Numerical Study on Unsteady Free Convection and Mass Transfer Flow past a Vertical Porous Plate

S. F. Ahmmed
Mathematics Discipline
Khulna University, Bangladesh..

R. Ahmed
Mathematics Discipline
Khulna University, Bangladesh.

L.E.Ali
Mathematics Discipline
Khulna University, Bangladesh.

Abstract:-* The unsteady free convection and mass transfer boundary layer flow past an accelerated infinite vertical porous plate by taking into account the viscous dissipation is considered when the plate accelerates in its own plane. The dimensionless momentum, energy and concentration equation are solved numerically by using explicit finite difference method with the help of a computer programming language Compaq visual FORTRAN 6.6. The obtained results of this study have been discussed for different values of well-known parameters with different time steps. The flow phenomenon has been identified with the help of flow parameters such as Porosity parameter (P), Grashof number for heat transfer (Gr), Modified Grashof number for mass transfer (Gc), Scmidth number (Sc), Prandtl number (Pr) and Eckert number (Ec). The effect of these parameters on the velocity field, temperature field and concentration field has been studied and results are presented graphically also skin friction and Nusselt number is represented by the tabular form

***Keywords:* Free convection, mass transfer, unsteady, Explicit finite difference method, viscous dissipation.**

I. INTRODUCTION

Free convection flow is often encountered in cooling of nuclear reactors or in the study of structure of stars and planets. Along with the free convection flow the phenomenon of mass transfer is also very common in the theories of stellar structure. The study of convective flow with mass transfer along a vertical porous plate is receiving considerable attention of many researchers because of its varied applications in the field of comical and geophysical sciences. Permeable porous plates are used in the filtration processes and also for a heated body to keep its temperature constant and to make the heat insulation of the surface more effective. The study of stellar structure on the solar surface is connected with mass transfer phenomena. Its origin is attributed to difference in temperature caused by the non-homogeneous production of heat, which in many cases can rest not only in the formation of convective currents but also in violent explosions. Mass transfer certainly occurs within the mantle and cores of planets of the size of or larger than the earth. It is therefore interesting to investigate this phenomenon and to study in particular, the case of mass transfer on the free convection flow.

Several workers have studied the problem of free convection flow with mass transfer. Gupta et al [1] have studied heat and mass transfer on a stretching sheet with suction or blowing. Free convection and mass transfer flow through porous medium bounded by an infinite vertical limiting Surface with constant suction have been analyzed by Raptis et al [2]. The free convection and mass transfer flow through a porous medium past an infinite vertical porous plate with time dependent temperature and concentration medium have been discussed by Sattar [3]. Das et al [4] have studied numerical solution of mass transfer effects on unsteady flow past an accelerated vertical porous plate with suction. Viscous dissipation in external natural convection flows have been discussed by Gebhart B. [5]. Viscous dissipation effects on unsteady free convection and mass transfer flow past an accelerated vertical porous plate with suction have been discussed by Bala Siddulu Malga, Naikoti Kishan. [6].

Chandran et al. [7] have discussed the unsteady free convection flow with heat flux and accelerated motion. Soundalgekar et al. [8] have analyzed the transient free convection flow of a viscous dissipative fluid past a semi-infinite vertical plate.

Free-convection flow with thermal radiation and mass transfer past a moving vertical porous plate have analyzed by Makinde, O. D [9]. Unsteady MHD free convection flow of a compressible fluid past a moving vertical plate in the presence of radioactive heat transfer have been discussed by Mbeledogu, I. U, Amakiri, A.R.C and Ogulu, A, [10]. Numerical Study on MHD free convection and mass transfer flow past a vertical flat plate has been discussed by S. F. Ahmmed [11].

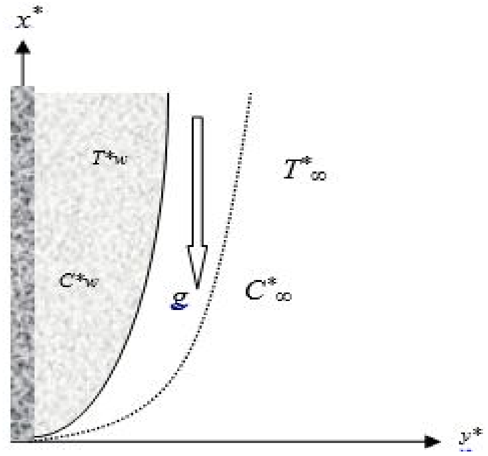
Recently, Das et al [4] have studied numerical solution of mass transfer effects on unsteady flow past an accelerated vertical porous plate with suction. The present study is extension of work; here we considered the effects of viscous dissipation on unsteady free convection and mass transfer boundary layer flow past an accelerated infinite vertical porous flat plate .In their paper they converted the governing equations which are in partial differential equations to ordinary differential equations by introducing similarity variables and then solved the governing equations by finite difference scheme. In the study we have solved the governing partial differential equations only by using the explicit finite difference method.

The effects of the flow parameters on the velocity, temperature and the concentration distribution of the flow field have been studied with the help of graphs. This type of problem has some significant relevance to geophysical and astrophysical studies.

In our present work, we have studied about numerical study on unsteady free convection and mass transfer flow past an accelerated vertical porous plate. The governing equations for the unsteady case are also studied. Then these governing equations are transformed into dimensionless momentum, energy and concentration equations are solved numerically by using explicit finite difference technique with the help of a computer programming language Compaq visual FORTRAN 6.6. The obtained results of this problem have been discussed for the different values of well-known parameters with different time steps. The tecplot is used to draw graph of the flow.

II. MATHEMATICAL FORMULATION

Let us consider the unsteady flow of an incompressible viscous fluid past an accelerating vertical porous plate. We also consider the *x*-axis be directed upward along the plate and *y*-axis normal to the plate. Again let *u* and *v* be the velocity components along the *x*-axis and *y* -axis respectively. Let us assume that the plate is accelerating with a velocity $u^* = U_0 t$ in its own plate at time $t \geq 0$. Then the unsteady boundary layer equations in the Boussineq's approximation, together with Brinkman's empirical modification of Darcy law are *Bala Siddulu Malga, Naikoti Kishan*[6]



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

$$\frac{\partial u^*}{\partial t^*} + V^* \frac{\partial u^*}{\partial y^*} = \upsilon \frac{\partial^2 u^*}{\partial y^{*2}} - \frac{\upsilon}{k^*} u^* + g\beta\left(T^* - T_\infty^*\right) + g\beta^*\left(C^* - C_\infty^*\right) \tag{2}$$

$$\frac{\partial T^*}{\partial t^*} + V^* \frac{\partial T^*}{\partial y^*} = D_T \frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\upsilon}{C_p}\left(\frac{\partial u^*}{\partial y^*}\right)^2 \tag{3}$$

$$\frac{\partial C^*}{\partial t^*} + V^* \frac{\partial C^*}{\partial y^*} = D_M \frac{\partial^2 C^*}{\partial y^{*2}} \tag{4}$$

where, D_T is the thermal diffusivity, υ is the kinematic viscosity, k^* is the permeability coefficient, β is the volumetric expansion coefficient for heat transfer, β^* is the volumetric expansion coefficient for mass transfer, ρ is the density, g is the acceleration due to gravity, T^* is the temperature, T_∞^* is the temperature of the fluid far away from the plate, C^* is the concentration, C_∞^* is the concentration far away from the plate and D_M is the molecular diffusivity.
The necessary boundary conditions are

$$\left.\begin{array}{lllll} u^* = U_0, & T^* = T_w^*, & C^* = C_w^* & \text{at} & y^* = 0 \\ u^* = 0, & T^* = T_\infty^*, & C^* = C_\infty^* & \text{as} & y^* \to \infty \end{array}\right\} \text{for } t > 0 \tag{5}$$

It is required to make the given equations dimensionless. For this intention we introduce the following dimensionless quantities

$$t = \frac{t^* U_0^{\,2}}{\upsilon},\ y = \frac{y^* U_0}{\upsilon},\ u = \frac{u^*}{U_0},\ V = \frac{V^*}{U_0},\ \theta = \frac{T^* - T_\infty^*}{T_w^* - T_\infty^*},\ C = \frac{C^* - C_\infty^*}{C_w^* - C_\infty^*}.$$

Prandtl number$(Pr) = \dfrac{\upsilon}{D_T}$, Eckert number$(Ec) = \dfrac{U_0^{\,2}}{Cp\left(T_w^* - T_\infty^*\right)}$, Schmidth number$(Sc) = \dfrac{\upsilon}{D_M}$

Porosity parameter$(P) = \dfrac{\upsilon^2}{k^* U_0^{\,2}}$, Grashof number for heat transfer$(Gr) = \dfrac{\upsilon g \beta \left(T_w^* - T_\infty^*\right)}{U_0^{\,3}}$

Modified Grashof number for mass transfer$(Gc) = \dfrac{\upsilon g \beta^* \left(C_w^* - C_\infty^*\right)}{U_0^{\,3}}$.

We choose

$$V = -\left(\frac{\upsilon}{t}\right)^{1/2}$$

Therefore following, ***Bala Siddulu Malga, Naikoti Kishan*** **[6]**

Finally, we obtain

$$\frac{\partial V}{\partial y} = 0 \tag{6}$$

$$\frac{\partial u}{\partial t} + V\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} - Pu + Gr\,\theta + Gc\,C \tag{7}$$

$$\frac{\partial \theta}{\partial t} + V\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} + Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{8}$$

$$\frac{\partial C}{\partial t} + V\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} \tag{9}$$

The corresponding boundary conditions for the problem are reduced in the following from

$$\left.\begin{array}{ll} u = 1,\ \ \theta = 1,\ \ C = 1 & \text{at}\ \ y = 0 \\ u = 0,\ \ \theta = 0,\ \ C = 0 & \text{as}\ \ y \to \infty \end{array}\right\} \text{for } t > 0 \tag{10}$$

III. NUMERICAL SOLUTIONS

Many physical phenomena in applied science and engineering when formulated into mathematical models fall into a category of systems known as non-linear coupled partial differential equations. Most of these problems can be formulated as second order partial differential equations. A system of non-linear coupled partial differential equations with the boundary conditions is very difficult to solve analytically. For obtaining the solution of such problems we adopt advanced numerical methods. The governing equations of our problem contain a system of partial differential equations which are transformed by usual transformations into a non-dimensional system of non-linear coupled partial differential equations with initial and boundary conditions. Hence the solution of the problem would be based on advanced numerical methods. The finite difference Method will be used for solving our obtained non-similar coupled partial differential equations.

From the concept of the above discussion, for simplicity the explicit finite difference method has been used to solve from equations (6) to (9) subject to the conditions given by (10).To obtain the difference equations the region of the flow is divided into a grid or mesh of lines parallel to *X* and *Y* axis is taken along the plate and *Y*-axis is normal to the plate.
Here the plate of height $X_{\max}(=20)$ i.e. X varies from 0 to 20 and regard $Y_{\max}(=50)$ as corresponding to $Y \to \infty$ i.e. *Y* varies from 0 to 50. There are *m*=100 and *n*=200 grid spacing in the *X* and *Y* directions respectively. It is assumed that ΔX and ΔY are constant mesh sizes along *X* and *Y* directions respectively and taken as follows,

$$\Delta X = 0.20\left(0 \le x \le 20\right)$$

$$\Delta Y = 0.25\left(0 \le x \le 50\right)$$

with the smaller time-step, Δt=0.005. Now, u', V', θ' and ϕ' denote the values of u, V, θ and C at the end of time step respectively.Now using the finite difference method we convert our governing equations in the following form

$$\frac{V_{i,j} - V_{i,j-1}}{\Delta Y} = 0 \qquad \textbf{(11)}$$

$$\frac{(u'_{i,j} - u_{i,j})}{\Delta t} + V_{i,j}\frac{u_{i,j+1} - u_{i,j}}{\Delta Y} = \frac{u_{i,j+1} - 2u_{i,j} + u_{i,j-1}}{(\Delta Y)^2} - Pu_{i,j} + Gr\theta_{i,j} + GcC_{i,j} \qquad (12)$$

$$\frac{(\theta'_{i,j} - \theta_{i,j})}{\Delta t} + V_{i,j}\frac{\theta_{i,j+1} - \theta_{i,j}}{\Delta Y} = \frac{1}{Pr}\frac{\theta_{i,j+1} - 2\theta_{i,j} + \theta_{i,j-1}}{(\Delta Y)^2} + Ec\frac{(u_{i,j+1} - u_{i,j})^2}{(\Delta Y)^2} \qquad (13)$$

$$\frac{(C'_{i,j} - C_{i,j})}{\Delta t} + V_{i,j}\frac{C_{i,j+1} - C_{i,j}}{\Delta Y} = \frac{1}{Sc}\frac{C_{i,j+1} - 2C_{i,j} + C_{i,j-1}}{(\Delta Y)^2} \qquad (14)$$

And the initial and boundary conditions with the finite difference scheme are

$$\left.\begin{array}{ll} u^0_{i,j} = 1,\ \theta^0_{i,j} = 1,\ C^0_{i,j} = 1 & \text{at} \quad y = 0 \\ u^n_{i,j} = 1,\ \theta^n_{i,j} = 1,\ C^n_{i,j} = 1 & \text{as} \quad y \to \infty \end{array}\right\} \text{for } t > 0 \qquad \textbf{(15)}$$

Here the subscripts i and j designate the grid points with x and y coordinates respectively.

IV. RESULTS AND DISCUSSION

To assess the physical situation of the problem of the study, the velocity field, temperature field and concentration field are express by assigning numerical values to different parameters encountered into the corresponding equations. To be realistic, the value of Schmidt number (*Sc*) are chosen for H_2 (*Sc*=0.22), CO_2 (*Sc*=0.30), NH_3 (*Sc*=0.78). The value of Prandtl number (*Pr*) number are chosen for air (*Pr*=0.71), H_2O vapor (*Pr*=1.0), Ammonia (NH_3) 40^0C (*Pr*=2.0). Grashof number for heat transfer is chosen to be *Gr*=1.0, 2.0, 3.0. Modified Grashof number for mass transfer is chosen to be *Gc*=1.0, 2.0, 3.0, 4.0. *P* and *Ec* are the porosity parameter and Eckert number respectively.

The velocity profilesfor different values of the above parameters are displayed in Figure 1 to Figure 12. The temperature profiles for different values of the above parameters are presented in Figure 9 to Figure 12 and the concentration profiles for different values of the above parameter are given in Figure 13 to Figure 14.Skin friction and the rate of heat transfer have been represented by the Table 1 and Table 2.
The Figure 1 displays that when the porosity parameter (*P*) changes then the velocity curves evince different shapes for fixed values of *Pr=0.71*, *t=0.50* and *Sc*=0.22. It is also noted that the curves of velocities decrease for *P*=1.0, 2.0 and 4.0 that is the increasing values of porosity parameter (*P*), results to decrease the velocity of the main flow. The effect of porosity parameters (*P*) is very low on the velocity profiles for *y*=17 (approximately) that is large values of *y* and all curves approximately meet with the *y*axis. The Figure 2 indicates that when the Grashof number for heat transfer (*Gr*), modified Grashof number for mass transfer(*Gc*) changes then the velocity curves show different shapes for fixed values of *Pr=0.71*, *t=0.50* and *Sc*=0.22 . The velocity profiles curve is in downward direction at *Gr*=2.0, 2.0, 1.0 and *Gc*=3.0, 2.0, 2.0. The decreasing value of Grashof number for heat transfer (*Gr*), modified Grashof number for mass transfer (*Gc*), results to an increasing of velocity main flow. In Figure 3 exposes that when the Schmidt number(*Sc*) decreases then the velocity curves is in upward direction with some Fixed values of *Pr=0.71 and t=0.50*. After analysis the Figure 3 it is noticed there is no significant effect near the wall for different values of *Sc*. When *y*=5 then the Figure expose significant effect for *Sc* and all curves tend to meet with the *y* axis for large values of *y*.

The velocity distribution for different values of Eckert number (*Ec*) with some fixed values of *Pr=0.71*, *P=1.0*, *t=0.50*.and *Sc*=0.22 are displayed in Figure 4. When *Ec*=0.90, 0.75, 0.50, 0.20 the velocity curves are coincide to each other. So there is no significant effect of *Ec* in velocity profiles.

The Figure 5 uncovers that when the is the Eckert number(*Ec*) changes then the velocity curves generate different shapes for fixed values of *Pr=0.71*, *t=0.50*, *P=4.0* and *Sc=0.78*. When *Gr=2.0* and*Gc=3.0* the curves are in upward direction at *Ec*= 0.0, 0.40, 0.50, 0.70. At *y*=3 there is a significant effect of *Ec* on the velocity profiles.
Figure 6 establishes the velocity profiles for the different values of Eckert number (*Ec*) with *Pr=0.71*, *t=0.50*, *P=0.50* and *Sc=0.78*. When *Gr=2.0* and*Gc=3.0* Figure 6 has described the velocity profiles increase with the increase of Eckert number (*Ec*). It is apparent that the velocity profiles curves have displayed different shape for different values of Eckert number (*Ec*) with *Pr=0.71*, *t=0.50*, *P=3.0* and *Sc=0.22*. By analyzing Figure 7, the velocity profiles increase with the increase of Eckert number (*Ec*). When *y*=5 then the figure expose significant effect for *Ec*. The velocity curves exhibit different shapes for different values of the Eckert number (*Ec*), Grashof number for heat transfer (*Gr*) and modified Grashof number for mass transfer (*Gc*) with fixed values of *Pr=0.71*, *t=0.50*and *P=2.0* is shown in Figure 8. The velocity profiles is in upward direction at *Ec*=0.40, 0.70, 0.70, 0.90, *Gr*=1.0, 2.0, 2.0, 2.0 and *Gc*=2.0, 3.0, 3.0, 4.0.

The Figure 9 bespeaks that when the Prandtl number(*Pr*) changes then the temperature curves bring out different shapes for fixed values of *Sc*=0.22 . When *t*=0.50, *Gr*=2.0, *Gc*=3.0and *P*=1.0, after analyzed Figure 9 it is apparent that the curves are upward direction at *Pr*=0.71, 1.0, 2.0. The Figure 10 discloses that when the Prandtl number(*Pr*) and time *(t)* changes then the temperature curves record different shapes for fixed values of *Sc*=0.22, *Gr*=2.0, *Gc*=3.0 and *P*=3.0. From Figure 10 the curves are upward direction at *t*=0.50, 0.50, 1.0, 1.0 and *Pr*=0.71, 0.10, 0.20. The temperature profiles curves exhibit different shapes when the Eckert number (*Ec*) changes with fixed values of *Sc*=0.22, *Pr*=2.0, *t*=0.50, *Gr*=1.0, *G*c=1.0and *P*=1.0. From Figure 11 it is apparent that the curves are upward direction at *Ec*=0.0, 0.20, 0.40, 0.80. The effect of Eckert number (*Ec*) is very low on the temperature profiles for *y*=8 (approximately).

When the Eckert number (*Ec)* and time (*t*) changes then the temperature curves let on different shapes for fixed values of *Sc*=0.22, *Pr*=2.0, *Gr*=2.0, *Gc*=1.0 and *P*=3.0 as shown in Figure 12. By analyzing Figure 12 it is apparent that the curves are upward direction at *t*=1.0, 1.0, 1.50, 2.0 and *Ec*=0.0, 0.30, 0.60, 0.80. When *y*=3.5 then the figure expose significant effect for *t* and *Ec* and the Figure 13 uncovers that when Schmidt number (*Sc*) changes then the concentration curves exhibit different shapes for fixed values of *Pr*=2.0, *t*=0.50, *Gr*=1.0, *Gc*=1.0 and *P*=1.0. The curves are in downward direction at *Sc*=0.22, 0.30, 0.78. i,e with the increase of *Sc* decrease the concentration profiles. The Figure 14 discloses that when the Schmidt number (*Sc*) and time *(t)* changes then the concentration curves record different shapes for fixed values of *Pr*=0.22, *Gr*=1.0, *Gc*=1.0 *Ec*=0.50 and *P*=1.0. From Figure 14 it is shown that the temperature profiles are upward direction at *t*=0.50, 0.50, 1.0 and *Pr*=0.22, 0.30, 0.78. The Figure 14 bring out significant effect for *t* and *Sc* at *y*=7.0. The effect of Schmidt number (*Sc*) and time (*t*) are very small on the concentration profiles for *y*=18 (approximately).

In our present paper we have solved our problem by using explicit finite difference method as the solution tool whereas*Bala Siddulu Malga [6]* used Glerkin's method as the solution tool. We see that there is an excellent agreement between our results and the pervious results of whereas*Bala Siddulu Malga [6]*.

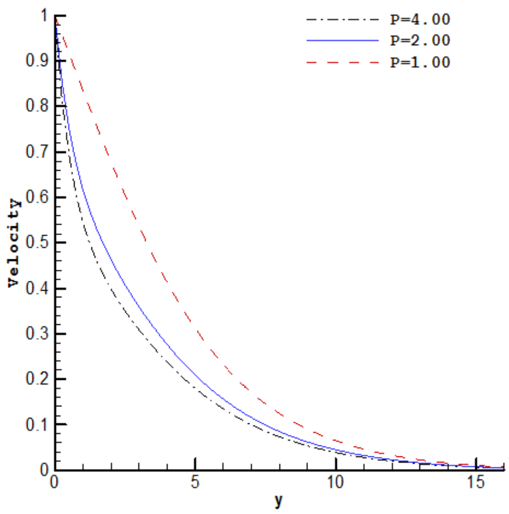


Figure 1: Velocity profiles with Gr=1.0 Gc=1.0, Pr=0.71, Sc=0.22 and t=0.50 for different values of P against y.

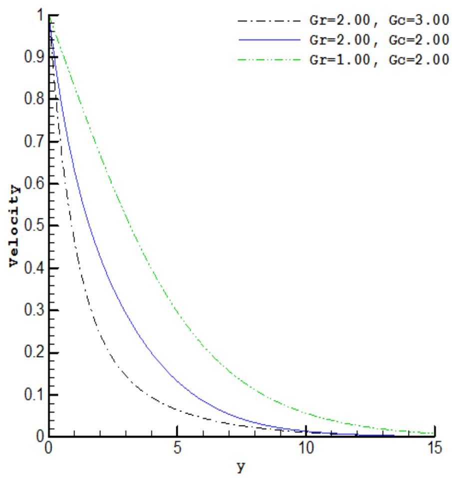


Figure 2: Velocity profiles with Gr=1.0 Gc=1.0, Pr=0.71, P=1.0 and t=0.50 for different values of Gr and Gc against y.

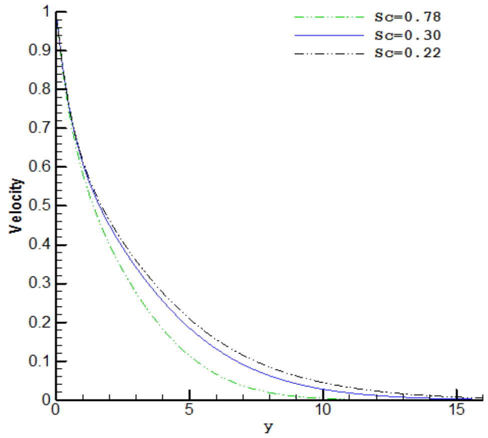


Figure 3: Velocity profiles with Gr=1.0 Gc=1.0, Pr=0.71, P=1.0 and t=0.50 for different values of Sc against y.

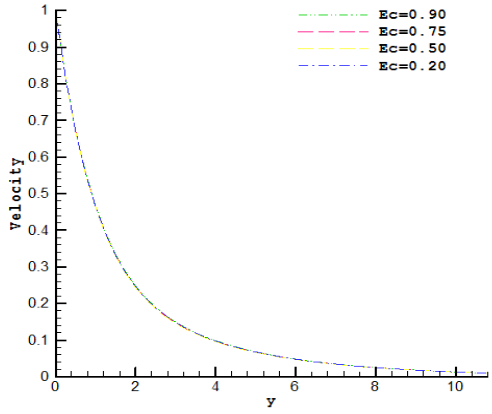


Figure 4: Velocity profiles with Gr=1.0 Gc=1.0, Pr=0.71, P=1.0 and t=0.50 for different values of Ec against y

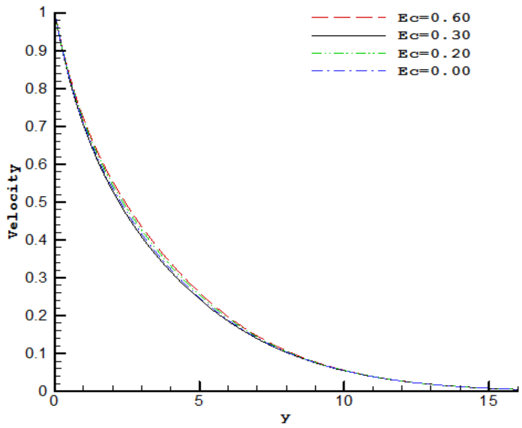


Figure 5: Velocity profiles with Gr=2.0 Gc=3.0, Pr=0.71, P=4.0, Sc=0.78 and t=0.50 for different values of Ec against y.

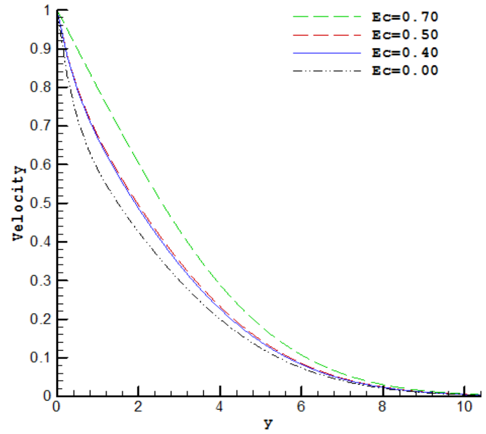


Figure 6: Velocity profiles with Gr=2.0 Gc=3.0, Pr=0.71, P=0.50, Sc=0.78 and t=0.50 for different values of Ec against y.

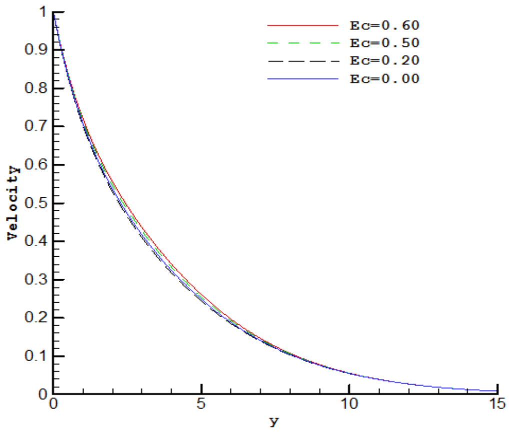


Figure 7: Velocity profiles with Gr=2.0 Gc=3.0, Pr=0.71, P=3.0, Sc=0.22 and t=0.50 for different values of Ec against y.

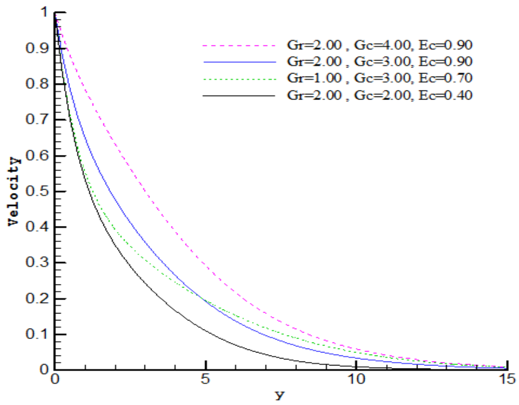


Figure 8: Velocity profiles with Pr=0.71 P=2.0, Sc=0.22 and t=0.50 for different values of Gr, Gc and Ec against y.

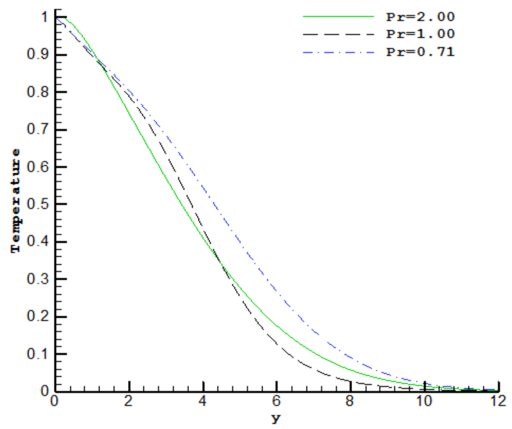


Figure 9: Temperature profiles with P=1.0, Gr=2.0 Gc=3.0 and t=0.50 for different values of Pr against y.

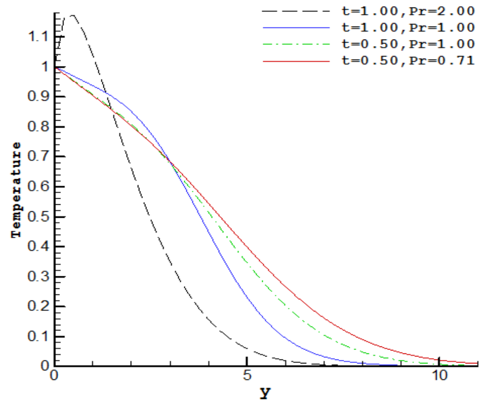


Figure 10: Temperature profiles with P=3.0, Gr=3.0, Gc=3.0, Sc=0.22 and t=0.50 for different values of t and Pr against y.

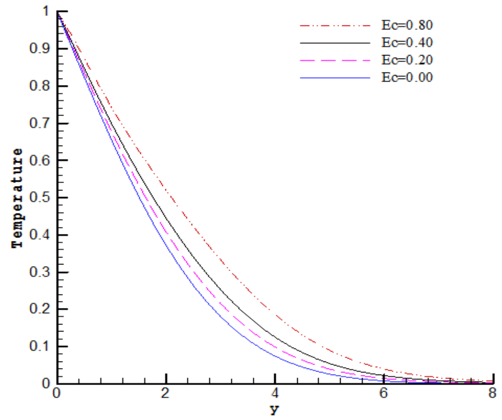


Figure 11: Temperature profiles with P=1.0 Gr=1.0, Gr=1.0, Gc=1.0, Sc=0.22, Pr=2.0 and t=0.50 for different values of Ec against y.

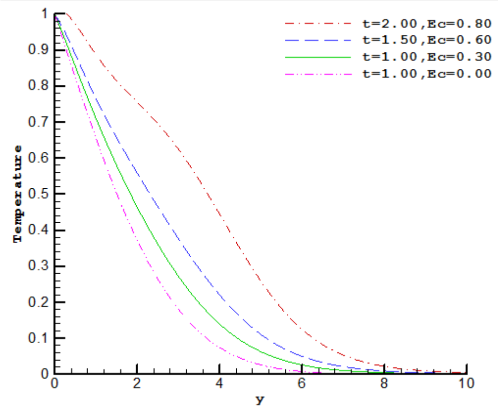


Figure 12: Temperature profiles with P=1.0 Gr=2.0, Gc=1.0, Sc=0.22 and Pr=2.0for different values of t and Ec against y.

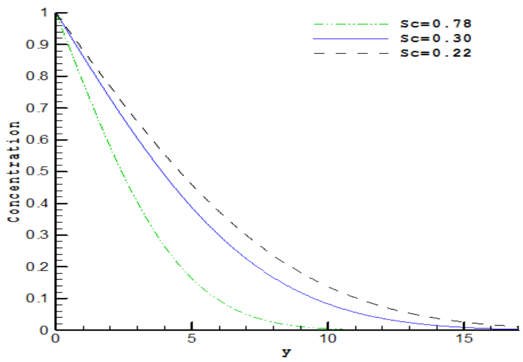


Figure 13: Concentration profiles with P=1.0 Gr=1.0, Gc=1.0, Sc=0.22, t=0.50 and Pr=2.0 for different values of Sc against y.

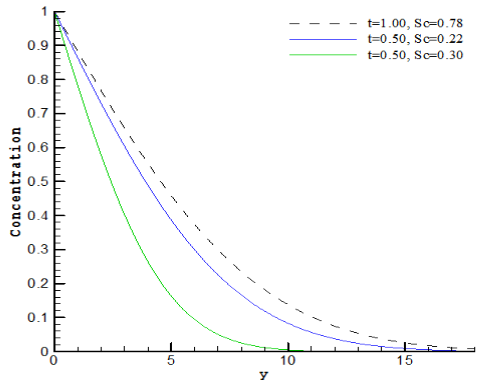


Figure 14: Concentration profiles with P=1.0 Gr=1.0, Gc=1.0, Ec=0.50 and Pr=0.22 for different values of t and Sc against y.

Table 1: Skin friction for different values of different flow parameters

Serial no	*Gr*	*Gc*	*Pr*	*Ec*	*P*	*Sc*	*t*	Skin Friction
1	1	2	0.71	0.40	2	0.22	0.51500	-3.06873
2	2	2	.71	0.40	2	0.22	0.51500	-1.81989
3	1	4	0.71	0.40	2	0.22	0.51500	-3.02816
4	1	2	2	0.40	2	0.22	0.51500	-3.07373
5	1	2	0.71	0.90	2	0.22	0.51500	-3.06872
6	1	2	0.71	0.40	4	0.22	0.51500	-3.08061
7	1	2	0.71	0.40	2	0.78	0.51500	-3.09453

Table 2: The rate of heat transfer i,e Nusselt number for different values of different flow parameters

Serial no	*Gr*	*Gc*	*Pr*	*Ec*	*P*	*Sc*	*t*	Nusselt number
1	1	2	0.71	0.40	2	0.22	0.51500	5.51842
2	2	2	.71	0.40	2	0.22	0.51500	3.28124
3	1	4	0.71	0.40	2	0.22	0.51500	5.51805
4	1	2	2	0.40	2	0.22	0.51500	7.21116
5	1	2	0.71	0.90	2	0.22	0.51500	5.50722
6	1	2	0.71	0.40	4	0.22	0.51500	5.51850
7	1	2	0.71	0.40	2	0.78	0.51500	5.51868

V. CONCLUSION

In the present research paper,the boundary layer equations become non-dimensional by using non-dimensional quantities. The non-dimensional boundary layer equations are nonlinear partial differential equations. These equations are solved by explicit finite difference method. Results are given graphically to display the variation of velocity, temperature, concentration, Nusselt number, Skin friction and Sherwood number. The following conclusions are set out through the overall observations.

- The velocity decreases with an increase of Suction parameter (*a*), Porosity parameter (*P*), Grashof number (*Gr*), modified Grashof number for mass transfer (*Gc*) and Scmidth number (*Sc*) whereas the velocity profiles increases with an increases of Eckert number (*Ec*).Also the velocity profiles increases with the combined increasing value of Grashof number (*Gr*), modified Grashof number for mass transfer (*Gc*), time step (*t*) and Eckert number (*Ec*).
- The temperature increases at a certain position and then decreases with the increasing value of time (*t*), Eckert number *(Ec)* and Prandtl number *(Pr)*.
- The concentration decreases with an increase of Scmidth number (*Sc*). Whereas concentration increases with the increasing value of time step (*t*).

VI. REFERENCES

[1] P.S. Gupta and A.S. Gupta, "Heat and mass transfer on a stretching sheet with suction or blowing". *Can J Chem Eng.*, 55, 744–746, 1977.

[2] A.Raptis. "Free convection and mass transfer flow through porous medium bounded by an infinite vertical limiting surface with constant suction." G.T Zivnidis, N.Kafousis, *Letters in heat and mass transfer,* 8, 5,417-424, 1981.

[3] M. A.Satter, "Free convection and mass transfer flow through a porous medium past an infinite vertical porous plate dependent temperature and concentration." *Int.J. Pure Appl.Math.* 23, 759-766, 1994.

[4] S.S. Das, S.K. Sahoo and G.C. Dash, Bull, "Numerical solution of mass transfer effects on unsteady flow past an accelerated vertical porous plate with suction."*Math. Sci. Soc., 2,* 29,(1), 33–42, 2006.

[5] B.Gebhart andMollendorf, "Viscous dissipation in external natural convection flows." *Journal of Fluid Mechanics,* 38, 97-107, 1969.

[6] Bala Siddulu Malga, Naikoti Kishan. " Viscous dissipation effects on unsteady free convection and mass transfer flow past an accelerated vertical porous plate with suction". *Pelagia research library advances in applied science research*, 2011, 2 (6):460-469.

[7] P.Chandran, N.C.Sacheti and A.K.Singh, "Unsteady free convection flow with heat flux and accelerated motion." *J. Phys. Soc. Japan* 67,124-129, 1998.

[8] V. M. Soundalgekar, B. S. Jaisawal, A. G. Uplekar and H. S. Takhar, "The transient free convection flow of a viscous dissipative fluid past a semi-infinite vertical plate." *J. Appl. Mech. Engng.4*, 203-218, 1999.

[9] O. D Makinde "Free-convection flow with thermal radiation and mass transfer past a moving vertical porous plate", *Int. Comm. Heat Mass Transfer, 32, pp.* 1411– 1419, 2005

[10] Mbeledogu, I. U, Amakiri, A.R.C and Ogulu "Unsteady MHD free convection flow of a compressible fluid past a moving vertical plate in the presence of radioactive heat transfer", *Int. J. of Heat and Mass Transfer, 50, pp.* 1668–1674, 2007.

[11**]** S. F. Ahmmed, S. Mondal and A. Ray." Numerical studies on MHD free convection and mass transfer flow past a vertical flat plate". *IOSR Journal of Engineering (IOSRJEN). ISSN* 2250-3021, vol. 3, Issue 5, pp 41-47, May. 2013.

