SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879

Magneto Hydrodynamic Effects on Unsteady Free Convection Casson Fluid Flow Past on Parabolic Accelerated Vertical Plate with Thermal Diffusion

Ganesan Radha[1], Ayothi Selvaraj[1,*], Soundararajan Bhavani[2], Periasamy Selvaraju[3]

[1] Department of Mathematics, Vels Institute of Science, Technology & Advanced Studies, Chennai-600117, Tamil Nadu, India
[2] Department of Mathematics, Rajalakshmi Engineering College, Chennai-602105, India
[3] Department of Computer Science and Engineering, Saveetha School of Engineering, SIMATS, Chennai-602105, Tamil Nadu, India

ARTICLE INFO

Article history:
Received 15 October 2023
Received in revised form 19 March 2024
Accepted 28 March 2024
Available online 15 April 2024

Keywords:
Parabolic; MHD; Casson fluid; Laplace transform; vertical plate

ABSTRACT

The free convection MHD flow of a viscous, chemically reactive, electrically conducted, incompressible, and Casson fluid past a parabolically accelerated vertical plate was examined in the present article along with the transfer of the heat & mass in the incidence of thermal radiation. The inverse Laplace method is used to resolve the dimensionless equations. The concentration and temperature fields, axial and transverse velocity are examined for distinct parameters like the λ (Casson fluid), Sc (Schmidt number), Gr (thermal Grashof number), Pr (Prandtl number), and Gm (mass Grashof number). Utilizing the temperature of fluid and concentration of species as a solution is also proposed. Graphical representations of the fluctuations in temperature of fluid and velocity along species concentration are provided for several values of relevant flow parameters.

1. Introduction

Many flow features within Newtonian fluid model are not understood. Consequently, it is beneficial to examine the non-Newtonian fluid model. Shear strain and shear stress rate have non-linear connections under the influence of non-Newtonian fluid. It has various uses in engineering and industry, particularly when it comes to crude oil extraction from petroleum-based products. The crucial non-fluid model is the Casson fluid. It has many uses in food preparation, drilling operations, and bio-engineering processes. The review of non-Newtonian fluid flow in the parabolically conducting, viscous, incompressible, as well as heat-absorbing fluid flow through an accelerating plate. Jose *et al.*, [16] determined the convective mass and heat transfer impacts of rotation on parabolic flow through an accelerated iso-thermal vertical plate during a first-order chemical process. Selvaraj *et al.*, [1] examined MHD-parabolic flow over an accelerated mass and heat diffusion and isothermal vertical plate during rotation. Lakshmikaanth *et al.*, [3] determined the heat and Hall

*Corresponding author.
E-mail address: aselvaraj_ind@yahoo.co.in

https://doi.org/10.37934/arfmts.116.1.184200

source impacts of chemical and radiation reactions on flow via parabolic accelerated isothermal vertical plate. Karthikeyan *et al*., [17] studied "uniform mass diffusion based on thermal radiation along with parabolic rotation within vertical plate MHD. Aruna *et al*., [13] hypothesized Magnetic and Hall influences on Stream Past a Parabolic Accelerated Vertical Plate with changing Heat as well as uniform mass diffusion within Thermal Radiation Appearance.

Sivakumar *et al*., [16] have addressed the impact of skin friction along with the transfer rate of mass and heat on MHD flow across an infinite isothermal vertical plate in the incidence of thermal chemical & radiation reaction. Kataria *et al*., [7] examined the chemical & radiation reactions' impacts on the Casson fluid flow of MHD via an oscillating vertical plate enclosed in porous media order. Muthucumaraswamy *et al*., [11] discusses the impacts of 1st order chemical reactions on a parabolic flow across an infinite vertical plate with changing mass and temp. diffusion. Muthucumaraswamy *et al*., [14,21] considered the MHD along with the radiation impacts on a moving isothermal vertical plate along with the variable and mass diffusion. Maran *et al.,* [4] showed 1st order of chemical reaction influence of MHD flow across an infinite vertical plate having variable diffusion of mass & thermal radiation in sight exponentially. The viscous dissipation influence on the Casson fluid's unstable natural convective flow across an oscillating vertical plate was investigated by Jithender Reddy *et al*., [5] who used the FEM. Khalid *et al*., [2] suggested Instable free convection MHD flow of past across an oscillating vertical plate in the existence of porous media Engineering Science and Technology. Additionally, Hataria *et al*., [6] observed the impacts of heat and Soret production on MHD Casson fluid flow using an oscillating vertical plate that was rooted in a porous media. Prasad *et al.,* [9] investigated the temperature and species content of MHD Casson fluid in a vertical sheet with changing fluid parameters. Vaddemani *et al*., [15] impacts of characteristics on MHD Casson fluid, flows via a vertical plate in a porous media. Ali Khan *et al*., [8] impacts of mass & heat transfer on unsteady boundary layer flow of the Casson fluid with chemical reacting. Mukhopadhyay et al.,[19] investigation of conducted on the unsteady two-dimensional flow of a non-Newtonian fluid over a stretching surface with a specified surface temperature.

with thermal diffusion along with chemical reaction impacts on above mentioned MHD convection with exponentially accelerated inclined plate. Siddiqa *et al*., [20] research on the heat transfer over a vertically wavy cone with a radiating surface including a fluid flow of Casson dusty. The effects of radiation on a parabolic flow moving along an infinite and isothermal vertical plate while an exponentially accelerating via porous medium by Selvaraj *et al*., [22,23]. Usharani *et al*., [24] researched impact of MHD exponentially accelerated inclined vertical plate with 1st order chemical reaction. Goud [25] study examines the effects of heat generation or absorption on the continuous MHD flow of a stretched, semi-infinite vertical plate through porous media with varying suction/injection and magnetic field participation.

Goud *et al.,* [26] examined the heat source influence on an unsteady MHD Casson fluid flow over a vertical oscillating plate in a porous material is solved numerically in this article. Goud, B. Shankar *et al.,* [27] find out the effect of the Dufour number, as well as viscous dissipation, on the non-steady flow of heat, as well as the mass transfer of Casson fluid, on vertical permeable laminate is explored using chemical reaction. Goud, B. Shankar *et al.,* [28] inspected the influence of the Eckert number and the Prandtl number on a magnetohydrodynamic natural convection flow of an incompressible viscous electrically conducting fluid flowing through a perpendicular microchannel is determined numerically. Analysis is done on conduction and non-conducting, immeasurable, perpendicular walls at the microchannel when temperature and velocity slip are present. Rebhi *et al.,* [29] study about the current research is primarily concerned with assessing thermal performance in solar receivers and heat exchangers that use forced thermal transfer. Alkasasbeh *et al.,* [30] using an Al_2O_3+CuO/SA Williamson hybrid nanofluid, investigate the properties of heat and mass transfer flow through a stretching sheet in conjunction with a magnetic field and thermal radiation. Armstrong, A. Neel et al., [31] the effects of medium rotation and porosity on the unsteady convection flow of a viscous, incompressible, and electrically conducting flow across a starting vertical plate under the impact of transversely applied uniform mass diffusion are investigated. Ilyas Khan *et al.,* [32] investigated the use of fractional derivatives to characterize and study blood flow behavior as well as the processes of blood flow over an inclined surface or structure when nanofluids are present. Makinde *et al*., [34] examined the unstable mixed convection flow through a vertical porous plate traveling through a binary mixture in the presence of radiative heat transfer. Soundalgekar *et al*., [10,33] the effects of mass and free exchange on the MHD Stokes (Rayleigh) problem of electric, incompressible, viscous fluids flowing through an incompressible initial vertical plate in conjunction with the workplace connection have been carefully studied.

The purpose of this article is to explore the development of an uncoupled, unstable model for vertical plate MHD. Casson fluid with thermal diffusion effects. A new feature of thermal explosive mass propagation has been discovered. The subject revolves around the nonlinear electric current of dimensionless magnetohydrodynamic flow of Carson fluid in a vertical plate, with a focus on mass propagation, which has received little attention previously. The Laplace transform method is used to solve differential equations with beginning and boundary conditions as well as control parameters. Convergence of the solution is critical since the nature of the problem is the output of the solution. This discovery could have applications in solar energy harvesting systems, recycling petroleum products, and fire-resistant insulating materials.

2. Mathematical Analysis

Figure 1 shows geometry of present model the coordinate system was designed to take into account the Casson fluid model's unsteady motion with electrically conducting fluid moving via a vertical plate with the, x^* axis along the plate in an upward direction, y^* -axis normal to the plate, as well as z^* -axis vertical to the, x^*y^* -plane. The fluid is permitted by the same transverse magnetic field B_0, this is employed diagonally to the y^*-axis. We assume that at the time $\bar{t} \leq 0$, both plate as well as fluid are at rest and kept at an even surface concentration $\bar{C}_\infty$ and uniform temperature $\bar{T}_\infty$. At time $\bar{t} \geq 0$, the plate starts to move in x^* -direction against gravitational field along with time dependent velocity $\bar{u}$. Plate temperature is decreased or increased to $\bar{T}_\infty + (\bar{T}_w - \bar{T}_\infty)\frac{{u_0}^2\bar{t}}{v}$ at $\bar{t} \geq 0$ and plate concentration is raised or lowered to $\bar{C}_\infty + (\bar{C}_w - \bar{C}_\infty)\frac{{u_0}^2\bar{t}}{v}$ at $\bar{t} \geq 0$. The rheological state equation for Cauchy stress tensor of Casson fluid is presented below

$$\tau_{ij=}\begin{Bmatrix} 2e_{ij}\left(\mu_B + \frac{py}{\sqrt{2\pi}}\right) & \pi > \pi_c \\ 2e_{ij}\left(\mu_B + \frac{py}{\sqrt{2\pi_c}}\right) & \pi < \pi_c \end{Bmatrix} \tag{1}$$

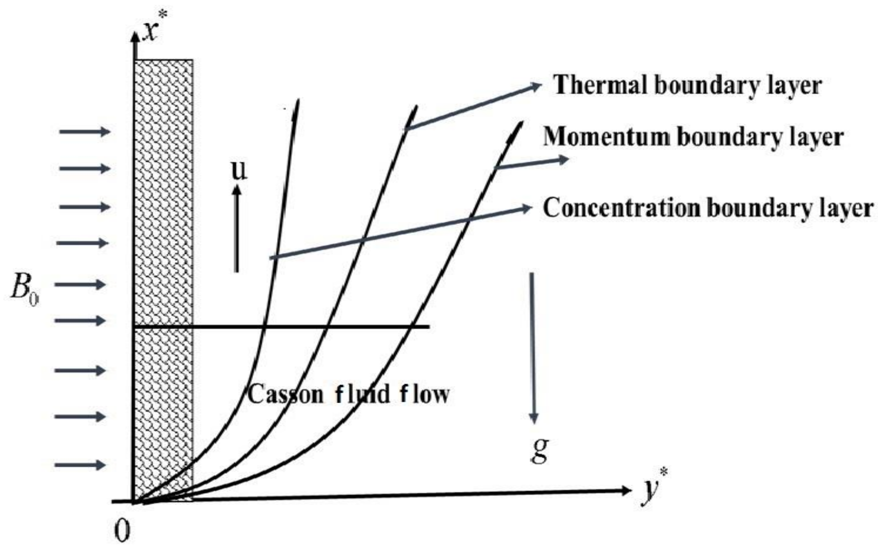

Fig. 1. Physical model

With the aforementioned conditions, we obtain the following equation for concentration, temperature, and velocity. Initial boundary conditions are provided below.

$$\frac{\partial \bar{u}}{\partial \bar{t}} = \frac{\mu_B}{\rho}\left(\frac{1}{1+\lambda}\right)\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} - \frac{\mu \bar{u}}{\rho \overline{k_1}} - \frac{\sigma {B_0}^2 \bar{u}}{\rho} + g\beta(\bar{T} - \bar{T}_\infty) + g\beta_c(\bar{C} - \bar{C}_\infty) \quad (2)$$

$$\frac{\partial \bar{T}}{\partial t} = \frac{k}{\rho c_p}\frac{\partial^2 \bar{T}}{\partial \bar{y}^2} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial \bar{y}} \quad (3)$$

$$\frac{\partial \bar{C}}{\partial \bar{t}} = D\frac{\partial^2 \bar{C}}{\partial \bar{y}^2} \quad (4)$$

Boundary conditions for flows are expressed as

$\bar{u} = 0, \bar{T} = \bar{T}_\infty, \bar{C} = \bar{C}_\infty$ for $\bar{t} \leq 0; \bar{y} \geq 0$

$\bar{u} = \frac{{u_0}^2 \bar{t}}{v},\ at\ y = 0\ \ for\ \bar{t} \geq 0$

$\bar{T} = \bar{T}_\infty + (\bar{T}_w - \bar{T}_\infty)\frac{{u_0}^2 \bar{t}}{v}$, at $\bar{y} = 0$ for $\bar{t} > 0$ (5)

$\bar{C} = \bar{C}_\infty + (\bar{C}_w - \bar{C}_\infty)\frac{{u_0}^2 \bar{t}}{v}$, at $\bar{y} = 0$ for $\bar{t} > 0$

$\bar{u} \to 0, \bar{T} \to \bar{T}_\infty, C \to \bar{C}_\infty$ at $\bar{y} \to \infty$ for $\bar{t} > 0$

The local gradient for optically slim gas can be written as

$$\frac{\partial q_r}{\partial y} = -4\bar{a}\,\sigma\,({\bar{T}_\infty}^4 - \bar{T}^4) \quad (6)$$

Temperature modifications within flow are appropriately small and that $\bar{T}^4$maybe denoted as a temperature's linear" function. To attained $\bar{T}^4$ solving Taylor series about $\bar{T}_\infty$ and overlooking the terms that are higher in order, we attain

$$\bar{T}^4 = 4\bar{T}_\infty{}^3\,\bar{T} - 3\bar{T}_\infty{}^4 \tag{7}$$

Substituting Eq. (6) and (7) in (3), we get

$$\frac{\partial \bar{T}}{\partial \bar{t}} = \frac{k}{\rho c_p}\frac{\partial^2 \bar{T}}{\partial \bar{t}^2} - \frac{16\bar{a}\sigma}{\rho c_p}\bar{T}_\infty{}^3(\bar{T} - \bar{T}_\infty) \tag{8}$$

The following definitions apply to the dimensionless parameters and variables.

$$y = \frac{\bar{y}u_0}{v}, \; u = \frac{\bar{u}}{u_0}, \; t = \frac{u_0{}^2\bar{t}}{v}, \; T = \frac{\bar{T}-\bar{T}_\infty}{\bar{T}_w-\bar{T}_\infty} \; C = \frac{\bar{C}-\bar{C}_\infty}{\bar{C}_w-\bar{C}_\infty}, \; \mu = \rho v, \; k_1 = \frac{u_0{}^2\bar{k}_1}{v^2}, \; P_{r=}\frac{\mu c_p}{k}$$

$$S_c = \frac{v}{D}, \; G_r = \frac{g\beta_T v(\bar{T}_w-\bar{T}_\infty)}{u_0{}^3}, \; G_m = \frac{g\beta_c v(\bar{C}_w-\bar{C}_\infty)}{u_0{}^3}, \; M = \frac{\sigma\, B_0{}^2 v}{\rho\, u_0{}^2}, \; R = \frac{16\bar{a}\sigma v^2\bar{T}_\infty{}^3}{k\, u_0{}^2}, \; k = \frac{v\bar{k}}{u_0{}^2} \tag{9}$$

We have the dimensionless version of the following governing equation.

$$\frac{\partial U}{\partial t} = \left(\frac{1}{1+\lambda}\right)\frac{\partial^2 U}{\partial y^2} - \frac{(Mk_1+1)}{k_1}U + G_r T + G_m C \tag{10}$$

$$\frac{\partial T}{\partial t} = \frac{1}{P_r}\frac{\partial^2 T}{\partial y^2} - \frac{R}{P_r}T \tag{11}$$

$$\frac{\partial^2 C}{\partial y^2} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} \tag{12}$$

and corresponding boundary conditions become

$$\begin{aligned} &U=0,\ T=0,\ C=0 \quad \text{for } y \geq 0 \;\&\; t \leq 0 \\ &U=t^2,\ T=t,\ C=t \quad \text{at } y=0 \text{ for } t>0 \\ &T\to 0,\ U\to 0,\ C\to 0, \quad \text{as } y\to\infty \text{ for } t>0 \end{aligned} \tag{13}$$

The above-mentioned eq. could be expressed in the following form

$$\frac{\partial U}{\partial t} = m\frac{\partial^2 U}{\partial y^2} - nU + G_r T + G_m C \tag{14}$$

$$\frac{\partial T}{\partial t} = \frac{1}{P_r}\frac{\partial^2 T}{\partial y^2} - \frac{R}{P_r}T \tag{15}$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} \tag{16}$$

3. The Method of Solution

The dimensionless governing equations from (14)-(16) according to boundary conditions (13) may be resolved with the Laplace transform approach to attain the precise solution for fluid concentration, velocity, and temperature, which is then found in the following method is used to get the solutions with help of Hetnarski [18] find out the inverse Laplace transform algorithm

The fluid concentration can be represented as

$$C = \left(t + \frac{y^2 S_c}{2}\right) erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right) - \frac{y\sqrt{S_c t}}{\sqrt{\pi}}\, exp\left(\frac{-y^2 S_c}{4t}\right) \tag{17}$$

The fluid temperature can be expressed as

$$T = \left(\frac{t}{2} - \frac{P_r y}{4\sqrt{R}}\right)\exp\left(-y\sqrt{R}\right) erfc\left(\frac{\sqrt{P_r}y}{2\sqrt{t}} - \sqrt{\left(\frac{R}{P_r}\right)t}\right) + \left(\frac{t}{2} + \frac{P_r y}{4\sqrt{R}}\right)\exp\left(y\sqrt{R}\right) erfc\left(\frac{\sqrt{P_r}y}{2\sqrt{t}} + \sqrt{\left(\frac{R}{P_r}\right)t}\right) \tag{18}$$

The fluid velocity could be expressed using the following formula

$$\begin{aligned}
U = & \left(\frac{y^2}{8mn} + \frac{t^2}{2}\right)\left[\begin{aligned} & exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ & + exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right)\end{aligned}\right] \\
& + \frac{y}{2\sqrt{mn}}\left(\frac{1}{4n} - t\right)\left[\begin{aligned} & exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ & - exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right)\end{aligned}\right] \\
& - \frac{y\sqrt{t}}{2n\sqrt{m\pi}}\exp\left(-\frac{y^2}{4mt} - nt\right) \\
& + \frac{A_1}{2}\left[\begin{aligned} & exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ & + exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right)\end{aligned}\right] \\
& + A_2\left\{\begin{aligned} & \left(\frac{t}{2} - \frac{c}{4\sqrt{n}}\right)\left[exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right)\right] \\ & + \left(\frac{t}{2} + \frac{c}{4\sqrt{n}}\right)\left[exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right)\right]\end{aligned}\right\} \\
& + \frac{A_3 e^{at}}{2}\left[\begin{aligned} & exp\left(\frac{-y\sqrt{a+n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{(a+n)t}\right) \\ & + exp\left(\frac{y\sqrt{a+n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{(a+n)t}\right)\end{aligned}\right] \\
& + \frac{A_4}{2}\left[\begin{aligned} & exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ & + exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right)\end{aligned}\right]
\end{aligned}$$

$$+A_5\left\{\begin{array}{l}\left(\frac{t}{2}-\frac{c}{4\sqrt{n}}\right)\left[exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right)\ erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{nt}\right)\right]\\+\left(\frac{t}{2}+\frac{c}{4\sqrt{n}}\right)\left[exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right)\ erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{nt}\right)\right]\end{array}\right\}$$

$$+\frac{A_6e^{at}}{2}\left[\begin{array}{l}exp\left(\frac{-y\sqrt{a+n}}{\sqrt{m}}\right)\ erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{(a+n)t}\right)\\+\ exp\left(\frac{y\sqrt{a+n}}{\sqrt{m}}\right)\ erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{(a+n)t}\right)\end{array}\right]$$

$$+\frac{A_7}{2}\left[\begin{array}{l}\exp\left(-y\sqrt{R}\right)\ erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}-\sqrt{\left(\frac{R}{P_r}\right)t}\right)\\+\exp\left(y\sqrt{R}\right)\ erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}+\sqrt{\left(\frac{R}{P_r}\right)t}\right)\end{array}\right]$$

$$+A_8\left\{\begin{array}{l}\left(\frac{t}{2}-\frac{P_ry}{4\sqrt{R}}\right)\exp\left(-y\sqrt{R}\right)\ erfc\left(\frac{\sqrt{P_r}y}{2\sqrt{t}}-\sqrt{\left(\frac{R}{P_r}\right)t}\right)\\+\left(\frac{t}{2}-\frac{P_ry}{4\sqrt{R}}\right)\exp\left(-y\sqrt{R}\right)\ erfc\left(\frac{\sqrt{P_r}y}{2\sqrt{t}}-\sqrt{\left(\frac{R}{P_r}\right)t}\right)\end{array}\right\}$$

$$+\frac{A_9e^{at}}{2}\left[\begin{array}{l}exp\left(-y\sqrt{R+aP_r}\right)\ erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}-\sqrt{\left(a+\frac{R}{P_r}\right)t}\right)\\+\ exp\left(y\sqrt{R+aP_r}\right)\ erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}+\sqrt{\left(a+\frac{R}{P_r}\right)t}\right)\end{array}\right]$$

$$+\ \frac{A_{10}}{2}\left[erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right)+\ erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right)\ \right]$$

$$+\ \frac{A_{11}}{2}\ \left[\left(\frac{t}{2}-\frac{y\sqrt{S_c}}{4}\right)\ erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right)\ +\left(\frac{t}{2}+\frac{y\sqrt{S_c}}{4}\right)\ erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right)\right]$$

$$+\frac{A_{12}e^{at}}{2}\left[\begin{array}{l}exp\left(-y\sqrt{aS_c}\right)\ erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}-\sqrt{at}\right)\\+exp\left(y\sqrt{aS_c}\right)\ erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}+\sqrt{at}\right)\end{array}\right] \tag{19}$$

4. Results and Discussion

The focus of study is likely determining the impacts of radiation on the intensity and mass transport properties of MHD. For various values of flow parameters like the Prandtl number (Pr), Schmidt number (Sc), and thermal radiation parameter (R), the Casson fluid flow and numerical results of velocity (U), temperature (T), and concentration (C) with the boundary layer were determined. The values listed below typically determine the parameters.

In these conditions, higher mass grazing numbers encourage higher velocity levels and stronger convective motion.

Figure 2 shows the plotted velocity profiles for a range of mass Grashof numbers. When all other contributing factors are held constant, the curve of the velocity profile against span-wise coordinate g is shown in the figure. The ratio of the species buoyant force to the viscous hydrodynamic force is defined by the mass Grashof number. It has been noted that as the mass Grashof number grows, so increase the velocity.

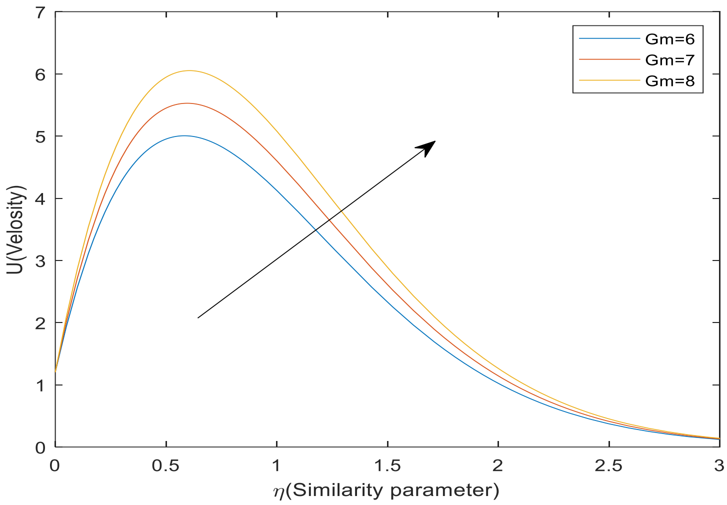

Fig. 2. Profiles of velocity for distinct *Gm* values having Gr=5, Sc=2.01, R=4, Pr=0.71, M =0.6, k=0.5, $\lambda = 0.35$, t = 1.1

In Figure 3 Higher flow velocities may result from more vigorous convective movement triggered by an increase in the thermal Grashof number. Higher thermal Grashof numbers indicate stronger buoyancy-driven flow, which can result from wider temperature differences or more variations in the fluid's properties (density). This is why this phenomenon happens. In conclusion, stronger convective motion may be caused by a rise in the thermal Grashof number, which could lead to higher flow velocities.

The effects of transverse velocity on the magnetic field parameter M are shown in Figure 4, as with axial velocity, it is shown that the transverse velocity rises with decreasing values of M.

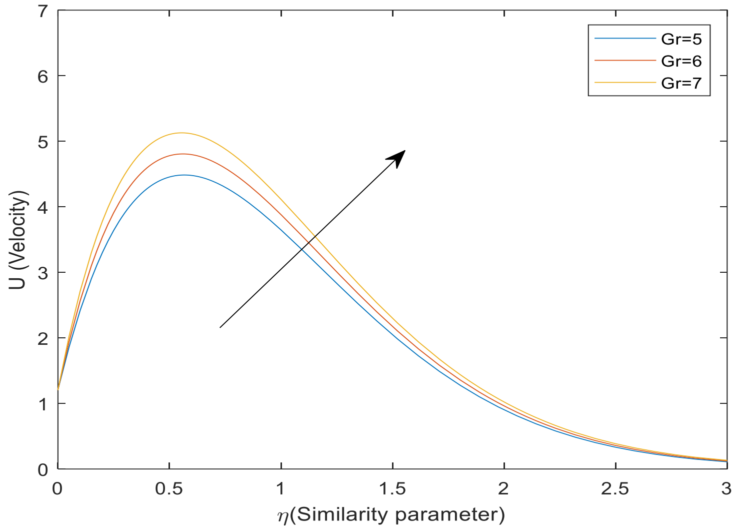

Fig. 3. Velocity profiles for distinct *Gr* values having Sc=2.01, Pr=0.71, R =4, *M* =0.6, $k = 0.5$, $\lambda = 0.35$, t = 1.1

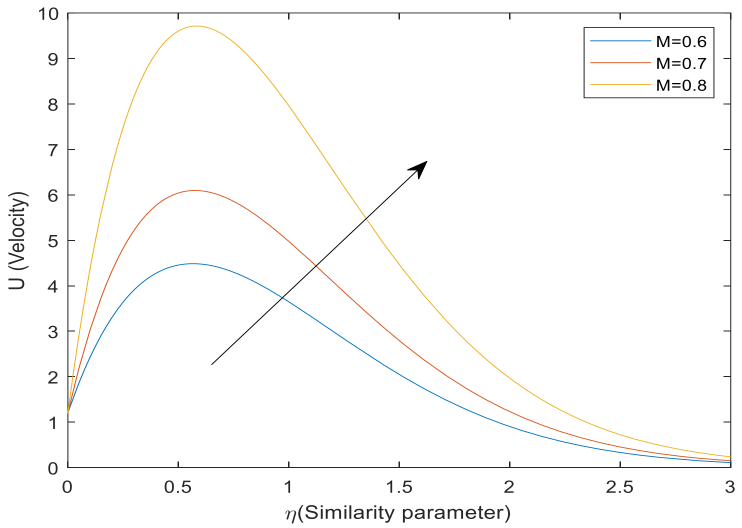

Fig. 4. Velocity profiles for distinct *M* values having Gm=5, Sc=2.01, Gr=5, Pr =0.71, R=4, $k = 0.5$, $\lambda = 0.35$, t = 1.1

The fluctuation of the velocity profiles with the Casson fluids parameter is displayed in Figure 5. It is observed that there is a marked consequence of raising values of λ on the velocity distribution within the boundary layer. It is observed that the velocity profiles rise with raising λ values.

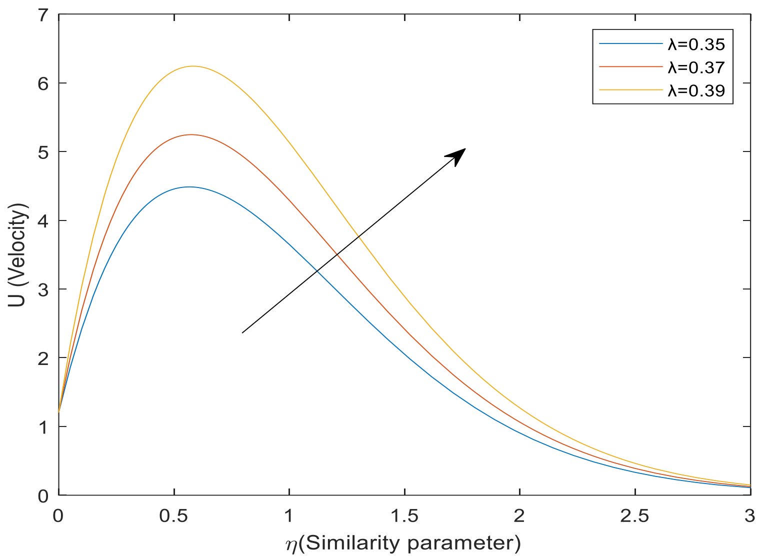

Fig. 5. Velocity profiles for distinct λ values having Gr=5, Pr=0.71, Sc=2.01, Gm=5, R=4, M =0.6, $k = 0.5$, t = 1.1

The effect of the Pr on velocity profiles is demonstrated in Figure 6. It is found that a rise in the Prandtl number leads to declines in the velocity profiles. The Prandtl number's effect on speed is dependent on the relevant movement conditions and thermal transfer mechanisms. In some cases, particularly in forced convection flows where heat transfer is significant.

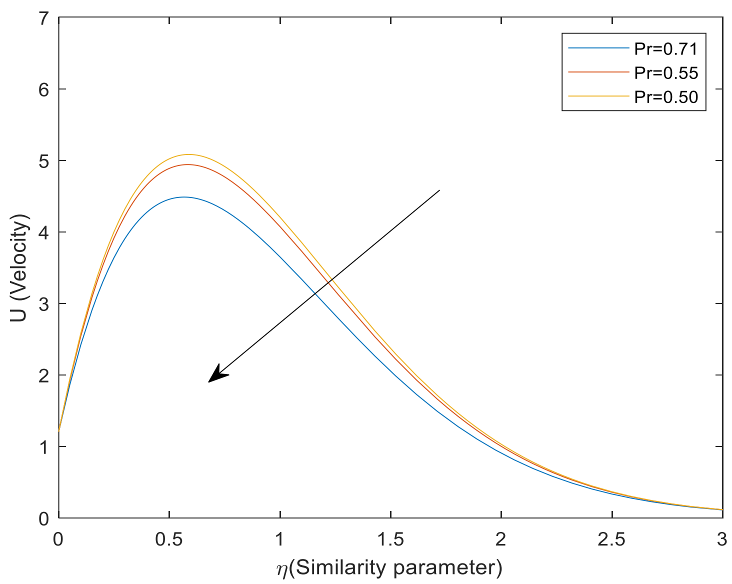

Fig. 6. Profiles of velocity for distinct Pr values *with* Gm=5, Gr=5, R=4, Sc=2.01, $k = 0.5$, $\lambda = 0.35$, t = 1.1

Figure 7 illustrates how the Schmidt number Sc affects the velocity profiles. It is evident that when Sc values rise, the fluid's velocity drops. This can be attributed to the fact that increasing Sc causes a decline in molecular diffusivity, which results in a drop in the velocity boundary layer thickness as well as concentration.

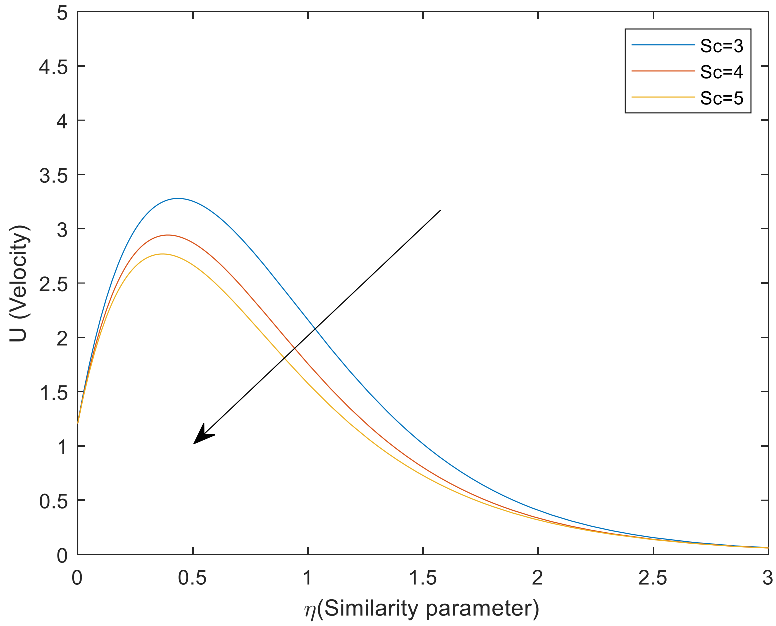

Fig. 7. Velocity profiles for distinct Sc values having Gr=5, Pr=0.71, R=4, Gm=5, M =0.6, $k = 0.5$, $\lambda =\ 0.35$, t = 1.1

The fluctuation of the velocity profiles with porous medium parameter K is exhibited in Figure 8. It is found that the fluid velocity rises with raising the value of pirogue medium parameter. This occurs as a result of buoyancy force, which increases fluid velocity and thickness in the "boundary layer" as k1 rises.

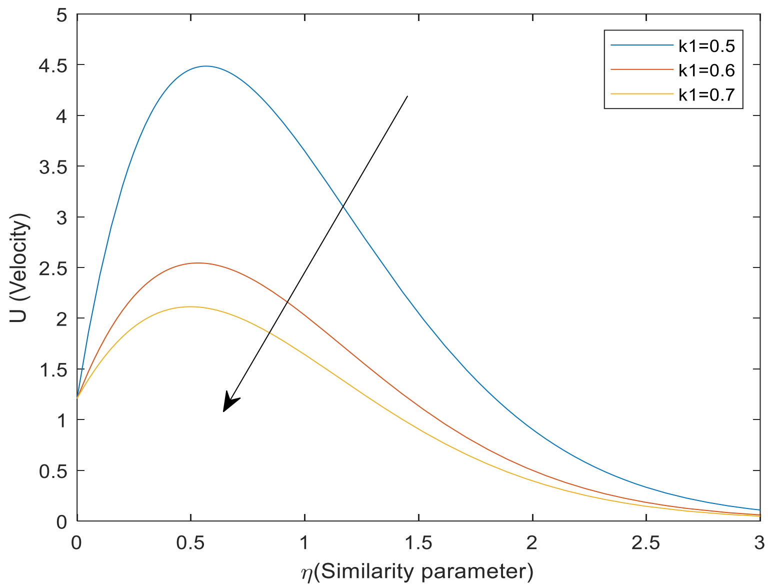

Fig. 8. Velocity profiles for distinct k_1 values having Pr=0.71, Sc=2.01, Gm=5, Gr=5, R=4, M =0.6, $\lambda = 0.35$, t = 1.1

The effect of thermal radiation number R on the profiles of velocity is revealed in Figure 9. It could be found that the fluid velocity decreases with decrement of rising values of the thermal radiation parameter.

Figure 10 displays how the Sc impacts the profiles of concentration. The concentration drops as the Schmidt number increases. A drop in molecular diffusivity, which in turn causes a drop in the concentration boundary layer, is the physical consequence of a rise in the Schmidt number.

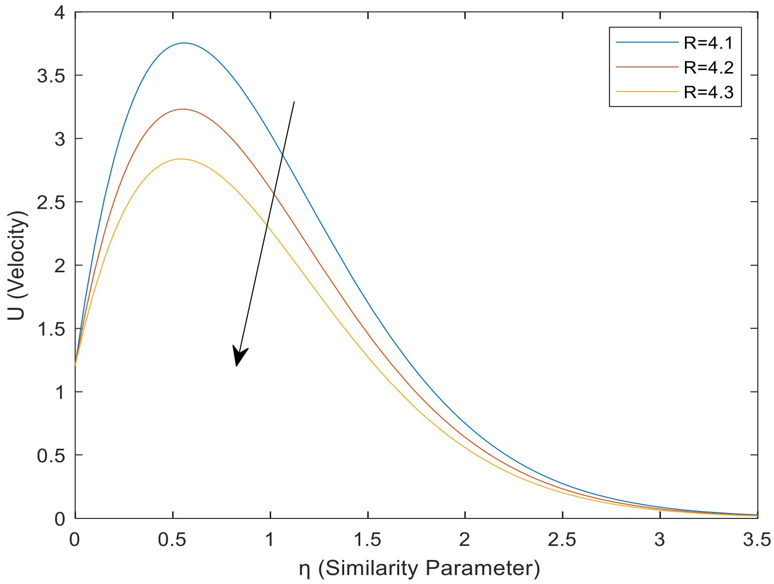

Fig. 9. Velocity profiles for distinct R values *with* Pr=0.71, Gm=Gr=5, Sc=2.01, R=4, M =0.6, $\lambda = 0.35$, t = 1.1

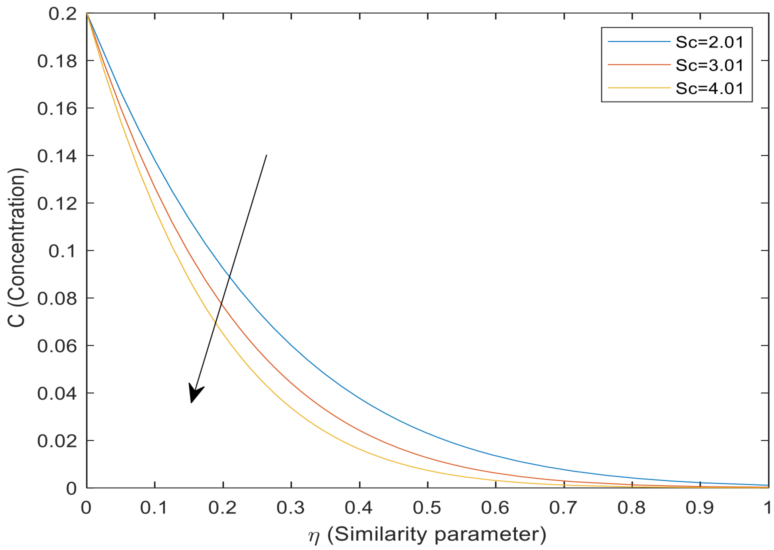

Fig. 10. Concentration profiles for distinct Sc values *with* t=0.2

The concentration profile is displayed in Figure 11 as a function of the time parameter t.(0.4,0.5,0.6) As the time parameter t increases, the concentration profiles become larger.

Figure 12 shows how temperature profiles affect different time values (0.5, 0.6, 0.7) It is noted that when t increases, the wall temperature rises as well.

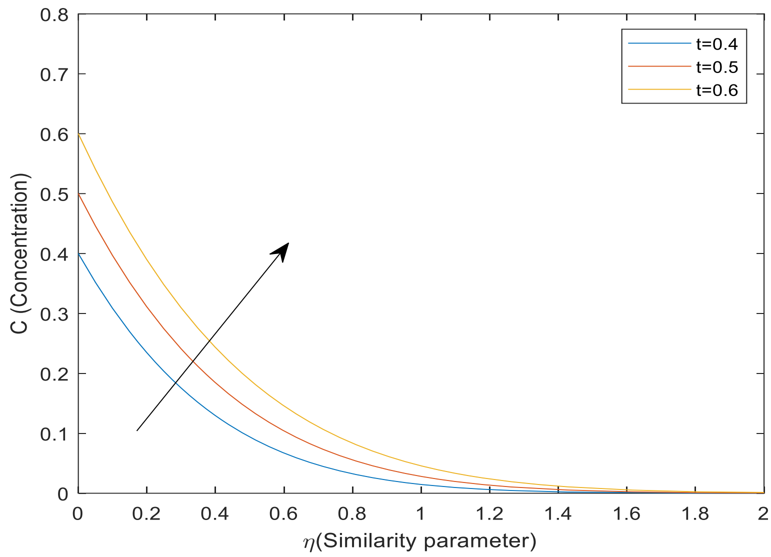

Fig. 11. Profiles of concentration for distinct t values with Sc=2.01

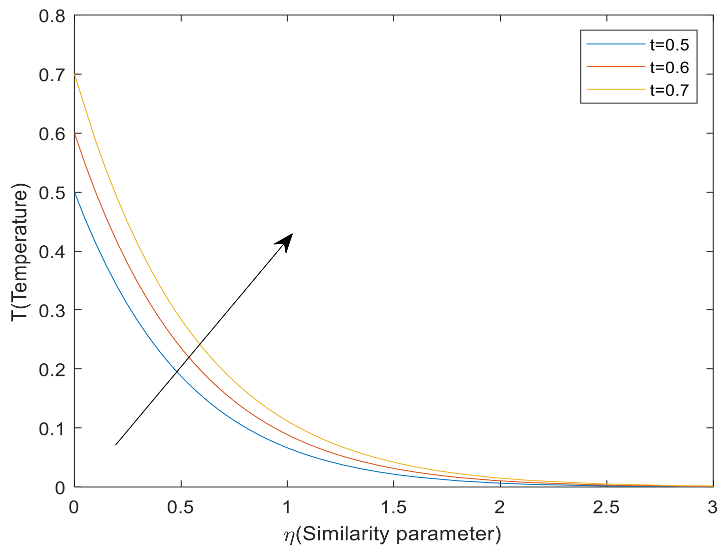

Fig. 12. Temperature Profiles for distinct t values having Pr=0.71, R=2

In Figure 13 examined the temperature response to the Prandtl number is influenced by flow behaviour and boundary conditions. In some cases, a higher Prandtl number can result in less thermal mixing, going to result in higher temperature gradients.

In Figure 14 displayed the effect of radiation on temperature is dependent on the system and the conditions under investigation. In general, higher radiation values can have a greater impact on radiative heat transfer. In the preceding example, as radiation values increase, the temperature curve decreases.

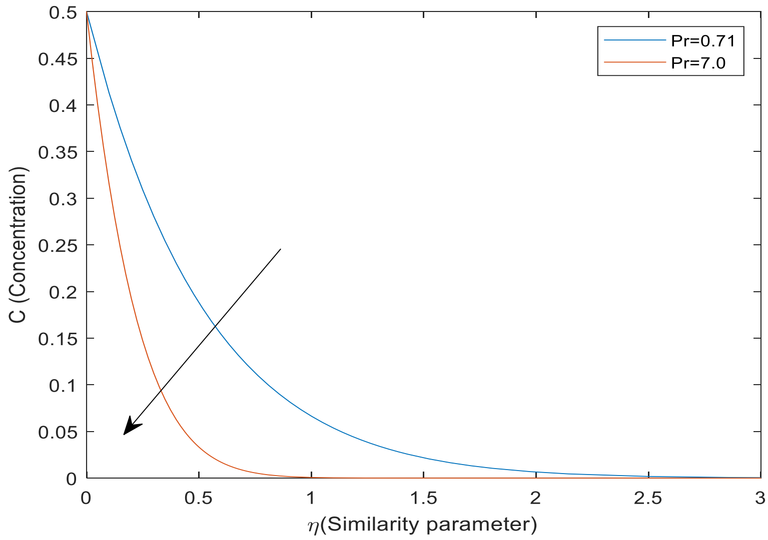

Fig. 13. Profiles of temperature for distinct (Pr) values with t=0.5, R=2

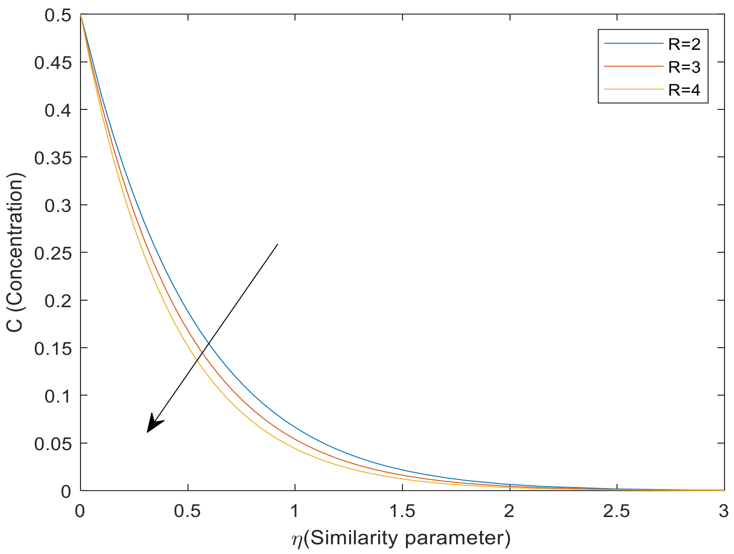

Fig. 14. Temperature profiles for various R values having Pr=0.71, t=0.5

5. Conclusion

The current study investigated the free convection MHD flow of a viscous, chemically reactive, electrically conducted, incompressible, and Casson fluid past a parabolically accelerated vertical plate, as well as the transfer of heat and mass in the incidence of thermal radiation. We obtain exact solutions and numerical results for the fluid flow through the vertical plate described above under the condition of a transverse constant M. The Laplace transform method is used to close the concentration and temperature in order to find the numerical solution of velocity. Using detailed graphics, the effects of the governing parameters—time, Pr, Gr, and Gm—are examined. The following analytical description is given for the concentration, temperature, and velocity profiles

i. Raising the thermal radiation (R) parameter causes the temperature to decrease, but raising the time (t) causes the temperature to rise.
ii. The concentration values are considered high when the Sc decreases, the level rises, and the time elapses.
iii. The velocity rises as Gr, Gm. Additionally, when Sc and Pr increase in value, the velocity lowers. As the M parameter and rotational parameter (λ) are raised, the velocity moves up .

Acknowledgement
I thank my Research Guide, Dr. A. Selvaraj, Professor, Vels University, for his continuous support for the carried research work.

References

[1] Selvaraj, A., S. Dilip Jose, R. Muthucumaraswamy, and S. Karthikeyan. "MHD-parabolic flow past an accelerated isothermal vertical plate with heat and mass diffusion in the presence of rotation." *Materials Today: Proceedings* 46 (2021): 3546-3549. https://doi.org/10.1016/j.matpr.2020.12.499
[2] Khalid, Asma, Ilyas Khan, Arshad Khan, and Sharidan Shafie. "Unsteady MHD free convection flow of Casson fluid past over an oscillating vertical plate embedded in a porous medium." *Engineering Science and Technology, an International Journal* 18, no. 3 (2015): 309-317. https://doi.org/10.1016/j.jestch.2014.12.006
[3] Lakshmikaanth, D., A. Selvaraj, P. Selvaraju, and S. Dilip Jose. "Hall and Heat Source Effects of Flow Past a Parabolic Accelerated Isothermal Vertical Plate in the Presence of Chemical Reaction and Radiation." *JP Journal of Heat and Mass Transfer* 34 (2023): 105-126. https://doi.org/10.17654/0973576323035
[4] Maran, D., A. Selvaraj, M. Usha, and S. Dilipjose. "First order chemical response impact of MHD flow past an infinite vertical plate with in the sight of exponentially with variable mass diffusion and thermal radiation." *Materials Today: Proceedings* 46 (2021): 3302-3307. https://doi.org/10.1016/j.matpr.2020.11.464
[5] Reddy, G. Jithender, R. Srinivasa Raju, and J. Anand Rao. "Influence of viscous dissipation on unsteady MHD natural convective flow of Casson fluid over an oscillating vertical plate via FEM." *Ain Shams Engineering Journal* 9, no. 4 (2018): 1907-1915. https://doi.org/10.1016/j.asej.2016.10.012
[6] Kataria, Hari R., and Harshad R. Patel. "Soret and heat generation effects on MHD Casson fluid flow past an oscillating vertical plate embedded through porous medium." *Alexandria Engineering Journal* 55, no. 3 (2016): 2125-2137. https://doi.org/10.1016/j.aej.2016.06.024
[7] Kataria, Hari R., and Harshad R. Patel. "Radiation and chemical reaction effects on MHD Casson fluid flow past an oscillating vertical plate embedded in porous medium." *Alexandria Engineering Journal* 55, no. 1 (2016): 583-595. http://dx.doi.org/10.1016/j. aej. 2016.01.019
[8] Khan, Kashif Ali, Asma Rashid Butt, and Nauman Raza. "Effects of heat and mass transfer on unsteady boundary layer flow of a chemical reacting Casson fluid." *Results in physics* 8 (2018): 610-620. https://doi.org/10.1016/j.rinp.2017.12.080
[9] Prasad, K. V., K. Vajravelu, Hanumesh Vaidya, Neelufer Z. Basha, and V. Umesh. "Thermal and species concentration of MHD Casson fluid at a vertical sheet in the presence variable fluid properties." *Ain Shams Engineering Journal* 9, no. 4 (2018): 1763-1779. https://doi.org/10.1016/j.asej.2016.08.017
[10] Soundalgekar, V. M., M. R. Patil, and M. D. Jahagirdar. "MHD Stokes problem for a vertical infinite plate with variable temperature." *Nuclear Engineering and design* 64, no. 1 (1981): 39-42. https://doi.org/10.1016/0029-5493(81)90030-3
[11] Muthucumaraswamy, R., and P. Sivakumar. "First order chemical reaction effects on a parabolic flow past an infinite vertical plate with variable temperature and mass diffusion in the presence of thermal radiation." (2006).
[12] ANURADHA, T., A. SELVARAJ, and T. GOWRI. "ANALYSIS OF ROTATIONAL EFFECTS ON FLOW PAST A PARABOLIC ACCELERATED VERTICAL PLATE WITH MASS DIFFUSION IN THE PRESENCE OF THERMAL RADIATION AND CHEMICAL REACTION." (2022).
[13] Aruna, M., A. Selvaraj, and V. Rekha. "Hall and Magnetic Impacts on Stream Past a Parabolic Accelerated Vertical Plate with Varying Heat and Uniform Mass Diffusion in the Appearance of Thermal Radiation." In *International Conference on Advancement in Manufacturing Engineering*, pp. 323-336. Singapore: Springer Nature Singapore, 2022. https://doi.org/10.17654/0973576323035
[14] Muthucumaraswamy, R., and B. Janakiraman. "MHD and radiation effects on moving isothermal vertical plate with variable mass diffusion." *Theoretical and Applied Mechanics* 33, no. 1 (2006): 17-29. https://doi.org/10.2298/TAM0601017M

[15] Vaddemani, Ramachandra Reddy, Raghunath Kodi, and Obulesu Mopuri. "Characteristics of MHD Casson fluid past an inclined vertical porous plate." *Materials Today: Proceedings* 49 (2022): 2136-2142. https://doi.org/10.1016/j.matpr.2021.08.328

[16] Jose, S. Dilip, and A. Selvaraj. "Convective heat and mass transfer effects of rotation on parabolic flow past an accelerated isothermal vertical plate in the presence of chemical reaction of first order." *JP Journal of Heat and Mass Transfer* 24, no. 1 (2021): 191-206. http://dx.doi.org/10.17654/HM024010191

[17] Karthikeyan, S., and A. Selvaraj. "Uniform mass diffusion on thermal radiation with rotation of parabolic in progress vertical plate set MHD." *Materials Today: Proceedings* 51 (2022): 1074-1078. https://doi.org/10.1016/j.matpr.2021.07.098

[18] Hetnarski, R. "On inverting the Laplace transforms connected with the error function." *Applicationes Mathematicae* 4, no. 7 (1964): 399-405. https://doi.org/10.4064/am-7-4-399-405

[19] Mukhopadhyay, Swati, Prativa Ranjan De, Krishnendu Bhattacharyya, and G. C. Layek. "Casson fluid flow over an unsteady stretching surface." *Ain Shams Engineering Journal* 4, no. 4 (2013): 933-938. https://doi.org/10.1016/j.asej.2013.04.004

[20] Siddiqa, Sadia, Naheed Begum, A. Ouazzi, Md Anwar Hossain, and Rama Subba Reddy Gorla. "Heat transfer analysis of Casson dusty fluid flow along a vertical wavy cone with radiating surface." International Journal of Heat and Mass Transfer 127 (2018): 589-596. https://doi.org/10.1016/j.ijheatmasstransfer.2018.08.022

[21] Muthucumaraswamy, R., and B. Janakiraman. "MHD and radiation effects on moving isothermal vertical plate with variable mass diffusion." *Theoretical and Applied Mechanics* 33, no. 1 (2006): 17-29. http://dx.doi.org/10.2298/tam0601017m2

[22] Selvaraj, A., 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* 46 (2021): 3490-3494. https://doi.org/10.1016/j.matpr.2020.11.919

[23] Jothi, E., A. Selvaraj, S. Dilipjose, A. Neel Armstrong, and S. Karthikeyan. "Effect of MHD and Radiation Absorption Fluid Flow Past an Exponentially Accelerated Vertical Plate with Variable Temperature and Concentration." In *Proceedings of First International Conference on Mathematical Modeling and Computational Science: ICMMCS 2020*, pp. 429-439. Springer Singapore, 2021. https://doi.org/10.1007/978-981-33-4389-4_39

[24] Usharani, V., A. Selvaraj, R. Constance Angela, and A. Neel Armstrong. "Impact of MHD Stream Past an Exponentially Inclined Vertical Plate of First-Order Chemical Response with Variable Mass Diffusion and Thermal Radiation." In *Proceedings of First International Conference on Mathematical Modeling and Computational Science: ICMMCS 2020*, pp. 485-497. Springer Singapore, 2021. https://doi.org/10.1007/978-981-33-4389-4_45

[25] Goud, B. Shankar. "Heat generation/absorption influence on steady stretched permeable surface on MHD flow of a micropolar fluid through a porous medium in the presence of variable suction/injection." *International Journal of Thermofluids* 7 (2020): 100044. https://doi.org/10.1016/j.ijft.2020.100044

[26] Goud, B. Shankar, P. Pramod Kumar, and Bala Siddulu Malga. "Effect of heat source on an unsteady MHD free convection flow of Casson fluid past a vertical oscillating plate in porous medium using finite element analysis." *Partial Differential Equations in Applied Mathematics* 2 (2020): 100015. https://doi.org/10.1016/j.padiff.2020.100015

[27] Goud, B. Shankar, P. Pramod Kumar, Bala Siddulu Malga, and Y. Dharmendar Reddy. "FEM to study the radiation, Soret, Dufour numbers effect on heat and mass transfer of magneto-Casson fluid over a vertical permeable plate in the presence of viscous dissipation." *Waves in Random and Complex Media* (2022): 1-22. https://doi.org/10.1080/17455030.2022.2091809

[28] Shankar Goud, Bejawada, Patlolla Pramod Kumar, and Bala Siddulu Malga. "Induced magnetic field effect on MHD free convection flow in nonconducting and conducting vertical microchannel walls." *Heat Transfer* 51, no. 2 (2022): 2201-2218. https://doi.org/10.1002/htj.22396

[29] Rebhi, Redha, Younes Menni, Giulio Lorenzini, and Hijaz Ahmad. "Forced-convection heat transfer in solar collectors and heat exchangers: a review." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 26, no. 3 (2022): 1-15.

[30] Alkasasbeh, Hamzeh, Feras M. Al Faqih, and Abedalrahman S. Shoul. "Computational simulation of magneto convection flow of williamson hybrid nanofluid with thermal radiation effect." *CFD Letters* 15, no. 4 (2023): 92-105. https://doi.org/10.37934/cfdl.15.4.92105

[31] Armstrong, A. Neel, N. Dhanasekar, A. Selvaraj, R. Shanmugapriya, P. K. Hemalatha, and J. Naresh Kumar. "Rotational effect of parabolic flow past in a vertical plate through porous medium with variable temperature and uniform mass diffusion." In *AIP Conference Proceedings*, vol. 2821, no. 1. AIP Publishing, 2023. https://doi.org/10.1063/5.0158630

[32] Khan, Ilyas, Aisha M. Alqahtani, Arshad Khan, Dolat Khan, Abdul Hamid Ganie, and Gohar Ali. "New results of fractal fractional model of drilling nanoliquids with clay nanoparticles." *Fractals* 30, no. 01 (2022): 2250024. https://doi.org/10.1142/S0218348X22500244

[33] Soundalgekar, V. M., S. K. Gupta, and N. S. Birajdar. "Effects of mass transfer and free convection currents on MHD Stokes' problem for a vertical plate." *Nuclear Engineering and Design* 53, no. 3 (1979): 339-346. https://doi.org/10.1016/0029-5493(79)90060-8

[34] Makinde, Oluwole Daniel, and Philip Oladapo Olanrewaju. "Unsteady mixed convection with Soret and Dufour effects past a porous plate moving through a binary mixture of chemically reacting fluid." *Chemical Engineering Communications* 198, no. 7 (2011): 920-938. https://doi.org/10.1080/00986445.2011.545296