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Viscosity and Soret Effects on Unsteady Hydro Magnetic Gas Flow along an Inclined Plane

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Abstract: ***The effects of viscosity and Soret number on an unsteady hydromagnetic gas flow (optically-thick gray gas) along an inclined plane in the presence of significant thermal radiation are considered. The Rosseland diffusion flux model is used to simulate the effects of thermal radiation. The explicit finite difference method is used to solve the dimensionless governing equations. The temperature and concentration profiles are found to be increased with increase of time, Dufour number and with Soret effects. The velocity, temperature and concentration profiles are discussed through graphs and tables.***

Keywords: Inclined plane, B-R Radiation parameter, Eckert number, Optically-thick gray gas, Dufour number and Soret number.

1. Introduction

Radiative MHD flows arise in many areas of technology and applied physics together with chemical compound soften materials process plasma flow switch performance was studied by Bowers et al. [4], MHD energy pumps in operation at terribly high temperatures was investigated by Biberman et al. [3]

Helliwell[10] thought-about the steady radiative magnetogasdynamics Couette flow mistreatment temperature dependent coefficients of body and thermal and electrical physical phenomenon, alongside a density-dependent absorptance. He numerically computed speed, induced flux, radiative flux and temperature profiles, showing that wall electrical physical phenomenon and emissivity exert a serious result on the speed and flux distributions however minor influence on temperatures. An identical study was presented by Raptis and Perdikis[14].

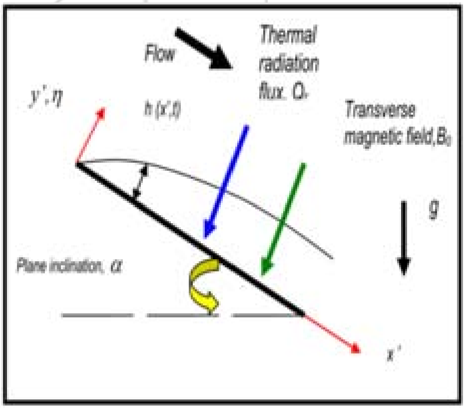
Azzam[1] measured thermal radiation flux influence on hydromagnetic mixed free – forced convective steady optically-thick laminal physical phenomenon flow additionally mistreatment the Rosseland approximation. Gbadeyan and Idowu [7] bestowed the MHD heat transfer between 2 homocentric rotating spheres using the optically skinny limit case for thermal radiation.

The on top of studies failed to live but the result associate inclined surface, a regime of serious importance in glass producing was investigated by Obidina and Kiseleva, [12]; Pankova[13],powder technology fluidisation processes by Doroodchi et al. [5], solar power collectors by fodder [9]; Bég et al. [2]; Fan et al. [6], film cooling chemical engineering systems by Yan and Soong [16], and electronic circuit cooling mechanisms by Manca et al. [11].

Radiation transient free convection result associate inclined plate has been investigated by Ghosh et al.[18]. They investigated associate unsteady gravity-driven thermal convection flow of a viscous incompressible, electrically-conducting, absorbing-emitting, optically-thick grey gas on associate machine within the presence of a transversal flux and vital thermal radiation effects. The Rosseland diffusion flux model is used to simulate thermal radiation effects. The momentum and energy conservation equations area unit non-dimensionalised and resolved precisely mistreatment the mathematician remodel methodology.

In this paper the Dufour and Soret effects and the effect of viscosity are investigated on radiative thermal effects on an unsteady MHD gas flow along an inclined plane.

2. Formulation of the Problem



The transient MHD flow of a viscous, incompressible, electrically conducting, optically-thick gas along an infinite plate inclined at α to the horizontal, the plate moving with constant velocity, u_0. as shown in the figure with the refractive index of the gas medium as constant is considered under the following assumptions.

1. A uniform magnetic field, B_0, is applied perpendicular to the plate. The x'-axis is orientated along the plate and the y'-axis perpendicular to the plate.
2. From an order of magnitude analysis, it can be shown (Sutton and Sherman 1965) that for two-dimensional (x-y) magneto-hydrodynamic gas dynamic flows, the hydromagnetic retarding force (Lorentz body force) acts only parallel to the flow and has the form :

$$F_{magnetic} \approx -\sigma B_y^2 u$$

Where by is the component of magnetic field in the y-direction.

3. The induced magnetic field effects, Joule electro - heating, and Hall current / ion - slip effects are neglected.
4. The temperature of the gas in the regime is T’ and an induced pressure gradient generated by indirect natural convection acts along the x’-direction.
5. All fluid properties are constant.
6. The plate temperature is prescribed $T_w^{'}$ and is of sufficiently high magnitude that thermal radiation effects are significant.
7. In accordance with the Boussinesq approximation, all fluid properties are constant with the exception of the density variation in the buoyancy term.
8. Unidirectional radiation flux, Q_r, is considered and it is assumed that $\frac{\partial Q_r}{\partial y^{'}} \gg \frac{\partial Q_r}{\partial x^{'}}$

Under these assumptions, the governing equations of the flow problem in the non – dimensional form are

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K}\right) u + Gr\left(Sin\,\alpha - F_1\,Cos\alpha\right) + Gm\,\phi$$

(1)

$$\frac{\partial \theta}{\partial t} = \left(\frac{1+N}{\Pr}\right)\frac{\partial^2 \theta}{\partial y^2} + Ec\left(\frac{\partial u}{\partial y}\right)^2 + Du\frac{\partial^2 \phi}{\partial y^2} \quad (2)$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} + Sr\frac{\partial^2 \theta}{\partial y^2} \quad (3)$$

The initial and boundary conditions, in the non – dimensional form are

$$\begin{aligned} &u = 0, \quad \theta = 0, \quad \phi = 0 \quad y \ge 0 \\ &u = 1 \quad \theta = 1, \quad \phi = 1 \quad y = 0 \\ (4)\ &u \to 0, \quad \theta \to 0, \quad \phi \to 0 \quad y \to \infty \end{aligned}$$

3. Solution Method

The governing equations, with the corresponding boundary conditions, using the explicit finite difference method are

$$\frac{u(i,j+1) - u(i,j)}{\Delta t} = \frac{u(i+1,j) - 2u(i,j) + u(i-1,j)}{\Delta y^2} + Gr\left[Sin\,\alpha - F_1\,Cos\,\alpha\right] + Gm\,\phi(i,j) \quad (5)$$

$$\frac{\theta(i,j+1) - \theta(i,j)}{\Delta t} = \left(\frac{1+N}{\Pr}\right)\frac{\theta(i+1,j) - 2\theta(i,j) + \theta(i-1,j)}{\Delta y^2} + Ec\left[\frac{u(i+1,j) - u(i,j)}{\Delta y}\right]^2 + Du\,\frac{\phi(i+1,j) - 2\phi(i,j) + \phi(i-1,j)}{\Delta y^2} \quad (6)$$

$$\frac{\phi(i,j+1) - \phi(i,j)}{\Delta t} = \frac{1}{\mathrm{Sc}}\,\frac{\phi(i+1,j) - 2\phi(i,j) + \phi(i-1,j)}{\Delta y^2} + Sr\,\frac{\theta(i+1,j) - 2\theta(i,j) + \theta(i-1,j)}{\Delta y^2} \quad (7)$$

$$u(i,0) = 0, \quad \theta(i,0) = 0, \quad \phi(i,0) = 0 \qquad for\ all\ i$$

$$(8)$$

$$u(0,j) = 1, \quad \theta(0,j) = 1, \quad \phi(0,j) = 1 \qquad for\ all\ i$$

$$u(i,j) \to 0, \quad \theta(i,j) \to 0, \quad \phi(i,j) \to 0 \qquad for\ all\ j$$

The suffixes, *i* corresponds to *y* and *j* corresponds to *t* and $\Delta t = t(j+1) - t(j)$ and $\Delta y = y(i+1) - y(i)$. The computations were carried out for different values the various physical parameters

4. Stability Analysis

The computations are carried out for different values of the various physical parameters. The procedure is repeated until the steady state. During computation Δt was chosen as 0.001.To judge the accuracy of the convergence of the finite difference scheme, the same program was run with Δt= 0.0009and 0.00125 and no significant change was observed. Hence, we conclude the finite difference scheme is stable and convergent.

5. Derivations

From the velocity, temperature, and concentration fields, the expressions for skin friction coefficient, the rate of heat transfer coefficient in terms of Nusselt number, and the rate of mass transfer in terms of Sherwood number are derived as

$$\tau = \frac{\tau'}{\rho u_0^2} = -\left(\frac{\partial u}{\partial y}\right)_{y=0} \quad (9)$$

$$Nu = -\frac{1}{\theta(0,t)}\left(\frac{\partial \theta}{\partial y}\right)_{y=0} \quad (10)$$

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} \quad (11)$$

6. Results and Discussion

The numerical solutions for the velocity, temperature and mass diffusion are computed for various physical parameters such as magnetic parameter (M), Plane inclination (α),Permeability (K), Dufour number(Du), Radiation convection parameter (N), and Soret number (Sr) etc. The shear stress at the wall (τ), the rate of heat transfer in terms of the Nusselt number (Nu), and the rate of mass transfer in terms of the Sherwood number (Sh) are also derived using the solutions of the velocity, temperature, and mass diffusion. The results are shown in graphs and tables.

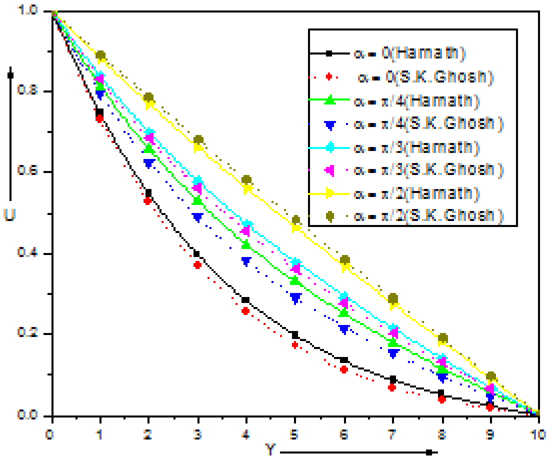


Fig.1 Comparision of velocity profiles for different α

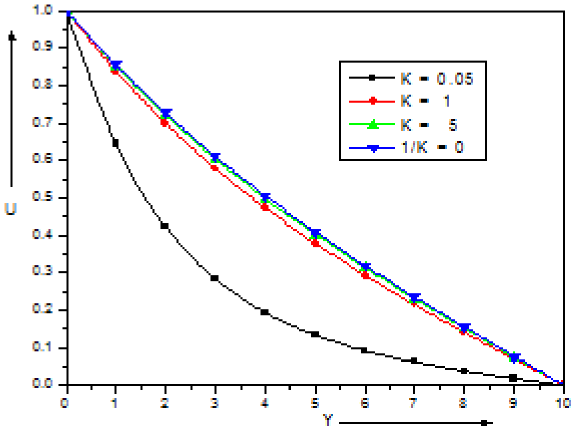


Fig. 2 Velocity profiles for diffrent values of K

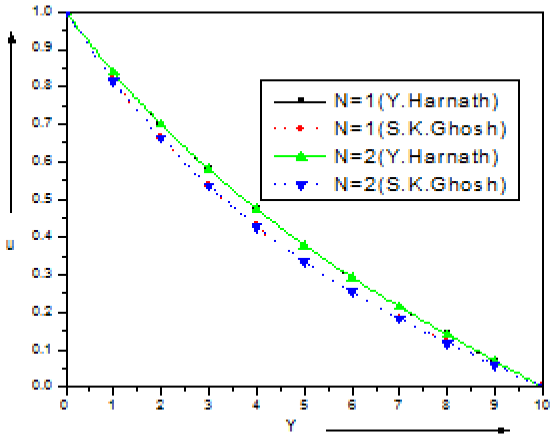


Fig.3 Comparision of velocity profiles for different N

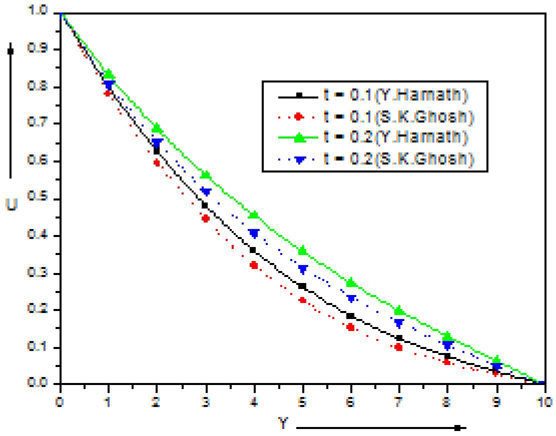


Fig.4 Comparision of velocity profiles for different t

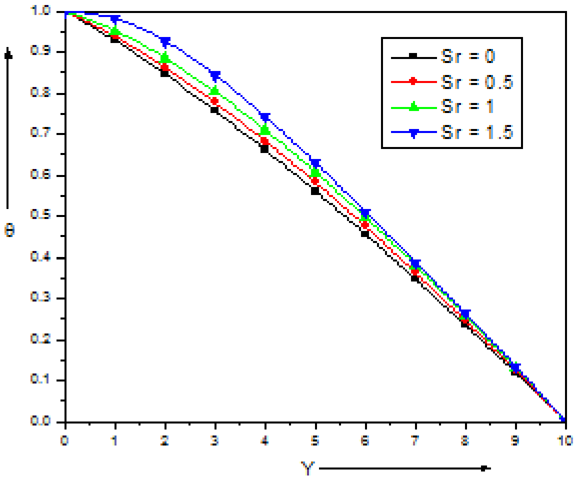


Fig.5 Temperature profiles for different Sr

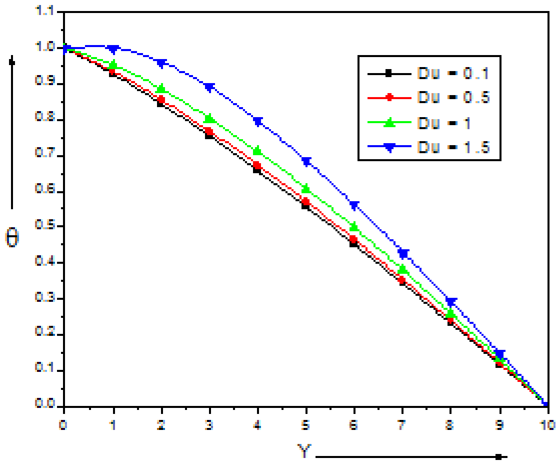


Fig. 6 Temperature profiles for diffrent Du

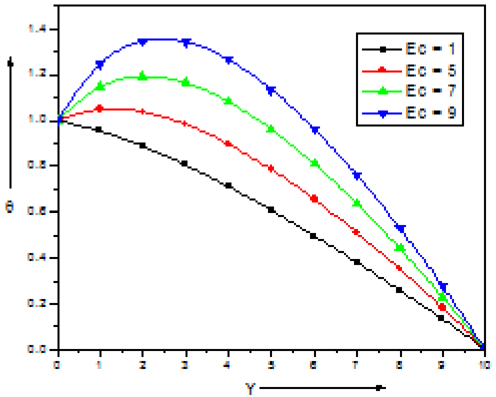


Fig. 7 Temperature profiles for diffemt Ec

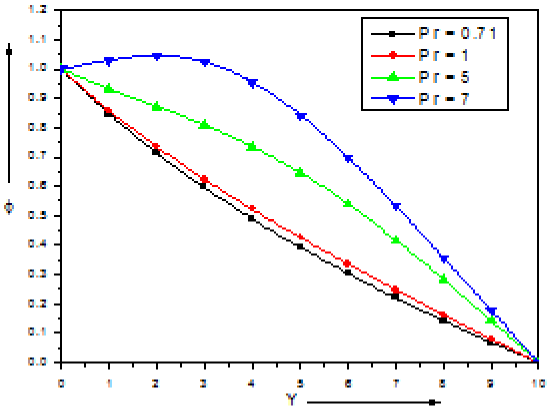


Fig. 8 Concentration profiles for different Pr

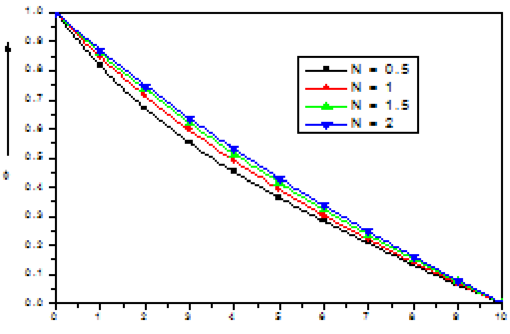


Fig. 9 Concentration profiles for different N

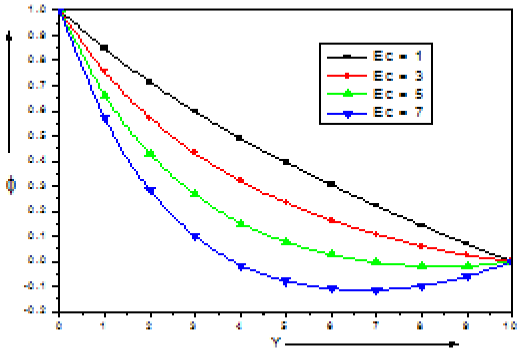


Fig. 10 Concentration profiles for different Ec

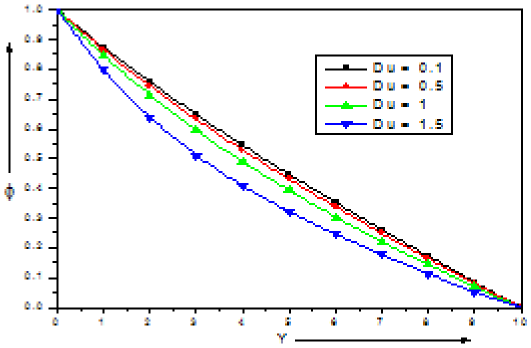


Fig. 11 Concentration profiles for different Du

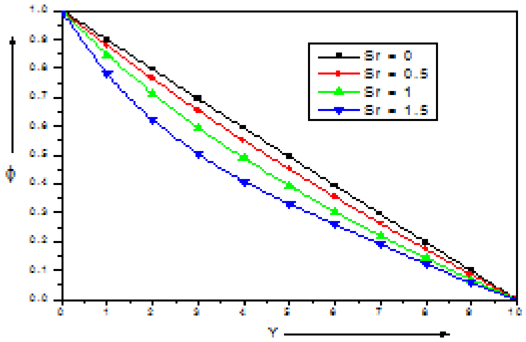


Fig. 12 Concentration profiles for diffrent Sr

The velocity profiles are shown in the graphs from 1 to 4. From the fig.1, it is evident that because the plane inclination (α) will increases, the velocity increases which can also be seen from the case of Ghosh et al. From the velocity increase with the increase of the plane inclination is showed in fig.1. This effect is observed by Ghosh et al. also. With the increase of porous parameter (K), the velocity increase is observed through the fig.2. From fig.3 and fig.4, it is seen that velocity profiles are good agreement with Ghosh et al. results for increase of radiation convection parameter (N) and time t.

The variation of temperature with various physical parameters is shown and the analysis of temperature distribution is carried out from fig.5 to fig.7. The increase of the temperature distribution in the fluid, with the increase of Soret number (Sr), and Dufour number (Du), are shown in the figures 5 and 6. As Eckert number (Ec) increases, the temperature increases accordingly. This is clearly observed from the fig. 7. The variation of concentration of the fluid is presented through fig.8 to fig.12

With the increase of Prandtl number (Pr), the concentration of the fluid increase is shown in the fig.8. As the radiation convection parameter (N) increases, the concentration of the fluid increases. This effect can be seen from the fig.9.With the increase of the Eckert number (Ec), concentration distribution decreases. This can be observed from the fig.10.The decrease in mass transfer with increase of the Dufour (Du) and Soret (Sr) numbers is observed from the fig.11 and fig.12.

Table 1: Variation of shear stress at the wall for various parameters

Pr	Ec	α	Sr	Du	K	t	N	Shear Stress
0.71	1	0	0.5	0.1	0.05	0.1	0.5	-2.053734
7	1	0	0.5	0.1	0.05	0.1	0.5	-1.66217
0.71	7	0	0.5	0.1	0.05	0.1	0.5	-1.83555
0.71	1	π/4	0.5	0.1	0.05	0.1	0.5	-2.053734
0.71	1	0	1.5	0.1	0.05	0.1	0.5	-1.78209
0.71	1	0	0.5	1.5	0.05	0.1	0.5	-1.770814
0.71	1	0	0.5	0.1	5	0.1	0.5	-1.581062
0.71	1	0	0.5	0.1	0.05	0.3	0.5	-1.755718
0.71	1	0	0.5	0.1	0.05	0.1	1.5	-1.753851

Table 2: Variation of rate of heat transfer (Nu) for various parameters

Pr	Ec	α	Sr	Du	K	t	N	Nusselt Number
0.71	1	0	0.5	0.1	0.05	0.1	0.5	-.2779795
7	1	0	0.5	0.1	0.05	0.1	0.5	-2.126806
0.71	7	0	0.5	0.1	0.05	0.1	0.5	3.362181
0.71	1	π/4	0.5	0.1	0.05	0.1	0.5	-.2779795
0.71	1	0	1.5	0.1	0.05	0.1	0.5	7.037273
0.71	1	0	0.5	1.5	0.05	0.1	0.5	.2574011
0.71	1	0	0.5	0.1	5	0.1	0.5	-.3880783
0.71	1	0	0.5	0.1	0.05	0.3	0.5	-.355465
0.71	1	0	0.5	0.1	0.05	0.1	1.5	-.5520148

Table 3: Variation of rate of mass transfer (Sh) for various parameters

Pr	Ec	α	Sr	Du	K	t	N	Sherwood number
0.71	1	0	0.5	0.1	0.05	0.1	0.5	-1.730354
7	1	0	0.5	0.1	0.05	0.1	0.5	.2577924
0.71	7	0	0.5	0.1	0.05	0.1	0.5	-5.202962
0.71	1	π/4	0.5	0.1	0.05	0.1	0.5	-1.730354
0.71	1	0	1.5	0.1	0.05	0.1	0.5	-2.539965
0.71	1	0	0.5	1.5	0.05	0.1	0.5	-2.253557
0.71	1	0	0.5	0.1	5	0.1	0.5	-1.617984
0.71	1	0	0.5	0.1	0.05	0.3	0.5	-1.651503
0.71	1	0	0.5	0.1	0.05	0.1	1.5	-1.473415

From the table – I, it is observed that, the Skin friction decreases with the increase of magnetic field, the plane inclination, with time *t*, and Dufour number. the Skin friction increases with the increase of Prandtl number, Eckert number, Soret number, Permeability of the medium, and radiation – convection parameter.

From the table – II, it can be seen that, the rate of heat transfer decreases with the increase of magnetic field, Prandtl number, Permeability of the medium, radiation – convection parameter and Dufour number. The rate of heat transfer increases with the increase of the plane inclination, Eckert number, Soret number, and with time *t*.

The table – III reveals that, the rate of mass transfer decreases with the increase of magnetic field, Eckert number and with time *t*. The rate of mass transfer increases with the increase of Prandtl number, the plane inclination, Soret number, Dufour number, Permeability of the medium and radiation convection parameter.

7. Conclusion

The effects of viscosity and Soret number on an unsteady hydromagnetic gas flow (optically-thick gray gas) along an inclined plane in the presence of significant thermal radiation are studied in this paper. The results are discussed through graph and the conclusions are

- The variation of velocity profiles are good agreement with Ghosh et al. for plane inclination, radiation convection parameter and time.
- The increase of K results the increase of velocity.
- Temperature profiles increase with the increase of Sr, Du and Ec.
- Concentration profiles increase for increase of Pr, N and decreases for Ec, Du and Sr.

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