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ANALYTICAL INVESTIGATIONS OF ALIGNED AND HALL EFFECTS ON UNSTEADY FREE CONVECTION FLOW PAST AN ACCELERATED INCLINED PLATE

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ABSTRACT

The objective of this study is to investigate aligned magnetic and hall effects on unsteady free convection chemically reacting fluid flow past an accelerated infinite inclined plate with variable temperature and mass diffusion under the influence of uniform transverse magnetic field. A general exact solution of the dimensionless governing partial differential equations are obtained by perturbation technique. The effects of various parameters describing the flow transport in the presence of thermal radiation and Dufour effect on the fluid velocity, temperature and concentration are concentrated on through graphs.

KEYWORDS: MHD, Free Convection, Exponentially Accelerated Plate & Inclined Plate

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INTRODUCTION

MHD flow has received wide attention to many researchers due to its varied and wide applications in many areas of science and technology. A magneto hydrodynamic stream alludes to the stream of electrically leading liquids, for example, plasmas or ionized gases under an attractive field. The effect of the magnetic field on the flow of the fluid can be derived using Reynolds's transport theorem and Maxwell's equations. Rossow (1960) first analyzed the Rayleigh problem in MHD without taking into account the induced magnetic field. The stream of electrically leading liquids within the sight of the attractive field prompts a potential toward a path typical to both the electric and attractive fields. This marvel is known as the Hall impact. At the point when the quality of the attractive field is solid, one can't disregard the impact of Hall current. It is of impressive significance and enthusiasm to contemplate how the consequences of the hydro dynamical issues get changed by the impact of Hall streams. The impact of Hall current on the MHD stream of liquids has been examined by a few creators. Pop (1971)studied the effect of Hall current on anhydromagnetic flow, which is short lived. Maleque and Sattar (2005) investigated the steady laminar MHD flow on a porous rotating disc taking the Hall effect into account. The effect of Hall current on an MHD flow has received significant attention from researchers recently. This is because

of the advancement of enhanced magneto hydrodynamic generators and magneto hydrodynamic quickening agents, oil control of fast turning machine parts under attractive field, and the investigation of planetary liquid progression. Force exchange from the sun powered breeze to the magnetosphere and ionosphere is a critical wellspring of geospace progression, which is upgraded amid times of geomagnetic action. Various outcomes are known to happen, for example, expanded field-adjusted streams (FACs) that stream between the ionosphere and magnetosphere, improved ionization because of accelerating particles. Recently, Rajuet al (2015)have been reported the effects of aligned magnetic field on steady two-dimensional flow over a vertical stretching surface. They found that increase in aligned angle decreases the velocity profiles and increases the temperature and concentration profiles of the fluid. Be that as it may, the limit layer streams contiguous slanted plates or wedges have gotten less consideration. The effect of Ohmic heating on the MHD free convection heat transfer has been examined for a Newtonian fluid by Hossain (1992). Hossain and Gorla (2013) studied Joule heating effect on magneto hydrodynamic mixed convection boundary layer flow. Beg et al (2009) solved magneto hydrodynamic Hartmann–Couette flow and heat transfer in a Darcian channel with Hall current, ionslip, viscous and Joule heating effects. Sibanda and Makinde (2010) proceeded on steady MHD flow and heat transfer past a rotating disk in a porous medium with Ohmic heating and viscous dissipation. Mixed convection of Non- Newtonian fluids from a vertical plate embedded in a porous medium is studied by Wang et al(1990) haudhury(2006) have analyzed the effect of radiation on heat transfer in MHD mixed convection flow with simultaneous thermal and mass diffusion from an infinite vertical plate with viscous dissipation and Ohmic heating. Dulal (2010) studied the combined effect of mixed convection with thermal radiation and chemical reaction on MHD flow of viscous and electrically conducting fluid past a vertical permeable surface embedded in a porous medium. Singh (2012) studied Heat and Mass Transfer in MHD Boundary Layer Flow past an Inclined Plate with Viscous Dissipation in Porous Medium. Mansour (2010) studied the boundary layer analysis has been presented for the free convection flow past an inclined surface in a Newtonian fluid-saturated porous medium. Hossain (1996) have studied the convection flow from an isothermal plate inclined at a small angle to the horizontal. Dulal pal (2010) investigated the unsteady mixed convection with thermal radiation and first order chemical reaction on magneto hydrodynamic. Noor (2012) studied the problem involving the conjugate phenomenon of heat and mass transfer analytically. Bhuvaneswari (2010) analyzed on the magneto hydrodynamic (MHD) free convection flow with simultaneous effects of heat and mass transfer. Ziyauddin (2010) developed closed form exact solutions for the unsteady MHD free convection flow of a viscous fluid over an inclined plate with variable heat and mass transfer in a porous medium. Alam (2009) studied the combined effect of viscous dissipation and Joule heating on steady MHD free convective heat and mass transfer flow of a viscous incompressible fluid past a semi-infinite inclined radiate isothermal permeable moving surface in the presence of thermophoresis. Ganesan et al. (2004) studied the problem of unsteady natural convection flow of a viscous incompressible electrically conducting fluid past an inclined plate with variable heat and mass flux's. OrthanAydm et al. (2009) studied MHD mixed convective heat transfer flow about an inclined plate.

Since, no author can study till now in the combination of both aligned and hall effects from above studies. In this article, we studied combined effects of hall current and aligned fluid flow in the presence of a magnetic field over an infinite inclined plate.

MATHEMATICAL ANALYSIS

Consider a free convective laminar limit layer stream of a gooey incompressible electrically directing, artificially receptive, Hall Current and adjusted liquid past a rashly semi-boundless plate slanted at an edge α.

The x' – axis is brought a plate vertically upward way and y' – axis is taken ordinary to it toward connected transverse attractive field. At the time t' ≥ 0, the plate is given an indiscreet movement with consistent speed u = $u_0\exp(a_0't')$. A magnetic field of uniform quality B_0 is thought to be connected ordinary to the flow. With the expectation of complimentary convection stream, it is likewise accepted that, the initiated attractive field is thought to be negligible as the attractive Reynolds number of the stream is taken to be little. The gooey scattering is disregarded in the vitality condition. The impacts of variety in thickness (ρ) with temperature and species fixation are viewed as just in the body drive term, as per common Boussinesq estimation. The liquid considered here is dim, retaining/transmitting radiation yet a non-diffusing medium. Since the stream of the liquid is thought to be toward x′ - axis, so the physical amounts are elements of the space co-ordinate y′ and t′ as it were.

With these physical contemplations, the conditions overseeing the liquid in Cartesian edge of reference are given beneath.

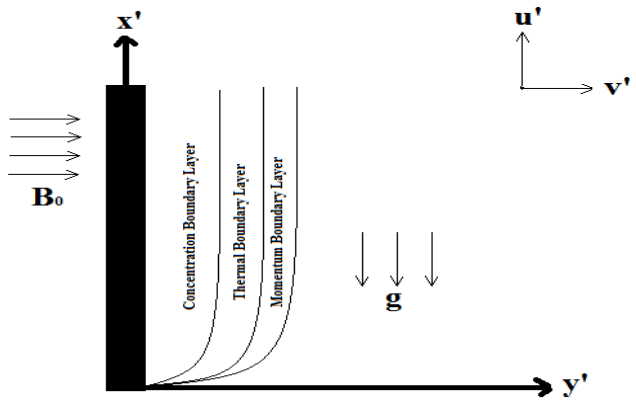

Figure 1: Flow Model Diagram

Then by usual Bossiness's approximation, the flow is governed by the following equations:

Momentum Equation

$$\frac{\partial u^*}{\partial t^*} = v\frac{\partial^2 u^*}{\partial y^{*2}} - \frac{m}{\rho(1+m^2)}\sigma B_0^2 u^* \sin^2\gamma + g\cos\alpha\,\beta(T^* - T_\infty^*) + g\cos\alpha\,\beta^*(C^* - C_\infty^*) \tag{1}$$

Energy Equation

$$\rho C_p v^* \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial t^{*2}} - \frac{\partial q_r^*}{\partial y^*} + \frac{D_m K_T}{C_s}\frac{\partial^2 C^*}{\partial y^{*2}} \tag{2}$$

Concentration Equation

$$\frac{\partial C^*}{\partial t^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - k^*(C^* - C_\infty^*) \tag{3}$$

Under these assumptions the appropriate boundary conditions for velocity, temperature and concentration fields are defined as

$$\left.\begin{array}{lll} u^* = 0, \quad T^* = T^*_\infty, \quad C^* = C^*_\infty & & for\ all\ y^*, t^* \le 0 \\ u^* = u_0 \cos(a_1^* t^*), \quad T^* = T^*_\infty + (T^*_w - T^*_\infty) A t^*, C^* = C^*_w & & at\ y^* = 0 \\ u^* \to 0, \quad T^* \to T^*_\infty, \quad C^* \to C^*_\infty & & as\ y^* \to \infty \end{array}\right\} t^* > 0 \tag{4}$$

Where $A = \dfrac{u_0^2}{\nu}$

Local radiant and non-dimensional quantities are not given due to restriction of number of pages.

The governing equations transforms into dimensionless form:

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr \cos\alpha\theta + Gm \cos\alpha C - \left(\frac{m}{1+m^2}\right) M \sin^2 \gamma\, u$$

$$\text{(OR)} \frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + z_1\theta + z_2 C - z_3\, u \tag{5}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - \frac{R}{\Pr}\theta + Du\frac{\partial^2 C}{\partial y^2} \tag{6}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} - kC \tag{7}$$

The corresponding boundary conditions in non-dimensional form are:

$$\left.\begin{array}{lll} u = 0, \quad \theta = 0, C = 0 & & for\ all\ y, t \le 0 \\ u = \cos(a_1 t), \quad \theta = t, C = 1 & & at \quad y = 0 \\ u \to 0, \theta \to 0, C \to 0 & & as\ y \to \infty \end{array}\right\} t > 0 \tag{8}$$

SOLUTION METHODOLOGY

By trial solution, we have

$$F_0'' - (M + n)F_0 = -GrG_0 - GmH_0 \tag{9}$$

$$G_0'' - (R + n\Pr)G_0 = -\Pr DuH_0'' \tag{10}$$

$$H_0'' - A_1^2 H_0 = 0 \tag{11}$$

Where prime denotes ordinary differentiation with respect to y

The corresponding boundary conditions can be written as

$$\begin{array}{ll} F_0 = \cos(a_1 t)e^{-nt}, G_0 = te^{-nt}, H_0 = e^{-nt} & at\ y = 0 \\ F_0 \to 0, \quad G_0 \to 0, \quad H_0 \to 0 & as\ y \to \infty \end{array} \tag{12}$$

Solving Equations (9)-(11) under the boundary conditions (12), we get

$$u(y,t) = B_4 e^{-A_3 y} - B_2 e^{-A_2 y} + B_3 e^{-A_1 y} \tag{13}$$

$$\theta(y,t) = (t + B_1) e^{-A_2 y} - B_1 e^{-A_1 y} \tag{14}$$

$$C(y,t) = e^{-A_1 y} \tag{15}$$

RESULTS AND DISCUSSIONS

Keeping in mind the end goal to get an unmistakable knowledge of the physical issue, the speed, temperature, concentration, skin-contact, the rate of warmth exchange and the rate of mass exchange have been examined by relegating numerical qualities to the parameters like radiation parameter (R), attractive parameter (M), exponential quickened parameter (a1), schmidt parameter (Sc), Prandtl number (Pr), Dufour number (Du), Aligned attractive parameter (γ), slanted point (α) and corridor parameter (m) from Figures 2 - 10, with the qualities t = 0.4, n = 0.1, Sc = 2.01, k = 1, R = 4, Pr = 0.71, Du = 1, Gr = 10, Gm = 5, M = 2, a1 = 1.5, m = 0.5, α = π/6, γ = π/3. The speed, temperature and focus profiles for an exponentially quickened plate are displayed from Figures 2 - 10. The impacts of M, Du, Gr, Gm, γ, α, m anda1on the three fieldsare appeared in Figures 2 - 10 within the sight of dufour, radiation and substance response separately when different parameters settled. From Figure 2 demonstrates that the speed diminishes with an expanding Aligned angle. From Figure 3 introduces that the speed diminishes with in expanding lobby parameter. From Figure 4 shows that the speed diminishes with in expanding slanted edge. From Figure 5 uncovers that the speed increments with in expanding exponential quickened parameter. Figure 6 delineates that the speed of different attractive parameter. It is examined that an expansion in attractive parameter the speed diminishes. It is because of the way that the utilization of transverse attractive field will come about a Lorentz constrain like drag drive, which tends to oppose the liquid stream and in this manner diminishing its velocity. From Figure 7, it is concentrated that an expansion in sc, decreases the speed field. A correlation of speed circulation bends because of cooling of the plate demonstrate that in the region of the plate the speed falls extremely rapidly. Figure 8 has been plotted to portray the variety of temperature profiles for various estimations of radiation parameter by settling other physical parameters. It is watched that the temperature diminish as an expanding the radiation parameter. Figure 9 portrays that the impacts of Dufour number on the liquid temperature. It is watched that as the Dufour number expands the temperature profiles increases. Figure 10 shows the impact of Schmidt number Sc on the focus profiles individually. As the Schmidt number expands the fixation diminishes.

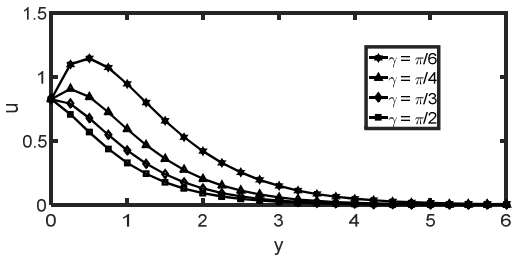

Figure 2: Velocity Profiles for Different Values of Γ

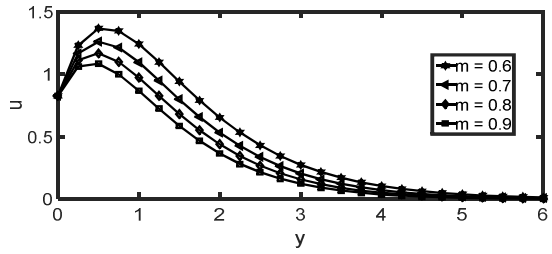

Figure 3: Velocity Profiles for Different Values of M

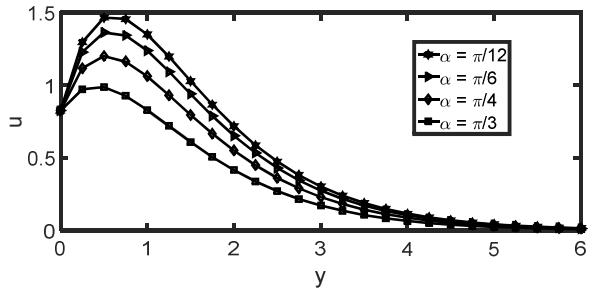

Figure 4: Velocity Profiles for Different Values of A

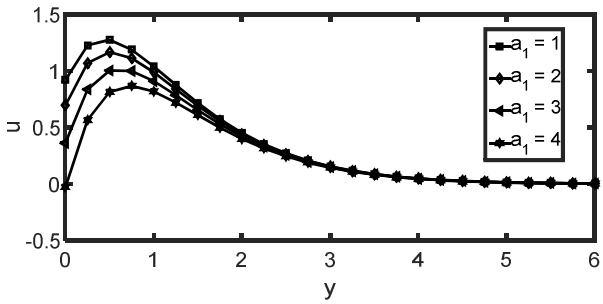

Figure 5: Velocity Profiles for Different Values of A_1

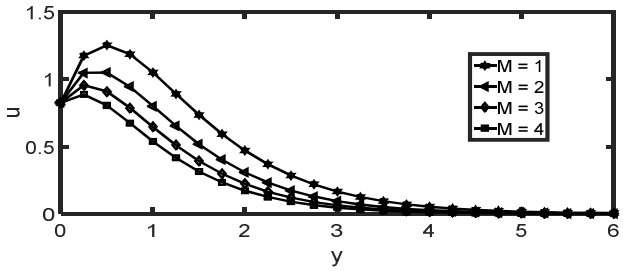

Figure 6: Velocity Profiles for Different Values of Magnetic M

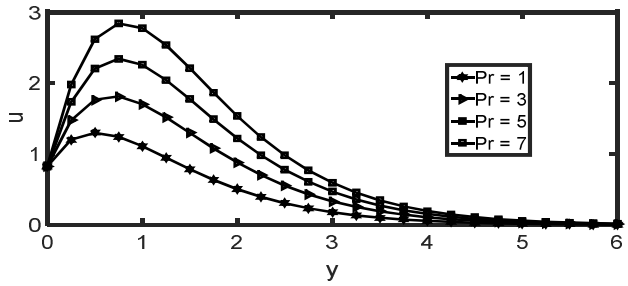

Figure 7: Velocity Profiles for Different Values of Pr

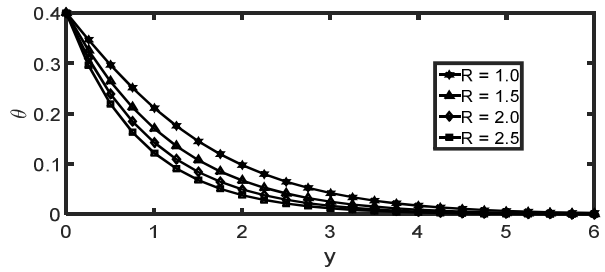

Figure 8: Temperature Profiles for Different Values of R

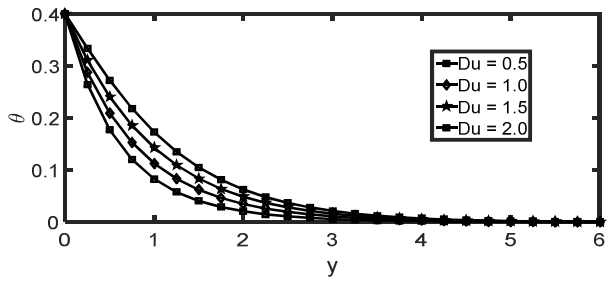

Figure 9: Temperature Profiles for Different Values of Du

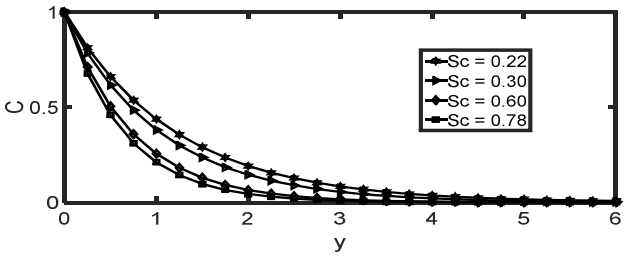

Figure 10: Concentration Profiles for Different Values of Sc

CONCLUSIONS

In this paper we have studied combined effects of both aligned magnetic and hall effects on unsteady free convection chemically reacting fluid flow past an accelerated infinite inclined plate with variable temperature and mass diffusion under the influence of uniform transverse magnetic field. From the present investigation the following conclusions can be drawn.

- There is a considerable effect of Aligned magnetic on the velocity.
- It is found that Schmidt number concentration is decreases significantly.
- The fluid temperature can be enhanced increased the Dufour number Du.

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