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NUMERICAL STUDY OF CHEMICALLY REACTIVE MHD HYDRODYNAMIC BOUNDARY LAYER FLUID FLOW OVER AN ABSORPTIVE SURFACE IN THE PRESENCE OF SLIP AND MIXED CONVECTION

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ABSTRACT. The present exploration includes the numerical study of chemically reactive MHD hydrodynamic boundary layer fluid flow over a absorptive surface in the presence of slip and mixed convection. Present study also emphasis the effect of Dufour number and Soret number on velocity, temperature and concentration as well. By using the method of similarity transformation, the system of coupled partial differential equations reduce into the system of coupled ordinary differential equations and then apply RK-4 method with shooting technique. The effect of various thermo-physical parameters managing the fluid dynamics in the flow region are discussed numerically and shown graphically.

1. INTRODUCTION

Heat Transport and mass Transport for MHD fluid flow through permeable media is now become a main objective for research, due to its vast application in the field of science and engineering. When fluid is moving, heat & mass Transport is applied on it then soret and dufour effect occurs. The energy flux generated by gradient of concentration is known as dufour effect and mass flux generated due to gradient of heat is known as soret effect. MHD fluid with generation/absorption of chemical reaction is analyzed for slip effect and

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Newtonian heating at a point where the local velocity of the fluid is zero by Sivasankaran et al. [9]. Effect of Soret and dufour, glutinous diffusion and heat generation/absorption are examined for mixed deportation flow of casson fluid through non linearly expanding plate with the slip and deportive boundary condition by Imran Ullah et al. [10]. Effect of glutinous dissipation, chemical reaction and black body radiation are investigated on a casson fluid in the existence of free deportation of combined heat and mass Transport studied by Shateyi [8]. Glutinous incomprehensive and electro-conducting fluid flow through upstanding channel bounded by wavy wall where emission of thermo (dufour) and thermal diffusion (soret) with internal heat and coupled heat and mass Transport by free deportation is analysed by Gbadeyan et al. [2]. A permeable upstanding moving plate placed through binary mixture in optically fine fluid environment for irregular free convective and MHD flow with chemical reaction is assessed and solved by Sharma et al. [7]. Electrically conducting fluid in wavy channel of permeable medium studied for soret effect described by Sasikumar and Govindarajan [6]. An electro- conducting nanofluid through a nano linear extending sheet analysed for two-D MHD free deportive boundary layer flows with chemical reaction and heat source and sink evaluated by Makinde Oluwole and et al. [5]. Under Deportive Boundary conditions effect of mixed convection for Newtonian fluid is studied with heat Transport, mass Transport and navier slip on chemically reactive porous media illustrated by Fenuga et al. [1]. MHD Flow over a expanding lamina is studied for soret and dufour effect, suction, injecton and black body radiation by Mabood and Shateyi [4]. Cross diffusions and chemical reaction effects are examined with the convective boundary condition of a incomprehensive mixed deportation laminar flow through concentric cylindrical annulus by Kaladhar et al. [3].

2. MATHEMATICAL FORMULATION

Consider a steady, 2-D boundary layer flow, incomprehensive, electro-conducting viscous fluid, coupled with heat and mass Transport through a permeable expanding surface in a soggy porous media. The x-axis assumed in the direction of the plate as direction of flow and y-axis is taken as perpendicular to the plate. In transverse direction to the flow a constant magnetic field B_0 is applied. By convection from a hot fluid with temperature T_f, the left side surface of the plate is heated which generates a heat Transport coefficient h_f . Also, by convection from a viscous fluid at concentration C_f, the left surface of the plate is heated which give rise to a mass Transport coefficient h_m. The right handed face of the plate is Newtonian fluid which is electro-conducting. u and v are the components of velocity in x & y direction respectively , T and C are the temperature and concentration components u_e, $T_\infty$and C_∞ are denotes the velocity, temperature and concentration outside the plate respectively.

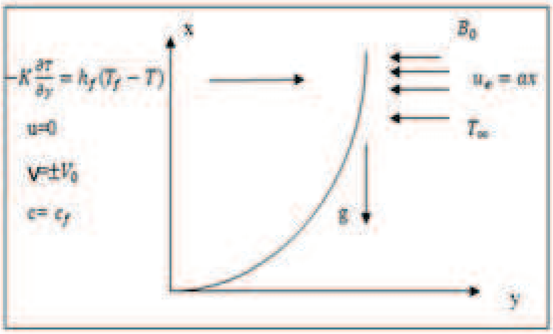

FIGURE 1. Flow configuration with coordinate system.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{2.1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\gamma\frac{\partial^2 u}{\partial y^2}+g\beta_T\left(T-T_\infty\right)-\frac{\sigma(u-u_e)\beta_0^2}{\rho}-\frac{\gamma}{K_p}\left(u-u_e\right)+g\beta_c\left(C-C_\infty\right) \tag{2.2}$$

$$\begin{aligned}u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2}+\frac{\gamma}{C_p}\left(\frac{\partial u}{\partial y}\right)^2+\frac{\sigma(u-u_e)^2\beta_0^2}{\rho C_p}+\frac{Q}{\rho C_p}\left(T-T_\infty\right)\\ -\frac{1}{C_p}\frac{\partial q_r}{\partial y}+\frac{DmK_T}{C_S C_P}\frac{\partial^2 C}{\partial y^2}+Q_1'(C-C_\infty)\end{aligned} \tag{2.3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}-K_r\left(C-C_\infty\right)+\frac{DmK_T}{T_m}\frac{\partial^2 T}{\partial y^2} \tag{2.4}$$

The Corresponding boundary conditions are

$$u\left(x,0\right)=L\frac{\partial u}{\partial x}\ , \quad v\left(x,0\right)\ =\pm V_0$$

$$-K\frac{\partial T}{\partial y}(x,0)=h_f\left(T_{f}-T(x,0)\right)$$

$$-D\frac{\partial C}{\partial y}(x,0)=h_m\left(C_f-C(x,\infty)\right)$$

$$u(x,\infty)=u_e\ ,\quad T(x,\infty)=T_\infty,\ C(x,\infty)=C_\infty \tag{2.5}$$

3. METHOD OF SOLUTION

Introducing the similarity variables as

$$\eta=x^{-\frac{1}{2}}y\sqrt{\frac{u_e}{\gamma}}\quad \text{and}\quad \psi=x^{\frac{1}{2}}\sqrt{\gamma u_e}f(\eta),$$

where

$$u=\frac{\partial\psi}{\partial y}\ ,v=-\frac{\partial\psi}{\partial x}\ ,\ \theta(\eta)=\frac{T-T_\infty}{T_f-T_\infty}\ ,\quad \phi(\eta)=\frac{C-C_\infty}{C_f-C_\infty} \tag{3.1}$$

Using the similarity variables, that satisfy (2.1) are

$$u=u_ef^{'}(\eta)\quad \text{and}\quad v=\frac{1}{2}\sqrt{\frac{\gamma u_e}{x}}\left(\eta f^{'}(\eta)-f(\eta)\right).$$

Using (3.1) to transform the momentum, energy and concentration (2.1) to (2.4), together with the boundary condition (2.5), we obtain

$$f^{'''}+\frac{1}{2}ff^{'}+\mathrm{Gr}\theta+\mathrm{Gc}\phi+(\mathrm{M}+Da)\left(f^{'}-1\right)=0 \tag{3.2}$$

$$\begin{aligned}\theta^{''}\left(1+\frac{4}{3}RaPr\right)+\frac{1}{2}Prf\theta^{'}+Pr\lambda\theta+PrEc\left(f^{''}\right)^2\\ +MEcPr\left(1-f^{'}\right)^2+DuPr\phi"+Q_1\phi=0\end{aligned} \tag{3.3}$$

$$\phi^{''}+\frac{1}{2}Scf\phi^{'}-Sc\beta\phi+ScSr\theta^{''}=0 \tag{3.4}$$

corresponding boundary conditions are now given as

$$\begin{aligned}f^{'}(0)=\delta f^{''}(0)\,;f(0)=F_w;\theta^{'}(0)=Bi\left(1-\theta(0)\right);-\phi^{'}(0)\\ =Bs(1-\phi(0))f^{'}(\infty)=1;\ \theta(\infty)=0;\ \phi(\infty)=0\end{aligned} \tag{3.5}$$

where dash represents derivatives with respect to η.
Since (3.2), (3.3) and (3.4) are highly nonlinear. To solve such type of equation we apply shooting technique.

4. RESULTS AND DISCUSSION

Numerical calculations have been done for different values of the flow parameters in the fluid flow profiles using Runge-Kutta fourth order method along with shooting technique is used for step by step integration and calculations are carried out on MATLAB software.

Fluid velocity rises due to increment in injection / suction Parameter fw, Dufour Number Du , Soret Number Sr and heat absorption parameter Q1, as shown in figure 2,5,8 and 11 respectively.

Fluid temperature reduces due to increment in Dufour Number Du , Soret Number Sr, heat absorption parameter Q1, while it rises due to increment in injection / suction Parameter fw as shown in figure 6,9,12 and 3 respectively.

Fluid Concentration decreases due to rise in injection / suction Parameter fw, Dufour Number Du, injection / suction Parameter fw while it increases due to increment in Soret Number Sr and heat absorption parameter Q1 as shown in figure 4,7, 10, and 13 respectively.

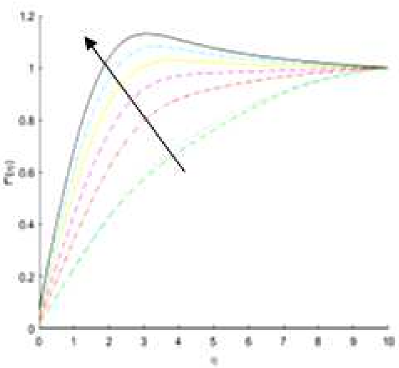

FIGURE 2. Fw=-0.2, Fw=-0.1, Fw=0, Fw=0.1, Fw=0.2, Fw=0.3, Fw=0.4, Effect of injection/suction parameter on velocity

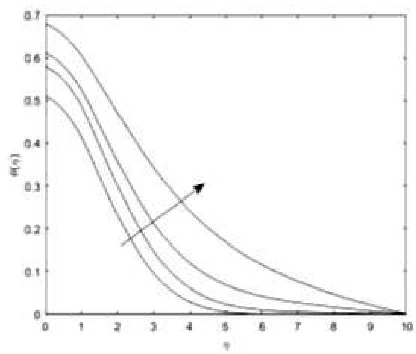

FIGURE 3. Fw=-0.2, Fw=-0.1, Fw=0.1, Fw=1, Effect of injection/suction parameter on temperature

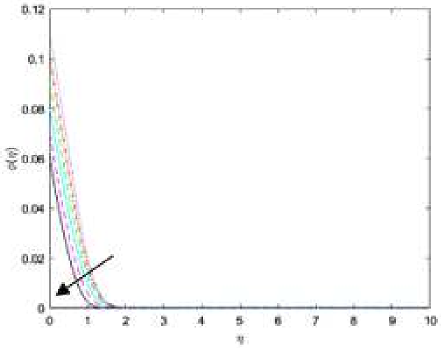

FIGURE 4. Fw=-0.1, Fw=-0.2, Fw=0, Fw=0.1, Fw=0.2, Fw=0.3, Effect of injection/suction parameter on concentration

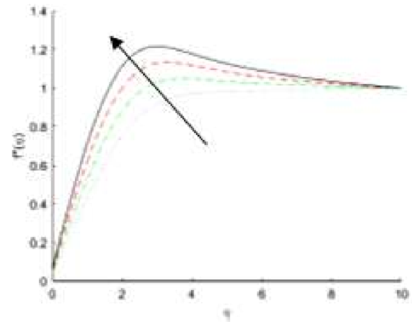

FIGURE 5. Du=0.1, Du=0.2, Du=0.3, Du=0.4, Effect of Dufour number on velocity

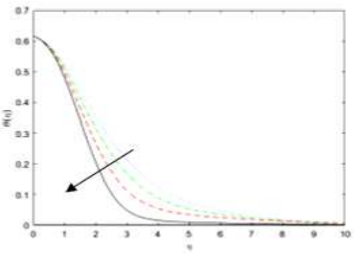

FIGURE 6. Du=1, 5, 10, 15, Effect of Dufour number on temperature

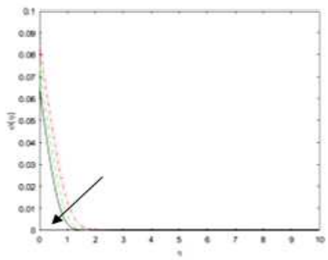

FIGURE 7. Du=0, Du=0.0001, 0.01, 100, Effect of Dufour number on concentration

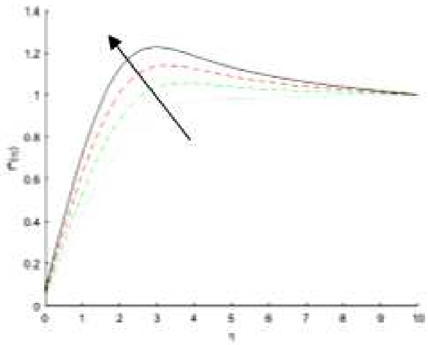

FIGURE 8. Sr=0.1, Sr=0.2, Sr=0.3, Sr=0.4, Effect of Soret number on velocity

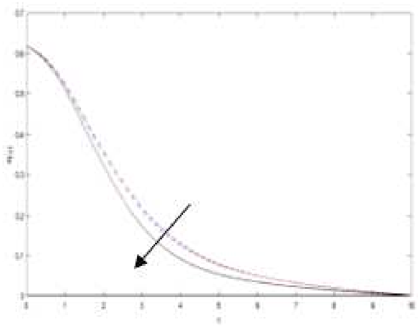

FIGURE 9. Sr=0.1, Sr=0.5, Sr=1, Sr=2, Effect of Soret number on temperature

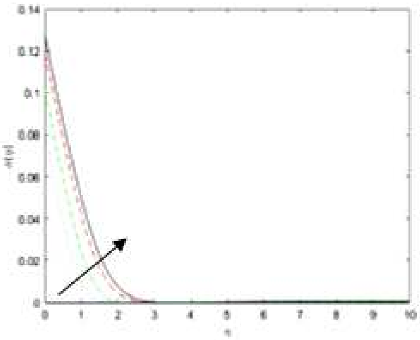

FIGURE 10. Sr=0.001, Sr=0.005, Sr=0.007, Sr=0.009, Effect of Soret number on concentration

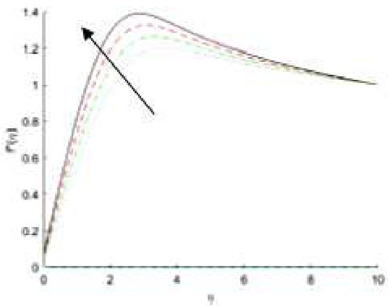

FIGURE 11. Q1=0.01, Q1=0.02, Q1=0.03, Q1=0.04, Effect of heat absorption parameter on velocity

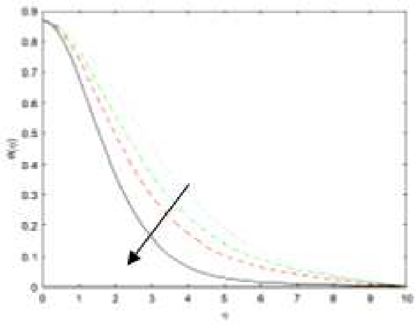

FIGURE 12. Q1=0.1, Q1=0.5, Q1=1, Q1=2, Effect of heat absorption parameter on temperature

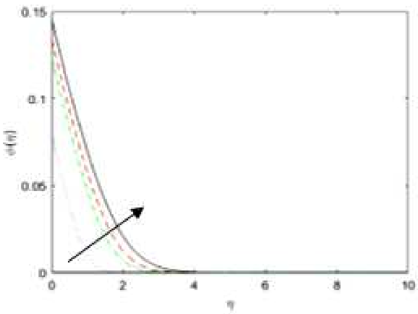

FIGURE 13. Q1=0.001, Q1=0.003, Q1=0.005, Q1=0.007, Effect of heat absorption parameter on concentration

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