Numerical study of effects of Soret-Dufour , Hall, radiation and chemical reaction on unsteady MHD flow of dusty viscous fluid past an inclined porous plate

[1]N. Pandya, [2]Ravi Kant Yadav
[1]Assistant Professor, [2]Research Scholar
[1]Department of Mathematics & Astronomy,
[1]University of Lucknow, Lucknow, India

Abstract: A study is presented with effects of Soret-Dufour, radiation, Hall and chemical reaction on unsteady MHD flow of a viscous incompressible dusty fluid past an infinite inclined porous plate immersed in porous medium. Non-dimensional form of governing equations are solved by Crank-Nicolson implicit finite difference method. The results of flow variables are presented through graphs and tables for effect of various parameters.

Index Terms - **Magnetohydrodynamics, Soret and Dufour effect, Hall effect, Radiation, Chemical reaction, Crank-Nicolson implicit finite difference method.**

I. Introduction

The momentum and heat transfer characteristics of MHD flow of dusty fluid with effect of soret, dufour, radiation, chemical reaction and hall parameter have important applications in applied sciences and engineering. Several research workers have explained these types of problems in theoretically and numerically ways. Saffman[1] investigated stability of laminar flow of dusty fluid. Attia [2] investigated unsteady MHD flow of dusty fluid with temperature dependent viscosity and thermal conductivity.

Generally, it was known that heat and mass fluxes were created from temperature and concentration gradient, respectively. However, heat flux is actually can existed due to the concentration gradient which is known as Soret effect. Same goes to the mass flux where the flux occurred by the temperature gradient and is called Dufour effect.The Soret and Dufour effects are significant in higher temperature and concentration gradients. Nirmal et al.[3] discussed the flow of unsteady dusty visco-elastic fluid between two moving plates in Frenet–Frame field system. Babu et. al. [8] considered chemical reaction to study Soret and Dufour effects on hydromagnetic free convective flow past an infinite vertical permeable plate. Manjunatha and Gireesha [9] studied the variable viscosity and the thermal conductivity effects on MHD flow and heat transfer of a dusty fluid. Dash et al.[4] have investigated the effect of Hall current and chemical reaction on MHD flow along an exponentially accelerated porous flat plate with internal heat absorption/generation. Varshney et. al.[5] have investigated on effect of the dusty viscous fluid on unsteady free convective flow along a porous hot vertical plate with thermal diffusion and mass transfer solved by perturbation techniques. Pandya and Shukla [6] studied effects of Soret, Dufour, Hall and radiation on an unsteady MHD flow past an inclined plate with viscous dissipation, chemical reaction and heat absorption & generation. Pandya and yadav [7] analysed Soret-Dufour effects on unsteady MHD flow of dusty fluid over inclined porous plate embedded in porous medium. Besides Soret and Dufour effects, Alam et al. [10] has considered suction variable on mixed convection flow over a semi-infinite vertical porous flat plat and they found that the wall suction stabilized the boundary layer growth of velocity, temperature and concentration

The aim of this paper is to investigate combined effects of Soret-Dufour, radiation, Hall and chemical reaction on unsteady MHD flow of dusty fluid past an inclined porous plate embedded in porous medium. Non dimensional form of Partial differential equations has been solved by Crank-Nicolson implicit finite difference method. The obtained results for velocity, temperature and concentration are discussed through graphs and table.

II. Mathematical analysis

Consider an unsteady MHD flow of viscous incompressible electrically conducting fluid past an inclined infinite porous plate with Soret effect, Dufour effect, Hall effect, radiation effect and chemical reaction. x'-axis is taken along plate, y'-axis is normal to it and z'-axis is normal to $x'y'$ plane. Magnetic field of uniform strength B_0 is applied transverse to the plate and induced magnetic field is not taken into consideration due to enough small Reynold number. Initially fluid and plate are at same temperature T'_∞ concentration C'_∞. For $t' > 0$, the plate moves with velocityu_0, its temperature and concentration raise exponentially with time.

$$J'_x = \frac{\sigma B_0}{1+m^2}(mu' - w')$$
$$J'_z = \frac{\sigma B_0}{1+m^2}(u' + mw') \qquad (2.1)$$

where J_x' and J_z' are electric current density, u' and w' are velocities along x'-axis and z'-axis respectively, m is Hall parameter. On account of infinite length in x' direction, flow variables are function of y' and t' only. Under usual Boussinesq approximation, governing equations are:

$$\frac{\partial v'}{\partial y'} = 0 \Rightarrow v' = -v_0 (const) \tag{2.2}$$

$$\frac{\partial u'}{\partial y'} + v'\frac{\partial u'}{\partial y'} = \nu \frac{\partial^2 u'}{\partial y'^2} + g\beta(T' - T'_\infty)\cos(\alpha) + g\,\beta^*(C' - C'_\infty)\cos(\alpha) - \frac{\sigma B_0}{1+m^2}(u' + mw') - \frac{\nu u'}{K'} + \frac{KN_0}{\rho}(u'_d - u') \tag{2.3}$$

$$\frac{\partial w'}{\partial y'} + v'\frac{\partial w'}{\partial y'} = \nu \frac{\partial^2 w'}{\partial y'^2} + \frac{\sigma B_0}{1+m^2}(mu' - w') - \frac{\nu w'}{K'} + \frac{KN_0}{\rho}(w'_d - w') \tag{2.4}$$

$$m_1 \frac{\partial u'_d}{\partial t'} = S_k (u' - u'_d) \tag{2.5}$$

$$m_1 \frac{\partial w'_d}{\partial t'} = S_k (w' - w'_d) \tag{2.6}$$

$$\rho c_p \left(\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} \right) = k \frac{\partial^2 T'}{\partial y'^2} - \frac{\partial q_r}{\partial y'} + \frac{\rho D_m K_T}{c_s} \frac{\partial^2 C'}{\partial y'^2} \tag{2.7}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D_m \frac{\partial^2 C'}{\partial y'^2} + \frac{D_m K_T}{T_m} \frac{\partial^2 T'}{\partial y'^2} - k_r (C' - C'_\infty) \tag{2.8}$$

subject to the following initial and boundary conditions:

$$\begin{aligned}
&t' \le 0 \quad u' = 0 \quad w' = 0 \quad u'_d = 0 \quad w'_d = 0 \quad T' = T'_\infty \quad C' = C'_\infty \quad \forall y' \\
&t' \ge 0 \quad u' = u_0 \quad w' = 0 \quad u'_d = u_0 \quad w'_d = 0 \quad v' = -v_0 \quad T' = T'_\infty + (T'_w - T'_\infty)\,\mathrm{e}^{-At'} \\
&C' = C'_\infty + (C'_w - C'_\infty)\,\mathrm{e}^{-At'} \quad at\ y' = 0 \\
&u' = 0 \quad w' = 0 \quad u'_d = 0 \quad w'_d = 0 \quad T' \to T'_\infty \quad C' \to C'_\infty \quad y' \to \infty
\end{aligned} \tag{2.9}$$

Here

$$q_r = -\frac{4\sigma_1}{3k_2} \frac{\partial T'^4}{\partial y'} \tag{2.10}$$

where σ_1 is the Stefan-Boltzmann constant and k_2 is the mean absorption coefficient. Considering small temperature difference between fluid temperature T' and free stream temperature T'_∞, T'^4 is expanded in Taylor series about the free stream temperature T'_∞. Neglecting second- and higherorder terms in $(T' - T'_\infty)$, we get

$$T'^4 = 4T'^3_\infty T' - 3T'^4_\infty \tag{2.11}$$

In the above equations, K_T is thermal diffusion ratio, μ is viscosity, ρ is fluid density, k is thermal conductivity of fluid, k_r is chemical reaction parameter, β is volumetric coefficient of thermal expansion, β^* is coefficient of volume expansion for mass transfer,u_d' and w_d' are the velocity of dust particles along x'-axis and y'-axis respectively, S_k is the stoke's resistance coefficient, v' is velocity along y'-axis, K' is permeability of porous medium, σ is electrical conductivity, D_m is molecular diffusivity, g is acceleration of gravity, C' and T' are dimensional concentration and temperature, C'_∞ and T'_∞ are concentration and temperature of free stream, N_0 is the number density of the dust particles which is constant, m_1 is the mass of dust particles, c_p is specific heat at constant pressure, q_r is radiative heat along y'-axis, ν is kinematic viscosity and T_m is mean fluid temperature. T'_w and C'_w are concentration and temperature respectively of plate and $A = \frac{v_0^2}{\nu}$.

We introduce the dimensionless variables,

$$u=\frac{u'}{u_0},\ t=\frac{t'v_0^2}{\nu},\ \theta=\frac{T'-T'_\infty}{T'_w-T'_\infty},\ C=\frac{C'-C'_\infty}{C'_w-C'_\infty},\ Gm=\frac{\nu g\beta^*(C'_w-C'_\infty)}{u_0v_0^2}$$

$$Gr=\frac{\nu g\beta(T'_w-T'_\infty)}{u_0v_0^2},\ Du=\frac{D_mK_T(C'_w-C'_\infty)}{c_sc_p\nu(T'_w-T'_\infty)},\ Sr=\frac{D_mK_T(T'_w-T'_\infty)}{T_m\nu(C'_w-C'_\infty)}$$

$$K=\frac{v_0^2K'}{\nu^2},\ \ \Pr=\frac{\mu c_p}{k},\ M=\frac{\sigma B_0^2\nu}{\rho v_0^2},\ R=\frac{4\sigma T'^3_\infty}{k_mk},\ Sc=\frac{\nu}{D_m},\ K_r=\frac{k_r\nu}{v_0^2} \tag{2.12}$$

$$y=\frac{y'v_0}{\nu},\ w=\frac{w'}{u_0},\ u_d=\frac{u'_d}{u_0},\ w_d=\frac{w'_d}{u_0},\ B=\frac{\nu S_kN_0}{\rho u_0^2},\ B=\frac{m_1v_0^2}{\nu S_k}$$

in Eq. (2)- Eq. (9), yielding

$$\frac{\partial u}{\partial t}-\frac{\partial u}{\partial y}=\frac{\partial^2u}{\partial y^2}+GrCos(\alpha)\theta+GmCos(\alpha)C+B_1(u_d-u)-\left(\frac{M}{1+m^2}+\frac{1}{K}\right)u-\left(\frac{mM}{1+m^2}\right)w \tag{2.13}$$

$$\frac{\partial w}{\partial t}-\frac{\partial w}{\partial y}=\frac{\partial^2w}{\partial y^2}+B_1(w_d-w)-\left(\frac{M}{1+m^2}+\frac{1}{K}\right)w+\left(\frac{mM}{1+m^2}\right)u \tag{2.14}$$

$$B\frac{\partial u_d}{\partial t}=u-u_d \tag{2.15}$$

$$B\frac{\partial w_d}{\partial t}=w-w_d \tag{2.16}$$

$$\frac{\partial\theta}{\partial t}-\frac{\partial\theta}{\partial y}=\frac{1}{\Pr}\left(1+\frac{4R}{3}\right)\frac{\partial^2\theta}{\partial y^2}+Du\frac{\partial^2C}{\partial y^2} \tag{2.17}$$

$$\frac{\partial C}{\partial t}-\frac{\partial C}{\partial y}=\frac{1}{Sc}\frac{\partial^2C}{\partial y^2}+Sr\frac{\partial^2\theta}{\partial y^2}-K_rC \tag{2.18}$$

$$\begin{aligned}&t\le 0\quad u=0\quad w=0\quad u_d=0\quad w_d=0\quad \theta=0\quad C=0\quad \forall y\\&t\ge 0\quad u=1\quad w=0\quad u_d=1\quad w_d=0\quad \theta=e^{-t}\quad C=e^{-t}\quad at\ y=0\\&u=0\quad w=0\quad u_d=0\quad w_d=0\quad \theta\to 0\quad C\to 0\quad y\to\infty\end{aligned} \tag{2.19}$$

For the engineering interest, non dimensional form of the skin friction coefficient τ_1 and τ_2 along wall x-axis and z-axis respectively, Nusselt number Nu and Sherwood number Sh are defined as

$$\begin{aligned}\tau_1&=\left(\frac{\partial u}{\partial y}\right)_{y=0}\\ \tau_2&=\left(\frac{\partial w}{\partial y}\right)_{y=0}\\ Nu&=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0}\\ Sh&=-\left(\frac{\partial C}{\partial y}\right)_{y=0}\end{aligned} \tag{2.20}$$

III. NUMERICAL PROCEDURE

Equations governing the flow are highly non-linear. Getting an exact analytical solution to them is not possible. We generate numerical solutions of the equations by using the finite difference method of Crank-Nicolson Method. The equations are solved subject to the initial and boundary conditions. The equivalent finite difference scheme of equations 2.13-2.19 is as follows

$$\begin{aligned}\frac{u_{i,j+1}-u_{i,j}}{\Delta t}-\frac{u_{i+1,j}-u_{i,j}}{\Delta y}&=\left(\frac{u_{i-1,j}-2u_{i,j}+u_{i+1,j}+u_{i-1,j+1}-2u_{i,j+1}+u_{i+1,j+1}}{2(\Delta y)^2}\right)\\&+B_1\left(\left(\frac{(u_d)_{i,j+1}+(u_d)_{i,j}}{2}\right)-\left(\frac{u_{i,j+1}+u_{i,j}}{2}\right)\right)\\&+Gr\cos(\alpha)\left(\frac{\theta_{i,j+1}+\theta_{i,j}}{2}\right)+Gr\cos(\alpha)\left(\frac{C_{i,j+1}+C_{i,j}}{2}\right)\\&-\left(\frac{M}{1+m^2}+\frac{1}{K}\right)\left(\frac{u_{i,j+1}+u_{i,j}}{2}\right)-\left(\frac{mM}{1+m^2}\right)\left(\frac{w_{i,j+1}+w_{i,j}}{2}\right)\end{aligned}\tag{3.1}$$

$$\begin{aligned}\frac{w_{i,j+1}-w_{i,j}}{\Delta t}-\frac{w_{i+1,j}-w_{i,j}}{\Delta y}&=\left(\frac{w_{i-1,j}-2w_{i,j}+w_{i+1,j}+w_{i-1,j+1}-2w_{i,j+1}+w_{i+1,j+1}}{2(\Delta y)^2}\right)\\&+B_1\left(\left(\frac{(w_d)_{i,j+1}+(w_d)_{i,j}}{2}\right)-\left(\frac{w_{i,j+1}+w_{i,j}}{2}\right)\right)\\&-\left(\frac{M}{1+m^2}+\frac{1}{K}\right)\left(\frac{w_{i,j+1}+w_{i,j}}{2}\right)+\left(\frac{mM}{1+m^2}\right)\left(\frac{u_{i,j+1}+u_{i,j}}{2}\right)\end{aligned}\tag{3.2}$$

$$B\left(\frac{(u_d)_{i,j+1}-(u_d)_{i,j}}{\Delta t}\right)=\left(\left(\frac{u_{i,j+1}+u_{i,j}}{2}\right)-\left(\frac{(u_d)_{i,j+1}+(u_d)_{i,j}}{2}\right)\right)\tag{3.3}$$

$$B\left(\frac{(w_d)_{i,j+1}-(w_d)_{i,j}}{\Delta t}\right)=\left(\left(\frac{w_{i,j+1}+w_{i,j}}{2}\right)-\left(\frac{(w_d)_{i,j+1}+(w_d)_{i,j}}{2}\right)\right)\tag{3.4}$$

$$\begin{aligned}\frac{\theta_{i,j+1}-\theta_{i,j}}{\Delta t}-\frac{\theta_{i+1,j}-\theta_{i,j}}{\Delta y}&=\frac{1}{\Pr}\left(1+\frac{4R}{3}\right)\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}+\theta_{i-1,j+1}-2\theta_{i,j+1}+\theta_{i+1,j+1}}{2(\Delta y)^2}\right)\\&+Du\left(\frac{C_{i-1,j}-2C_{i,j}+C_{i+1,j}+C_{i-1,j+1}-2C_{i,j+1}+C_{i+1,j+1}}{2(\Delta y)^2}\right)\end{aligned}\tag{3.5}$$

$$\begin{aligned}\frac{C_{i,j+1}-C_{i,j}}{\Delta t}-\frac{C_{i+1,j}-C_{i,j}}{\Delta y}&=\frac{1}{Sc}\left(\frac{C_{i-1,j}-2C_{i,j}+C_{i+1,j}+C_{i-1,j+1}-2C_{i,j+1}+C_{i+1,j+1}}{2(\Delta y)^2}\right)\\&+Sr\left(\frac{\theta_{i-1,j}-2\theta_{i,j}+\theta_{i+1,j}+\theta_{i-1,j+1}-2\theta_{i,j+1}+\theta_{i+1,j+1}}{2(\Delta y)^2}\right)-K_r\left(\frac{C_{i,j+1}+C_{i,j}}{2}\right)\end{aligned}\tag{3.6}$$

with the transformed initial and boundary conditions

$$\begin{aligned} &u_{i,0}=0 \quad w_{i,0}=0 \quad (u_d)_{i,0}=0 \quad (w_d)_{i,0}=0 \quad \theta_{i,0}=0 \quad C_{i,0}=0 \quad \forall i \\ &u_{0,j}=1 \quad w_{0,j}=0 \quad (u_d)_{0,j}=1 \quad (w_d)_{0,j}=0 \quad \theta_{0,j}=\mathrm{e}^{-j\Delta t} \quad C_{0,j}=\mathrm{e}^{-j\Delta t} \\ &u_{n,j}=0 \quad w_{n,j}=0 \quad (u_d)_{n,j}=0 \quad (w_d)_{n,j}=0 \quad \theta_{n,j}\to 0 \quad C_{n,j}\to 0 \end{aligned} \tag{3.7}$$

Where N corresponds to ∞ The suffix i and j corresponds to y and t respectively. Also $\Delta y = y_{i+1} - y_i$ and $\Delta t = t_{j+1} - t_j$.

IV. RESULT AND DISCUSSION

In order to solve the system of non-linear partial differential Eqs. (3.1) to (3.6) with the help of initial and boundary conditions of the flow represented by Eq. (3.7), we make use of Crank- Nicolson finite difference method. Further the effects of various parameters on velocity and temperature distribution involved in the Eqs.(10) to (12) are studied thrtough graphs.

Figs. 1, 2 and 3 illustrate the effect of Soret number Sr on concentration C, velocity u, and w. It is observed that on increasing Soret number C, u and w increase. Figs. 4, 5 and 6 depict that increasing Schmidt number Sc, Concentration C, velocity profile u and w decrease. Figs 7, 8, 9 and 10 show effect of radiation parameter R on Concentration profile C, velocity profiles u, w and temperature profile θ that when R increase C decreases near wall and after some distance it starts increases, velocities u, w and temperature increase when R increase. On increasing Dufour number Du it is seen in figs 11 and 12 that C decreases and θ increases.

It is observed from Figs. 13 and 14 that velocity u concentration C decrease as chemical reaction parameter Kr increases. Figs 15 and 16 show that velocity u and w decrease as dusty particle parameter B increases. From Figs 17 and 18 it is clear that increasing dust fluid parameter B_1, velocity profiles u and w decrease. Velocity profiles u decreases in Fig 19 and w increases rapidly in Fig 20 when magnetic parameter M increases. Figs 21 and 22 show that increasing inclination angle α velocity profiles u and w decrease. It is seen from Figs 23 and 24 that velocity u and w increases as time t increase while in Figs 25 and 26 it is observed for same that Concentration C and temperature θ decrease near wall after that increase. It is analyzed from Fig 27 and 28 velocity u and w increase when Hall parameter m increases.

Table 1 shows that skin friction coefficients along y and z direction τ_1 and τ_2 increase when parameters Gr, Gm, m, R, Sr, t increase on other hand τ_1 and τ_2 decrease as parameter Sc, Kr, B, B_1 increase and τ_1 decreases and τ_2 increases as parameter M increases.

Table 2 depicts that Nusselt number Nu decreases and Sherwood number Sh increases when parameters Du, R, Sc, Kr, t increase while Nusselt number Nu increases and Sherwood number Sh decreases when parameter Sr increases.

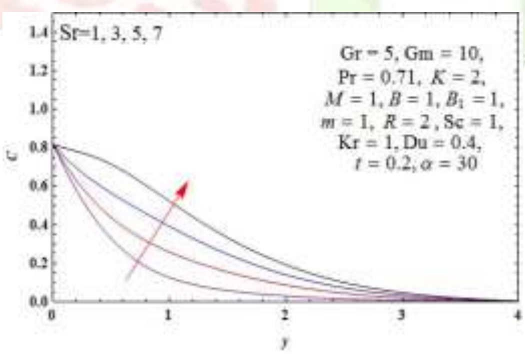


Fig. 1. Concentration profile C for different value of Sr

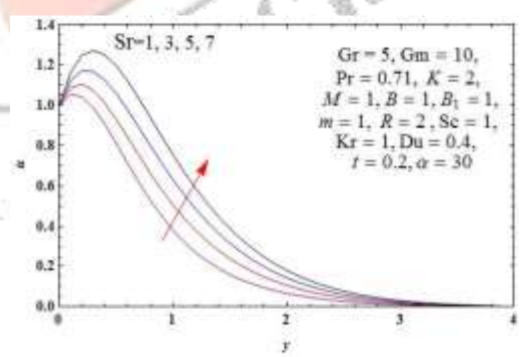


Fig. 2. Velocity profile u for different value of Sr

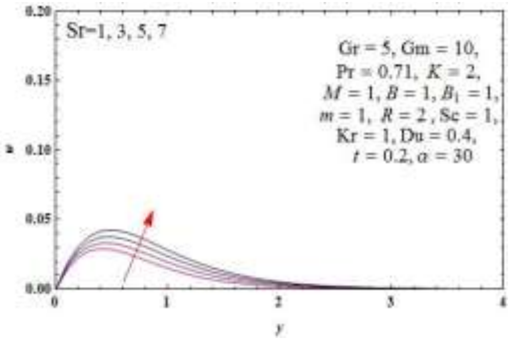


Fig. 3. Velocity profile w for different value of Sr

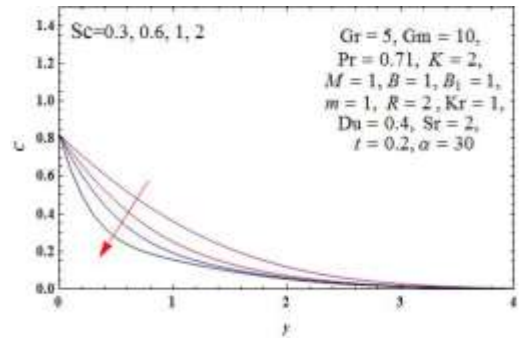


Fig. 4. Concentration profile C for different value of Sc

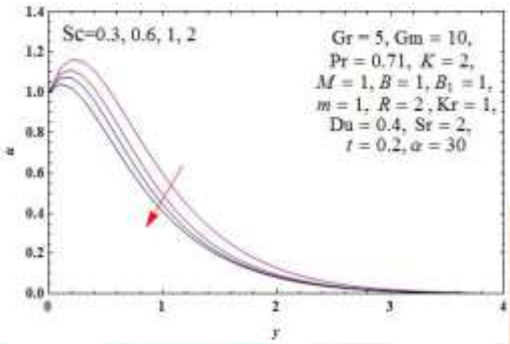


Fig. 5. Velocity profile u for different value of Sc

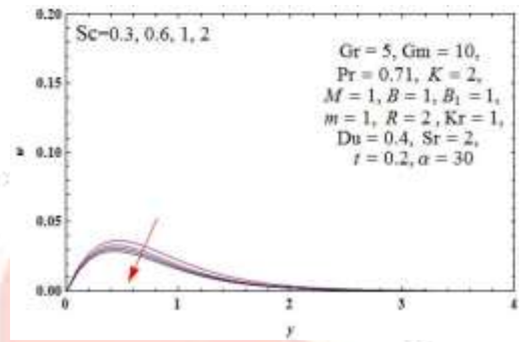


Fig. 6. Velocity profile w for different value of Sc

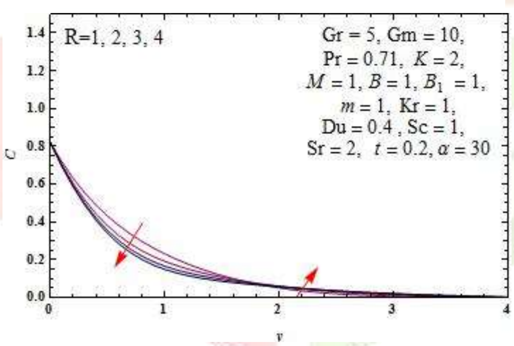


Fig. 7. Concentration profile C for different value of R

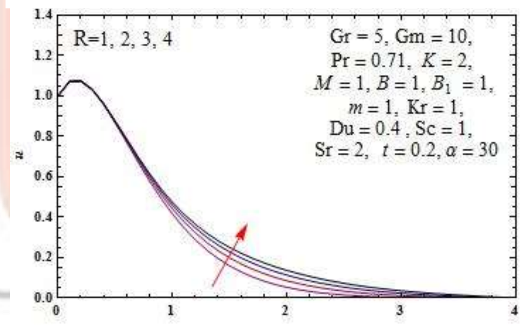


Fig. 8. Velocity profile u for different value of R

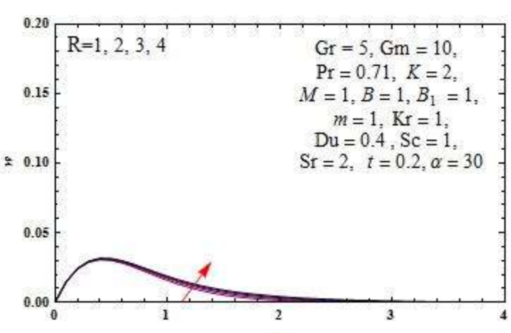


Fig. 9. Velocity profile w for different value of R

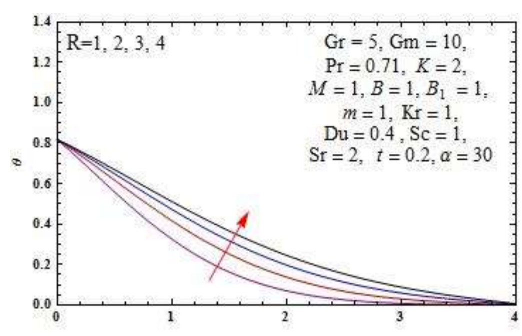


Fig. 10. Temperature profile θ for different value of R

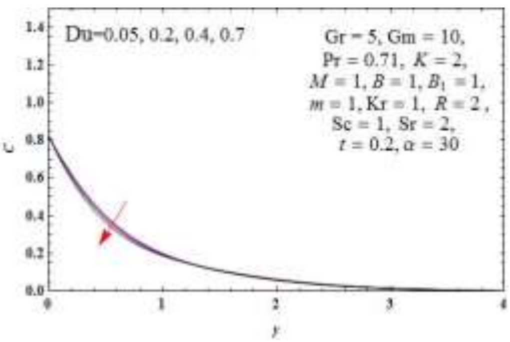


Fig. 11. Concentration profile C for different value of Du

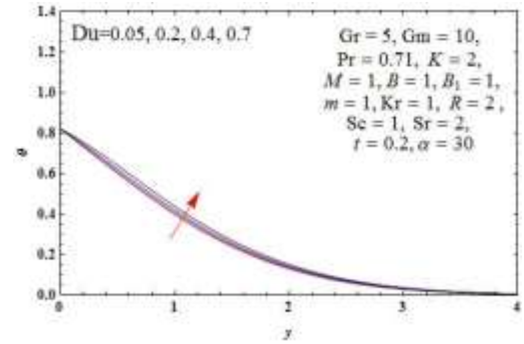


Fig. 12. Temperature profile θ for different value of Du

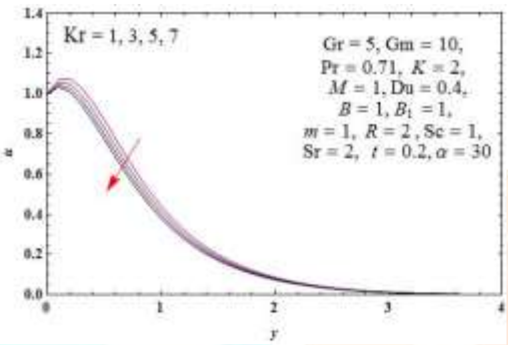


Fig. 13. Velocity profile u for different value of Kr

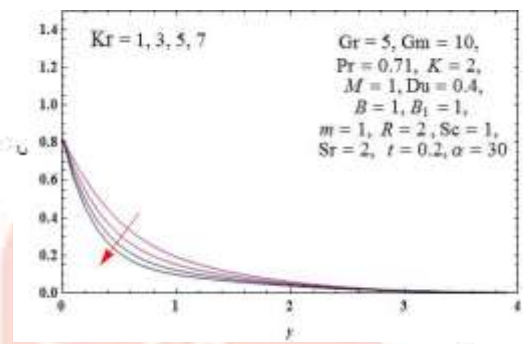


Fig. 14. Concentration profile C for different value of Kr

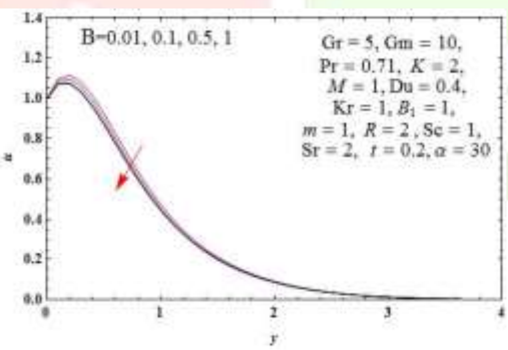


Fig. 15. Velocity profile u for different value of B

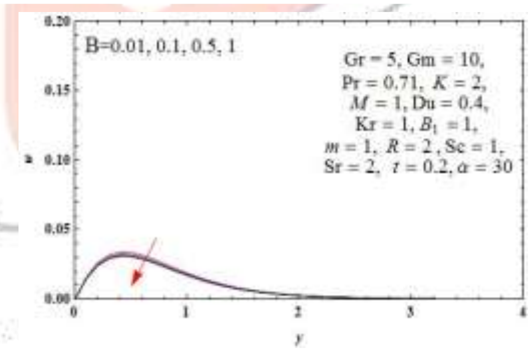


Fig. 16. Velocity profile u for different value of B

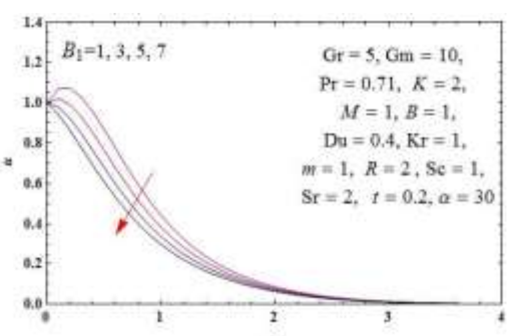


Fig. 17. Velocity profile u for different value of B_1

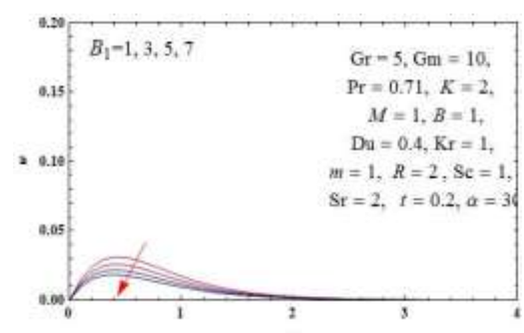


Fig. 18. Velocity profile w for different value of B_1

Fig. 18. Velocity profile w for different value of B_1

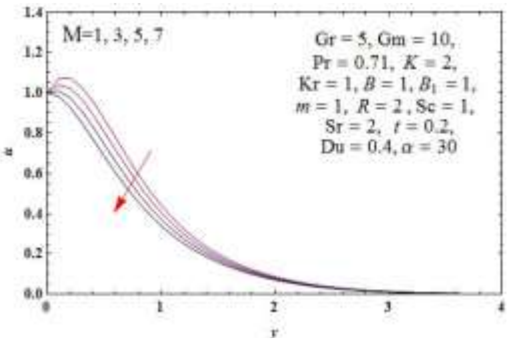


Fig. 19. Velocity profile u for different value of M

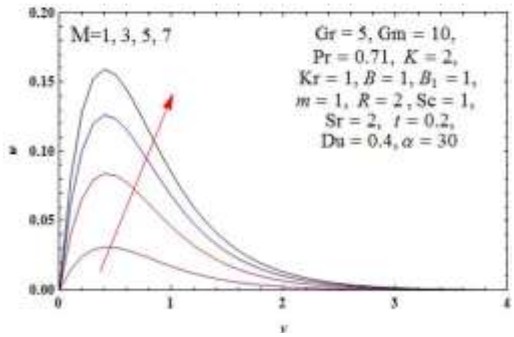


Fig. 20. Velocity profile w for different value of M

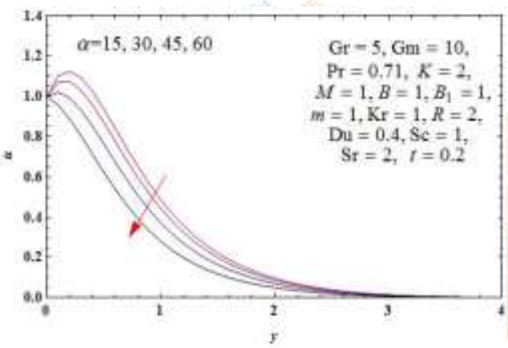


Fig. 21. Velocity profile u for different value of α

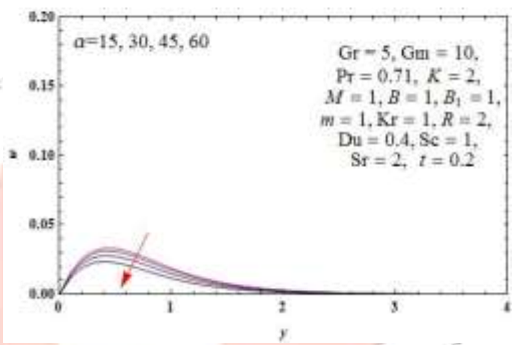


Fig. 22. Velocity profile w for different value of α

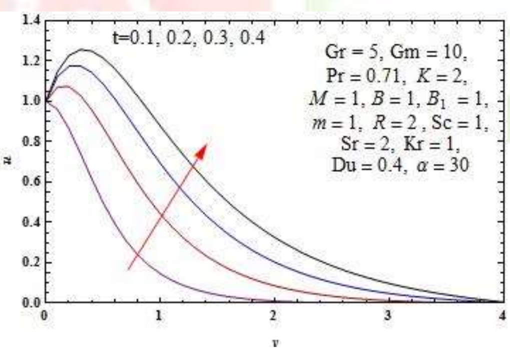


Fig. 23. Velocity profile u for different value of t

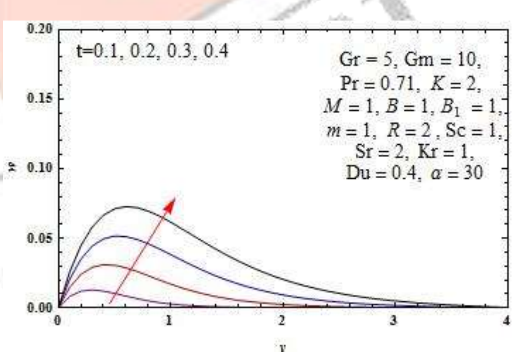
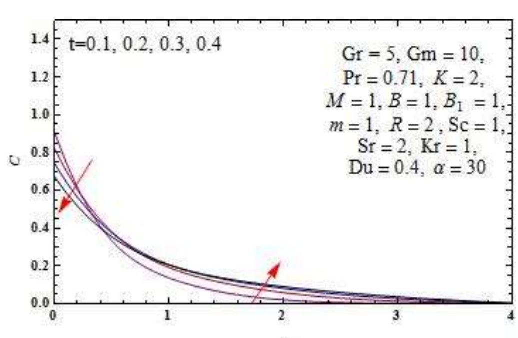


Fig. 24. Velocity profile w for different value of t



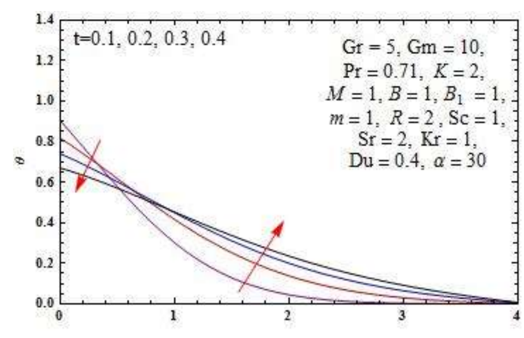


Fig. 25. Concentration profile C for different value of t

Fig. 26. Temperature profile θ for different value of t

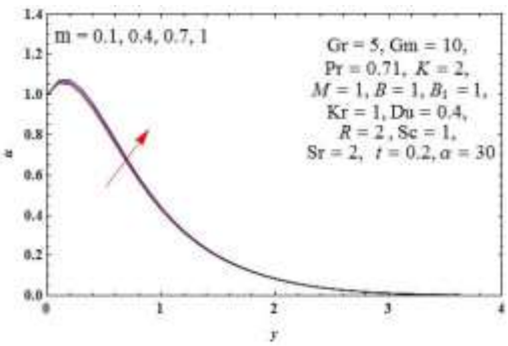


Fig. 27. Velocity profile u for different value of m

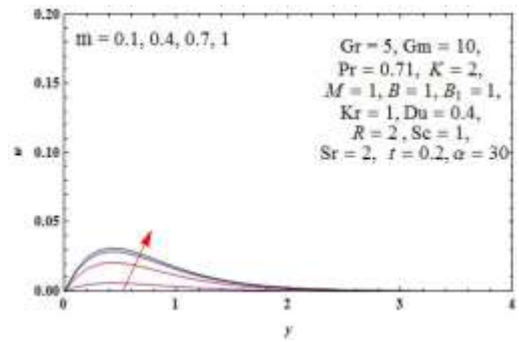


Fig. 28. Velocity profile w for different value of m

Table 1. Skin friction coefficients τ_1 and τ_2 for different values of parameters

Gr	*Gm*	*B*	*B₁*	*K*	*M*	*m*	*Pr*	*Du*	*R*	*Sc*	*Sr*	*Kr*	*t*	τ_1	τ_2
0	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	-0.411809	0.117982
10	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	1.8192	0.176258
15	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	2.9347	0.205396
5	0	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	-0.898639	0.110226
5	5	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	-0.0974728	0.128673
5	15	1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	1.50486	0.165567
5	10	0.01	1	2	1	1	0.71	0.4	2	1	2	1	0.2	0.96447	0.157651
5	10	0.1	1	2	1	1	0.71	0.4	2	1	2	1	0.2	0.850978	0.151777
5	10	0.5	1	2	1	1	0.71	0.4	2	1	2	1	0.2	0.72947	0.147851
5	10	1	3	2	1	1	0.71	0.4	2	1	2	1	0.2	0.212945	0.127243
5	10	1	5	2	1	1	0.71	0.4	2	1	2	1	0.2	-0.211592	0.111195
5	10	1	7	2	1	1	0.71	0.4	2	1	2	1	0.2	-0.582649	0.0981155
5	10	1	1	2	3	1	0.71	0.4	2	1	2	1	0.2	0.399965	0.406589
5	10	1	1	2	5	1	0.71	0.4	2	1	2	1	0.2	0.103285	0.624137
5	10	1	1	2	7	1	0.71	0.4	2	1	2	1	0.2	-0.183169	0.805546
5	10	1	1	2	1	0.1	0.71	0.4	2	1	2	1	0.2	0.565094	0.0280218
5	10	1	1	2	1	0.4	0.71	0.4	2	1	2	1	0.2	0.600269	0.0985762
5	10	1	1	2	1	0.7	0.71	0.4	2	1	2	1	0.2	0.654063	0.136348
5	10	1	1	2	1	1	0.71	0.4	1	1	2	1	0.2	0.723986	0.146507
5	10	1	1	2	1	1	0.71	0.4	3	1	2	1	0.2	0.701829	0.147865
5	10	1	1	2	1	1	0.71	0.4	4	1	2	1	0.2	0.70538	0.148583
5	10	1	1	2	1	1	0.71	0.4	2	0.3	2	1	0.2	1.1911	0.164257
5	10	1	1	2	1	1	0.71	0.4	2	0.6	2	1	0.2	0.914687	0.153831
5	10	1	1	2	1	1	0.71	0.4	2	2	2	1	0.2	0.414646	0.139721
5	10	1	1	2	1	1	0.71	0.4	2	1	1	1	0.2	0.544466	0.140827
5	10	1	1	2	1	1	0.71	0.4	2	1	3	1	0.2	0.871049	0.153602
5	10	1	1	2	1	1	0.71	0.4	2	1	5	1	0.2	1.23497	0.167201
5	10	1	1	2	1	1	0.71	0.4	2	1	7	1	0.2	1.64947	0.181794
5	10	1	1	2	1	1	0.71	0.4	2	1	2	3	0.2	0.559248	0.143931
5	10	1	1	2	1	1	0.71	0.4	2	1	2	5	0.2	0.438504	0.141196
5	10	1	1	2	1	1	0.71	0.4	2	1	2	7	0.2	0.336662	0.138834
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.1	-0.398566	0.081592
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.3	1.21037	0.205522
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.4	1.45738	0.256988

Table 2. Nusselt number and Sherwood number Nu and Sh respectively for different values of parameters

Gr	Gm	B	B_1	K	M	m	Pr	Du	R	Sc	Sr	Kr	t	Nu	Sh
5	10	1	1	2	1	1	0.71	0.05	2	1	2	1	0.2	0.4385	1.06803
5	10	1	1	2	1	1	0.71	0.2	2	1	2	1	0.2	0.413475	1.10247
5	10	1	1	2	1	1	0.71	0.7	2	1	2	1	0.2	0.312481	1.2463
5	10	1	1	2	1	1	0.71	0.4	1	1	2	1	0.2	0.496333	1.01348
5	10	1	1	2	1	1	0.71	0.4	3	1	2	1	0.2	0.316346	1.21524
5	10	1	1	2	1	1	0.71	0.4	4	1	2	1	0.2	0.27834	1.24991
5	10	1	1	2	1	1	0.71	0.4	2	0.3	2	1	0.2	0.418751	0.564316
5	10	1	1	2	1	1	0.71	0.4	2	0.6	2	1	0.2	0.399482	0.840238
5	10	1	1	2	1	1	0.71	0.4	2	2	2	1	0.2	0.323944	1.86464
5	10	1	1	2	1	1	0.71	0.4	2	1	1	1	0.2	0.368374	1.27277
5	10	1	1	2	1	1	0.71	0.4	2	1	3	1	0.2	0.386249	1.01957
5	10	1	1	2	1	1	0.71	0.4	2	1	5	1	0.2	0.410145	0.686317
5	10	1	1	2	1	1	0.71	0.4	2	1	7	1	0.2	0.444527	0.214177
5	10	1	1	2	1	1	0.71	0.4	2	1	2	3	0.2	0.349625	1.54461
5	10	1	1	2	1	1	0.71	0.4	2	1	2	5	0.2	0.326582	1.87042
5	10	1	1	2	1	1	0.71	0.4	2	1	2	7	0.2	0.306746	2.14621
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.1	0.641393	1.56838
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.3	0.249073	0.954058
5	10	1	1	2	1	1	0.71	0.4	2	1	2	1	0.4	0.170024	0.824342

REFERENCES

[1] Saffman P.G. 1962. On Stability of laminar flow of a dusty gas. J. Fluid Mech., 13(1) : 12.-129.

[2] Attia H. A. 2006. Unsteady hydromagnetic channel flow of a dusty fluid with temperature dependent Viscosity and thermal conductivity. Heat & Mass Transfer, 42 : 779-787.

[3] Nirmala T., Vishalakshi C. S. , Gireesha B. J. and Bagewadi C.S. 2009. Flow of unsteady dust visco-elastic fluid between two moving plates and frenet-frame field system. Bulet-inuel Academiei De Stinte A Republiell Moldova Mathematics, 3(61) : 30-41 .

[4] Dash G. C., Patra A. K. and Rath P. K. 2010. Effects of Hall current and chemical reaction on MHD flow along and exponentially accelerated porous flat plate with internal heat absorption / generation. Proc. Nat. Acad. Sci. , 80(A): 295-308.

[5] Varshney N. K. , Saxena S. S. and Dubey G. K. 2009. Effect of dusty viscous fluid on unsteady free convective flow along a moving porous hot vertical plate with thermal diffusion, and mass transfer. J. Purvanchal Academy of Science, 15: 1-12.

[6] Pandya N. and Shukla A. K. 2016. Effect of soret, Dufour, Hall and Radiation on an unsteady MHD flow past an inclined plate with viscous dissipation , chemical reaction and heat absorption & generation. Journal of Applied Fluid Mechanics, 9(1): 475-485.

[7] Pandya N. and R. K. Yadav 2015. Soret-Dufour effect on unsteady MHD flow of dusty fluid over inclined porous plate embedded in porous medium. Int. J. of Inn. Sci. Eng. & Tech., 2(10): 902-908.

[8] Babu N. V. N., Paul A. and Murali G. 2015. Soret and Dufour effects on unsteady Hydromagnetic free convective fluid flow past an infinite vertical porous plate in the presence of chemical reaction. Journal of Science and Arts, 30: 99- 111.

[9] Manjunatha S. and Gireesha B. J. 2016. The effects of variable viscosity and thermal conductivity on MHD flow and heat transfer of a dusty fluid. Ain Shams Eng. J., 7: 505 – 515.

[10] Alam MR, Samad M. 2006. Dufour and Soret effects on unsteady MHD free convection and mass transfer flow past a vertical porous plate in a porous medium. Nonlinear Anal. Model. Control, 119: 217-226.