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MHD EFFECTS ON FLOW PAST AN EXPONENTIALLY ACCELERATED INFINITE VERTICAL PLATE WITH VARIABLE MASS DIFFUSION

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Abstract— **The problem of magnetohydrodynamic free convective flow past an exponentially accelerated isothermal vertical plate in the presence of variable mass diffusion has been considered in this paper. The plate is assumed to be exponentially accelerated with a prescribed velocity against the gravitational field. The dimensionless governing equations are solved by using Laplace transform technique and the effect of various physical parameters on the flow quantities are studied through graphs and the results are discussed.**

Keywords: **Accelerated, Exponential, Mass diffusion, Vertical plate.**

I. INTRODUCTION

Mass diffusion is of considerable interest in nature and in many industrial applications such as geophysics, oceanography, drying processes, solidification of binary alloy and chemical engineering. In recent years MHD flow problems have become in view of its significant applications in industrial manufacturing processes such as plasma studies, petroleum industries Magneto hydrodynamics power generator cooling of clear reactors, boundary layer control in aerodynamics, nuclear reactors and geothermal applications. The experimental investigation of the thermal diffusion effect on mass transfer related problems was first performed by Charles Soret in 1879.

Mass diffusion effect on transient convection flow past a surface was studied by Cheng et.al. [1]. Das, Deka and Soundalgekar [2] studied effects of mass transfer on flow past an impulsively started infinite vertical plate with chemical reaction. Jha, Prasad and Rai [3] presented mass transfer effects on the flow past an exponentially accelerated vertical plate with constant heat flux. Muthucumaraswamy et al [4] analysed mass transfer effects on exponentially accelerated isothermal vertical plate. Ramana Reddy and Ramana Murthy [5] investigated effect of critical parameters of MHD flow over a moving isothermal vertical plate with variable mass diffusion. Raptis and Singh [6] worked MHD free convection flow past an accelerated vertical plate..Seethamahalakshmi, Prasad and Ramana Reddy [7] considered MHD free convective mass transfer flow past an infinite vertical porous plate with variable suction and soret effect. Singh and Naveen Kumar [8] analysed free convection flow past an exponentially accelerated vertical plate. Soundalgekar and Gupta [9] worked free convection effects on the flow past an accelerated vertical plate. Vahidi and Asadi Corshooli [10] studied on the Laplace transform decomposition algorithm for solving nonlinear differential equations.

The objective of the present paper examines flow past an exponentially accelerated infinite vertical plate with variable mass diffusion. The dimensionless governing equations are solved using Laplace transform technique. The solutions are obtained in terms of exponential and complementary error functions.

II. BASIC EQUATIONS AND ITS SOLUTION

Magnetohydrodynamic flow past an exponentially accelerated infinite vertical plate with uniform mass diffusion has been presented. The flow is assumed to be in x-direction which is taken along the plate in the vertically upward direction and the y-axis is taken to be normal to the plate. All the physical variables become functions of t' and y only. At time $t' \leq 0$, the plate and fluid are at the same concentration C'_∞ lower than the constant concentration C'_w respectively. At time $t' > 0$, the plate is accelerated with a velocity $u = u_0 e^{at}$ in its own plane and the concentration from the plate is raised to $C' = C'_\infty + (C'_w - C'_\infty)At'$. A magnetic field of uniform strength Bo is applied transversely to the plate. Under the above assumptions as well as Boussinesq's approximation, the equations of conservation of mass, momentum, the free convection boundary layer flow

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past an exponentially accelerated vertical plate can be expressed as:

$$\frac{\partial u}{\partial t'} = \nu \frac{\partial^2 u}{\partial y^2} + g\beta(C' - C'_\infty) - \frac{\sigma B_0 u}{\rho} \quad (1)$$

$$\frac{\partial C'}{\partial t'} = D \frac{\partial^2 C'}{\partial y^2} \quad (2)$$

The initial and boundary conditions are

$$t' \le 0, u = 0, C' = C'_\infty \text{ for all y,}$$

$$t' > 0, u = u_0 e^{at}, C' = C'_\infty + (C'_w - C'_\infty)At' \text{ at } y = 0$$

$$u \to 0, C' \to C'_\infty \text{ as } y \to \infty \quad (3)$$

where $A = \frac{u_0^2}{\gamma}$

Here u is the velocity in the x -direction, g the acceleration due to gravity, β the coefficient of thermal expansion, C' the concentration of the fluid near the plate, ν the kinematic viscosity and σ the electrical conductivity.

Let us introducing the following non-dimensional quantities

$$U = \frac{u}{u_0}, Y = \frac{yu_0}{\nu}, t = \frac{t'u_0^2}{\nu}, M = \frac{\sigma B_0^2 \nu}{\rho u_0^2}, a = \frac{a'\nu}{u_0{}^2}$$

$$Gc = \frac{g\beta\nu(C'_w - C'_\infty)}{u_0{}^3}, C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, Sc = \frac{\nu}{D} \quad (4)$$

where M the magnetic field parameter, Gc the Grashof number, Sc the Schmidt number and C the dimensionless concentration.

Using these boundary conditions in above equations, we obtain the following dimensionless form of the governing equations:

$$\frac{\partial U}{\partial t} = \frac{\partial^2 U}{\partial Y^2} + GcC - MU \quad (5)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial Y^2} \quad (6)$$

The boundary conditions for corresponding order are

$$t \le 0, U = 0, C = 0 \text{ for all Y}$$

$$t > 0, U = e^{at}, C = t \text{ at } Y = 0 \quad (7)$$

$$U \to 0, C \to 0 \text{ as } Y \to \infty$$

The dimensionless governing equations (5) and (6), subject to the boundary conditions (7), are solved by the usual Laplace-transform technique and the solutions are derived as follows:

$$C(Z,t) = t\left(\left(1 + 2\eta^2 Sc\right)erfc\left(\eta\sqrt{Sc}\right) - \frac{2\eta\sqrt{Sc}}{\sqrt{\pi}}\exp\left(-\eta^2 Sc\right)\right) \quad (8)$$

$$U(Z,t) = f(\exp(2\eta\sqrt{(M+a)t})erfc(\eta + \sqrt{(M+a)t})$$
$$+\exp(-2\eta\sqrt{(M+a)t})erfc(\eta - \sqrt{(M+a)t}))$$
$$-A(\exp(2\eta\sqrt{Mt})erfc(\eta + \sqrt{Mt}) +$$
$$\exp(-2\eta\sqrt{Mt})erfc(\eta - \sqrt{Mt})) +$$
$$\frac{A}{2}(\exp(2\eta\sqrt{(Mt)})erfc(\eta + \sqrt{(Mt)}) +$$
$$\exp(-2\eta\sqrt{Mt})erfc(\eta - \sqrt{(Mt)}) +$$
$$A(\exp(2\eta\sqrt{Sct})erfc(\eta\sqrt{Sc} + \sqrt{t}) +$$
$$\exp(-2\eta\sqrt{Sct})erfc(\eta\sqrt{Sc} - \sqrt{t}))$$
$$-\frac{A}{2}(\exp(2\eta\sqrt{Sct})erfc(\eta\sqrt{Sc} + \sqrt{t}) +$$
$$\exp(-2\eta\sqrt{Sct})erfc(\eta\sqrt{Sc} - \sqrt{t})$$

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III. RESULTS AND DISCUSSION

The effects of the various flow parameters upon the nature of the flow are carried out. The numerical values of the velocity and concentration are computed for different physical parameters like magnetic parameter, accelerating parameter, Grashof number, Schmidt number and time are studied graphically. Figure (1) represents the effect of concentration profiles at time t=0.2 for different Schmidt number (Sc=0.4, 0.6, 0.7, 1.5). It is observed that the concentration increases with decreasing values of the Schmidt number. Figure (2) illustrate the influence of the magnetic parameter on the velocity profiles in the boundary layer respectively. it is clear that the velocity increases with decreasing values of M. In the figure (3), it is observed that the velocity increases with increasing values of Grashof number. In figure (4) it is observed that the velocity increases with decreasing values of Schmidt number (Sc). The velocity profiles for different values of time t are presented in figure (5). It is observed that the velocity increases with increasing values of t. The velocity profiles for different 'a' are studied and presented in figure (6). It is evident from figures that the velocity increases with increasing values of 'a'.

IV. CONCLUSION

Flow past an exponentially accelerated infinite vertical plate with variable mass diffusion has been studied. The dimensional governing equations are solved by Laplace transform technique. The effect of different parameters like magnetic parameter, accelerating parameter, Schmidt number, Grashof number and time are presented graphically. In the analysis of the flow the following conclusions are made

- The concentration increases with decreasing values of the Schmidt number.
- The velocity rises due to increasing value of the accelerating parameter, Grashof number and time.
- The velocity U increases with decreasing values of the magnetic parameter, Schmidt number.

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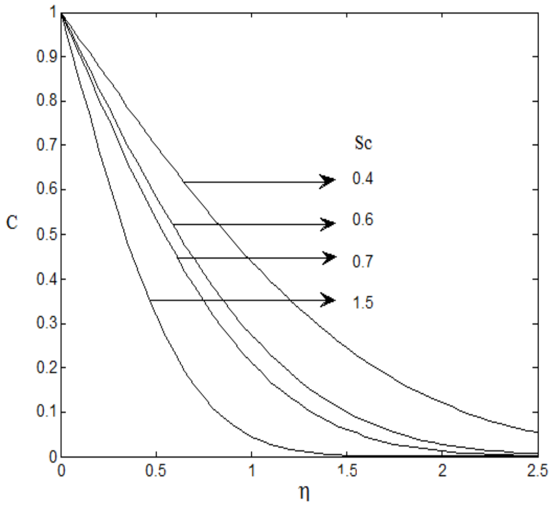

Fig.1 Concentration profiles for different values of Sc

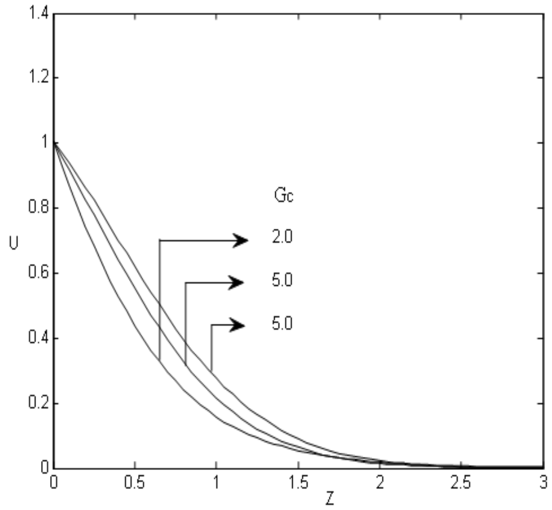

Fig.3 velocity profiles for several values of Gc

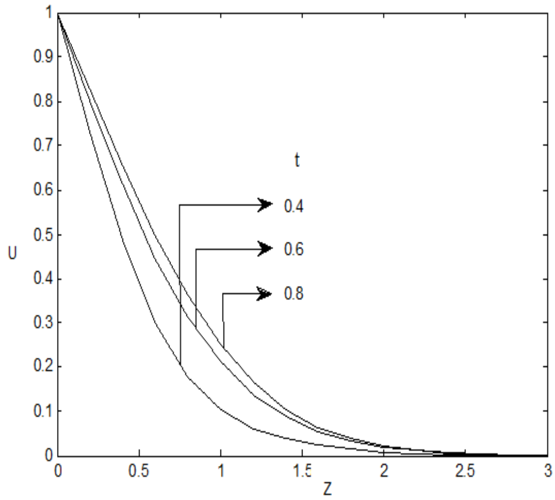

Fig.5 velocity profiles for several values of t

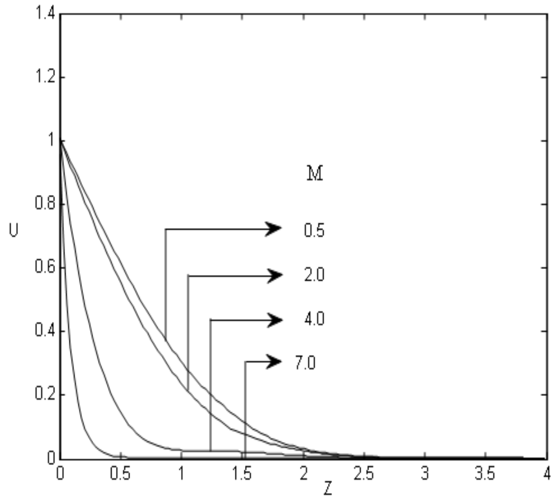

Fig.2 velocity profiles for several values of M

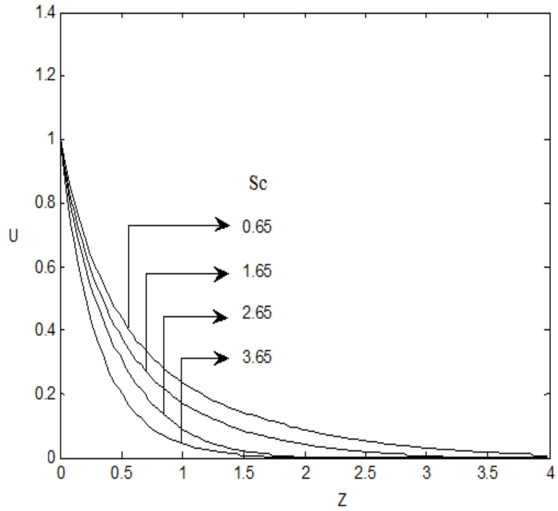

Fig.4 velocity profiles for several values of Sc

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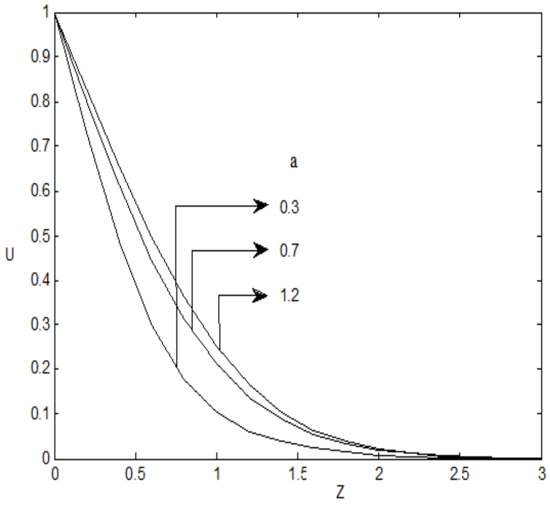

Fig.6 velocity profiles for several values of a