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Unsteady MHD free Convective flow in a Rotating System with Soret Effect on nth order chemical reaction

S.Anuradha[1]
K.Sasikala[2]

Abstract

An Investigation on Soret effect with nth order chemically reactive MHD free convection flow through a porous medium in a rotating system is carried out in this present study. Similarity transformations are used to convert the governing nonlinear boundary layer equations into ordinary differential equations and solved it numerically. The numerical solutions of various dimensionales parameters on the velocity, temperature, concentration profiles, skin friction, Nusselt number, Sherwood number have been studied through graphs. The present study concluded that Soret Effect on nth order chemical reaction play major role in many industrial applications.

Keywords:

Magnetohydronamics (MHD); Soret Effect; Rotating system; Thermal Diffusion; Chemical reaction;.

Author correspondence:

[1]Professor & Head in Department of Mathematics, Hindusthan College of Arts & Science, Coimbatore,Tamilnadu,India,Email:anu.prasanthi@gmail.com.
[2]Assistant Professor in Department of mathematics, Hindusthan College of Arts & Science, Coimbatore,Tamilnadu,India

1. Introduction

Investigations on an unsteady MHD free convective heat and mass transfer flow over a porous medium find variety of applications in modern metal-working processes and manufacturing processes. Some of the applications are the lamination, hot rolling, crystal growing, purification of molten metals, melt-spinning processes and wire drawing etc. From model studies on the Dufour and soret effect of MHD free convective flows have been made by several investigators. Raptis *et al.*, (1985) obtained the unsteady free convection flow through a porous medium with a semi-infinite vertical porous plate [1]. Dursunkaya *et al.*, (1992) investigated the steady natural convection from a vertical surface with the effects of diffusion-thermo and thermal-diffusion [2]. Kafoussias *et al.*, (1995) reported the temperature dependent viscosity on mixed free-forced convective and mass transfer flow with thermal-diffusion and diffusion-thermo effects [3]. Lavanya *et al.*, (2004) analyzed the two-dimensional steady MHD free convection flow along a vertical porous plate with thermal radiation, heat generation, viscous dissipation and chemical reaction, Dufour and Soret effects [4]. Alam and Rahman (2005) was established the on steady MHD free convective heat and mass transfer flow past a semi-infinite vertical porous plate with Dufour and Soret effects [5]. On numerical study of MHD combined free-forced convective and mass transfer flow past a semi-infinite vertical plate in the presence of dufour and soret effect was reported by Alam (2006) [6]. Alam *et al.*, (2006) examined an unsteady MHD free convective flow past a vertical porous plate in a porous medium with the presence of heat and mass transfer effect [7]. Nazmul Islam and Mahmud Alam (2007) investigated the steady MHD free convection heat and and mass transfer fluid flow through a porous medium with thermal diffusion and diffusion thermo past a semi-infinite vertical porous plate in a rotating system [8]. Emmunuel *et al.*, (2008) discussed the combined heat and mass transfer of a steady MHD convective and slip flow due to a rotating disk with the effects of Thermal-diffusion and diffusion thermos, viscous dissipation and ohmic heating [9]. Anjali Devi and Uma Devi (2011) studied the MHD slip flow with thermal radiation over a porous rotating infinite disk in the presence of Soret and Dufour effects [10]. Sharma and Borgohain (2014) explained the effects of Soret and Dufour on heat and mass transfer of a binary fluid mixture in porous medium over a rotating disk [11]. In view of the above studies, an investigation on Soret effect with nth order chemically reactive MHD free convection fow through a porous medium in a rotating system is carried out in this present study.

2. Mathematical Model

Consider time dependent, two dimensional, MHD free convection heat and mass transfer flow in a rotating system of an electrically conducting viscous fluid through a porous medium along an infinite vertical porous plate y=0. The flow direction x and y axis are taken along the plate and normal to it. The temperature and the concentration at the plate are defined as T_w and C_w where B is magnetic field and the fluid is assumerd to be slightly conducting therefore the effect of magnetic Reynolds number which is very small and less than unity . Hence the induced magnetic field is negligible.
The governing boundary layer equations of momentum, energy, and concentrations are written as follows;
The continuity equation

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

The momentum equations

$$\frac{\partial u}{\partial t}+v\frac{\partial u}{\partial y}=g_0\beta(T-T_\infty)+g_0\beta^*\left(C-C_\infty\right)+\nu\frac{\partial^2 u}{\partial y^2}+2\Omega w-\frac{\nu}{K'}u-\frac{\sigma' B_0{}^2 u}{\rho} \tag{2}$$

$$\frac{\partial w}{\partial t}+v\frac{\partial w}{\partial y}=\nu\frac{\partial^2 w}{\partial y^2}-2\Omega u-\frac{\nu}{K'}w-\frac{\sigma' B_0{}^2 w}{\rho} \tag{3}$$

The energy equation

$$\frac{\partial T}{\partial t}+v\frac{\partial T}{\partial y}=\frac{k}{\rho c_p}\frac{\partial^2 T}{\partial y^2}+\frac{D_m k_T}{c_s c_p}\frac{\partial^2 C}{\partial y^2}+q_r\left(T-T_\infty\right) \tag{4}$$

The concentration equation

$$\frac{\partial C}{\partial t}+v\frac{\partial C}{\partial y}=D_m\frac{\partial^2 C}{\partial y^2}+\frac{D_m k_T}{T_m}\frac{\partial^2 T}{\partial y^2}+K_r\left(C-C_\infty\right)^n \tag{5}$$

Subject to the following boundary conditions,

$t\le 0, u=0, v=0, \ w=0, T=T_\infty, C=C_\infty$ for all values of y.

$$t>0, u=U_0, \ v=v(t), \ w=0, \ T=T_w, \ C=C_w, at \text{ at } \ y=0 \tag{6}$$

$$t>0, \ u=0, \ v=0, \ w=0, \ T\to T_\infty, \ C\to C_\infty, \ at \text{ at } y\to\infty \tag{7}$$

We introduce a similar parameter σ which is the time dependent length scale,

$$\sigma=\sigma(t) \tag{8}$$

$v=-v_0\dfrac{\upsilon}{\sigma}$, $\sigma=\sqrt{2c\upsilon t}$, $\sigma=0$ when $t=0$, $\sigma=2\sqrt{\upsilon t}$

Introducing the following non-dimensionl variables to find a similarity solution

$$\eta=\frac{y}{\sigma}, f(\eta)=\frac{u}{U_0}, g(\eta)=\frac{w}{U_0}, \theta(\eta)=\frac{T-T_\infty}{T_w-T_\infty}, \phi(\eta)=\frac{C-C_\infty}{C_w-C_\infty} \tag{9}$$

Where we use the following physical quantities,

$$G_r=\frac{g_0\beta\left(T_w-T_\infty\right)\sigma^2}{U_0\upsilon}, G_m=\frac{g_0\beta^*\left(C_w-C_\infty\right)\sigma^2}{U_0\upsilon}, M=\frac{\sigma' B_0{}^2\sigma^2}{\rho\upsilon}, R=\frac{\Omega\sigma^2}{\upsilon}$$

$$P_r=\frac{\rho\upsilon c_p}{k}, D_f=\frac{D_m k_T}{c_s c_p \upsilon}\frac{\left(C_w-C_\infty\right)}{\left(T_w-T_\infty\right)}, S_c=\frac{\upsilon}{D_m}, S_r=\frac{D_m k_T}{\upsilon T_m}\frac{\left(T_w-T_\infty\right)}{\left(C_w-C_\infty\right)}, \xi=\eta+\frac{\upsilon_0}{2}$$

By introducing the above non-dimensional varibles, equations (2)-(5) become

$$f''+2\xi f'+G_r\theta+G_m\phi-Kf-Mf+2Rg=0 \tag{10}$$

$$g''+2\xi g'-Kg-Mg-2Rf=0 \tag{11}$$

$$\theta''(\eta)+2\xi P_r\theta'(\eta)+P_rD_f\phi''(\eta)+P_rQ_r\theta(\eta)=0 \quad (12)$$

$$\phi''(\eta)+2\xi S_c\phi'(\eta)+S_cS_r\theta''(\eta)+S_cK_r\phi^n(\eta)=0 \quad (13)$$

The corresponding boundary conditions are,

$$f=1, g=0, \theta=1, \phi=1, at \qquad \eta=0 \quad (14)$$

$$f=0, g=0, \theta=0, \phi=0, at \qquad \eta\to\infty \quad (15)$$

3. Numerical Analysis

In this present article, we investigatigated unsteady MHD free convective and mass transfer flow through a porous medium with thermal diffusion, dufour effect and soret effect on nth order chemical reaction past an infinite vertical porous plate in a rotating system. The governing boundary layer equations (2)-(5) are transformed to ordinary differential equations (10)-(13) by using similarity transformation. Then they are solved by using Runge-Kutta 6th order Scheme. The obtained numerical results are illustrated graphically for various non-dimensional parameters on velocity, temperature, concentration profiles, skin friction, Nusselt number, Sherwood number..

4. Results and Discussion

It is very important to study the influence of various dimensionless parameters ingrained in the flow model on velocity, temperature and concentration. The physical parameters involved in the flow problem is Prandtl number(Pr), Dufour number(Df), Activation energy (E), Fitted rate constant(n), temperature difference parameter(δ) and reaction rate(σ). Graphs are showed to describe the behavior of the flow fields with different values of flow parameters.

Fig 1, Fig.2, and Fig.3 are made for the flow velocity, temperature and concentration profiles against the Prandtl number(Pr). It reveals that the velocity and temperature field develops but reverse effect on concentration profile with the hike in Pr.

Fig.4, Fig.5, and Fig.6 visualized the variations of Skin friction, Nusselt number and Sherwood number of the fluid under the influence of Prandtl number(Pr). It is evident that, inflating the values of Pr causes depreciation in Skin friction and nusselt number and enhances the Sherwood number profiles.

Fig.7, Fig.8, and Fig.9 elucidate the dimensionless velocity, temperature ad concentration distribution for different values of Dufour number(Df). It is noticed that the velocity and temperature fields are enlarge but the concentration field reduced with the improvement in Df.

Fig.10, Fig.11, and Fig.12 exhibit the Skin friction, Nusselt number and Sherwood number distribution for various values of Df. It is established that rising values of Df increases the Skin friction and nusselt number profiles but reverse trend has been observed in the Sherwood number.

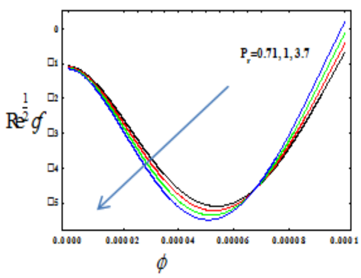

Figure.5. Skin Friction profile for different values of P_r with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5, R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

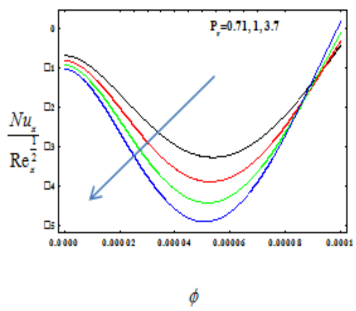

Figure.6. Nusselt Number profile for different values of P_r with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5, R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

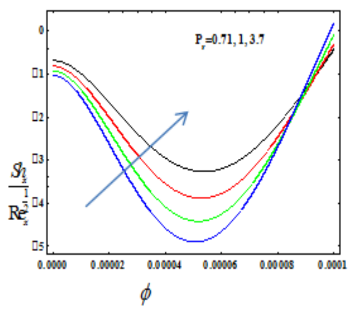

Figure.7. Sherwood Number profile for different values of P_r with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5, R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

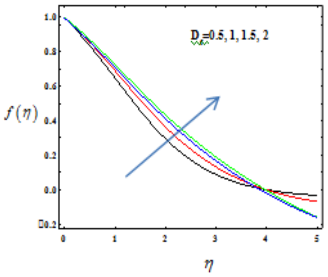

Figure8. Velocity profile for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

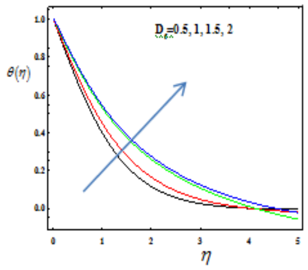

Figure9. Temperature profile for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

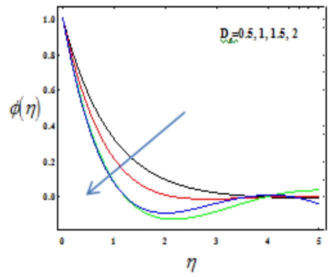

Figure10. Concentration profile for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

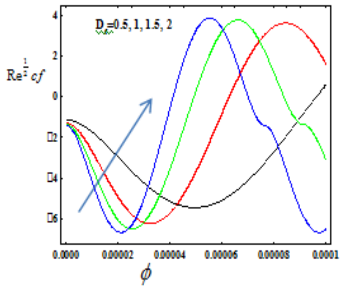

Figure11. Skin Friction for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

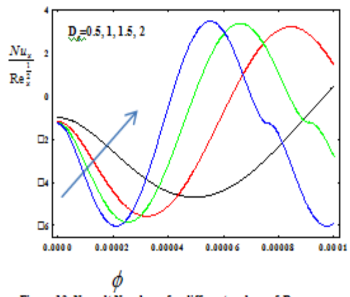

Figure12. Nusselt Number for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

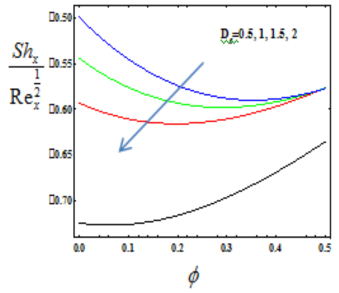

Figure13. Sherwood Number for different values of D_f with $V_0=0.5, G_r=10.0, G_m=4.0, M=0.5$, $R=0.2, S_r=1.0, S_c=0.6, D_f=0.2, K=0.5$.

5.Conclusion

This study is an investigation of unsteady MHD free convective and mass transfer flow through a porous medium with thermal diffusion, dufour effect and soret effect on nth order chemical reaction past an infinite vertical porous plate in a rotating system. The results are as follows;

- The velocity and temperature field develops but reverse effect on concentration profile with the hike in Pr.
- Increasing the values of Pr causes depreciation in Skin friction and nusselt number and enhances the Sherwood number profiles.
- The velocity and temperature fields are enlarge but the concentration field reduced with the improvement in Df.
- Increasing values of Df increases the Skin friction and nusselt number profiles but reverse trend has been observed in the Sherwood number.

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