the polarization of charges. From every one of these conditions governing condition created for momentum, energy & diffusion abandoning viscous and Joules dissipation under Boussinesq estimate given below.

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0
\]  

...(1)

\[
u \frac{\partial u}{\partial x} + \nu \frac{\partial v}{\partial y} = \nu \frac{\partial^2 u}{\partial y^2} + g \beta (T - T_0) + g \beta' (C - C_\infty) + \frac{\sigma B^2}{\rho} u
\]  

...(2)

\[
u \frac{\partial^2 \theta}{\partial y^2} - \frac{\alpha^2}{\nu} \theta = \frac{g}{\rho c} (T - T_\infty)
\]  

...(3)

\[
u \frac{\partial C}{\partial x} + \nu \frac{\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} - k_i (C - C_\infty)
\]  

...(4)

Where u, v are the velocity components along x, y directions, respectively.

The proper boundary condition are given by

\[
u = U(x) = ax, v = 0, T = T_w(x), C = C_w(x), \text{ at } y \to 0
\]

\[
u \to 0, T \to T_w(x) = (1 - n)T_0 + nT_w(x), C \to C_w(x) \text{ as } y \to \infty ...
\]

...(5)

Here \( \alpha \) is thermal stratification constant and \( \alpha \) is dimensional constant, and is lies between 0 \( \leq \alpha \leq 1 \)

\( \text{alowwhich is equal to} \ \frac{m_1}{1 + m_1} (\text{Ref.}[1]). \) Now by defining the stream functions \( (\text{Ref.}[2]) \), \(u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x}\) it can be easily proved that the Eqns.(1) isidentically satisfied and using the nondimensional variables.Similarity clarifications exist if undertake that \( U(x) = ax \) and present the dimensionless form of energy and concentration as

\[
\psi = \sqrt{uxU(x)} f(\eta), \eta = y \frac{U(x)}{ux}, T = T_w + (T_w - T_\infty)\theta(\eta), C = C_w + (C_w - C_\infty)\phi(\eta)
\]

Using the similarity and dimensionless variables, eqns.(2) and (4) reduce to the subsequent form:

\[
f'' + \frac{f'}{m} + \text{Re} \text{Gr}_\theta \theta + \text{Re} \text{Gr}_c \phi - \left(f'\right)^2 - \frac{f}{\text{Re}^2} = 0
\]  

...(6)

\[
\theta'' - Pr f' \left(\theta + \frac{\alpha}{1 + \alpha}\right) + Pr \text{Gr}_\theta \theta' - SPr \theta = 0
\]  

...(7)

\[
\phi' \text{Sc} (f' \phi + \text{f} \phi') + Scf' = 0
\]  

...(8)

The boundary constraints become in the resulting form:

\[
f = 0, \ f' = 1, \ \theta = 0, \ \phi = 1, \text{ at } \eta \to 0
\]

\[
f' \to 0, \ \theta \to 0, \ \phi \to 0 \text{ as } \eta \to 0
\]  

...(9)
Where prime represents diff. with resp. to $\eta$. In this effort temperature deviation and concentration variation of the surface is taken into consideration and also the temperature and concentration power given by $T_w - T_\infty = N x^n, C_w - C_\infty = N_1 x^n$.

**Fig. 1.** Velocity profiles for various values of magnetic parameter.

**Fig. 2.** Temperature profiles for various values of Magnetic parameter.
Fig. 3. Concentration profiles for various values of Magnetic parameter.

Fig. 4. Velocity profiles for several of thermal stratification parameter.
Fig. 5. Temperature profiles for various values of thermal stratification parameter.

Fig. 6. Concentration profiles for various values of thermal stratification parameter.
Fig. 7. Velocity profile for various values of chemical reaction parameter.

Fig. 8. Temperature profile for various values of chemical reaction parameter.
3. RESULTS AND DISCUSSION

Graphical sketches used to investigate the numerical findings. Dimensionless parameters such as velocity, temperature, concentration curves for various estimations of magnetic field with fixed chemical reaction and substance thermal stratification represented in the Fig.1,2 and Fig. 3 respectively. Temperature and concentration of the fluid increment with attractive boundary Concentration of the fluid and temperature increase with magnetic parameter. Fig. 4, 5 and Fig 6 shows. Fig. 4, 5 and Fig 6 showsthe dimensionless parameters such as velocity, temperature along with concentration curves for different estimations of thermal stratifications with uniform magnetic field and unaltered compound reaction determinations. fluid velocity and fluid temperature decreases with a rise in thermal strata specification while concentration is directly proportional to thermal stratification specification. The dimensionless parameters such as temperature, velocity along with concentration curves for various magnitudes of chemical reaction specifications where the magnetic field kept uniform and thermal stratification not changed noted in Fig 7, 8 and Fig 9 respectively. It likewise saw that the speed of the fluid reduced with the chemical response boundary. Velocity of the fluid and fluid concentration are inversely proportional to chemical reactions specification while fluid temperature is directly proportional.

4. CONCLUSION

The conclusions of the present are:

- When thermal stratification and magnetic field kept uniform, fluid velocity and fluid concentration are inversely proportional to chemical reaction specification while fluid temperature is directly proportional.
- Thermal stratification and reactions of chemical nature are unchanged fluid temperature and fluid concentration are directly proportional while fluid velocity is inversely proportional to magnetic specification.
- When the magnetic field kept uniform and chemical reaction, specifications kept constant, the fluid velocity and the fluid temperature is inversely proportional to thermal stratification specification while the fluid concentration is directly proportional.
- The velocity near the plate first increased and then decreases when evaluated.
- As magnetic field increased, it also increases the temperature at a slow pace.

Fig. 9. Concentration profiles for various values of chemical reaction parameter.
Nomenclature

| Symbol | Description |
|--------|-------------|
| \( \text{Pr} = \frac{\nu c_p}{k} \) | Prandtl number |
| \( \text{Re}_x = \frac{U x}{\nu} \) | Reynolds number |
| \( \text{Gr}_x = \frac{\nu g \beta (T_x - T_w)/U^3}{2} \) | Grashof number |
| \( \text{Sc} = \frac{\nu}{D} \) | Schmidt number |
| \( \text{M}^2 = \frac{\sigma B_0^2}{\rho a} \) | Magnetic parameter |
| \( \gamma = \frac{\nu k_v}{U^2} \) | Chemical reaction parameter |
| \( S = \frac{2XQ}{U} \) | Heat source parameter |
| \( N, N_1, n_1, m_1 \) | Constants |
| \( w, \infty \) | Surface and ambient conditions. |

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