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The Effect of Hall Current on an Unsteady MHD Flow Along a Porous Flat Plate with Viscous Dissipation and Heat Absorption

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Abstract: An analysis is presented to investigate the effect of Hall current and heat absorption on MHD flow of an electrically conducting incompressible fluid along an infinite vertical porous plate with viscous dissipation. The governing partial differential equations are non-dimensionalized and transformed into a system of nonlinear partial differential similarity equations. The resulting nonlinear equations are solved under appropriate transformed boundary conditions by using Galerkin finite element method. Computations are performed for a wide range of the governing flow parameters viz. Grashof Number, Modified Grashof Number, Transpiration cooling parameter, Prandtl Number, Schmidt Number, Eckert number, Hartmann number, Heat absorption parameter and Hall parameter on the flow field. Numerical results for the dimensionless velocity, temperature and concentration profiles are obtained and displayed graphically for the above parameters.

Key words: MHD flow, Hall current, Heat and mass transfer, heat absorption, viscous dissipation, finite element method.

Nomenclature

C	Dimensionless concentration
ε	Porosity of the porous medium
C'	Concentration of the fluid
C'_w	Concentration near the plate
C'_∞	Concentration of the fluid away from the plate
θ	Dimensionless Temperature
T'	Temperature of the fluid
T'_w	Temperature of the plate
T'_∞	Temperature of the fluid away from the plate
u'	Velocity component in x' -direction
w'	Velocity component in z' - direction
x'	Spatial co–ordinate along the plate
υ	Kinematics viscosity, m^2/s
y'	Spatial co – ordinate normal to the plate
α	Thermal Diffusivity
k	Thermal conductivity, W/mK
m	Hall parameter
σ	Electrical conductivity, ohm/m
μ	Viscosity, Ns/m^2
μ_e	Magnetic permeability, Henry/meter
C_p	Specific heat at constant Pressure, J/kg-K
ρ	Density, kg/m^3
ω_e	Electron frequency, radian/sec
D	Chemical molecular diffusivity
τ_e	Electron collision time in Sec

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U_o	Reference velocity
e	Electron charge, coulombs
M	Hartmann number
n_e	Number density of the electron
$\Pr$	Prandtl number
Q	Heat absorption parameter
P_e	Electron Pressure, N/ m^2
Sc	Schmidt Number
Gr	Grashof Number
Ec	Eckert number
β	Volumetric co – efficient of thermal
Gc	Modified Grashof Number Expansion, K^{-1}
$\overline{V}$	Velocity vector, m/s
β^*	Co–efficient of volume expansion with Species concentration
λ	Non – dimensional transpiration parameter
g	Acceleration due to Gravity, 9.81 m/s^2

INTRODUCTION

In recent years, the analysis of hydromagnetic flow involving heat and mass transfer in porous medium has attracted the attention of many scholars because of its possible applications in diverse fields of science and technology such as–soil sciences, astrophysics, geophysics, nuclear power reactors etc. These new problems draw the attention of the researchers due to their varied significance, in liquid metals, electrolytes and ionized gases etc. In addition, the applications of the effect of Hall current on the fluid flow with variable concentration have been seen in MHD power generators, astrophysical and meteorological studies as well as in plasma physics. The Hall Effect is due merely to the sideways magnetic force on the drifting free charges. Hall Effect results in a development of an additional potential difference between opposite surfaces of a conductor for which a current is induced perpendicular to both the electric and magnetic field. This current is termed as Hall current.

Model studies on the effect of Hall current on MHD convection flows have been carried out by many authors due to application of such studies in the problems of MHD generators and Hall accelerators. Abdul Maleque et al. [1] studied the effects of variable properties and Hall current on steady MHD laminar convective fluid flow due to a porous rotating disk. Ajay Kumar Singh [2] made an attempt to study the steady MHD free convection and mass transfer flow with hall current, viscous dissipation and joule heating, taking in to account the thermal diffusion effect. Alam et al. [3] have studied unsteady free convective heat and mass transfer flow in a rotating system with Hall currents, viscous dissipation and Joul heating. Anand Rao et al. [4] investigated applied magnetic field on transient free convective flow of an incompressible viscous dissipative fluid in a vertical channel. Anand Rao and Srinivasa Raju [5] studied the effect of hall current on an unsteady magnetohydrodynamic flow past along a porous flat plate with heat and mass transfer in presence of viscous dissipation. Anjali Devi et al. [6] discussed pulsated convective MHD flow with Hall current, heat source and viscous dissipation along a vertical porous plate. Chaudhary et al. [7] analyzed Hall Effect on MHD mixed convection flow of a viscoelastic fluid past an infinite vertical porous plate with mass transfer and radiation. Chowdhary et al. [8] studied heat and mass transfer in elasticoviscous fluid past an impulsively started infinite vertical plate with Hall Effect. Cookey et al. [9] studied influence of viscous dissipation and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium with time dependent suction.

Hossain et al. [10] investigated the effect of hall current on the unsteady free convection flow of a viscous incompressible fluid with heat and mass transfer along a vertical porous plate subjected to a time dependent transpiration velocity when the constant magnetic field is applied normal to the flow. Lai [11] studied the coupled heat and mass transfer by mixed convection from vertical plate in a saturated porous medium. MHD stationary symmetric flows with Hall effect was analyzed by Palumbo et al. [12]. Raja Shekhar et al. [13] studied the effect of hall current on free convection and mass transfer flow through a porous medium bounded by an infinite vertical porous plate, when the plate was subjected to a constant suction velocity and heat flux. Singh et al. [14] studied the effects of mass transfer on the flow past a vertical porous plate. Singh et al. [15] analyzed the free convection heat and mass transfer along a vertical surface in a porous medium. Later, Soundalgekar et al. [16] studied the coupled heat and mass transfer by natural convection from vertical surfaces in a porous medium. Hall Effect on MHD Flow and Heat Transfer along a Porous Flat Plate with Mass Transfer

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and Source/Sink was analyzed by Srihari et al. [17]. Sriramulu et al. [18] discussed the effect of Hall Current on MHD flow and heat transfer along a porous flat plate with mass transfer.

In view of the above observations the main objective of this paper is to study the Hall Effect on MHD flow and mass transfer of an electrically conducting incompressible fluid along an infinite vertical porous plate with viscous dissipation and heat source. Also, the effects of different flow parameters encountered in the equations are studied. The results obtained are good agreement with the results of Sriramulu et al. [18]. The problem is governed by system of coupled non–linear partial differential equations whose exact solution is difficult to obtain. Hence, the problem is solved by using Galerkin finite element method, which is more economical from computational view point.

2. MATHEMATICAL ANALYSIS

We consider the effects of hall current and heat absorption on an unsteady free convection flow of an incompressible, viscous, electrically conducting fluid with mass transfer along a porous flat plate with viscous dissipation has been studied. The flow is assumed to be in x' – direction, which is taken along the plate in upward direction. The y' – direction which is taken along the normal to the direction of the plate. Initially, for time $t' \leq 0$, the plate and the fluid are maintained at the same constant temperature T'_∞ in a stationary condition with the same species concentration C'_∞ at all points so that, the Soret and Dufour effects are neglected. When $t' > 0$, the temperature of the plate is instantaneously raised (or lowered) to T'_w and the concentration of the species is raised (or lowered) to C'_w, which are hereafter regarded as constant. We also assumed that the level of species concentration is very low and hence species thermal diffusion and diffusion thermal energy effects can be neglected. A magnetic field of uniform strength is applied normal to the porous plate. The magnetic Reynolds number of the flow is taken to be small enough so that the induced magnetic field can be neglected.

Using the relation $\nabla.\overline{H} = 0$ for the magnetic field $\overline{H} = (H_x, H_y, H_z)$, we obtain H_y = constant = H_o (say) where H_o is the externally applied transverse magnetic field so that $\overline{H} = (0,\ H_o,\ 0)$. The equation of conservation of electric charge $\nabla.\overline{J} = 0$ gives j_y = constant, where $\overline{J} = (j_{x,}\ j_{y,}\ \ j_z)$. We further assume that the plate is non–conducting. This implies $j_y = 0$ at the plate and hence zero everywhere.

The generalized Ohm's law in the absence of electric field takes the following form:

$$\overline{J} + \frac{\omega_e \tau_e}{B_o} \overline{J} \times \overline{H} = \sigma\left(\mu_e \overline{V} \times \overline{H} + \frac{1}{en_e} \nabla P_e\right) \tag{1}$$

Under the assumption that the electron pressure (for weakly ionized gas), the thermo–electric pressure and ion–slip conditions are negligible, equation (1) becomes:

$$j_x = \frac{\sigma \mu_e H_o}{1+m^2}\left(mu' - w'\right) \text{ and } \quad j_z = \frac{\sigma \mu_e H_o}{1+m^2}\left(mw' + u'\right) \tag{2}$$

Where u' is the x' –component of $\overline{V}$, w' is the z' –component of $\overline{V}$ and $m(=\omega_e \tau_e)$ is the hall parameter. Within the above framework, the equations which govern the flow under the usual Boussinesq's approximation are as follows:

$$\frac{\partial v'}{\partial y'} = 0 \tag{3}$$

$$\frac{\partial u'}{\partial t'} + v' \frac{\partial u'}{\partial y'} = \upsilon \frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma \mu^2{}_e H_o^2}{\rho(1+m^2)}\left(u' + mw'\right) + g\beta(T - T_\infty) + g\beta^*\left(C' - C_\infty\right) \tag{4}$$

$$\frac{\partial w'}{\partial t'} + v' \frac{\partial w'}{\partial y'} = \upsilon \frac{\partial^2 w'}{\partial y'^2} - \frac{\sigma \mu^2{}_e H_o^2}{\rho(1+m^2)}\left(w' - mu'\right) \tag{5}$$

$$\frac{\partial T'}{\partial t'} + v' \frac{\partial T'}{\partial y'} = \frac{k}{\rho\, C_p} \frac{\partial^2 T'}{\partial y'^2} + \frac{\upsilon}{C_p}\left(\frac{\partial u'}{\partial y'}\right)^2 - \frac{Q_o}{\rho\, C_p}(T' - T'_\infty) \tag{6}$$

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$$\frac{\partial C'}{\partial t'} + v' \frac{\partial C'}{\partial y'} = D \frac{\partial^2 C'}{\partial y'^2} \tag{7}$$

The initial and boundary conditions of the problem are:

$$t' \le 0: \; u' = 0, \quad w' = 0, \; T' = T'_{\infty}, \; C' = C'_{\infty} \quad for\ all \quad y'$$

$$t' > 0: \begin{cases} u' = 0, \quad w' = 0, \; T' = T'_{w}, \; C' = C'_{w} \quad at \quad y' = 0 \\ u' = 0, \; w' = 0, \; T' = T'_{\infty}, \; C' = C'_{\infty} \quad as \quad y' \to \infty \end{cases} \tag{8}$$

The non – dimensional quantities introduced in the equations (3) – (7) are:

$$\left. \begin{array}{l} t = \dfrac{t' U_o^2}{\upsilon}, \; y = \dfrac{y' U_0}{\upsilon}, \; (u, v, w) = \dfrac{(u', v', w')}{U_o}, \theta = \dfrac{(T' - T'_{\infty})}{(T'_w - T'_{\infty})}, u = \dfrac{u'}{u'_0}, w = \dfrac{w'}{u'_0} \\ C = \dfrac{(C' - C'_{\infty})}{(C'_w - C'_{\infty})}, \; M = \dfrac{\sigma \mu_e^2 H_0^2 \upsilon}{\rho U_o^2}, \; \Pr = \dfrac{\mu C_p}{k}, \; Ec = \dfrac{U_o^2}{C_p (T'_w - T'_{\infty})}, \\ Sc = \dfrac{\upsilon}{D}, \; Gr = \dfrac{\upsilon g \beta (T'_w - T'_{\infty})}{U_o^3}, Gc = \dfrac{\upsilon g \beta^* (C'_w - C'_{\infty})}{U_o^3}, \; Q = \dfrac{\upsilon Q_o}{\rho C_p U_o^2}, \end{array} \right\} \tag{9}$$

Where U_o is the reference velocity. The governing equations can be obtained in the dimensionless form as:

$$\frac{\partial v}{\partial y} = 0 \tag{10}$$

$$\frac{\partial u}{\partial t} + v \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} - \frac{M}{(1 + m^2)} (u + mw) + (Gr)\theta + (Gc)C \tag{11}$$

$$\frac{\partial w}{\partial t} + v \frac{\partial w}{\partial y} = \frac{\partial^2 w}{\partial y^2} - \frac{M}{(1 + m^2)} (w - mu) \tag{12}$$

$$\frac{\partial \theta}{\partial t} + v \frac{\partial \theta}{\partial y} = \frac{1}{\Pr} \frac{\partial^2 \theta}{\partial y^2} + (Ec) \left(\frac{\partial u}{\partial y} \right)^2 - Q\theta \tag{13}$$

$$\frac{\partial C}{\partial t} + v \frac{\partial C}{\partial y} = \frac{1}{Sc} \frac{\partial^2 C}{\partial y^2} \tag{14}$$

The initial and boundary conditions (8) in the non – dimensional form are:

$$\left. \begin{array}{ll} t \le 0: & u = 0, \; w = 0, \; \theta = 0, C = 0 \quad for all \quad y \\ t > 0: & \begin{cases} u = 0, \; w = 0, \; \theta = 1, \; C = 1 \quad at \; y = 0 \\ u = 0, \; w = 0, \; \theta = 0, \; C = 0 \quad as \; y \to \infty \end{cases} \end{array} \right\} \tag{15}$$

From equation (10), we see that ν is either constant or a function of time t. Similarly solutions of equations (11) – (14) with the boundary conditions (15) exisists only if we take

$$\nu = \lambda t^{\frac{-1}{2}} \tag{16}$$

where λ is a non – dimensional transpiration parameter. For suction $\lambda > 0$ and for blowing $\lambda < 0$. From (16), it can be observed that the assumption is valid only for small values of time variable.

3. METHOD OF SOLUTION

The set of differential Equations (11) to (14) subject to the boundary conditions (15) are highly nonlinear, coupled and therefore it cannot be solved analytically. Hence, following Reddy (Reddy 1985) and Bathe (Bathe 1996) the finite

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element method is used to obtain an accurate and efficient solution to the boundary value problem under consideration. The fundamental steps comprising the method are as follows:

Step 1: Discretization of the domain into elements: The whole domain is divided into finite number of sub-domains, a process known as discretization of the domain. Each sub-domain is termed a finite element. The collection of elements is designated the finite element mesh.

Step 2: Derivation of the element equations: The derivation of finite element equations i.e. algebraic equations among the unknown parameters of the finite element approximation, involves the following three steps:

a) Construct the variational formulation of the differential equation.

b) Assume the form of the approximate solution over a typical finite element.

c) Derive the finite element equations by substituting the approximate solution into variational formulation.

Step 3: Assembly of element equations: The algebraic equations so obtained are assembled by imposing the inter-element continuity conditions. This yields a large number of algebraic equations, constituting the global finite element model, which governs the whole flow domain.

Step 4: Impositions of boundary conditions: The physical boundary conditions defined in equation (15) are imposed on the assembled equations.

Step 5: Solution of the assembled equations: The final matrix equation can be solved by a direct or indirect (iterative) method. For computational purposes, the coordinate y is varied from 0 to 4. $y_{max} = 4$, where max y represents infinity i.e. external to the momentum, energy and concentration boundary layers. Numerical solutions for these equations are obtained by C -program. In order to prove the convergence and stability of finite element method, the same C -program was run with slightly changed values of h and k and no significant change was observed in the values of of u , w , θ and C . This process is repeated until the desired accuracy is obtained. Hence the Galerkin finite element method is stable and convergent.

4. SHEARING STRESS, RATE OF HEAT AND MASS TRANSFER

The skin – friction at the wall along x' – axis is given by $\tau_1 = \left(\frac{\partial u}{\partial y}\right)_{y=0}$

The skin – friction at the wall along z' – axis is given by $\tau_2 = \left(\frac{\partial w}{\partial y}\right)_{y=0}$

5. RESULTS AND DISCUSSIONS

The problem of Hall Effect on MHD flow and mass transfer of an electrically conducting incompressible fluid along an infinite vertical porous plate with viscous dissipation and heat absorption has been studied and solved by using Galerkin finite element method. The effects of material parameters such as Prandtl number ($\Pr$), Schmidt number (Sc), Hall parameter (m), Eckert number (Ec), Heat absorption parameter (Q) and Transpiration cooling parameter (λ) separately in order to clearly observe their respective effects on the primary velocity, secondary velocity, temperature and concentration profiles of the flow. And also numerical values of skin–friction coefficients $(\tau_1 \& \tau_2)$ have been discussed in table 1. We discussed the effects of material parameters on primary velocity profiles from figures (1) to (6), secondary velocity profiles from figures (7) to (12), temperature profiles from figures (13) to (16) and concentration profiles from the figures (17) and (18). For the physical significance, the numerical discussions in the problem at t = 1.0, stable values for primary velocity, secondary velocity, temperature and concentration fields are obtained. To examine the effect of parameters related to the problem on the velocity field and skin–friction numerical computations are carried out at $\Pr$ = 0.71. To find out the solution of this problem, we have placed an infinite vertical plate in a finite length in the flow. Hence, we solve the entire problem in a finite boundary. However, in the graphs, the y values vary from 0 to 4, and the velocity, temperature, and concentration tend to zero as y tends to 4.

The nature of primary velocity profiles in presence of foreign species such as Hydrogen (Sc = 0.22), Oxygen (Sc = 0.60) and Ammonia (Sc = 0.78) are shown in figure (1). The flow field suffers a decrease in primary velocity at all points in presence of heavier diffusing species. The influence of the viscous dissipation parameter i.e., the Eckert number (Ec) on the velocity and temperature are shown in figures (2) and (14) respectively. Greater viscous dissipative heat causes a rise in the temperature as well as the velocity. Figure (3) depicts the effect of Prandtl number on primary velocity profiles in presence of foreign species such as Mercury ($\Pr$ = 0.025), Air ($\Pr$ = 0.71) and Water ($\Pr$ = 7.00) .We observe that from figure (3), the primary velocity decreases with increasing of Prandtl number (Pr).

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Figure (4) depicts the primary velocity profiles as the Hall parameter m increases. We see that u increases as m increases. It can also be observed that u profiles approach their classical values when Hall parameter m becomes large ($m > 5$). Figures (5) and (15) illustrate the influence of Heat absorption parameter (Q) on the velocity and temperature at $t = 1.0$ respectively. Physically speaking, the presence of heat absorption (thermal sink) effects has the tendency to reduce the fluid temperature. This causes the thermal buoyancy effects to decrease resulting in a net reduction in the fluid velocity. These behaviors are clearly obvious from figures (5) and (15) in which both the velocity and temperature distributions decrease as (Q) increases. From figure (9) the primary velocity profiles against y for several values of the transpiration cooling parameter (λ) keeping other parameters of the flow field are constant. The transpiration cooling parameter is found to retard the primary velocity of the flow field at all points. The reduction in primary velocity at any point of the flow field is faster as the transpiration cooling parameter becomes larger.

In figure (10), we see that w profiles increase for $m < 1$ and decrease for $m > 1$.The effect of Eckert number (Ec) on the secondary velocity flow field is presented in the figure (8). Here, the secondary velocity profiles are drawn against y for three different values of Ec. The Eckert number is found to accelerate the secondary velocity of the flow field at all points.

The nature of secondary velocity profiles in presence of foreign species such as H_2 ($Sc = 0.22$), O_2 ($Sc = 0.60$) and NH_3 ($Sc = 0.78$) are shown in figure (7) where the flow field suffers a decrease in secondary velocity in presence of heavier diffusing spices. Figure (9) depicts the effect of Prandtl number on secondary velocity profiles in presence of foreign species such as Mercury ($\Pr = 0.025$), Air ($\Pr = 0.71$) and Water ($\Pr = 7.00$) .We observe that from figure (9) the velocity is decreasing with increasing of Prandtl number ($\Pr$). The effect of Heat absorption parameter (Q) on the secondary velocity is as shown in the figure (11). From this figure the secondary velocity decreases with increasing values of Q.Figure (12) shows that the secondary velocity profiles against y for several values of the transpiration cooling parameter (λ). As the transpiration cooling parameter is to retard the secondary velocity.

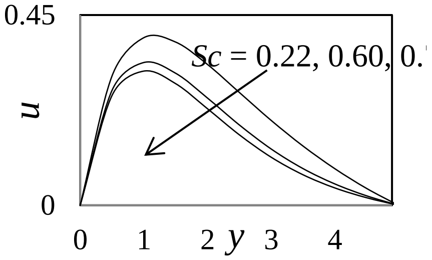

Figure 1. Effect of Schmidt number Sc on primary velocity profiles u

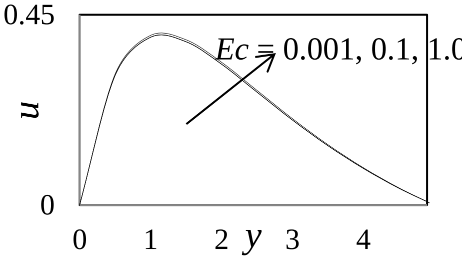

Figure 2. Effect of Eckert number Ec on primary velocity profiles u

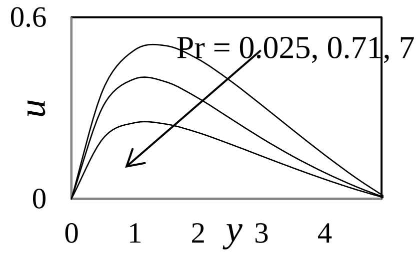

Figure 3. Effect of Prandtl number $\Pr$ on primary velocity profiles u

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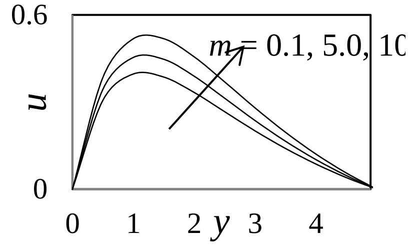

Figure 4. Effect of Hall parameter m on primary velocity profiles u

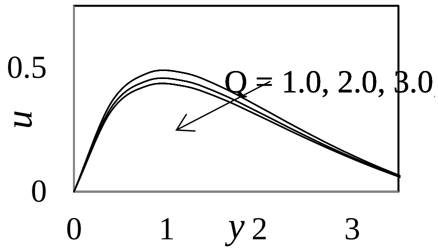

Figure 5. Effect of Heat absorption 'Q' on primary velocity profiles 'u'

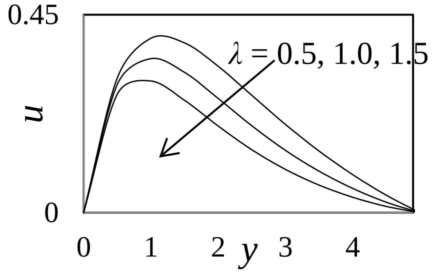

Figure 6. Effect of Transpiration cooling parameter λ on primary velocity profiles u

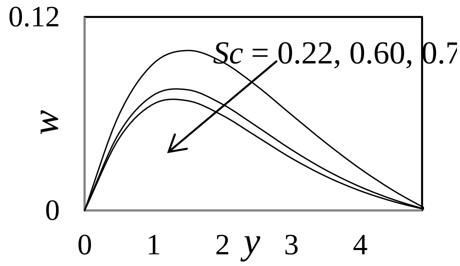

Figure 7. Effect of Schmidt number Sc on secondary velocity profiles w

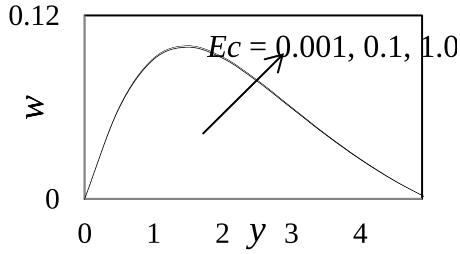

Figure 8. Effect of Eckert number Ec on secondary velocity profiles w

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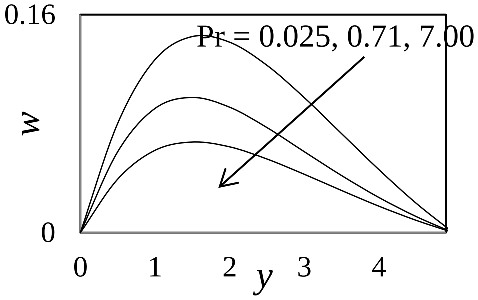

Figure 9. Effect of Prandtl number Pr on secondary velocity profiles w

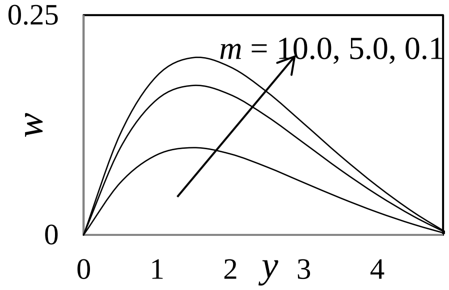

Figure 10. Effect of Hall parameter m on secondary velocity profiles w

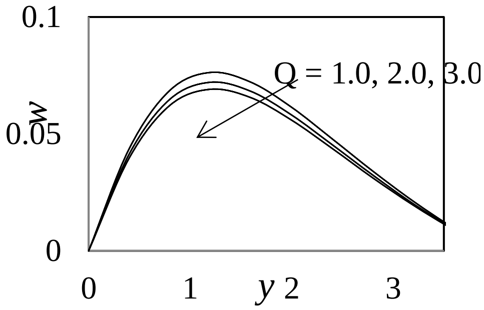

Figure 11. Effect of Heat absorption 'Q' on secondary velocity profiles 'w'

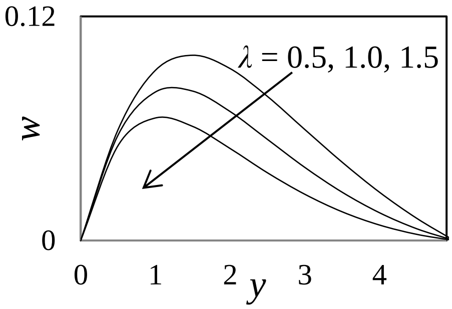

Figure 12. Effect of λ on secondary velocity profiles w

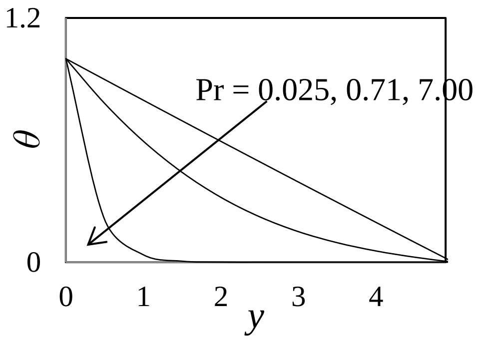

Figure 13. Effect of Prandtl number Pr on temperature profiles θ

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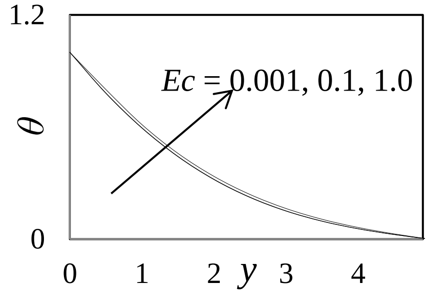

Figure 14. Effect of Eckert number Ec on temperature profiles θ

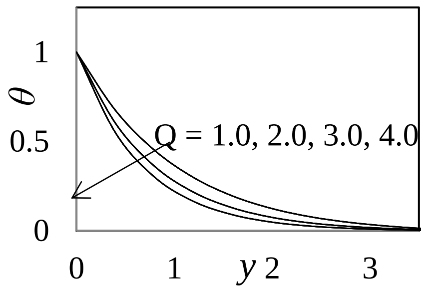

Figure 15. Effect of Heat absorption ‘Q’ on temperature profiles ‘θ’

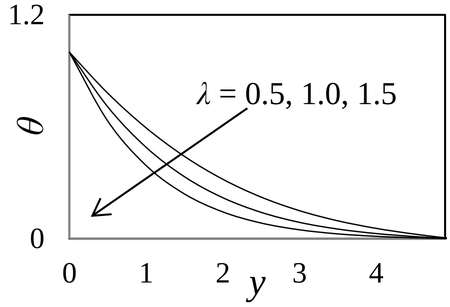

Figure 16. Effect of Transpiration cooling parameter λ on temperature profiles θ

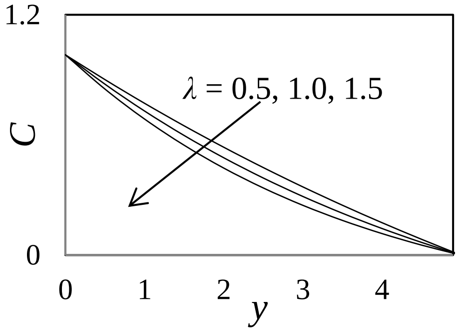

Figure 17. Effect of Transpiration cooling parameter λ on concentration profiles C

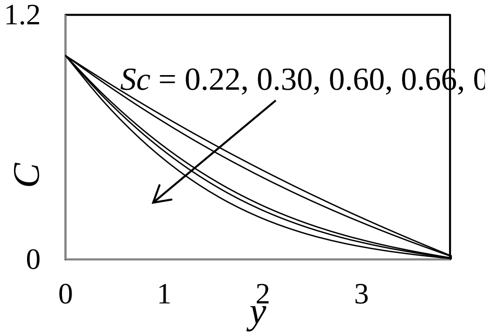

Figure 18. Effect of Schmidt number Sc on concentration profiles C

From figure (13) it is observed that an increase in the Prandtl number leads to decrease in the temperature field. Also, temperature field falls more rapidly for water in comparison to air and the temperature curve is exactly linear for mercury. From figure (16) depicts the temperature profiles against y for various values of transpiration cooling parameter (λ) keeping other parameters are constant. Transpiration cooling parameter is found to decrease the temperature of the flow field at all points.

The effects of Transpiration cooling parameter (λ) and Schmidt number (Sc) on the concentration field are presented in figures (17) and (18). Figure (18) shows the concentration field due to variation in Schmidt number (Sc) for the gasses Hydrogen, Helium, Water – vapour, Oxygen and Ammonia. It is observed that concentration field is steadily for Hydrogen and falls rapidly for Oxygen and Ammonia in comparison to Water – vapour. Thus Hydrogen can be used for maintaining effective concentration field and Water – vapour can be used for maintaining normal concentration field. Figure (17) shows the plot of concentration distribution against y for different values of transpiration cooling parameter (λ) and fixed $Sc = 0.22$. A comparative study of the curves of the above figure shows that the concentration distribution of the flow field decreases faster as the transpiration cooling parameter (λ) becomes larger. Thus greater transpiration cooling leads to a faster decrease in concentration of the flow field.

Table (1) shows the variation of different values $Gr, Gc, Sc, \Pr, M, m, Ec, Q$ and λ. From this table it is concluded that the magnitude of shearing stress τ_1 and τ_2 increase as the value of Gr, Gc, m, Ec increase and this behavior is found just reverse with the increase of $\Pr, Sc, M, Q, \lambda$. In order to ascertain the accuracy of the numerical results, the present skin – friction (τ_1) results are compared with the previous skin–friction (τ_1^*) results of Sriramulu et al. [18] in table 2. They are found to be in an excellent agreement.

Table 1: Variation of shearing stress τ_1 and τ_2 for different values of $Gr, Gc, Sc, \Pr, M, m, Ec, Q$ and λ

Gr	Gc	$\Pr$	Sc	M	m	Ec	Q	λ	τ_1	τ_2
1.0	1.0	0.71	0.22	2.0	0.5	0.001	1.0	0.5	1.1507	0.2336
2.0	1.0	0.71	0.22	2.0	0.5	0.001	1.0	0.5	1.6979	0.3404
1.0	2.0	0.71	0.22	2.0	0.5	0.001	1.0	0.5	1.7544	0.3604
1.0	1.0	7.00	0.22	2.0	0.5	0.001	1.0	0.5	0.7697	0.1404
1.0	1.0	0.71	0.60	2.0	0.5	0.001	1.0	0.5	1.1070	0.2180
1.0	1.0	0.71	0.22	4.0	0.5	0.001	1.0	0.5	0.8314	0.1908
1.0	1.0	0.71	0.22	2.0	1.0	0.001	1.0	0.5	1.2552	0.4211
1.0	1.0	0.71	0.22	2.0	0.5	0.100	1.0	0.5	1.1537	0.2345
1.0	1.0	0.71	0.22	2.0	0.5	0.001	2.0	0.5	0.9824	0.1208
1.0	1.0	0.71	0.22	2.0	0.5	0.001	1.0	1.0	1.1482	0.2275

Table 2: Comparison of present Skin – friction results (τ_1) with the Skin – friction results (τ_1^*) obtained by Sriramulu et al. [18] for different values of $Gr, Gc, Sc, \Pr, M, m$ and λ

Gr	Gc	$\Pr$	Sc	M	m	λ	τ_1	τ_1^*
1.0	1.0	0.71	0.22	2.0	0.5	0.5	1.1472	1.1469
2.0	1.0	0.71	0.22	2.0	0.5	0.5	1.4361	1.4353
1.0	2.0	0.71	0.22	2.0	0.5	0.5	1.6958	1.6941
1.0	1.0	7.00	0.22	2.0	0.5	0.5	0.6381	0.6365
1.0	1.0	0.71	0.60	2.0	0.5	0.5	1.0736	1.0725
1.0	1.0	0.71	0.22	4.0	0.5	0.5	0.7694	0.7685
1.0	1.0	0.71	0.22	2.0	1.0	0.5	1.2419	1.2410
1.0	1.0	0.71	0.22	2.0	0.5	0.5	1.1503	1.1501
1.0	1.0	0.71	0.22	2.0	0.5	1.0	1.1403	1.1395

5. CONCLUSIONS

The problem "The effect of Hall current on unsteady MHD flow of an electrically conducting incompressible fluid along a porous flat plate with viscous dissipation and heat absorption" is studied. The dimensionless equations are solved by

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using Galerkin finite element method. The Effects of primary velocity, secondary velocity, temperature and concentration for different parameters are studied. The study concludes the following results.

1). It is observed that both the primary (u) and secondary (w) velocities of the fluid increases with the increasing of parameters m, Ec and decreases with the increasing of parameters $\Pr, Q, Sc$ and λ.

2). The fluid temperature increases with the increasing of Ec and decreases with the increasing of $\Pr,\ Q$ and λ.

3). The Concentration of the fluid decreases with the increasing of λ and Sc.

4). From table (1) it is concluded that the magnitude of shearing stress τ_1 and τ_2 increases as the increasing values of Gr, Gc, m, Ec and this behavior is found just reverse with the increasing of $\Pr,\ Sc$, M, Q and λ.

5). On comparing the skin–friction (τ_1) results with the skin – friction (τ_1^*) results of Sriramulu et al. [18] it can be seen that they agree very well.

REFERENCES

[1] Abdul Maleque, Kh. and Abdur Sattar, Md., The Effects of Variable properties and Hall current on steady MHD laminar convective fluid flow due to a porous rotating disk. Int. Journal of Heat and Mass Transfer, 48, 4460 – 4466,2005.

[2] Ajay Kumar Singh, MHD Free – convection and Mass Transfer Flow with Hall Current Viscous Dissipation, Joule Heating and Thermal Diffusion, Indian Journal of Pure and Applied Physics, 41, 24 – 35, 2003.

[3] Alam, M.M and Sattar, M.A., Unsteady free convection and mass transfer flow in a rotating system with Hall currents, viscous dissipation and Joul heating., Journal of Energy heat and mass transfer, V. 22, pp, 31 – 39, 2000.

[4] Anand Rao, J. and Srinivasa Raju, R., Applied Magnetic Field on Transient Free Convective Flow of an Incompressible Viscous Dissipative Fluid in a Vertical Channel, Journal of Energy, Heat and Mass Transfer, 33, 313 – 332, 2010.

[5] Anand Rao, J. and Srinivasa Raju, R., Hall Effect on an unsteady MHD flow and heat transfer along a porous flat plate with mass transfer and viscous dissipation, Journal of Energy, Heat and Mass Transfer, 32, 265 – 277, 2011.

[6] Anjali Devi, S. P., Shailendhra, K., and Hemamalini, P. T., 2011. Pulsated convective MHD flow with Hall current, heat source and viscous dissipation along a vertical porous plate, Int. J. of App. Math. and Computation, 3(2), 141–150, 2011.

[7] Chaudhary, R. C., Jain, P., Hall Effect on MHD mixed convection flow of a Viscoelastic fluid past an infinite vertical porous plate with mass transfer and radiation, Ukr. J. Phys., 52(10), 2007.

[8] Chowdhary R. C. and Kumar Jha. A., Heat and mass transfer in elasticoviscous fluid past an impulsively started infinite vertical plate with Hall Effect, Latin American Applied Research, 38, 17 – 26, 2008.

[9] Cookey C. I., Ogulu A., and Omubo-Pepple V. B., Influence of Viscous Dissipation and Radiation on Unsteady MHD Free-convection Flow Past an Infinite Heated Vertical Plate in a Porous Medium with Time Dependent Suction, Int. J. Heat Mass Transfer., 46, 2305 – 2311, 2003.

[10] Hossain, M. A., and Rashid, R. I. M. A., Hall effects on Hydro magnetic Free Convection Flow along a Porous Flat Plate with Mass Transfer, Journal of the Physical Society of Japan, 56, 97 – 104, 1987.

[11] Lai, F. C., Coupled Heat and Mass Transfer by Mixed Convection from a Vertical Plate in a Saturated Porous Medium, International Journal of Heat and Mass Transfer, 18, 93 – 106, 1991.

[12] Palumbo, L. J., Platzeck, A. M., MHD stationary symmetric flows with Hall effect, Journal of Plasma Physics, 72, 457-467, 2006.

[13] Rajashekhar, M. N., Anand Rao, J., and Shanker, B., Numerical Solutions of Hall Effects on Heat and Mass Transfer Flow through Porous Medium, Journal of Energy Heat and Mass Transfer, 21, 1 – 7, 1999.

[14] Singh, N. P., Mass Transfer effects on the Flow Past a vertical Porous Plate, Proceedings of Math Soc.,12, 109 – 114, 1996.

[15] Singh, N. P., Singh, A. K., and Kumar, R., Free Convection Heat and Mass Transfer along a Vertical Surface in a Porous Medium, Indian Journal of Theoretical Physics, 44, 255 – 264, 1996.

[16] Soundalgekar, V. M., Ray, S. N., and Dass, V. N., Coupled Heat and Mass transfer by Natural Convention from Vertical Surfaces in Porous Medium, Proceedings of Math Soc., 11, 95 – 98, 1995.

[17] Srihari, K., Kishan, N., and Anand Rao, J., Hall Effect on MHD Flow and Heat Transfer along a Porous Flat Plate with Mass Transfer and Source/Sink, Journal of Energy, Heat and Mass Transfer, 30, 361 – 376, 2008.

[18] Sriramulu, A., Kishan, N., and Anand Rao, J., Effect of Hall Current on MHD Flow and Heat Transfer along a Porous Flat Plate with Mass Transfer, J. Inst. Eng., 87, 24 – 34, 2007.

