MHD Casson nano fluid flow along an infinite vertical permeable plate embedded in a porous media in the presence of Chemical reaction, Soret effect, Radiation and Activation Energy

Swetha Lanka[1], Venkata Subrahmanyam Sajja[2], Sridhar Wuriti[3]
[1]*Department of Mathematics, Sir C R Reddy College of Engineering, Eluru-534007, A.P., India*
[2,3]*Department of Engineering Mathematics, Koneru Lakshmaiah Education Foundation, Guntur-522302, A.P., India*

Abstract: The primary objective of this article is to investigate the flow of transient magnetohydrodynamics, as well as the transfer of heat and mass through a permeable medium by employing a two-term perturbation scheme approach. Thermal radiation has an effect on the flow of liquid films, which are taken into consideration. The effects of flow physical parameters, such as the thermoporesis parameter (So), the Schmidt number (Sc), the radiation parameter (R), the Prandtl number (Pr), the permeability parameter (K), the slip parameter (h), the chemical reaction parameter (Kc), the Grashof number (Gr), the modified Grashof number (Gc), and the perturbation parameter (E), on the distributions of fluid velocity, temperature, and concentration are analyzed and discussed in great detail. Two different situations of velocity profiles were investigated in this study. The first case involved the flow of a cooled plate with a temperature greater than zero, while the second case involved the flow of a heated plate with a temperature less than zero.

Keywords: Heat and Mass Transfer, Transient, Radiation, Activation energy, soret effect

I. INTRODUCTION

It is a very significant mechanism that is active in a range of contexts, ranging from the cooling of electronic circuit boards in computers to the causing of large-scale circulation in the atmosphere, as well as in lakes and seas, which influences the weather. Natural convection, also known as buoyant or free convection, is a synonym for "free" convection. Specifically, it is brought about by the interaction of gravitational fields and density gradients. You will gain a better understanding of the qualitative characteristics of a range of scenarios that you might come across by reading this quick introduction.

In classical MHD flow control, the boundary layer flow of an electrically conducting fluid can be controlled by applying an external magnetic field and subjecting it to the condition that the electric conductivity of the fluid should be high (for example, the liquid form of semiconductors, plasma, electrolytes, and liquid metals). This would be done in order to achieve the desired effect. Because of the high electric conductivity of the fluid, the influence of an external magnetic field that is applied is very considerable, even when the magnetic field is of moderate strength (around 1 Tesla). It is also not necessary to make use of an external electric field in order to accomplish the goal of achieving an effective flow control. The electric current that is created by the external magnetic field is insufficient to control the flow separation in the case of fluids that have a poor conductivity, such as sea water. In this scenario, an external electric field is required to be applied. The motion that occurs within the boundary layer can be stabilized by the Lorentz force that is parallel to the wall. This is accomplished by slowing down the expansion of the boundary layer. In his article [1], Midya discusses the effects of chemical reactions and magnetic fields on the flow of second-grade fluids that are electrically conducting. Seddeek et al. [2], Salem and Abd El-Aziz [3], Mohamed [4], and Ibrahim et al. [5] are only a few examples of the many studies that have been conducted on the combined impacts of heat and mass transfer in the presence of MHD and chemical reaction. Because of its potential uses in soil physics, geohydrology, and the filtration of solids from liquids, chemical engineering, and biological systems, natural convection flow over a vertical plate that is immersed in porous media constitutes an extremely important phenomenon. Convection fluxes in permeable media have recently garnered a lot of attention due to the fact that they are extremely important in a variety of architectural applications. Some examples of these applications include geothermal systems, strong network heat exchangers, warm protections, oil extraction, and the storage of nuclear substances. These can also be coupled to regular convection in the earth's outer layer, underground coal gasifcation, ground water hydrology, divider-cooled synergist reactors, energy-efficient drying techniques, and other similar processes. It is possible to find in (Nield and Benjan [6]) detailed surveys of flow through and flow through permeable media. Employemath and Patil [7] focused their attention on the influence that free convection streams have on the oscillatory movement that occurs through a permeable medium. This movement is restricted by a vertical plane surface that maintains a constant temperature distribution. There has been discussion by Sharma et al. [8] regarding the fluctuating temperature and mass exchange that occurs via a permeable medium that has varying porousness. Literature written by Pop and Ingham [9], Ingham and Pop [10], Vafai [11], Vadasz [12], and others provide a complete review of the material that is currently accessible in this sector. It is impossible to ignore the effects of thermal radiation heat transfer when technological activities are carried out at higher temperatures (Siegel and Howel [13]). This phenomena has become highly essential. In the industrial sector, the influence of radiation on MHD flow, heat transfer, and mass transfer is becoming increasingly significant. In the field of engineering, there are several processes that take place at high temperatures, and thus, having knowledge of radiation heat transfer becomes highly significant for the design of the equipment that is relevant to these processes. Knowledge of radiative heat transmission in the system can lead to the creation of a product that possesses the attributes that are wanted, and the quality of the final product is heavily dependent on the parameters that control the heat. Following the presence of thermal radiation, Olanrewaju et al. [14] conducted an investigation on the three-dimensional unsteady MHD flow and mass transfer in a porous space. A number of studies have been conducted to investigate the effects of heat radiation on various flows, including those conducted by Cortell [15], Bataller [16], Ibrahim et al. [17], Shateyi [18], Shateyi and Motsa [19], Aliakbar et al. [20], Hayat [21], and Cortell [22], Sindhu Devi et al. [23] amongst other researchers.

The chemical reaction and Soret effects on unstable MHD free convective heat and mass transfer via an infinite vertical plate imbedded in a porous material when thermal radiation is present have gotten very little attention, despite the fact that all of these research have been conducted. In light of this, the primary objective of the current investigation is to investigate the impacts of thermal radiation, chemical reaction, and Soret effects on the flow of unsteady MHD free convection fluid from a vertical porous plate. An application of the 2-term perturbation strategy is used to change the governing equations. Graphical representations are taken of the effects that a number of controlling parameters have on the profiles of velocity, temperature, and concentration.

II. MATHEMATICAL FORMULATION

An unsteady 2D fluid flow of an incompressible and electrically conducting viscous fluid, upon an infinite vertically permeable flat plate induced in a porous environment is considered.

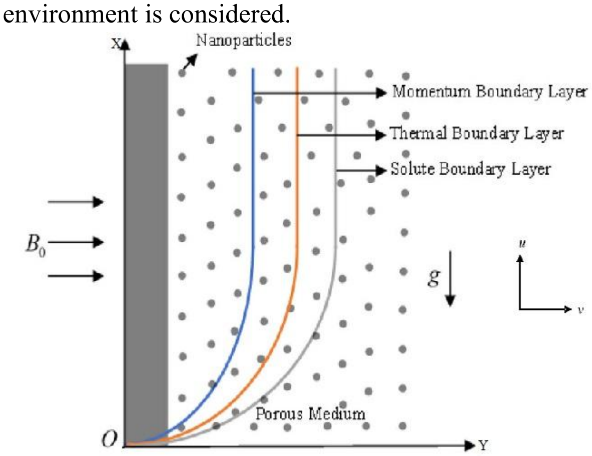

Fig. I. Flow configuration of the current research

- ❖ The y-axis is taken normal to the plate, whereas the x-axis is taken on the infinite plate and parallel to the vertical free-steam velocity.
- ❖ A uniform strength magnetic field is applied transversely to the flow direction. At first, the fluid and the plate are both at the same temperature and in a stationary state with constant concentration levels.
- ❖ As a result, the temperature and concentration level at the plate are increased, and the plate begins to

move impulsively in its own plane with a velocity. The fluid is assumed to have constant properties except that the influence of the density variations with temperature and concentration, which are considered only the body force term.

- ❖ This means that the viscous dissipation and Darcy's dissipation are not taken into account when the velocity is low.
- ❖ The flow that occurs in the medium is solely attributed to the buoyancy force that arises from the disparity in temperature that exists between the porous plate and the fluid.
- ❖ Illustration of the flow arrangement and coordinate system can be found in Figure I. The physical variables are just functions of y and t, according to the premise that was presented before, and the equations that regulate the conservation of mass (continuity), momentum, energy, and concentration can be stated as follows:

$$\frac{\partial \tilde{v}}{\partial \tilde{y}} = 0 \tag{1}$$

$$\frac{\partial \tilde{u}}{\partial \tilde{t}} + \tilde{v}\frac{\partial \tilde{u}}{\partial \tilde{y}} = g\beta_T[\tilde{T} - \tilde{T}_\infty] + g\beta_C[\tilde{C} - \tilde{C}_\infty] + \upsilon\left(1 + \frac{1}{\beta}\right)\frac{\partial^2 \tilde{u}}{\partial \tilde{y}^2} - \frac{\upsilon}{\tilde{k}}\tilde{u} - \frac{\sigma B_0^2}{\rho}\tilde{u} \tag{2}$$

$$\frac{\partial \tilde{T}}{\partial \tilde{t}} + \tilde{v}\frac{\partial \tilde{T}}{\partial \tilde{y}} = \frac{K_T}{\rho Cp}\frac{\partial^2 \tilde{T}}{\partial \tilde{y}^2} - \frac{1}{\rho Cp}\frac{\partial q_r}{\partial \tilde{y}} \tag{3}$$

$$\frac{\partial \tilde{C}}{\partial \tilde{t}} + \tilde{v}\frac{\partial \tilde{C}}{\partial \tilde{y}} = D\frac{\partial^2 \tilde{C}}{\partial \tilde{y}^2} + D_1\frac{\partial^2 \tilde{T}}{\partial \tilde{y}^2} - \tilde{K}_C\left[\tilde{C} - \tilde{C}_\infty\right] \tag{4}$$

The relevant boundary conditions are

$$\tilde{u} = L_1\left(\frac{\partial \tilde{u}}{\partial \tilde{y}}\right), \quad \tilde{T} = \tilde{T}_w, \quad \tilde{C} = \tilde{C}_w \quad at \quad \tilde{y} = 0 \tag{5}$$

$$\tilde{u} \to 0, \quad \tilde{T} \to \tilde{T}_\infty, \quad \tilde{C} \to \tilde{C}_\infty \quad as \quad \tilde{y} \to \infty \tag{6}$$

Based on Sparrow and Cess's [24] assumptions about radiative heat flux and the equation of continuity (1), we may deduce that. In this case, x represents the dimension along the plate and y represents the dimension perpendicular to it. In this equation, u and v represent the x- and y-components of velocity, g stands for gravitational acceleration, β_T and β_C denote the thermal and concentration expansion coefficients, respectively. K stands for the permeability parameter, $B_0$is for magnetic induction, T for the thermal temperature inside the thermal boundary layer and C for the corresponding concentration., for electric conductivity, is the variable to consider. Cp for specific heat at constant pressure, k_T the thermal diffusion ratio,D the diffusion coefficient, t for time, and ρ is the fluid density are all variables to consider.

The non-dimensional quantities are:

$$U = \frac{\tilde{u}}{\xi_0}, y = \frac{\tilde{y}\xi_0}{\upsilon}, n = \frac{4\upsilon\tilde{n}}{\xi_0^2}, L_1 = \frac{2 - M_x}{M_x}, h = \frac{L_1\xi_0}{\upsilon}, Kc = \frac{\tilde{K}_c\upsilon}{\xi_0^2}, S_0 = \frac{D_1\left[\tilde{T}_w - \tilde{T}_\infty\right]}{\upsilon\left[\tilde{C}_w - \tilde{C}_\infty\right]},$$
$$R = \frac{4\upsilon\tilde{I}}{\rho Cp\xi_0^2}, M = \frac{\sigma B_0^2\upsilon}{\rho\xi_0^2}, Gc = \frac{g\beta_C\upsilon\left[\tilde{C}_w - \tilde{C}_\infty\right]}{\xi_0^3}, Gr = \frac{g\beta_T\upsilon\left[\tilde{T}_w - \tilde{T}_\infty\right]}{\xi_0^3},$$
$$K = \frac{\tilde{K}_0\xi_0^2}{\upsilon^2}, t = \frac{\xi_0^2\tilde{t}}{4\upsilon}, M_1 = -\left(M - \left(\frac{n}{4}\right)\right) \tag{7}$$

Using above quantities in equations (1)-(6), we can obtain

$$\frac{1}{4}\frac{\partial U}{\partial t} - \left(1 + Ee^{-nt}\right)\frac{\partial U}{\partial y} - GrT - GcC - \frac{\partial^2 U}{\partial y^2} + M_1 U = 0 \tag{8}$$

$$\frac{1}{4}\frac{\partial T}{\partial t} - \left(1 + Ee^{-nt}\right)\frac{\partial T}{\partial y} - \frac{1}{\Pr}\frac{\partial^2 T}{\partial y^2} + RT = 0 \tag{9}$$

$$\frac{1}{4}\frac{\partial C}{\partial t} - \left(1 + Ee^{-nt}\right)\frac{\partial C}{\partial y} - \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} + KcC - S_0\frac{\partial^2 T}{\partial y^2} = 0 \tag{10}$$

And

$$U = h\left(\frac{\partial U}{\partial y}\right), \quad T = 1, \quad C = 1 \quad at \quad y = 0 \tag{11}$$

$$U \to 0, \quad T \to 0, \quad C \to 0 \quad as \quad y \to \infty \tag{12}$$

Solving Methodology:

The set of partial differential equations (8) – (10) cannot be solved in closed form. However, they can be solved analytically after reducing them into a set of ordinary differential equations by taking the expressions for velocity U(y), temperature T(y) and concentration C(y) in dimensionless form as follows:

$$U(y,t) = f_0 + Ee^{-nt}f_1 \tag{13}$$

$$T(y,t) = g_0 + Ee^{-nt}g_1 \tag{14}$$

$$C(y,t) = h_0 + Ee^{-nt}h_1 \tag{15}$$

Substituting (13) – (15) in (8) – (10) and equating the coefficients of zeroth order and equating the coefficients of the first order, neglecting the higher order of and simplifying we obtain the following set of equations:

$$f_0'' + f_0' - Mf_0 + Gch_0 + Grg_0 = 0 \tag{16}$$

$$f_1'' + f_1' - M_1 f_1 + f_0' + Grg_1 + Gch_1 = 0 \tag{17}$$

$$g_0'' + \Pr g_0' - R\Pr g_0 = 0 \quad (18)$$

$$g_1'' + \Pr g_1' + \left[\left(\frac{n}{4}\right) - R\right]\Pr g_1 + g_0' \Pr = 0 \quad (19)$$

$$h_0'' + Sch_0' - KcSch_0 + ScS_0 g_0'' = 0 \quad (20)$$

$$h_1'' + Sch_1' + \left[\left(\frac{n}{4}\right) - Kc\right]Sch_1 + Sch_0' + ScS_0 g_1'' = 0 \quad (21)$$

The final solutions of velocity, temperature and concentration are

$$\begin{aligned} U(y,t) &= f_0 + Ee^{-nt} f_1 \\ &= \left[H_9 e^{-m_5 y} - H_7 e^{-m_1 y} - H_8 e^{-m_3 y}\right] + \\ &\quad Ee^{-nt}\left[H_{15}e^{-m_6 y} - H_{10}e^{-m_1 y} - H_{11}e^{-m_2 y} - H_{12}e^{-m_3 y} - H_{13}e^{-m_4 y} + H_{14}e^{-m_5 y}\right] \end{aligned} \quad (22)$$

$$\begin{aligned} T(y,t) &= g_0 + Ee^{-nt} g_1 \\ &= \left[e^{-m_1 y}\right] + Ee^{-nt}\left[H_1\left(e^{-m_1 y} - e^{-m_2 y}\right)\right] \end{aligned} \quad (23)$$

$$\begin{aligned} C(y,t) &= h_0 + Ee^{-nt} h_1 \\ &= \left[(1+H_2)e^{-m_3 y} - H_2 e^{-m_1 y}\right] + \\ &\quad Ee^{-nt}\left[H_6 e^{-m_4 y} - H_3 e^{-m_1 y} + H_4 e^{-m_2 y} + H_5 e^{-m_3 y}\right] \end{aligned} \quad (24)$$

Where

$$m_1 = \frac{\Pr + \sqrt{(\Pr)^2 + 4R\Pr}}{2};$$

$$m_2 = \frac{\Pr + \sqrt{(\Pr)^2 - 4\Pr\left[\left(\frac{n}{4}\right) - R\right]}}{2};$$

$$H_1 = \frac{\Pr m_1}{m_1^2 - \Pr m_1 + \Pr\left[\left(\frac{n}{4}\right) - R\right]};$$

$$m_3 = \frac{Sc + \sqrt{(Sc)^2 + 4ScKc}}{2}; \quad H_2 = \frac{ScS_0 m_1^2}{m_1^2 - Scm_1 - scKc}$$

$$; \; m_4 = \frac{Sc + \sqrt{(Sc)^2 - 4Sc\left[\left(\frac{n}{4}\right) - Kc\right]}}{2};$$

$$H_3 = \frac{\left[ScH_2 m_1 + ScS_0 H_1 m_1^2\right]}{m_1^2 - Scm_1 + \left[\left(\frac{n}{4}\right) - Kc\right]Sc};$$

$$H_4 = \frac{ScS_0 H_1 m_2^2}{m_2^2 - Scm_2 + \left[\left(\frac{n}{4}\right) - Kc\right]Sc};$$

$$H_5 = \frac{Sc(1+H_2)m_3}{m_3^2 - Scm_3 + \left[\left(\frac{n}{4}\right) - Kc\right]Sc};$$

$$m_5 = \frac{1 + \sqrt{1+4M}}{2}; \quad H_6 = H_3 - H_4 - H_5;$$

$$H_7 = \frac{(Gr + H_2)}{m_1^2 - m_1 - M}; \quad H_8 = \frac{Gc(1+H_2)}{m_3^2 - m_3 - M};$$

$$H_9 = \frac{(hm_1 + 1)H_7 + (hm_3 + 1)H_8}{(hm_5 + 1)};$$

$$m_6 = \frac{1 + \sqrt{1 - 4M_1}}{2}; \; H_{10} = \frac{m_1 H_7 + GrH_1 - GcH_3}{m_1^2 - m_1 - M_1};$$

$$H_{11} = \frac{GrH_1 - GcH_4}{m_2^2 - m_2 - M_1}; \quad H_{12} = \frac{m_3 H_8 + GcH_5}{m_3^2 - m_3 + M_1};$$

$$H_{13} = \frac{GcH_6}{m_4^2 - m_4 + M_1}; \; H_{14} = \frac{m_5 H_9}{m_5^2 - m_5 + M_1};$$

$$H_{15} = \frac{(hm_1+1)H_{10} - (hm_2+1)H_{11} + (hm_3+1)H_{12} + (hm_4+1)H_{13} - (hm_5+1)H_{14}}{(hm_6+1)}$$

III. RESULTS AND DISCUSSION:

Through the utilisation of the 2-term perturbation technique, the partial differential equations that govern flow and heat transfer are converted into a set of ordinary differential equations that are non-linear. This is the set of values that we utilised in order to make graphs: h=1, K=1, Gc=5, Gr=5, M=2, S0=1, Kc=1, Pr=0.71. The purpose of this paper was to investigate two different cases involving velocity profiles. The first case involved a flow of a cooled plate with a temperature greater than zero, while the second case involved a flow of a heated plate with a temperature less than zero. Figures 1-18 are depicted to illustrate the variations in the concentration, temperature, and velocity distributions according to the Soret parameter (So), the Schmidt number (Sc), the radiation parameter (R), the Prandtl number (Pr), the permeability parameter (K), the slip parameter (h), the chemical reaction parameter (Kc), the Grashof number (Gr), modified Grashof Number (Gc), and the perturbation parameter (E). An increase in the magnetic field parameter causes a decrease in the velocity of the fluid when the plate is cooled. This is because the presence of a magnetic field that is normal to the flow in an electrically conducting fluid introduces a Lorentz force that acts against the flow, while the Lorentz force increases when the plate is heated. Figure 1 illustrates the effect of the magnetic field parameter on the velocity of the fluid. The influence that the soret parameter has on velocity is illustrated in Figure 2. As a result of the plate's cooling, the velocity increases as the value of So increases. While the plate is being heated, it has been discovered that the velocity reduces as a result of the presence of So. From Figure 3, it can be noted that when the value of R is greater than zero, it results in an increase in the velocity, whereas when the value of Gr is less than zero, it results in a decrease in the velocity. Additionally, the influence of the chemical reaction parameter Kc on the velocity profile is illustrated in Figure 4. In the case of cooling the plate, it has been shown that an increase in the chemical reaction parameter results in a decrease in velocity with increasing values of the chemical reaction parameter Kc. On the other hand, the velocity increases when the plate is heated. Figure 5 illustrates how the thermal Grashof number Gr affects the distribution of the velocity versus the temperature. It has been discovered that a rise in the thermal Grashof number results in a decrease in velocity in both the case of cooled plates and the case regarding heated plates. According to Figure 6, it has been noticed that when the value of Gc is greater than zero, it results in an increase in the velocity, whereas when the value of Gr is less than zero, it results in a drop in the velocity. Figure 7 illustrates the velocity profiles for varied values of the permeability parameter K. These profiles are shown in the figure. In the case of a cooled plate, it can be observed that the velocity experiences an increase with decreasing values of the permeability parameter, whereas in the case of a heated plate, the velocity experiences an increase. In figure 8, we saw that when the value of h is increased, the velocity increases when the value of Gr is more than zero, and when the value of Gr is less than zero, the velocity decreases. The velocity is also seen to increase in the vicinity of the plate, as was previously mentioned. From Figure 9, it can be noted that when the value of E is greater than zero, it results in an increase in the velocity, whereas when the value of Gr is less than zero, it indicates a drop in the velocity. A representation of the velocity profiles for a variety of Sc values can be found in Figure 10. As a result of this, it can be observed that the velocity increases with decreasing values of Sc in the case of a cooled plate, whereas it increases in the case of a heated plate. A representation of the velocity profiles for a variety of Pr values can be found in Figure 11. As a result of this, it can be observed that the velocity increases with decreasing values of Pr in the case of a cooled plate, whereas it increases in the case of a heated plate. From a physical standpoint, the Prandtl number is a dimensionless quantity that is calculated by dividing the kinematic viscidity by the thermal diffusivity. In situations where the value of momentum diffusivity is higher than the value of thermal diffusivity, the Pr experiences an increase. Because of this, the amount of heat that is transmitted at the surface increases as the Pr values increase, whereas the amount of mass that is transmitted increases as the Prandtl number increases. Figure 12 illustrates the impact that Pr has on the situation. It demonstrates quite clearly that the temperature drops when the Pr number is increased. Taking into consideration the fact that the thermal layer of the boundary decreases when Pr is increased, this is the reasoning for this. Because the breadth of the thermal boundary layer is relatively higher, the effect is more obvious for a Prandtl quantity that is relatively small. Figure 13 illustrates the factors that influence temperature in relation to the thermal radiation parameter R. It has been discovered that the value of T(y) decreases as the values of R grow. Because of this, a sizeable portion of the fluid that is contained within the boundary layer has a low temperature, and as a result, the thermal diffusivity decreases as the thermal boundary layer becomes thinner. The profiles of concentration distribution are displayed in Figure 14, which depicts a variety of Kc values. As the parameter is increased, the figure suggests that the concentration of the fluid would decrease. This is something that can be observed. Through the use of different measurements of the parameter Sc, as depicted in Figure 15, the non-dimensional concentration profile is improved. The fact that a flow portion grows in the horizontal direction by causing an increase in the Schmidt number is something that is readily apparent. It should come as no surprise that increases in the Schmidt number are accompanied by an increase in the flow part in the x-direction. Because the

Schmidt parameter is the ratio of the momentum diffusivities to the concentration diffusivities, this is the reasoning behind it. An illustration of the influence that radiation parameter has on concentration profiles can be found in Figure 16. When the setting is increased, the profiles become more prominent. Figure 17 illustrates the negative relationship that exists between the concentration profile and the Pr number displayed. The flow in the x-direction is mirrored in the graph, which indicates that the thinning of the thermal boundary layer is responsible for the progression of the flow pattern. At the same time that the concentration profile is increasing, the thermophoresis parameter So is increasing. A description of this phenomenon can be found in Figure 18.

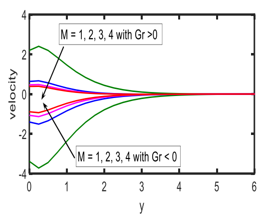

Fig. 1. Behavior of M on U(y)

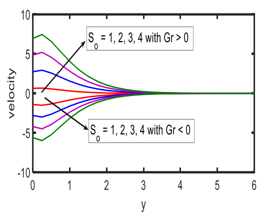

Fig. 2. Behavior of So on U(y)

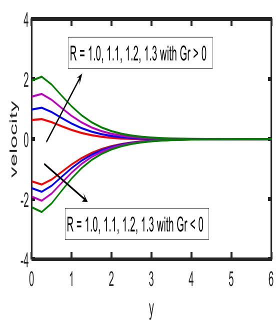

Fig. 3. Behavior of R on U(y)

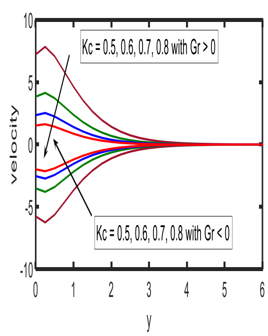

Fig. 4. Behavior of Kc on U(y)

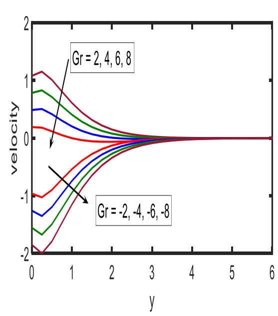

Fig. 5. Behavior of Gr on U(y)

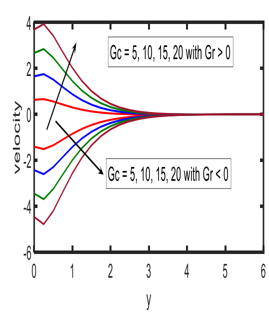

Fig. 6. Behavior of Gc on U(y)

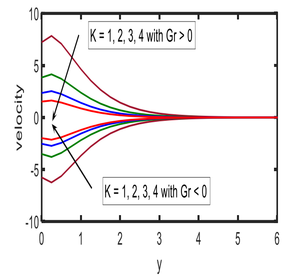

Fig. 7. Behavior of K on U(y)

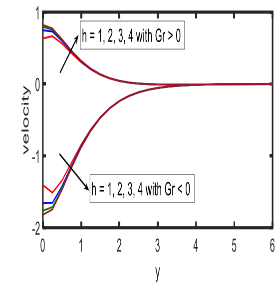

Fig. 8. Behavior of h on U(y)

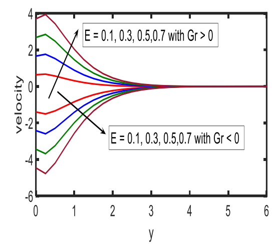

Fig. 9. Behavior of E on U(y)

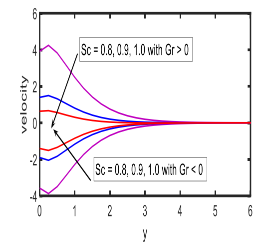

Fig. 10. Behavior of Sc on U(y)

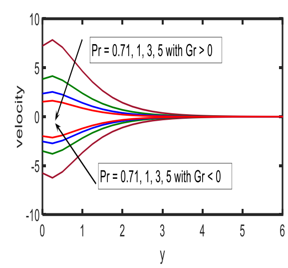

Fig. 11. Behavior of Pr on U(y)

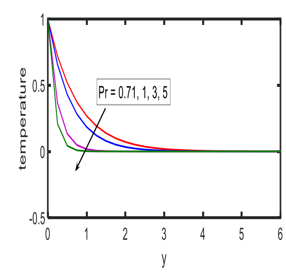

Fig. 12. Behavior of Pr on T(y)

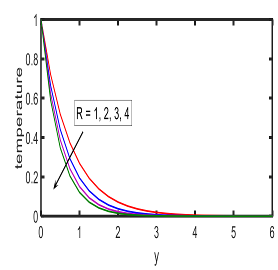

Fig. 13. Behavior of R on T(y)

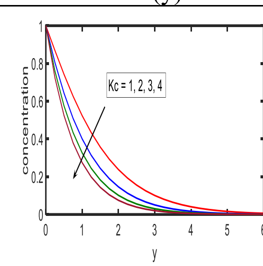

Fig. 14. Behavior of Kc on C(y)

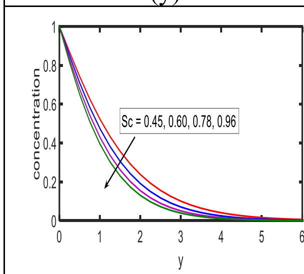

Fig. 15. Behavior of Sc on C(y)

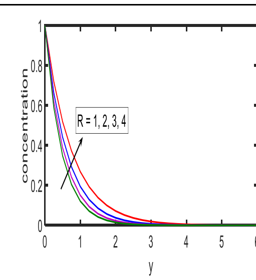

Fig. 16. Behavior of R on C(y)

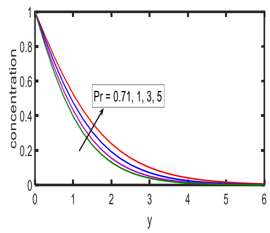

Fig. 17. Behavior of Pr on C(y)

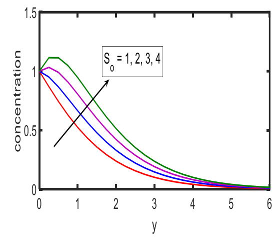

Fig. 18. Behavior of So on C(y)

IV.CONCLUSIONS

In this research, a mathematical model has been developed for the influence of radiation and thermophoresis on MHD free convective flow via a vertical porous plate in a porous medium under the influence of chemical reaction effects. The model was proposed in order to explain the relationship between these two phenomena. In accordance with the similarity transformation, a collection of ordinary differential equations has been constructed for the purpose of preserving mass, momentum, and species diffusion in the boundary layer. Using the perturbation approach, these nonlinear differential equations that are coupled were solved under appropriate boundary conditions. The following are the findings and conclusions of the study:

1. The velocity of a cooled plate reduces as the magnetic field parameter is increased, but the velocity of a heated plate increases when the magnetic field parameter is increased.

2. When the case of the cooled plate is considered, it is observed that the velocity increases with decreasing values of the permeability parameter, whereas in the case of the heated plate, the velocity increases.

3. When the Pr number is really high, the temperature drops.

4. It has been discovered that the value of T(y) lowers the more the values of R grow.

5. The graphic demonstrates that the concentration of the fluid falls as the parameter increases, which is something that can be observed there.

6. The fact that a flow portion grows in the horizontal direction by causing an increase in the Schmidt number is something that is obviously clear.

REFERENCES

[1] Midya C (2012), Electrically conducting second-grade fluid flow in a porous medium over a shrinking sheet in the presence of a chemical reaction and magnetic field, Int. J. Mathematical Archieve, Vol. 3, No. 12, pp. 4938 – 4944.

[2] Seddeek, M.A., Darwish, A.A. & Abdelmeguid, M.S. (2007). Effects of chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through porous media with radiation, Commun Nonlinear Sci. Numer.simulat.,15, 195-213.

[3] Salem, A.M. & Abd El-Aziz, M. (2008). Effect of Hall currents and chemical reaction on hydromagnetic flow of a stretching vertical surface with internal heat generation/absorption.Applied Mathematical Modelling, 32, 1236-1254.

[4] Mohamed, R. A., (2009). Double-Diffusive Convection-radiation Interaction on Unsteady MHD Flow over a Vertical Moving Porous Plate with Heat Generation and Soret Effects, Applied Mathematical Sciences, 3, (13), 629-651.

[5] Ibrahim, F.S., Elaiw, A.M., & Bakr, A.A. (2008). Effect of chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi infinite vertical permeable moving plate with heat source and suction.Commun Nonlinear Sci. Numer.simulat.,13, 1056-1066.

[6] Nield, D. A., & Bejan, A., (1999). Convection in Porous Media, 2nd edition.Springer-Verlag, New York .

[7] P. S. Hiremath and P. M. Patil (1993), "Free Convection Effects on Oscillatory Flow of Couple Stress Field through a Porous Medium," Acta Mechanica, Vol. 98, No. 1-4, 1993, pp. 143-158.

[8] B. K. Sharma, R. C. Chaudhary and P. K. Sharma (2007), "Fluctuating Mass Transfer on Three-Dimensional Flow through a Porous Medium with Variable Permeability," Advancesin Theoretical and Applied Mathematics, Vol. 2, No. 3, pp. 257-267.

[9] I. Pop and D. B. Ingham (2001), Convective heat transfer: Mathematical and computational modeling of viscous fluids and porous media, Pergamon, Oxford, UK.

[10] D. B. Ingham and I. Pop (2005), Transport Phenomena in porous media III, Elsevier, Oxford.

[11] K. Vafai (2005), Handbook of Porous media, Taylor and Francis, New York, NY,USA,2 edition.

[12] P. Vadasz (2008), Emerging Topics in Heat and Mass Transfer in Porous Media (Springer, New York.

[13] Siegel, R., & Howell, J.R. (2001). Thermal Radiation Heat Transfer, Speedy Hen, London,
CA, United Kingdom .
[14] Olanrewaju P O., Olanrewaju M A. and Ajadi D A (2012), Unsteady three dimensional MHD flow and mass transfer in a porous space in the presence of thermal radiation, Journal of Petroleum and Gas Exploration Research, Vol. 2, No. 2, pp. 044-051.
[15] Cortell, R., (2008). Effects of viscous dissipation and radiation on the thermal boundary layer over a nonlinearly stretching sheet.Phys Lett A, 372, 631-636.
[16] Bataller, R.C., (2008). Radiation effects for the Blasius and Sakiadis flows with a convective surface boundary condition. Appl Math Comput, 206: 832-840.
[17] Ibrahim, F.S., Elaiw, A.M., & Bakar, A.A. (2008). Effect of the chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi infinite vertical permeable moving plate with heat source and suction. Communications in Nonlinear Science and Numerical Simulation, 13, 1056-1066.
[18] Shateyi, S. (2008). Thermal Radiation and Buoyancy Effects on Heat and Mass Transfer over a Semi-Infinite Stretching Surface with Suction and Blowing, Journal of Applied Mathematics, Volume 2008, Article ID 414830, 12 pages doi:10.1155/2008/414830.
[19] Shateyi, S., & Motsa, S.S. (2009). Thermal Radiation Effects on Heat and Mass Transfer over an Unsteady Stretching Surface. Mathematical Problems in Engineering, Volume 2009, Article ID 965603, 13 pages doi:10.1155/2009/965603.
[20] Aliakbar, V., Alizadeh-Pahlavan, A. & Sadeghy, K., (2009). The influence of thermal radiation on MHD flow of Maxwellian fluids above stretching sheets.Commun Nonlinear Sci Numer Simulat, 14(3): 779-794.
[21] Hayat, T., & Qasim, M. (2010). Influence of thermal radiation and Joule heating on MHD flow of a Maxwell fluid in the presence of thermophoresis. Int. J. Heat Mass Transfer, doi:10.1016/j.ijheatmasstransfer.2010.06.014.
[22] Cortell, R, (2010). Suction, viscous dissipation and thermal radiation effects on the flow and heat transfer of a power-law fluid past an infinite porous plate, Chem Eng Res Des, doi:10.1016/j.cherd.2010.04.017.
[23] Sindhu Devi, K., Nirakara Pradhan, Venkata Subramanyam, S., and Sridhar, W., (2025), Nonlinear Thermal Radiation Effect On Magneto Casson-Williamson Nanofluid Flow Over An Inclined Porous Stretching Sheet. JP Journal of Heat and Mass Transfer, 38 (4): 561-584
[24] E.M. Sparrow and R.D Cess, (1978), Radiation heat transfer, Augmented Edition, Hemisphere Publishing Corp, Washington, DC.