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Simulation of reactive flow over a parabolic vertical plate using MATLAB

Sivakumar Pushparaj[1], Balaji Ramalingam[2], Ramesh Adhimoolam[2], P. Venkata Mohan Reddy[2], Andal Srinivasan[3], Muthucumaraswamy Rajamanickam[4]
[1]Department of Mathematics, Panimalar Engineering College, Chennai, India
[2]Department of Mathematics, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India
[3]Department of Mathematics, PG and Research Department of Mathematics, Mannar Thirumalai Naicker College, Madurai, India
[4]Department of Applied Mathematics, Sri Venkateswara College of Engineering, Sriperumbudur, India

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ABSTRACT

This article examines how fluid flows around an infinitely large, parabolic-shaped vertical plate, which is heated at an exponentially accelerating rate and undergoes a chemical reaction with the fluid. The plate's temperature increases at an exponential rate, adding complexity to the heat transfer process. Additionally, the fluid undergoes a chemical reaction in this environment, impacting both the flow and concentration of chemical species. The article includes graphs that show how different parameters such as the rate of temperature increase, strength of thermal radiation, and reaction rate, effect the flow, heat, and concentration profiles. This graphical analysis provides a visual understanding of how each parameter influences the behavior of the fluid.

Corresponding Author:

Sivakumar Pushparaj
Department of Mathematics, Panimalar Engineering College
Chennai- 600 123, Tamilnadu, India
Email: sivakumarpushparaj@gmail.com

LIST OF NOMENCLATURE

B_0	Externally applied magnetic field	T_w	The fluid temperature close to the plate surface
C'	Concentration of specific particles	T_∞	Fluid temperature at a distance from the plate
C'_w	Concentration of the fluid close to the surface of the plate	t'	Time in seconds
C'_∞	Fluid concentration at a distance from the plate	u	The fluid velocity
C	Non-dimensional concentration	u_0	Velocity of the plate
C_p	Heat capacity at constant pressure	U	Dimensionless velocity
D	Mass diffusivity	x	Spatial coordinate along the plate
g	Gravitational acceleration	y	Coordinate axis normal to the plate
k	Heat conduction coefficient	ρ	Fluid mass density
Y	The non-dimensional perpendicular axis to the plat	τ	Non-dimensional skin friction coefficient
α	Coefficient of thermal diffusion	θ	Non-dimensional temperature
β	Thermal expansion coefficient per unit volume	η	Similarity index
β^*	Coefficient of volumetric expansion due to concentration	$erfc$	Complementary error function
μ	Dynamic viscosity coefficient	∞	Free stream conditions
ν	Kinematic viscosity coefficient	w	Conditions at the wall

1. INTRODUCTION

This research, which employs the Laplace transform to analyze the influence of diverse parameters on the flow and transport behavior of an infinite vertical plate with consistent mass diffusion, offers both similarities and distinctions when compared to prior investigations concerning heat and mass transfer over a vertical plate, the present the study's strengths lie in its clear presentation of numerical results, the use of a closed-form solution and the detailed physical interpretations of each parameter's influence. However, it further extends these insights by incorporating acceleration effects, showing that velocity stabilizes over time, a factor often overlooked in earlier research. Additionally, the study highlights the interplay between radiation and buoyancy forces, reinforcing findings from prior works that increased radiation enhances heat transfer while simultaneously reducing velocity. A key strength of this study is its analytical approach using the Laplace procedure, which provides closed-form solutions, offering precise insights into the effects of governing parameters. Furthermore, it captures the transient behavior of temperature and concentration fields, adding depth to conventional steady-state analyses. However, a notable limitation is the assumption of an infinite vertical plate, which may not fully represent practical scenarios with finite boundaries. Additionally, the study does not account for turbulence or three-dimensional effects, which could further refine the understanding of flow dynamics in real-world applications. Despite these limitations, the study contributes valuable analytical and numerical insights into convective heat and mass transfer processes.

Fluids, with their flow and unique properties like viscosity, are studied in fluid dynamics. Unsteady fluid motion, influenced by changing properties, affects heat transfer, often via convection, where fluid speed enhances heat movement (e.g., car radiators, stirring). The transfer of mass is a function of concentration gradients, involves particle movement towards equilibrium in mixtures.

The movement of mass, resulting from concentration differences, is increasingly vital in chemical processing, environmental, and biomedical fields, and impacting applications like air purification, drug delivery, and chemical reactions. Similar to heat transfer via temperature gradients, it seeks equilibrium. Mass transfer fluxes are crucial in climatology, astrophysics, and geophysics, exemplified by everyday phenomena like smoke dispersion and evaporation. Combined heat and mass exchange is essential in engineering, particularly in devices like humidifiers, dehumidifiers, cooling towers, and evaporative condensers, where heat and moisture move simultaneously.

The primary objective of this study was to provide a detailed understanding of the intricate relationships between momentum, heat, and mass transfer in the boundary layer region of an infinite vertical plate. To achieve this, the research analyzed the effects of radiation temperature, chemical reaction coefficients, Schmidt number, Grashof numbers, Prandtl number, and time on fluid velocity, concentration, and temperature profiles. The Laplace transform method was used to obtain analytical solutions, and numerical computations were performed to visualize and interpret the impact of these diverse parameters on the flow and transport characteristics.

2. LITERATURE REVIEW

Jha and Prasad [1] explored the flow devoid of resistance and mass transfer in the scenario of flow behind an accelerating vertical plate. This study likely examined how mass transfer occurs when the flow is influenced by the acceleration of a plate, a situation common in applications like aerodynamics and fluid mechanics. Chambré and Young [2] concentrated on the transport of chemical reaction substance within a laminar boundary layer flow. The research explored how a chemically reactive substance diffuses within this layer, which is important in processes like chemical engineering and environmental sciences. Cussler [3] analyzed mass transfer via diffusion in fluid systems. This is a classic study in mass transfer, focusing on how particles (like chemicals or solutes) move through a fluid medium due to diffusion, an important process in various industries such as pharmaceutical, chemical processing, and environmental engineering. Das *et al.* [4] examined Mass transfer affects flow dynamics over a suddenly started infinite plate with steady thermodynamic chemical reactions. The study explored how the onset of mass transfer affects flow characteristics when a plate suddenly starts moving, a situation encountered in many fluid-structure interaction applications. An abruptly started infinite vertical plate, undergoing chemical reactions, was studied by Das *et al.* [5] to determine the impact of mass transfer on the resulting flow. Gupta *et al.* [6] examined how free convection affects flow past a vertically accelerating plate in an incompressible, energy-conserving fluid. The study combined convection (heat transfer due to fluid motion) with acceleration, which is useful for understanding natural convection in various engineering applications like cooling systems and natural ventilation. To determine the effects of mass transfer and free convection, Kafousias and Raptis [7] analyzed the flow of a vertically accelerating infinite plate with variable suction or injection.

The inclusion of suction or injection adds complexity, as it involves controlling the flow by removing or adding fluid from the surface, which is critical in heat exchangers and filtration systems.

Mazumdar and Deka [8] analyzed magnetohydrodynamic (MHD) flow interacting with an infinite vertical surface impulsively begun by thermal radiation. The Laplace-transformation approach was attuned to solve dimensionless governing equations. Selvaraj and Jothi [9] aimed to determine how heat sources influence MHD flow across an accelerated plate, taking into account variable temperature and mass diffusion. MHD flow involves the interaction of a conducting fluid (e.g., plasma or molten metal) with a magnetic field, which is important in advanced engineering applications like nuclear reactors and space technology. Raptis *et al*. [10] studied suction and heat flux effects in hydromagnetic convection flow past an accelerating infinite vertical plate. This work combined MHD and heat transfer, investigating how suction (removal of fluid) and heat flux affect fluid flow in magnetic fields. This is critical for processes like cooling in nuclear reactors or electromagnetic pumps. Raptis and Singh [11] analyzed the free convection stirring of a vertical plate in the MHD domain. This research investigated free convection dynamics in a magnetic field for an electrically conductive fluid flowing past a moving plate, with applications in designing space technology devices like electromagnetic pumps and heat exchangers. Singh and Singh [12] explored the effect of mass transfer on flow past a vertically accelerating plate under constant heat flux. The study is relevant to applications where heat and mass need to be transferred simultaneously, such as in heat exchangers, chemical reactors, and environmental systems. Soundalgekar [13] examined how mass transfer affects a constantly moving vertical plate, a scenario applicable to material processing and cooling. In contrast, the study by Uwanta and Sarki [14] evaluated the consequences of significant mass diffusion and temperature variations on the mechanisms of heat and mass transfer. This research likely dealt with cases where mass diffusion follows an exponential pattern, which occurs in many diffusion-driven processes, and how temperature influences these processes in applications such as drying or chemical reactions.

Rajput and Kumar [15] analyzed the dynamic behavior of unsteady MHD flow over an impulsively inclined plate, with particular attention to the coupled effects of variable temperature, mass diffusion, and hall current. MHD boundary layer flow over vertical plates under ramping temperature circumstances is studied. In their work, Sarma and Ahmed [16] examined how heat sources impact MHD flow around an accelerated plate, while also accounting for temperature and mass diffusion variations. Research studies Krishna and Chamkha [17] examine many phenomena, including hall and ion slip, elastico-viscous fluid behavior, and nanofluid dynamics, in distinct MHD settings. These investigations elucidate the influence of porous media and thermal conditions on flow characteristics and heat transfer. The investigation conducted by Reddy *et al.* [18] focused on unsteady MHD flow over accelerating vertical plates, considering a constant heat flux and ramping plate temperature. Ahmed *et al.* [19] then investigated hall current effects in MHD flow over an accelerating plate. Studies by Chamkha [20] and Elbashbeshy [21] further examined MHD free convection and heat/mass transport, respectively. Later work by Aboeldahab and Elbarbary [22] explored buoyancy effects, Pop *et al.* [23] analyzed forced convection using numerical methods, and Kim [24] studied unsteady flow. This body of work shows the progression of research in this area. Early research into MHD and free convection phenomena, such as that by England and Emery [25] on thermal radiation, laid the groundwork for subsequent studies.

3. FORMULATION AND APPROACH

At the initial condition, both the plate and the fluid are at the same temperature, and the concentration of species in the fluid is uniform at across all points. Under these initial conditions, the plate is stationary. At a time $t' > 0$, the plate begins with a velocity$u = u_0 . t'^2$ within its own plane. The unsteady, buoyancy-driven flow of a fluid near a vertical plate, characterized by linearly increasing temperature and species concentration, is analyzed. A uniform, transverse magnetic field (B0) is applied. Under the Boussinesq approximation, the coupled governing equations for mass, momentum, energy, and species transport, including radiation and chemical reaction terms, are solved to obtain the flow, velocity temperature, and concentration fields.

$$\frac{\partial u(y,t')}{\partial t'} = g\beta(T(y,t') - T_\infty) + g\beta * (C'(y,t') - C'_\infty) + \nu \frac{\partial^2 u(y,t')}{\partial y^2} \quad (1)$$

$$\rho C_p \frac{\partial T(y,t')}{\partial t'} = k \frac{\partial^2 T(y,t')}{\partial y^2} - \frac{\partial q_r(y,t')}{\partial y} \quad (2)$$

$$\frac{\partial C'(y,t')}{\partial t'} = D \frac{\partial^2 C'(y,t')}{\partial y^2} - k_l(C'(y,t') - C'_\infty) \quad (3)$$

These are the conditions,

For all y, $t \leq 0: u(y,0) = 0, T(y,0) = T_\infty, C'(y,0) = C'_\infty$
$$If y = 0: U(0,t') = u_0 . t'^2, T(0,t') = T_\infty + (T_W - T_\infty)e^{a't'}, C'(0,t') = C'_w \quad (4)$$
$$If Y \to \infty: u(\infty,t') = T_\infty T(\infty,t') = 0, C'(\infty,t') = C'_\infty$$

We can make equations (1), (2), and (3) dimensionless by using these parameters:

$$U = u\left(\frac{u_0}{\nu^2}\right)^{\frac{1}{3}}, t = \left(\frac{u_0{}^2}{\nu}\right)^{1/3} t', a = a'\left(\frac{\nu}{u_0^2}\right)^{\frac{1}{3}}, Y = y\left(\frac{u_0}{\nu^2}\right)^{\frac{1}{3}}, C = \frac{C'-C'_\infty}{C'_w-C'_\infty} \theta = \frac{T \quad -T_\infty}{T_W-T_\infty}, Sc = \frac{\nu}{D}$$
$$Pr = \frac{\mu C_p}{k}, Gr = \frac{g\beta(T_W-T_\infty)}{(\nu.u_0)^{\frac{1}{3}}}, Gc = \frac{g\beta(C'_W-C'_\infty)}{(\nu.u_0)^{\frac{1}{3}}}, R = \frac{16a*\sigma.T_\infty{}^3}{k}\left(\frac{\nu^2}{u_0}\right)^{\frac{2}{3}}, K = K_l\left(\frac{\nu}{u_0^2}\right)^{\frac{1}{3}} \quad (5)$$

In (5) is employed to perform a transformation on the governing (1), (2), and (3), leading to,

$$\frac{\partial U(Y,t)}{\partial t} = Gr\theta(Y,t) + GcC(Y,t) + \frac{\partial^2 U(Y,t)}{\partial Y^2} \quad (6)$$

$$Pr\frac{\partial \theta(Y,t)}{\partial t} = \frac{\partial^2 \theta(Y,t)}{\partial Y^2} - R\theta(Y,t) \quad (7)$$

$$\frac{\partial C(Y,t)}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C(Y,t)}{\partial Y^2} - KC(Y,t) \quad (8)$$

The form of the conditions in (4) is now changed to,

For all Y, $t \leq 0: U(Y,0) = 0, \theta(Y,0) = 0, C(Y,0) = 0$
$$If Y = 0: U(0,t) = t^2, \theta(0,t) = L_{00}, C(0,t) = 1$$
$$If Y \to \infty: U(\infty,t) = 0, \theta(\infty,t) = 0, C(\infty,t) = 0 \quad (9)$$

4. SOLUTION DETERMINATION

By the Laplace techniques to dimensionless (6) to (8) with conditions (9), the following solution is derived:

Temperature: $\theta(Y,t) = \frac{L_{00}}{2}[L_{11} + L_{12}]$

Concentration: $C(Y,t) = \frac{1}{2}[L_3 + L_4]$

Velocity:

$$U(Y,t) = 2\left(\frac{t^2}{6}\left[(3 + 12\eta^2 + 4\eta^4)L_1 - \frac{\eta}{\sqrt{\pi}}(10 + 4\eta^2)L_2\right]\right) + C\left(\frac{L_{01}}{2}[L_9 + L_{10}] - \frac{L_{01}}{2}[L_{15} + L_{16}]\right)$$
$$+ A\left(\left(L_1 - \frac{L_{02}}{2}[L_7 + L_8] - \frac{1}{2}[L_3 + L_4] + \frac{L_{02}}{2}[L_{13} + L_{14}]\right) + B\left(\frac{L_{00}}{2}[L_{11} + L_{12}] - \frac{L_{00}}{2}[L_5 + L_6]\right)$$

Where $A = \frac{Gc}{d(1-Sc)}, B = \frac{Gr}{(1-Pr)(a-c)}, C = \frac{Gr}{(1-Pr)(c-a)}, b = \frac{R}{Pr}. c = \frac{R}{1-\mathrm{Pr}}, d = \frac{KSc}{1-Sc}, \eta = \frac{Y}{2\sqrt{t}}$

$L_{00} = exp(at)), L_{01} = exp(ct)), L_{02} = exp(dt)) \; L_1 = erfc(\eta), L_2 = exp(-\eta^2)$,
$L_{03} = 2\eta\sqrt{(Sc)(Kt)} L_3 = exp(L_{03})\,erfc(L_{04}), L_{04} = \eta\sqrt{Sc} + \sqrt{Kt}, L_4 = exp(L_{05})erfc(L_{06})$,
$L_{05} = -2\eta\sqrt{ScKt}, L_{06} = \eta\sqrt{Sc} - \sqrt{Kt}, L_5 = exp(L_{07})erfc(L_{08}), L_{07} = 2\eta\sqrt{at}, L_{08} = \eta + \sqrt{at}$,
$L_{09} = -2\eta\sqrt{at} L_6 = exp(L_{09})erfc(L_{10}), L_{10} = \eta - \sqrt{at}, L_{16} = exp(L_{11})erfc(L_{12}), L_{11} = -2\eta\sqrt{ct}$,
$L_{12} = \eta - \sqrt{ct}, L_{15} = exp(L_{29})erfc(L_{30}) L_{29} = 2\eta\sqrt{ct}, L_{30} = \eta + \sqrt{ct}, L_7 = exp(L_{13})erfc(L_{14})$,
$L_{13} = 2\eta\sqrt{dt}$, $L_{14} = \eta + \sqrt{dt}, L_{15} = -2\eta\sqrt{dt}, L_{16} = \eta - \sqrt{dt}, L_9 = exp(L_{17})erfc(L_{18}), L_{17} =$
$2\eta\sqrt{Pr(b+c)\,t}, L_{18} = \eta^{\sqrt{(b+c)t}}\sqrt{Pr}, L_{10} = exp(L_{19})erfc(L_{20}), L_{19} = -2\eta\sqrt{Pr(b+c)\,t}$,
$L_{20} = \eta^{\sqrt{(b+c)t}}\sqrt{Pr}, L_{11} = exp(L_{21})erfc(L_{22}), L_{21} = 2\eta\sqrt{(Pr)\,(b+a)t}, L_{22} = \eta^{\sqrt{(b+a)t}}\sqrt{Pr}$,
$L_{12} = exp(L_{23})erfc(L_{24}), L_{13} = exp(L_{25})erfc(L_{26}), L_{23} = -2\eta\sqrt{(Pr)\,(b+a)t}, L_{24} = \eta^{\sqrt{(b+a)t}}\sqrt{Pr}$,
$L_{14} = exp(L_{27})erfc(L_{28}), L_{25} = 2\eta\sqrt{(Sc)(K+d)t}, L_{26} = \eta\sqrt{Sc} + \sqrt{(K+d)t}$,
$L_{27} = -2\eta\sqrt{(Sc)(K+d)t}, \; L_{28} = \eta\sqrt{Sc} - \sqrt{(K+d)t}$

5. PROBLEM ANALYSIS

The objective of this comprehensive study, which provides explicit mathematical solutions, is to explore the impact of consistent mass transfer from an idealized vertical plate of infinite extent. Governing equations were solved; resulting physical consequences are detailed below.

Mathematical simulations are conducted to explore the physical consequences of the problem, with a focus on how parameters such as K, R, Sc, Gr, Gc, and tt influence the flow and transport dynamics. The (Sc) is taken as 0.6, representing water vapor, while the (Pr) is set to 0.71, corresponding to air.

As shown in Figures 1 and 2, As the radiation temperature component increases, the fluid experiences more heat transfer via radiation, Therefore, the fluid's speed is diminished, owing to the combined effect of stronger buoyancy forces and a modified flow regime. Similarly, an augmentation of the chemical reaction coefficient raises the rate of reactions, which also causes a reduction in velocity as it alters the concentration and thermal properties of the fluid, creating further resistance to the flow. As shown in Figures 3 and 4, as both time and acceleration increase, the velocity of the fluid increases. Higher acceleration provides more driving force, which promotes faster fluid motion. Additionally, as time progresses, the system stabilizes, and the fluid's velocity reaches a higher, more steady value. Therefore, the combined influence of these factors leads to a gradual increase in flow velocity.

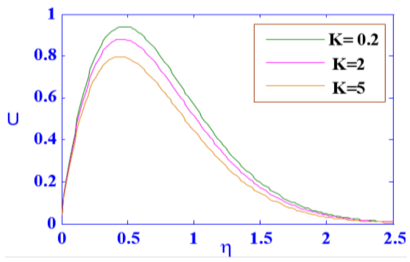

Figure 1. Impact of chemical reaction effects on velocity profiles

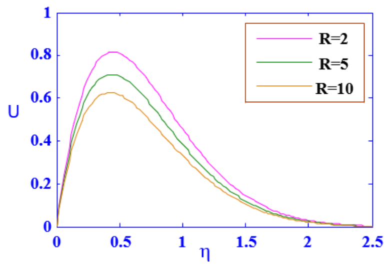

Figure 2. Impact of thermal radiation effects on velocity profiles

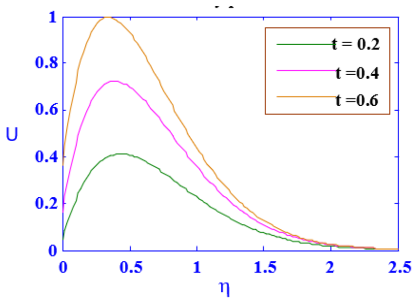

Figure 3. Comparison profiles of the flow velocity for various 't' values

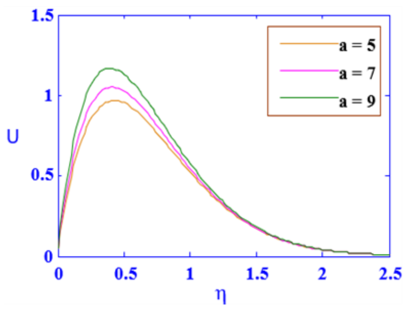

Figure 4. Comparison profiles of the flow velocity for various 'a' values

Figure 5 visualize the (Sc) influences the velocity field of the fluid. As these numbers increase, the (Sc) causes the velocity to decrease because it signifies that mass transfer is slower than momentum transfer, increasing the resistance to fluid movement. Figures 6 and 7 display the (Gr) and (Gc) increase, the buoyancy forces become more pronounced, leading to a higher velocity. This is due to the stronger convective effects arising from both temperature gradients (for Gr) and concentration gradients (for Gc), which enhance fluid motion near the surface and increase the boundary layer velocity profile. Figure 8 visualize the (Pr) influences the velocity field of the fluid in opposite ways. As these numbers increase, the (Sc) causes the velocity to decrease because it signifies that mass transfer is slower than momentum transfer, increasing the resistance to fluid movement. The (Pr) also causes a velocity decrease because it indicates slower thermal diffusivity compared to momentum diffusivity, leading to thicker thermal boundary layers and reduced heat transfer, which in turn affects the flow velocity. It is thus evident that an augmentation of either the Schmidt or the Prandtl numbers engenders a reduction in fluid velocity. Specifically, an upward trend in the Prandtl number results in the fluid's momentum diffusivity exceeding its thermal diffusivity, thus, the thermal boundary layer becomes more substantial.

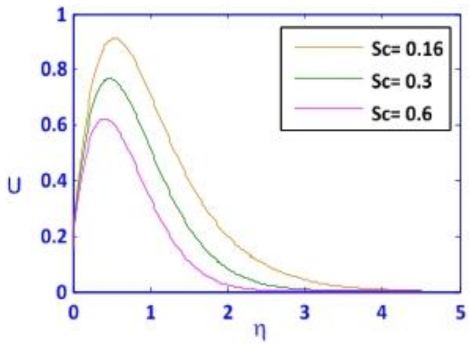

Figure 5. Comparison profiles of the flow velocity for various ‘Sc’ values

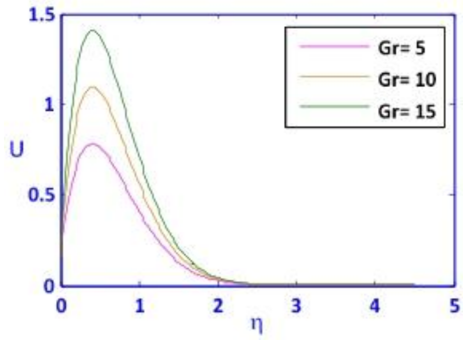

Figure 6. Impact of Grash of number for themal ‘Gr’ effects on velocity profiles

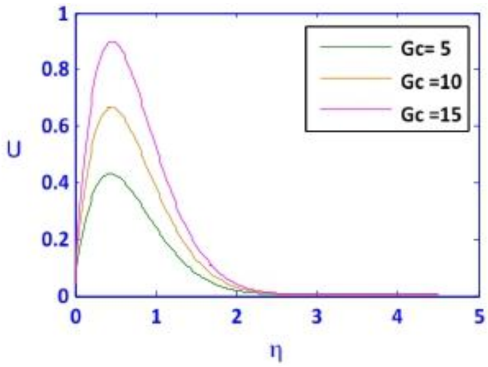

Figure 7. Visual representation of Gc’s impact on velocity

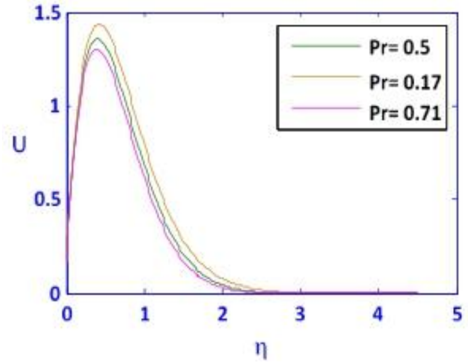

Figure 8. Comparison profiles of the flow velocity for various ‘Pr’ values

Figure 9 illustrates, as the (Sc) increases, the concentration falls due to the slower mass diffusion rates. This slower diffusion prevents the species from spreading efficiently from the surface into the bulk fluid, resulting in lower absorption levels and a reduced concentration in the boundary layer. Figure 10 demonstrates that shorter time periods (t) lead to higher surface concentrations, as diffusion is limited and the species remains concentrated near the surface. Conversely, longer time periods allow for greater diffusion, resulting in a lower and more uniform surface concentration. Figure 11 illustrates that increasing the Prandtl number (Pr) reduces temperature. Figure 12 shows the expected temperature rise over time, reflecting the accumulation and spread of heat.

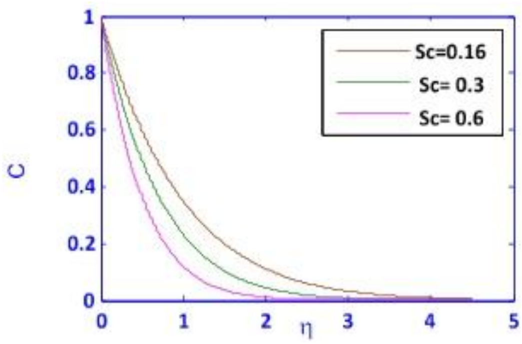

Figure 9. Visual representation of Sc’s impact on concentration

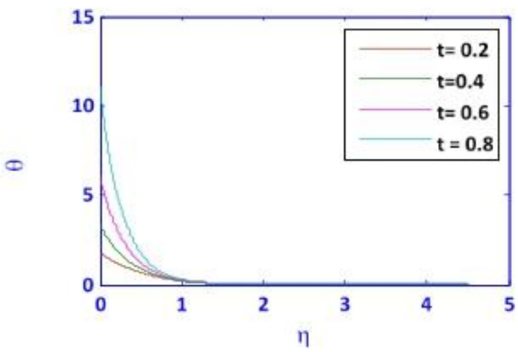

Figure 10. Effects of time ‘t’ concentration profiles

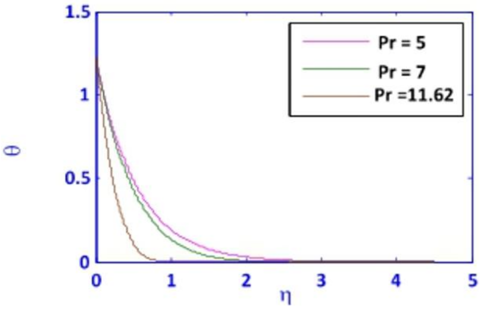

Figure 11. Comparison of temperature profiles for various 'Pr' values

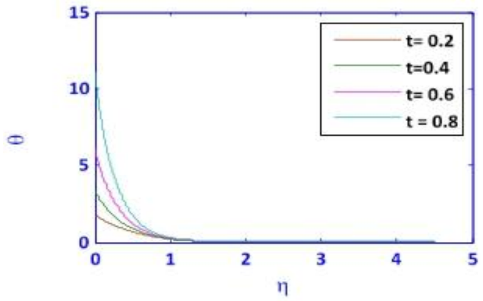

Figure 12. Comparison of temperature profiles for various 'a' values

Table 1 demonstrates that increased radiation and chemical reactions slow fluid velocity due to enhanced buoyancy and altered fluid properties. Conversely, higher acceleration and time lead to increased velocity as they provide greater driving force and system stabilization. Table 2 illustrates that increased Grashof numbers (Gr and Gc) enhance buoyancy and accelerate fluid velocity due to stronger temperature and concentration gradients. Conversely, higher Prandtl and Schmidt numbers (Pr and Sc) decelerate the fluid, indicating slower thermal and mass diffusion relative to momentum diffusion. Table 3 display the higher Schmidt number (Sc) decreases concentration due to slower mass diffusion, limiting species spread. Concentration inversely relates to time: shorter times mean higher surface concentration, while longer times allow for broader diffusion and lower concentration. Increased Prandtl number (Pr) lowers temperature, while increased time raises it, reflecting typical heat accumulation and spread.

Table 1. Presents the experimentally derived numerical comparison of velocity profiles for 'K', 'R', 't'and 'a', 'Gr'and 'Pr'

Parameter	Figure-1	Figure-2	Figure-3	Figure-4
K	0.2, 2, 5	2	4	4
R	6	2, 5, 10	4	4
Pr	0.71	0.71	0.71	0.71
Gc	15	5	5	15
Gr	5	15	5	5
Sc	0.6	0.16	0.6	0.6
t	0.2	0.6	0.2, 0.4, 0.6	0.2
a	0.2	0.2	0.2	5, 7, 9

Table 2. Presents the experimentally derived numerical comparison of velocity profiles for 'Sc', 'Gr'

Parameter	Figure-5	Figure-6	Figure-7	Figure-8
K	2	2	2	4
R	2	4	4	4
Pr	0.71	0.71	0.71	0.5, 0.17,0.71
Gc	5	5	5, 10, 15	5
Gr	2	5, 10, 15	5	15
Sc	0.16, 0.3, 0.6	0.6	0.6	0.78
t	0.4	0.4	0.2	0.4
a	0.2	0.2	0.2	0.2

Table 3. Presents the experimentally derived numerical comparison of concentration and temperature profiles for varying Sc, Pr, and t

Parameter	Figure-9	Figure-10	Figure-11	Figure-12
K	4	4	2	2
R	4	4	2	2
Pr	0.71	0.71	0.17, 0.71, 5	0.71
Gc	20	15	5	5
Gr	20	5	15	5
Sc	0.16, 0.3, 0.6	0.16	0.16	0.6
t	0.4	0.2, 0.4, 0.6, 0.8	0.6	0.2, 0.4, 0.6, 0.8
a	0.2	3	0.5	3

6. CONCLUSIONS AND FUTURE PERSPECTIVES

The process of analysis is implemented to determine the role of chemical reactions regarding the flow dynamics of a parabolic vertical plate of infinite with an exponential temperature gradient and uniform mass transfer applied. Velocity increases with rising time, acceleration, and both (Gr) and (Gc), while it decreases with higher (Sc), (Pr), and thermal radiation values. Temperature is observed to rise with increasing time, but it decreases as the (Pr) increases. Additionally, the (Sc) increases as concentration decreases, while concentration rises with increasing time. This study investigates the impact of various chemically reactive species. The findings of this research have practical applications within the chemical processing industry. The findings also have practical applications for the aerospace industries. This study may also be expanded to consider hall effects. Furthermore, instead of using a Newtonian fluid, a nanofluid may be employed. The combined analysis of chemical processes is highly relevant to aerospace and space research. This relevance is particularly due to the parabolic trajectories of space vehicles in orbit. Mass diffusion plays a critical role in the occurrence and dynamics of chemical reactions.

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AUTHOR CONTRIBUTIONS STATEMENT

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Balaji Ramalingam			✓	✓	✓	✓	✓	✓						
Ramesh Adhimoolam			✓	✓	✓	✓	✓	✓						
P. Venkata Mohan Reddy			✓	✓	✓	✓	✓	✓						
Andal Srinivasan			✓	✓	✓	✓	✓	✓						
Muthucumaraswamy Rajamanickam	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
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R : **R**esources
D : **D**ata Curation
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E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

DATA AVAILABILITY

No data were used to support the findings of this study.

REFERENCES

[1] B. K. Jha and R. Prasad, "Free-convection and mass transfer effects on the flow past an accelerated vertical plate with heat sources," *Mechanics Research Communications*, vol. 17, no. 3, pp. 143–148, May 1990, doi: 10.1016/0093-6413(90)90042-B.

[2] P. L. Chambré and J. D. Young, "On the diffusion of a chemically reactive species in a laminar boundary layer flow," *Physics of Fluids*, vol. 1, no. 1, pp. 48–54, Jan. 1958, doi: 10.1063/1.1724336.

[3] E. L. Cussler, "Diffusion mass transfer in fluid systems," *Cambridge University Press*, 1988.

[4] U. N. Das, R. Deka, and V. M. Soundalgekar, "Effects of mass transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction," *Forschung im Ingenieurwesen: Engineering Research*, vol. 60, no. 10, pp. 284–287, Oct. 1994, doi: 10.1007/BF02601318.

[5] U. N. Das, R. K. Deka, and V. M. Soundalgekar, "Transient free convection flow past an infinite vertical plate with periodic temperature variation," *Journal of Heat Transfer*, vol. 121, no. 4, pp. 1091–1094, 1999, doi: 10.1115/1.2826063.

[6] A. S. Gupta, I. Popp, and V. M. Soundalgekar, "Free convection effects on the flow past an accelerated vertical plate in an incompressible dissipative fluid.," *Revue roumaine des sciences techniques. Serie de mecanique appliquee*, vol. 24, no. 4, pp. 561–568, 1979.

[7] N. G. Kafousias and A. A. Raptis, "Mass transfer and free convection effects on the flow past an accelerated vertical infinite plate with variable suction or injection.," *Revue roumaine des sciences techniques. Serie de mecanique appliquee*, vol. 26, no. 1, pp. 11–22, 1981.

[8] M. K. Mazumdar and R. K. Deka, "MHD flow past an impulsively started infinite vertical plate in presence of thermal radiation," *Romanian Journal of Physics*, vol. 52, no. 5–7, pp. 565–573, 2007.
[9] A. Selvaraj and E. Jothi, "Heat source impact on MHD and radiation absorption fluid flow past an exponentially accelerated vertical plate with exponentially variable temperature and mass diffusion through a porous medium," *Materials Today: Proceedings*, vol. 46, pp. 3490–3494, 2020, doi: 10.1016/j.matpr.2020.11.919.
[10] A. A. Raptis, G. J. Tzivanidis, and C. P. Perdikis, "Hydromagnetic free convection flow past an accelerated vertical infinite plate with variable suction and heat flux," *Letters in Heat and Mass Transfer*, vol. 8, no. 2, pp. 137–143, Mar. 1981, doi: 10.1016/0094-4548(81)90035-7.
[11] A. Raptis and A. K. Singh, "MHD free convection flow past an accelerated vertical plate," *International Communications in Heat and Mass Transfer*, vol. 10, no. 4, pp. 313–321, Jul. 1983, doi: 10.1016/0735-1933(83)90016-7.
[12] A. K. Singh and J. Singh, "Mass transfer effects on the flow past an accelerated vertical plate with constant heat flux," *Astrophysics and Space Science*, vol. 97, no. 1, pp. 57–61, Nov. 1983, doi: 10.1007/BF00684609.
[13] V. M. Soundalgekar, "Effects of mass transfer on flow past a uniformly accelerated vertical plate," *Letters in Heat and Mass Transfer*, vol. 9, no. 1, pp. 65–72, Jan. 1982, doi: 10.1016/0094-4548(82)90049-2.
[14] I. J. Uwanta and M. N. Sarki, "Heat and mass transfer with variable temperature and exponential mass diffusion," *International Journal Of Computational Engineering Research (ijceronline.com)*, vol. 2, no. 5, pp. 2250–3005, 2012.
[15] U. S. Rajput and G. Kumar, "Radiation effect on unsteady MHD flow through porous medium past an oscillating inclined plate with variable temperature and mass diffusion in the presence of hall current," *Malaysian Journal of Fundamental and Applied Sciences*, vol. 12, no. 2, Aug. 2016, doi: 10.11113/mjfas.v12n2.445.
[16] S. Sarma and N. Ahmed, "Thermal diffusion effect on unsteady MHD free convective flow past a semi-infinite exponentially accelerated vertical plate in a porous medium," *Canadian Journal of Physics*, vol. 100, no. 10, pp. 437–451, Oct. 2022, doi: 10.1139/cjp-2021-0361.
[17] M. V. Krishna and A. J. Chamkha, "Hall and ion slip effects on MHD rotating flow of elastico-viscous fluid through porous medium," *International Communications in Heat and Mass Transfer*, vol. 113, p. 104494, Apr. 2020, doi: 10.1016/j.icheatmasstransfer.2020.104494.
[18] Y. D. Reddy, B. S. Goud, and M. A. Kumar, "Radiation and heat absorption effects on an unsteady MHD boundary layer flow along an accelerated infinite vertical plate with ramped plate temperature in the existence of slip condition," *Partial Differential Equations in Applied Mathematics*, vol. 4, p. 100166, Dec. 2021, doi: 10.1016/j.padiff.2021.100166.
[19] N. Ahmed, H. Kalita, and D. Barua, "Unsteady MHD free convective flow past a vertical porous plate immersed in a porous medium with Hall current, thermal diffusion and heat source," *International Journal of Engineering, Science and Technology*, vol. 2, no. 6, Feb. 2011, doi: 10.4314/ijest.v2i6.63699.
[20] A. J. Chamkha, "MHD-free convection from a vertical plate embedded in a thermally stratified porous medium with Hall effects," *Applied Mathematical Modelling*, vol. 21, no. 10, pp. 603–609, Oct. 1997, doi: 10.1016/S0307-904X(97)00084-X.
[21] E. M. A. Elbashbeshy, "Heat and mass transfer along a vertical plate with variable surface tension and concentration in the presence of the magnetic field," *International Journal of Engineering Science*, vol. 35, no. 5, pp. 515–522, Apr. 1997, doi: 10.1016/s0020-7225(96)00089-4.
[22] E. M. Aboeldahab and E. M. E. Elbarbary, "Hall current effect on magnetohydrodynamic free-convection flow past a semi-infinite vertical plate with mass transfer," *International Journal of Engineering Science*, vol. 39, no. 14, pp. 1641–1652, Sep. 2001, doi: 10.1016/S0020-7225(01)00020-9.
[23] I. Pop, M. Kumari, and G. Nath, "Conjugate MHD flow past a flat plate," *Acta Mechanica*, vol. 106, no. 3–4, pp. 215–220, Sep. 1994, doi: 10.1007/BF01213563.
[24] Y. J. Kim, "Unsteady MHD convective heat transfer past a semi-infinite vertical porous moving plate with variable suction," *International Journal of Engineering Science*, vol. 38, no. 8, pp. 833–845, May 2000, doi: 10.1016/S0020-7225(99)00063-4.
[25] W. G. England and A. F. Emery, "Thermal radiation effects on the laminar free convection boundary layer of an absorbing gas," *Journal of Heat Transfer*, vol. 91, no. 1, pp. 37–44, Feb. 1969, doi: 10.1115/1.3580116.

BIOGRAPHIES OF AUTHORS

Sivakumar Pushparaj received his Ph.D. degree in mathematics from Periyar University, M.Phil. degree in mathematics from Alagappa University, M.Sc. degree in mathematics from Sri Ramaswamy Naidu Memorial College-Madurai Kamaraj University and B.Sc. degree in mathematics from Sri Ramakrishna Mission Vidyalaya College of Art and Science-Bharathiyar University. He has served for more than 20 years in engineering colleges, At Present, he is an Assistant Professor (Grade-1), Department of Mathematics in Panimalar Engineering College, Chennai, India. His area of specialization is computational fluid dynamics. Heat and Mass Transfer, Radiative heat transfer and Nanofluids Flow. His research interests include machine learning. He has published research papers in reputed national and international journals. He can be contact at email: sivakumarpushparaj@gmal.com.

Balaji Ramalingam received the Ph.D. degree from Bharathidasan University in the year 2016. He is working as Professor, Department of Mathematics, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-602105. His area of specialization is nanofluid, magnetohydrodynamics, thermal radiation, ideal topological spaces, differentiability, valued function, differential equation. His research interests include machine learning. He can be contacted at email: balaji_2410@yahoo.co.in.

Ramesh Adhimoolam received the Ph.D. degree from Anna University in the year 2020. He is working as associate professor, Department of Mathematics, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-602105. His research area includes fuzzy set theory, fuzzy soft set, fuzzy rough set, and nanofluid. His research interests include artificial intelligent and machine learning. He can be contacted at email: ramesh.adhimoolam@gmail.com.

P. Venkata Mohan Reddy is full time Professor, Department of Mathematics, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-602105. He obtained his graduation, post-graduation and M.Phil from Loyola College, Chennai, University of Madras in 1997, 1999 and 2000 respectively and Ph.D. degree from Anna University in the year 2021. His research area includes differential equations and difference equations. His research interests include artificial intelligent and machine learning. He can be contacted at email: drvmr.maths@gmail.com.

Andal Srinivasan received her Ph.D. degree in mathematics from Madurai Kamaraj University, M.Phil. Degree in mathematics from Alagappa University, M.Sc. degree in mathematics from Sri S. Ramasamy Naidu Memorial College, Sattur affiliated to Madurai Kamaraj University and B.Sc. degree in mathematics from G. Venkatasamy Naidu College, Kovilpatti affiliated to Manonmanium Sundaranar University, Tirunelveli. At present she is working as an associate professor in Mannar Thirumalai Naicker College, Madurai, Tamilnadu. Her area of specialization is fuzzy optimization techniques. Her area of interest includes graph theory and number theory. She published research papers in reputed national and international journals. She can be contact at email: andals@mannarcollege.ac.in.

Muthucumaraswamy Rajamanickam received his B.Sc. degree in mathematics, from Gurunanank College, University of Madras in 1985, M.Sc. degree in applied mathematics from Madras Institute of Technology, Anna University in 1987, M.Phil. degree in mathematics from Pachaiyappa's College, University of Madras in 1991 and Ph.D. degree in mathematics from Anna University in 2001. His area of specialization in theoretical and computational fluid dynamics. He published 310 papers in national/international journals and in conferences. He completed two funded projects from Defence Research and Developmental Organization in 2009 and 2012. He received best teacher award in the year 2001. Currently, working as a professor and head, Department of Applied Mathematics, Sri Venkateswara College of Engineering, Sriperumbudur, India. He can be contact at email: msamy@svce.ac.in.