# COMBINED IMPACTS ON MHD FLOW PAST AN EXPONENTIALLY ACCELERATED VERTICAL PLATE IN THE PRESENCE OF UNIFORMLY HEAT AND MASS TRANSFER EFFECTS

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Ayothi Selvaraj
Vels University

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# COMBINED IMPACTS ON MHD FLOW PAST AN EXPONENTIALLY ACCELERATED VERTICAL PLATE IN THE PRESENCE OF UNIFORMLY HEAT AND MASS TRANSFER EFFECTS

**E. Jothi and A. Selvaraj**

Department of Mathematics
Vels Institute of Science, Technology and Advanced Studies
Chennai-600117, India
e-mail: jothi.1983@rediffmail.com
aselvaraj_ind@yahoo.co.in

## Abstract

In the presence of a transversal magnetic field, the effect of rotation and radiation on the MHD flow with extended exponentially accelerating vertical plate with varying temperature and differing mass distribution is investigated. The Laplace transform method is used to solve the dimensionless governing equations. The velocity increases as the time ($t$) increases, the concentration increases as the Schmidt number ($Sc$) decreases, and the concentration likewise increases

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as the Prandtl number ($Pr$) decreases. The velocity, temperature and concentration profiles are calculated graphically in terms of the parameters exponential index ($a$), the magnetic field ($M$), Schmidt number ($Sc$) and Prandtl number ($Pr$).

## Nomenclature

| | |
|---|---|
| $A$ | Constants |
| $B_0$ | External magnetic field |
| $C$ | Dimensionless concentration |
| $C_p$ | Specific heat at constant pressure, $Jkg^{-1}k$ |
| $C'$ | Species concentration in the fluid, $kgm^{-3}$ |
| $C'_w$ | Wall concentration in the fluid |
| $C'_\infty$ | Concentration in the fluid far away from the plate |
| $D$ | Mass diffusion coefficient, $m^2s^{-1}$ |
| $Gc$ | Mass Grashof number |
| $Gr$ | Thermal Grashof number |
| $g$ | Acceleration due to gravity, $m^2s^{-1}$ |
| $k$ | Thermal conductivity, $Wm^{-1}k^{-1}$ |
| $Pr$ | Prandtl number |
| $Sc$ | Schmidt number |
| $T$ | Temperature of the fluid near the plate |
| $T_w$ | Temperature of the plate |
| $T_\infty$ | Temperature of the fluid far away from the plate |
| $t$ | Dimensionless time |
| $t'$ | Time, s |
| $u$ | Velocity of the fluid in the $x'$-direction, $ms^{-1}$ |

| | |
|---|---|
| $u_0$ | Velocity of the plate, $ms^{-1}$ |
| $U$ | Dimensionless velocity |
| $y$ | Co-ordinate axis normal to the plate, m |
| $Y$ | Dimensionless coordinate axis normal to the plate |
| $M$ | Magnetic field parameter |

**Greek Symbols**

| | |
|---|---|
| $\beta$ | Volumetric coefficient of thermal expansion, $K^{-1}$ |
| $\beta^*$ | Volumetric coefficient of expansion with concentration, $K^{-1}$ |
| $\mu$ | Coefficient of viscosity, Ras |
| $\nu$ | Kinematic viscosity, $m^2s^{-1}$ |
| $\sigma$ | Electrical conductivity |
| $\rho$ | Density of the fluid, $kgm^{-3}$ |
| $\tau$ | Dimensionless skin- friction, $kgm^{-3}$ |
| $\theta$ | Dimensionless temperature |
| $\mu$ | Similarity parameter |
| erfc | Complementary error function |

**Subscripts**

| | |
|---|---|
| $w$ | Conditions at the wall |
| $\infty$ | Free stream conditions |

## 1. Introduction

Magnetohydrodynamics (MHD) defines measured evolution of an electrically leading fluid which is a lot of plasma consisting electrons and protons (perhaps less processed with other positive ions). MHD [1] slowing means that individual particles evolve over time scales rather than being important are that electrons and irons can form independently of each other. Many types of production and equipment are gradually turning to heat transfer. In the purpose of heat exchangers such as containers, condensers, heaters, etc., for example, heat transfer evaluation is basic to measure such equipment. In the purpose of nuclear device cores, the heat transfer study is notable for the proper measurement of fuel mechanisms to prevent combustion.

Biswas et al. [2] presented the effects of radiation and chemical reaction on MHD unsteady heat and mass exchange of Casson fluid flow past a vertical plate. The numerical procedure of change and the subsequent limited dimensional distinction conditions are understood utilizing the unequivocal limited contrast strategy. Chaudhary et al. [3] examined the impacts of radiation on MHD blended convection and heat and mass exchange. A vast vertical plate [4] with Ohmic heating and viscous scattering are examined. Estimated answers for speed, temperature field, fixation profiles, skin rubbing and heat transfer rate have been obtained using multi-boundary irritation strategy.

Kumar et al. [5] have analyzed that the point of the current examination was to research the impacts of thermal diffusion and heat radiation on the passing MHD [6] stream which started suddenly on the unlimited vertical plate with temperature and mass dispersion within the sight of the warmth wellspring of through a permeable medium. The liquid being tested is a dark, non-scattering medium that retains and transmits radiation. Muthucumaraswamy and Visalakshi [7] have researched the effects of MHD and thermal radiation on the flow of an exponentially accelerated infinite isothermal vertical plate with uniform mass distribution.

The study aims to examine the effects of thermal radiation and chemical reactions on an unstable MHD flow past an abruptly accelerated tilted porous plate with a changing temperature inside the nearness of warmth creation under the action of a fixed attractive field. The steady weight slope is exposed to the outer attractive field of consistent power along the bearing of the plate and the stream. Rajesh et al. [8] have combined the mass transfer feature with the chemical reaction of their work. Seddeek [9] has considered the effect of radiation and transient thickness on account of the precarious stream with a magnetic field lined up with a semi-infinite level plate. The liquid stability is accepted to differ as a function a reverse of the temperature.

## 2. Mathematical Formulation

In the appearance of a dependable thermal flux, the transitory flow of a viscous irremediable fluid past an infinite vertical plate with uniform distribution is assumed. The $x'$-horizontal axis is moved vertically to the plate. The plate is being routinely aligned along the $y'$-axis. The plate and fluid are at the equal temperature $T_\infty$, and the concentration $C'_\infty$ at $t' \leq 0$ and at $t' > 0$, the plate begins with a velocity $u = u_0 t'^2 \exp(a't')$ on its plate, especially in contrast to the gravitational field from the plate, the temperature is enhanced to $T_w$ and the concentration level closed adjacent to the plate is increased to $C'_w$. Then the Boussinesq's approximation for regular transient parabolic initialization is then coordinated by the given form under conditions:

$$\frac{\partial u}{\partial t'} = g\beta(T - T_\infty) + g\beta^*(C' - C'_\infty) + v\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho}u, \tag{1}$$

$$\rho C_p \frac{\partial T}{\partial t'} = k\frac{\partial^2 T}{\partial y^2}, \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y^2}, \tag{3}$$

along the successive basic and limit constraints

$$\left.\begin{array}{llll} u = 0, & T = T_\infty & C' = C'_\infty & \text{as } y, t' \leq 0 \\ t' > 0: & u = u_0 t'^2 \exp(a't') & T = T_w, \quad C' = C'_w & \text{on } y = 0 \\ u \to 0, & T \to T_\infty & C' \to C'_\infty & \text{as } y \to \infty \end{array}\right\} \tag{4}$$

on presenting along with dimensionless quantities

$$\left.\begin{aligned} &U = \frac{u}{u_0},\ t = \frac{t' u_0^2}{\nu},\ Y = \frac{y u_0}{\nu},\ \theta = \frac{T - T_\infty}{T_w - T_\infty} \\ &Gr = \frac{g\beta\nu(T_w - T_\infty)}{u_0^3},\ C = \frac{C' - C'_\infty}{C'_w - C'_\infty},\ Gc = \frac{g\beta^*\nu(C'_w - C'_\infty)}{u_0^3} \\ &M = \frac{\sigma B_0^2 \nu}{\rho u_0^2},\ Pr = \frac{\mu c_p}{k},\ a = \frac{a'\nu}{u_0^2},\ Sc = \frac{\nu}{D} \end{aligned}\right\} \tag{5}$$

in equations (1)-(4), relates to

$$\frac{\partial q}{\partial t} = Gr\theta + GcC + \frac{\partial^2 q}{\partial z^2} - mq, \tag{6}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial z^2}, \tag{7}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial z^2}. \tag{8}$$

The basic and limit constrains dimensionless measures exist

$$\left.\begin{array}{llll} q = 0, & \theta = 0 & C = 0 & \text{as } Z, t \le 0 \\ t > 0 & q = t^2 e^{at} & \theta = 1, \quad C = 1 & \text{on } Z = 0 \\ q \to 0, & \theta \to 0 & C \to 0 & \text{as } Z \to \infty \end{array}\right\}. \tag{9}$$

The non-dimensional quantities are characterized in the classification.

## 3. Method of Solution

The non-dimensional governing equations (6)-(8), subject to the corresponding initial and boundary conditions (9), are solved using the Laplace transform technique, and the solutions are as follows:

$$\theta = \text{erfc}(\eta\sqrt{Pr}), \tag{10}$$

$$C = \text{erfc}(\eta\sqrt{Sc}), \tag{11}$$

$$q = \frac{(\eta^2 + (a+m)t)t}{2(a+m)} e^{at} \begin{bmatrix} \exp(-2\eta\sqrt{(a+m)t})\operatorname{erfc}(\eta - \sqrt{(a+m)t}) \\ + \exp(2\eta\sqrt{(a+m)t})\operatorname{erfc}(\eta + \sqrt{(a+m)t}) \end{bmatrix}$$

$$+ \frac{\eta\sqrt{t}(1 - 4(a+m)t)}{4(a+m)^{\frac{3}{2}}} e^{at} \begin{bmatrix} \exp(-2\eta\sqrt{(a+m)t})\operatorname{erfc}(\eta - \sqrt{(a+m)t}) \\ + \exp(2\eta\sqrt{(a+m)t})\operatorname{erfc}(\eta + \sqrt{(a+m)t}) \end{bmatrix}$$

$$- \frac{\eta t}{m\sqrt{\pi}}[\exp(-\eta^2 - mt)] + \frac{Gr}{2b(1-Pr)} \begin{bmatrix} \exp(-2\eta\sqrt{mt})\operatorname{erfc}(\eta - \sqrt{mt}) \\ + \exp(2\eta\sqrt{mt})\operatorname{erfc}(\eta + \sqrt{mt}) \end{bmatrix}$$

$$- \frac{Gr}{2b(1-Pr)} e^{bt} \begin{bmatrix} \exp(-2\eta\sqrt{(b+m)t})\operatorname{erfc}(\eta - \sqrt{(b+m)t}) \\ + \exp(2\eta\sqrt{(b+m)t})\operatorname{erfc}(\eta + \sqrt{(b+m)t}) \end{bmatrix}$$

$$+ \frac{Gc}{2c(1-Sc)} \begin{bmatrix} \exp(-2\eta\sqrt{mt})\operatorname{erfc}(\eta - \sqrt{mt}) \\ + \exp(2\eta\sqrt{mt})\operatorname{erfc}(\eta + \sqrt{mt}) \end{bmatrix}$$

$$- \frac{Gc}{2c(1-Sc)} e^{ct} \begin{bmatrix} \exp(-2\eta\sqrt{(c+m)t})\operatorname{erfc}(\eta - \sqrt{(c+m)t}) \\ + \exp(2\eta\sqrt{(c+m)t})\operatorname{erfc}(\eta + \sqrt{(c+m)t}) \end{bmatrix}$$

$$- \frac{Gr}{b(1-Pr)}[\operatorname{erfc}(\eta\sqrt{Pr})]$$

$$+ \frac{Gr}{2b(1-Pr)} e^{bt} \begin{bmatrix} \exp(-2\eta\sqrt{Prbt})\operatorname{erfc}(\eta\sqrt{Pr} - \sqrt{bt}) \\ + \exp(2\eta\sqrt{Prbt})\operatorname{erfc}(\eta\sqrt{Pr} + \sqrt{bt}) \end{bmatrix}$$

$$- \frac{Gc}{c(1-Sc)}[\operatorname{erfc}(\eta\sqrt{Sc})]$$

$$+ \frac{Gr}{2c(1-Sc)} e^{ct} \begin{bmatrix} \exp(-2\eta\sqrt{Scct})\operatorname{erfc}(\eta\sqrt{Sc} - \sqrt{ct}) \\ + \exp(2\eta\sqrt{Scct})\operatorname{erfc}(\eta\sqrt{Sc} + \sqrt{ct}) \end{bmatrix}, \tag{12}$$

where $b = \frac{m}{Pr - 1}$, $c = \frac{m}{Sc - 1}$ and $\eta = \frac{z}{2\sqrt{t}}$.

## 4. Result and Discussion

To get the physical information into the issue, we have plotted velocity, temperature, concentration, the rate of heat transfer and the level of mass transfer for distinct estimations of the physical boundaries like magnetic parameter (*M*), Schmidt number (*Sc*), warm Grashof number (*Gr*), mass Grashof number (*Gc*), time (*t*), exponential index (*a*) and Prandtl number (*Pr*), as shown in Figures 1 to 6 using MATLAB software. It is observed that the velocity decreases when exponential index, Schmidt number and magnetic parameter increase (Figures 1-3). It is observed that the velocity increases when time increases (Figure 4). It is seen that the concentration increases by reducing the Schmidt number (Figure 5). It is found that the temperature increases by diminishing the Prandtl number (Figure 6).

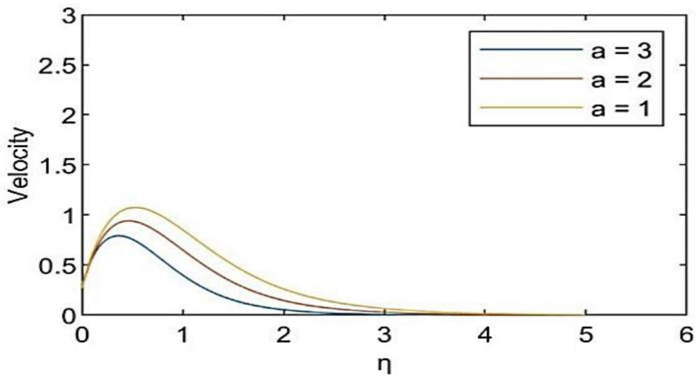


**Figure 1.** Velocity outlines for distinct values of *a*.

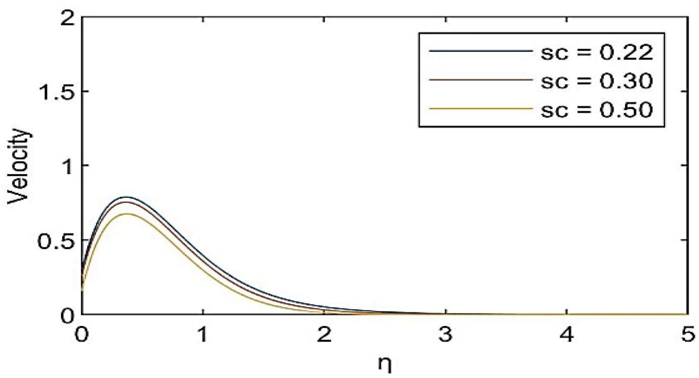


**Figure 2.** Velocity outlines for distinct values of *Sc*.

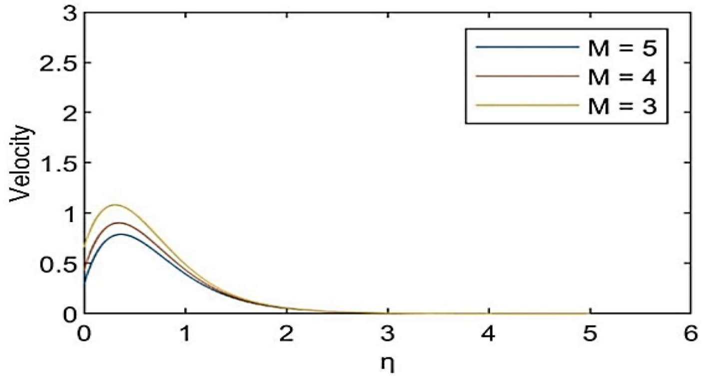


**Figure 3.** Velocity outlines for distinct values of *M*.

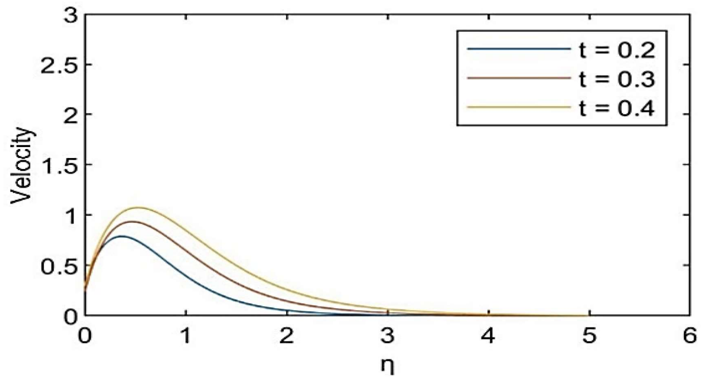


**Figure 4.** Velocity outlines for distinct values of *t*.

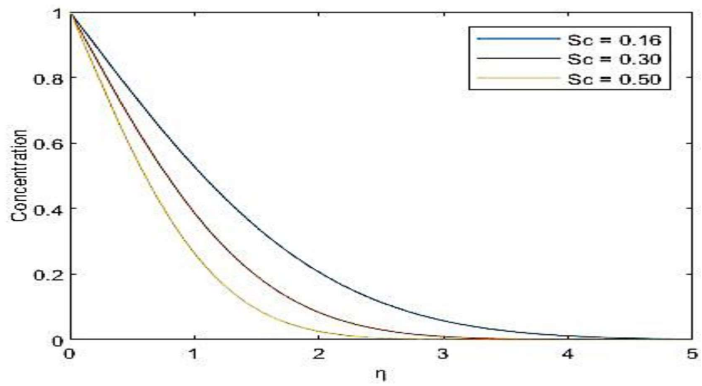


**Figure 5.** Concentration outlines for distinct values of *Sc*.

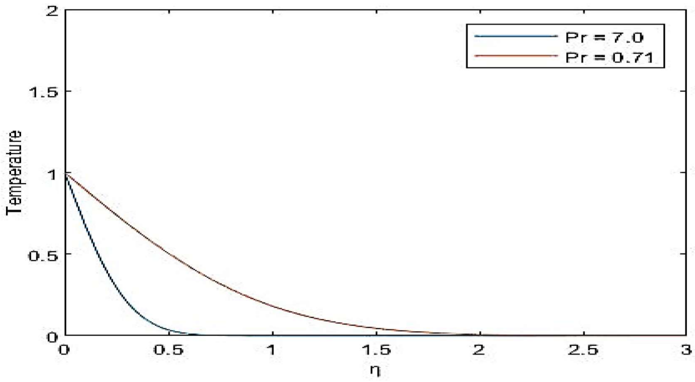


**Figure 6.** Temperature outlines for distinct values of *Pr*.

## 5. Conclusion

In this paper, we have discussed the impacts of MHD and radiation assimilation fluid flow past an exponentially accelerated vertical plate. The dimensionless overseeing conditions are understood by the regular Laplace change method. The findings of this investigation include (i) the velocity profiles increment in the exponential list ($a$) with decreasing velocity in the plate, (ii) the velocity profiles enlargement in the Schmidt number ($Sc$) with decreasing velocity in the plate, (iii) the velocity profiles extension in the magnetic parameter ($M$) with reducing velocity in the plate, (iv) the velocity profiles enlargement the time ($t$) outcome in increasing velocity in the plate, (v) the concentration outlines that the concentration increases with reducing the Schmidt number, and (vi) the temperature profiles that the temperature increase with diminishing the Prandtl number.

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