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Magneto Hydrodynamic Effects On Unsteady Free Convection Casson Fluid Flow Past On Parabolic Accelerated Vertical Plate With Thermal Radiation And Chemical Reaction

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This article investigates the free convective magnetohydrodynamic (MHD) flow of a viscous, incompressible, chemically reactive, electrically conducting Casson fluid past a parabolically vertical plate, considering thermal radiation and mass transfer. The dimensionless governing equations are solved using the inverse Laplace transform method. The study analyses the effects of several parameters—such as the Casson fluid(λ), Schmidt number (Sc), thermal Grashof number (Gr), Prandtl number (Pr), and mass Grashof number (Gm)—on the temperature, concentration, and velocity fields. The study also suggests using the temperature and species concentration of the fluid as a solution method. Numerical results for velocity, temperature, and concentration profiles illustrate the impacts of these parameters on the flow fields, providing a comprehensive understanding of the physical processes governing MHD Casson fluid flow graphically

Keywords: Magnetohydrodynamics, Thermal Radiation, Casson fluid ,Vertical plate, Chemical reaction

1. Introduction

There are many unknown flow characteristics in the Newtonian fluid model. Studying the non-Newtonian fluid model is therefore convenient. Under the influence of a non-Newtonian fluid, shear stress & shear strain incidence show nonlinear correlations. In mechanical engineering and industry, it is widely applied, particularly in the process of removing crude oil from products that contain petroleum. The Casson liquid represents a critical non-liquid model. It can used in a wide variety of biotechnological, drilling and food preparation applications. The identification of non-Newtonian fluid flow using an acceleration plate in viscous, incompressible, heat-absorbing, and parabolically conductive fluid flow. The radiation and chemical reactions effects on MHD were investigated by Kataria et al. [1]. Casson fluid flow through a vertical plate embedded in an oscillating porous medium. According to Muthucumaraswamy et al. [2], MHD and radiation effects were measured on a moving isothermal vertical plate with variable mass diffusion. Vaddemani et al. [3] reported hypothetical properties of MHD Casson fluid flowing through an inclined vertical porous plate. Muthucumaraswamy et al. [4] examined the effects of first order chemical reactions on a parabolic flow past an infinite vertical plate with variable mass diffusion and temperature in the presence of thermal radiation. Mukhopadhyay et al. discussed Casson fluid flow over an unstable stretching surface. [5]. Siddiqa et al. have proposed a heat transfer analysis of Casson dusty fluid flow along a vertical wavy cone with radiating surface and mass diffusion. [6]. Selvaraj et al. [7] investigated MHD-parabolic flow past an accelerated isothermal vertical plate with heat and mass diffusion in the presence of rotation.

A precise solution for unsteady magnetohydrodynamic free convection flow with constant heat flux method is found by Sacheti Nirmal C et al. [8]. The impact of an MHD stream passing over an exponentially inclined vertical plate with variable mass diffusion along with thermal radiation has been studied by Usharani et al. [9]. Goud et al.'s research [10–11] examined the impact of heat generation and absorption on a steady stretched permeable surface during micropolar fluid MHD flow through a porous medium with variable suction and injection. Effect of heat source on an unsteady MHD free convection flow of Casson fluid past a vertical oscillating plate in porous medium utilizing finite element analysis. In order to investigate the effects of radiation, Soret, and Dufour numbers on the mass and heat transfer of a magneto-Casson fluid over a vertical permeable plate in the presence of viscous dissipation, Goud et al. [12] reviewed the use of FEM. Devi and colleagues [13]investigated and analysed the Convective MHD flow of Casson fluid through a porous medium using the Darcy-Forchheimer model while considering the influence of designated heat sources. Vijayaragavan and V. Bharathi [14] investigated the effects of thermal diffusion and chemical reactions on unsteady MHD free convection using an inclined plate that was exponentially accelerated. The Casson fluid flow and heat transfer past an exponentially porous stretching surface in the presence of thermal radiation have been discussed by Pramanik [15]. The effects of mass transfer and free convection currents on the MHD Stokes problem for a vertical plate were examined by Soundalgekar et al. [16–17], who also assessed the MHD Stokes problem for a vertical plate with varying temperature. MHD free convection flow past an accelerated vertical plate was examined by Raptis et al. [18]. Free convection flow past an exponentially accelerated vertical plate was studied by Singh et al. [19].

The effects of mass transfer on flow past an infinite vertical plate that was started abruptly and had a constant heat flux during a chemical reaction were studied by Das et al. [20]. The idea of the rotational effect of parabolic flow through a porous medium with uniform mass diffusion and variable temperature in a vertical plate was examined by Armstrong et al. [21]. In the presence of rotation, chemical reaction, and thermal radiation, Nandakumar et al.'s study from [22] examined the work effort with the Soret and MHD Effects of Parabolic Flow Past through an Accelerated Vertical Plate with Constant Heat and Mass Diffusion. In the presence of chemical reaction, Kavitha et al. [23] establish a Parabolic Flow with MHD, the Dufour and Rotational Effects of Uniform Temperature, and Mass Diffusion through an Accelerating Vertical Plate. Scientists Muthukumaraswamy R. and P. Ganesan[24] looked into the unsteady flow past a vertical plate that was started abruptly and involved mass and heat transfer. The effects of chemical reaction, heat, and mass transfer on laminar flow along a semi-infinite horizontal plate were studied by Anjalidevi S. P. and R. Kandasamy [25]. Understanding the idea of new findings from the fractal fractional model of drilling nano liquids with clay nanoparticles is provided by Khan et al. [26]. Unsteady mixed convection with Soret and Dufour effects is discussed by Makinde et al. [27] as it passes through a binary mixture of fluids that are chemically reacting through a porous plate. Lakshmikaanth D et al., [28-29] works out the exploration of the Impacts of Hall Effect, Dufour Effect, and Heat Source on Parabolic Flow over an Infinite Vertical Plate in the Presence of Rotation, Chemical Reaction, and Radiation in a Porous Medium also studied Hall with Heat Source Effects of Flow State on a Vertically Accelerating Plate in an Isothermal Environment, Including Chemical Reactions, Rotation, Radiation, And the Dufour Effect. Dhanalakshmi et al., [30] studied the "Stability of bonds, kinetic stability, energy parameters, spectral characterization, GC–MS and molecular descriptors studies on coumarine, 3-[2-(1-methyl-2-imidazolylthio)-1-oxoethyl]". In the field study Unraveling the Complexities of Thermal Radiation and Rotational Dynamics in Parabolic Flow, Sebastian, Dilip Jose, et al., [31] conducted research. The first order chemical response impact of MHD flow past an infinite vertical plate within the sight of exponentially changing mass diffusion and thermal radiation was examined by Maran et al. [32].

2. Mathematical Analysis

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, $\bar{x}$ axis along the plate in an upward direction, $\bar{y}$-axis normal to the plate, as well as $\bar{z}$ -axis vertical to the, $\bar{x}\,\bar{y}$ -plane. The fluid is permitted by the same transverse magnetic field B_0, this is employed diagonally to the $\bar{y}$-axis. We assume that at the time $\bar{t} \le 0$, both plate as well as fluid are at rest and kept at an even surface concentration $\bar{C}_\infty$ anduniform temperature $\bar{T}_\infty$. At time $\bar{t} \ge 0$, the plate starts to move in $\bar{x}$-direction against gravitational field along with time-dependent velocity $\bar{u}$. Plate temp. is decreased or increased to $\bar{T}_\infty + (\bar{T}_w - \bar{T}_\infty)\frac{{u_0}^2\bar{t}}{v}$ at $\bar{t} \ge 0$ 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 $\bar{t} \ge 0$.
The rheological state eq. for Cauchy stress tensor of Casson fluid is" presented below

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

(1) (

With the conditions we get the following equation for concentration, temperature and velocity the initial boundary conditions are listed below.

$$\frac{\partial \bar{u}}{\partial \bar{t}} = \frac{\mu_B}{\rho}\left(\frac{1}{1+\lambda}\right)\frac{\partial^2 \bar{u}}{\partial \bar{y}^2} - \frac{\mu \bar{u}}{\rho \bar{k}_1} - \frac{\sigma {B_0}^2 \bar{u}}{\rho} + g\beta(\bar{T} - \bar{T}_\infty) + g\beta_c(\bar{C} - \bar{C}_\infty) \quad (2)$$

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

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

Boundary conditions for flows are expressed as

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

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

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

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

$\bar{u} \to 0, \bar{T} \to \overline{T_\infty},\ \bar{C} \to \overline{C_\infty}$ 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

$$\bar{T}^4 = 4{\bar{T}_\infty}^3\,\bar{T} - 3{\bar{T}_\infty}^4 \quad (7)$$

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

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

The following definitions apply to the dimensionless parameters and variables.

$$y = \frac{\bar{y}u_0}{v},\ u = \frac{\bar{u}}{u_0},\ t = \frac{{u_0}^2\bar{t}}{v},\ T = \frac{\bar{T}-\bar{T}_\infty}{\bar{T}_w-\bar{T}_\infty}\ \ C = \frac{\bar{C}-\bar{C}_\infty}{\bar{C}_w-\bar{C}_\infty},\ \mu = \rho v,\ k_1 = \frac{{u_0}^2\bar{k}_1}{v^2}, P_{r=}\frac{\mu c_p}{k} \quad (9)$$

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

We have the dimensionless version of the following governing equation.

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

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

$$\frac{\partial^2 C}{\partial y^2} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} - KC$$
(12)

and corresponding boundary conditions become

$$U = 0, T = 0, C = 0 \; for \; y \geq 0 \; and \; t \leq 0$$
$$U = t^2, T = 1, C = 1 \; at \; y = 0 \; for \; t \geq 0$$
(13)
$$T \to 0, U \to 0, C \to 0 \; as \; y \to \infty \; for \; t > 0$$

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

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

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

$$\frac{\partial^2 C}{\partial y^2} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} - KC$$
(16)

3. Method of Solution

The concentration, velocity, and temperature of the fluid can be precisely determined by applying the Laplace transform method to the dimensionless governing equations (14)–(16) in accordance with the boundary conditions (13). This solution can then be found via the following path.

$$C = \frac{t}{2}\left[exp\left(-y\sqrt{KS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} - \sqrt{Kt}\right) + exp\left(y\sqrt{KS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} + \sqrt{Kt}\right)\right] \quad (17)$$

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

$$U = \left(\frac{y^2}{8mn} + \frac{t^2}{2}\right)\begin{bmatrix} exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ + exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right) \end{bmatrix}$$
(19)

$$+ \frac{y}{2\sqrt{mn}}\left(\frac{1}{4n} - t\right)\begin{bmatrix} exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} - \sqrt{nt}\right) \\ - exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right) erfc\left(\frac{y}{2\sqrt{mt}} + \sqrt{nt}\right) \end{bmatrix}$$

$$-\frac{y\sqrt{t}}{2n\sqrt{m\pi}}exp\left(-\frac{y^2}{4mt}-nt\right)$$

$$+A_1\left[exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{nt}\right)++exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{nt}\right)\right]$$

$$+A_2\left[exp\left(\frac{-y\sqrt{a+n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{(a+n)t}\right)+exp\left(\frac{y\sqrt{a+n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{(a+n)t}\right)\right]$$

$$+A_3\left[exp\left(\frac{-y\sqrt{n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{nt}\right)++exp\left(\frac{y\sqrt{n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{nt}\right)\right]$$

$$+A_4\left[exp\left(\frac{-y\sqrt{b+n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}-\sqrt{(b+n)t}\right)+exp\left(\frac{y\sqrt{b+n}}{\sqrt{m}}\right)erfc\left(\frac{y}{2\sqrt{mt}}+\sqrt{(b+n)t}\right)\right]$$

$$+A_5\left[exp\left(-y\sqrt{R}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}-\sqrt{\frac{Rt}{P_r}}\right)+exp\left(y\sqrt{R}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}+\sqrt{\frac{Rt}{P_r}}\right)\right]$$

$$+A_6\left[\begin{matrix}exp\left(-y\sqrt{R+aP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}-\sqrt{\left(a+\frac{R}{P_r}\right)t}\right)\\+exp\left(y\sqrt{R+aP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}+\sqrt{\left(a+\frac{R}{P_r}\right)t}\right)\end{matrix}\right]$$

$$+A_7\left[exp\left(-y\sqrt{S_cR}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}-\sqrt{Rt}\right)+exp\left(y\sqrt{S_cR}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}+\sqrt{Rt}\right)\right]$$

$$+A_8\left[\begin{matrix}exp\left(-y\sqrt{S_c(R+b}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}-\sqrt{(R+b)t}\right)\\+exp\left(y\sqrt{S_c(R+b}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}+\sqrt{(R+b)t}\right)\end{matrix}\right]$$

3. Results & Discussion

Determining the effects of radiation on the intensity and mass transport properties of MHD is probably the study's main goal. For different values of the flow parameters, including the temperature (T), concentration (C), velocity (U), and Schmidt number (Sc), as well as the thermal radiation parameters (R), Casson fluid flow and numerical results are presented with the boundary layer. In general, the parameters are determined by the values mentioned below

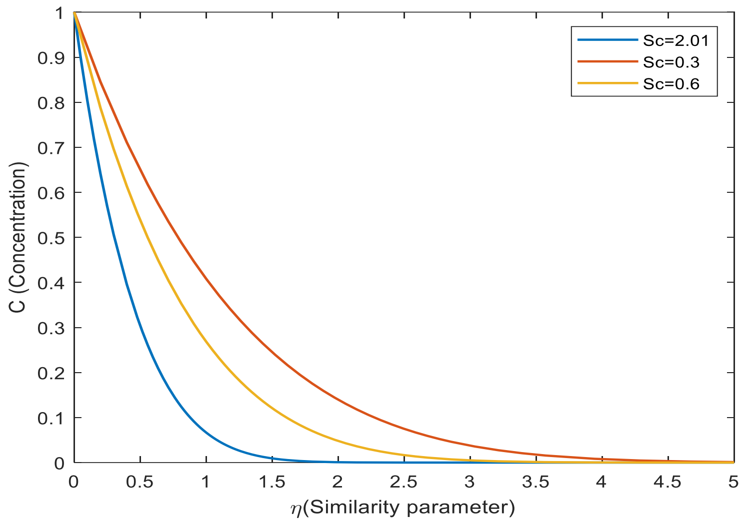

Fig. 1— Concentration profiles for distinct Sc values with t=0.4

Fig.1 This explains how the "concentration profile" is affected by the Schmidt number Sc. The concentration falls as the Schmidt number Sc rises. Physically, increasing the number of Sc decreases molecular diffusion, thereby reducing the concentration boundaries layer. The results show that species concentrations are highest at low Sc and lowest at high Sc

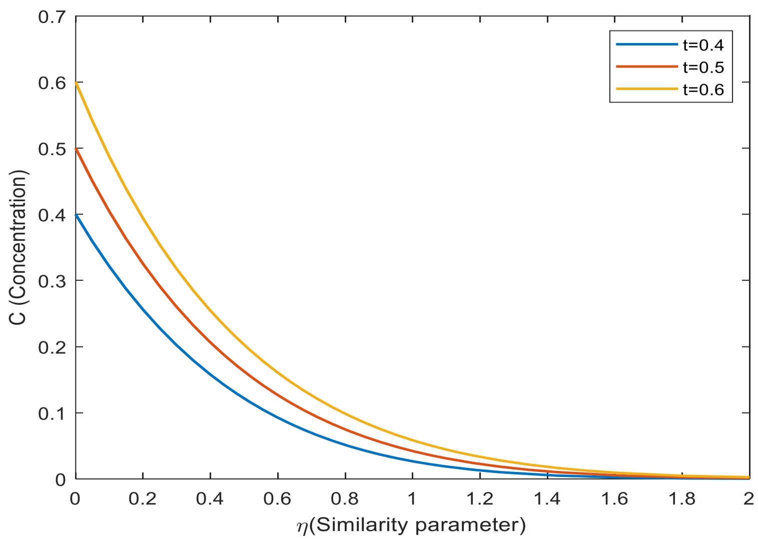

Fig. 2— Profiles of concentration for distinct t values with Sc=2.01,

Fig.2 The concentration (C) profiles get bigger as the time parameter (t) increases, indicating that the diffusion process gets stronger over time. Higher C values and a wider concentration distribution are the results of this throughout the fluid domain. Increasing t permits particles to diffuse from higher to lower concentrations, resulting in bigger and more important concentration profiles with time

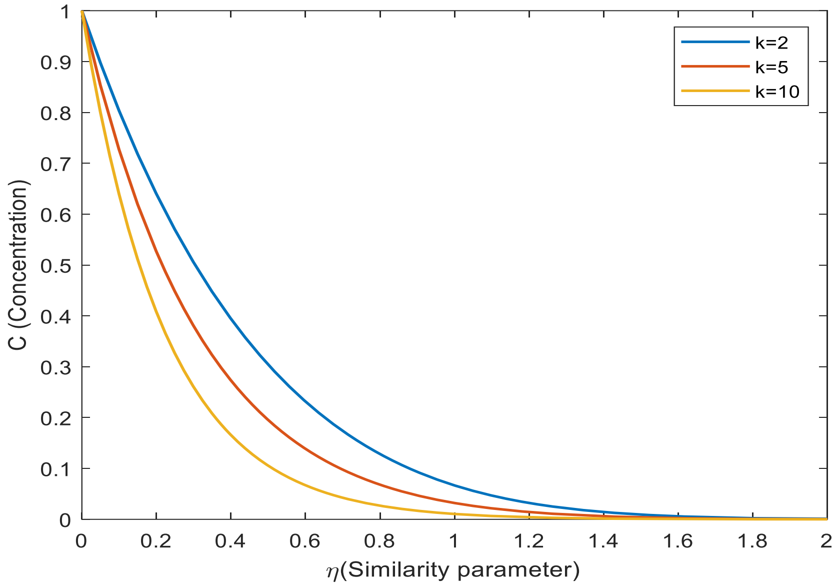

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Fig. 3 — Profiles of concentration for distinct k values with Sc=2.01,

Fig.3 depicts how k influences the "concentration profiles". The concentration decreases significantly as the value of k increases.

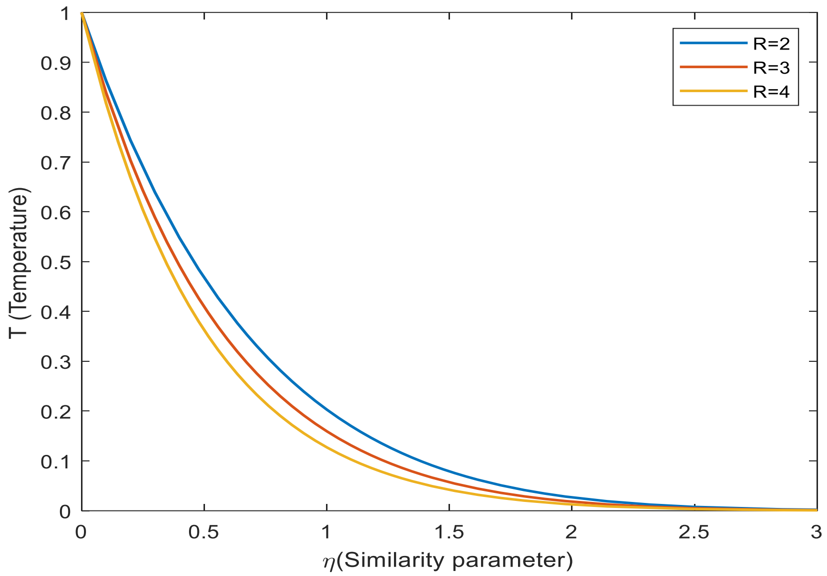

Fig. 4 — Temperature profiles for various R values having Pr=0.71, t=0.4

Fig.4 The influence of radiation on temperature depends on the system and the conditions examined. In general, higher radiation levels can have a greater impact on radiant heat transfer. In the previous example, the temperature curve decreases as radiation levels increase.

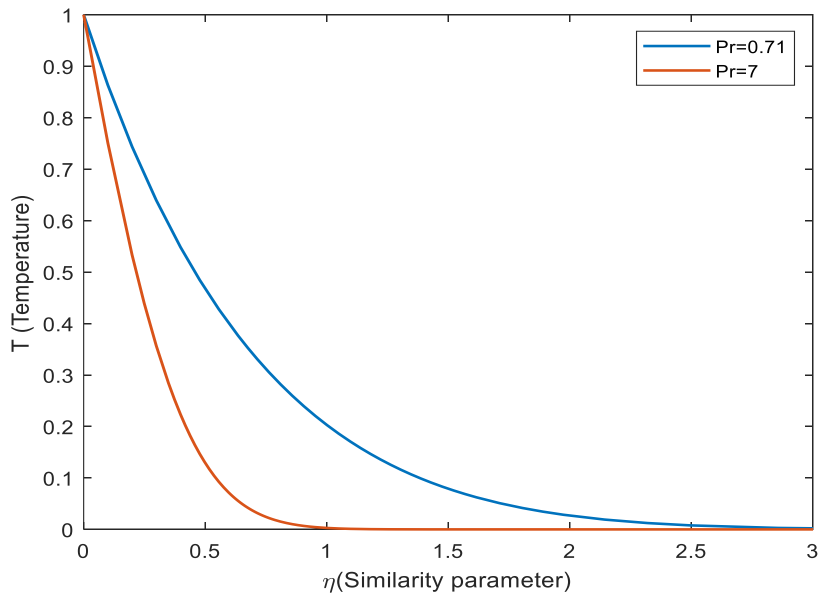

Fig. 5 — Profiles of temperature for distinct (Pr) values with t=0.4, R=2.

Fig.5 The temperature response to the Prandtl number is influenced by the flow behaviour and the boundary conditions. In some cases, a higher Prandtl number can lead to less thermal mixing and thus higher temperature gradients.

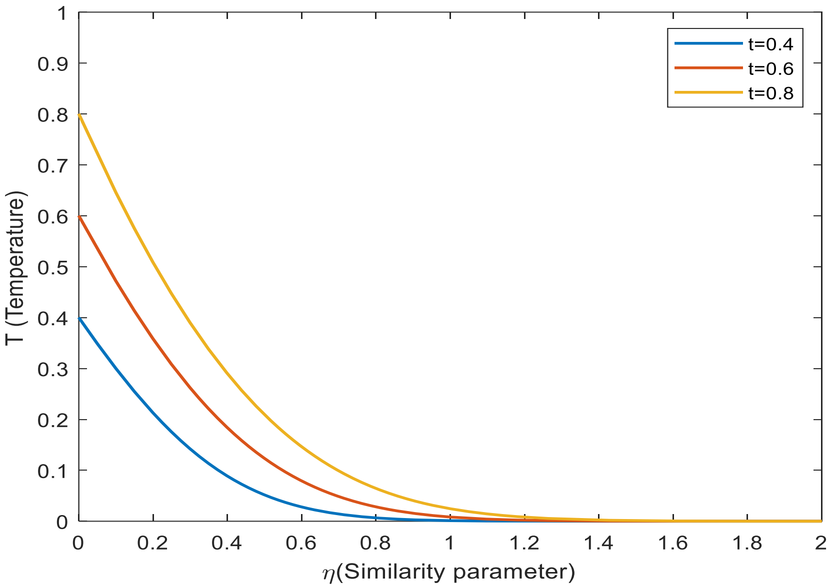

Fig. 6 — Temperature Profiles for distinct t values having Pr=0.71, R=2

The temperature is shown in Fig.6 as a function of the time parameter t. As the time parameter t increases, the temperature profiles become larger.

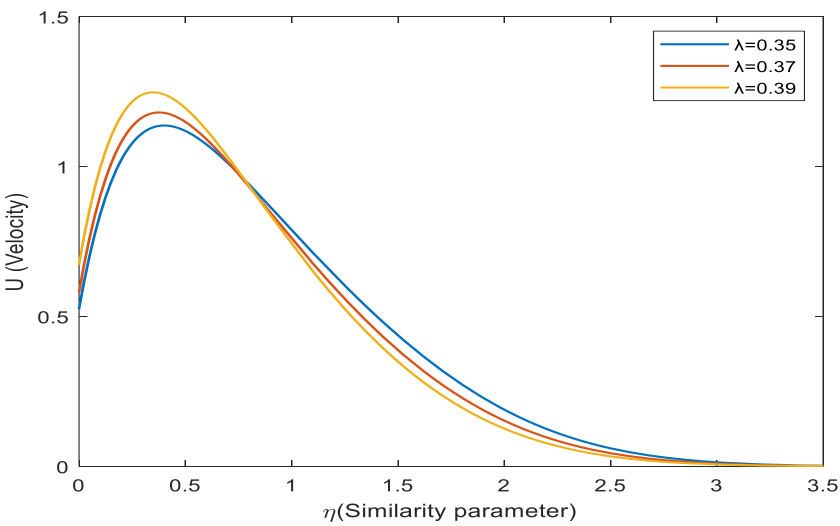

Fig. 7— Velocity profiles for distinct λ values having Gr=5, Pr=0.71, Sc=2.01, Gm=5, R=4, M =0.6, t = 0.4

As shown in Fig. 7, the Casson fluid component influences the velocity curves (profiles). hence the thickness of the velocity confinement layer

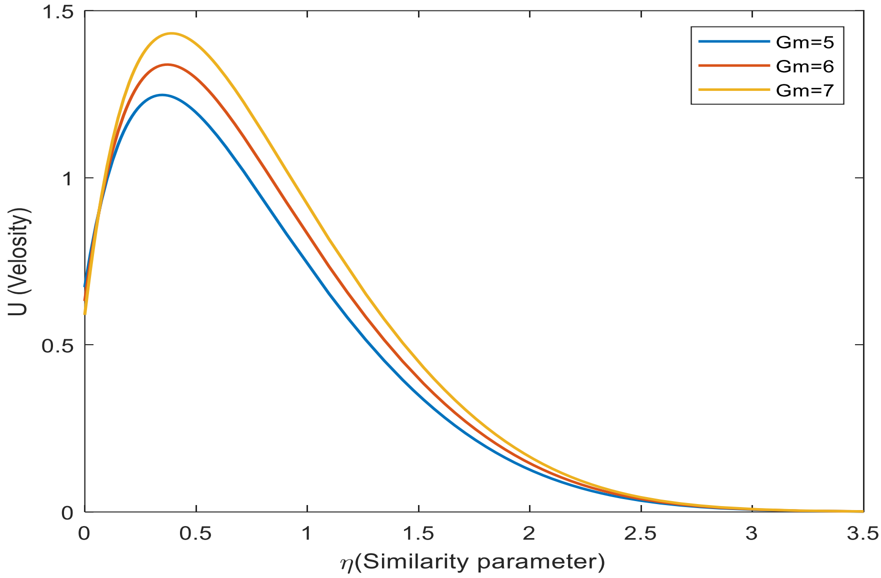

Fig. 8— Profiles of velocity for distinct Gm values having Gr=5, Sc=2.01, R=4, Pr=0.71, M =0.6, $\lambda = 0.35$, t = 0.4

Under these conditions, higher mass grazing rates promote higher velocity levels and stronger convective motion

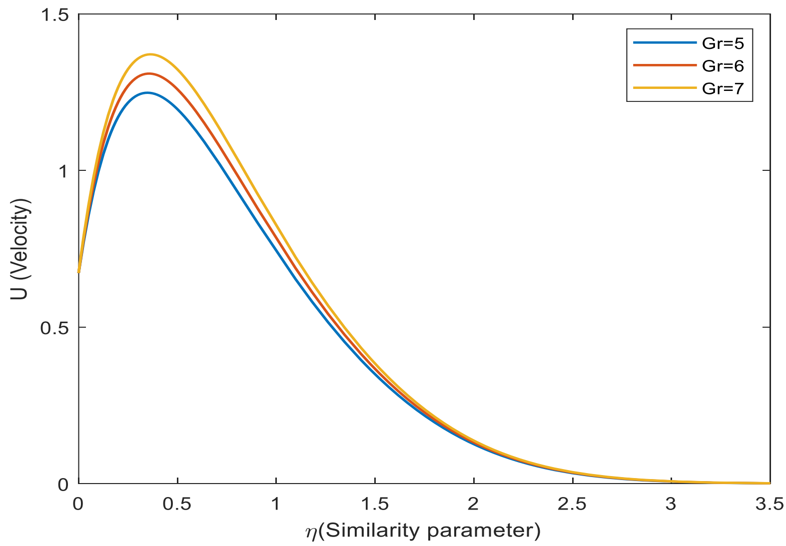

Fig.9—Velocity profiles for distinct Gr values having Sc=2.01, Pr=0.71, R =4, M =0.6,$\lambda = 0.35$,t = 0.4

In summary, stronger convective motion could be caused by an increase in the thermal Grasshopper number, which could lead to higher flow.

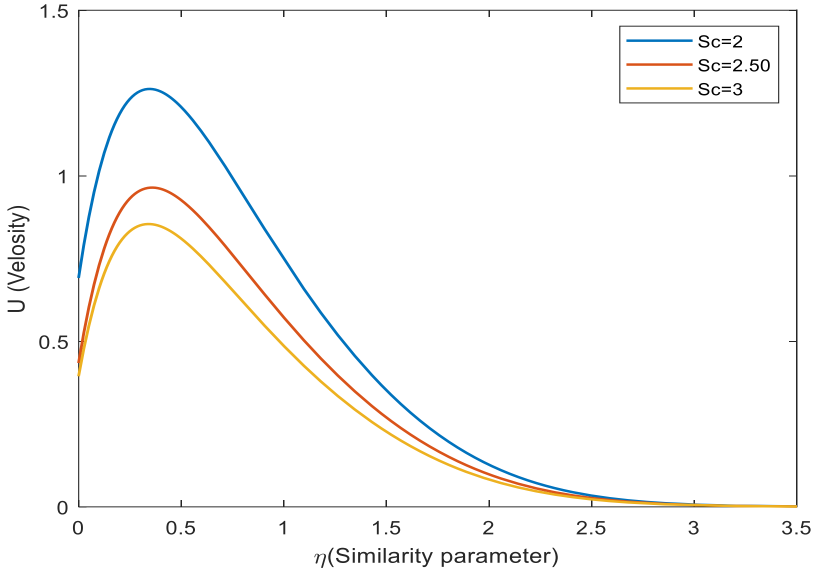

Fig. 10— Velocity profiles for distinct Sc values having Gr=5, Pr=0.71, R=4, Gm=5, M =0.6,$\lambda = 0.35$,t = 0.4

The effect of the Sc (Schmidt) values on the velocity depends on the flow conditions, boundary parameters and the properties of the mass transfer process. In some cases, an increase in Schmidt numbers can lead to a decrease in velocity.

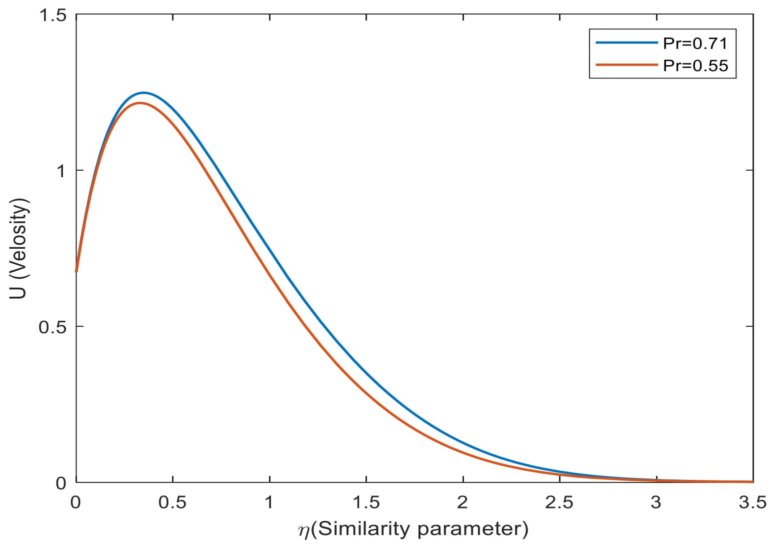

Fig. 11— Profiles of velocity for distinct Pr values with Gm=5, Gr=5, R=4, Sc=2.01, k = 0.5,$\lambda = 0.35$,t = 0.4

The influence of the Prandtl number on the speed depends on the respective motion conditions and heat transfer mechanisms. In some cases, particularly in forced convection flows where heat transfer is significant, an increase in Pr a result in a reduction in velocity. This phenomenon occurs because slower velocity diffusion is associated with higher Prandtl numbers.

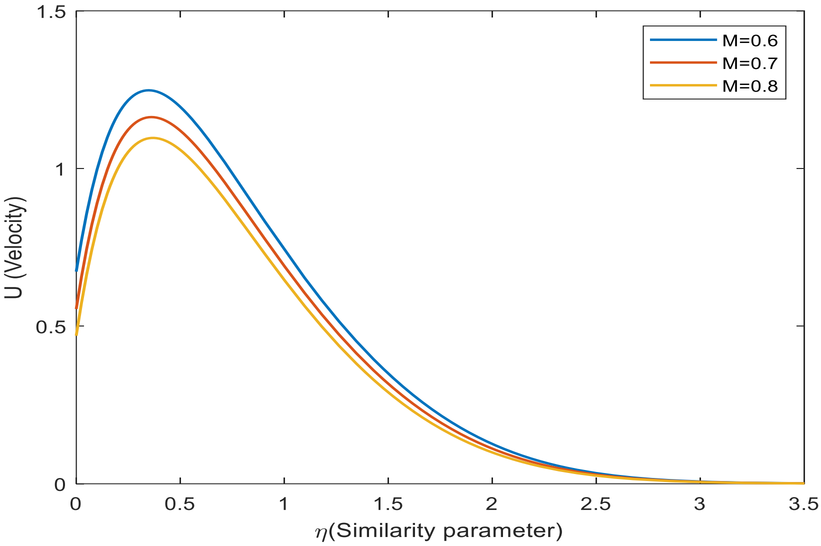

Fig. 12—Velocity profiles for distinct M values having Gm=5, Sc=2.01, Gr=5, Pr =0.71, R=4, $\lambda = 0.35$, t = 0.4

The influence of a magnetic field on fluid motion is measured using Hartmann values, which specifically measure the reduction in velocity fluctuations due to the Lorentz force of the magnetic field.

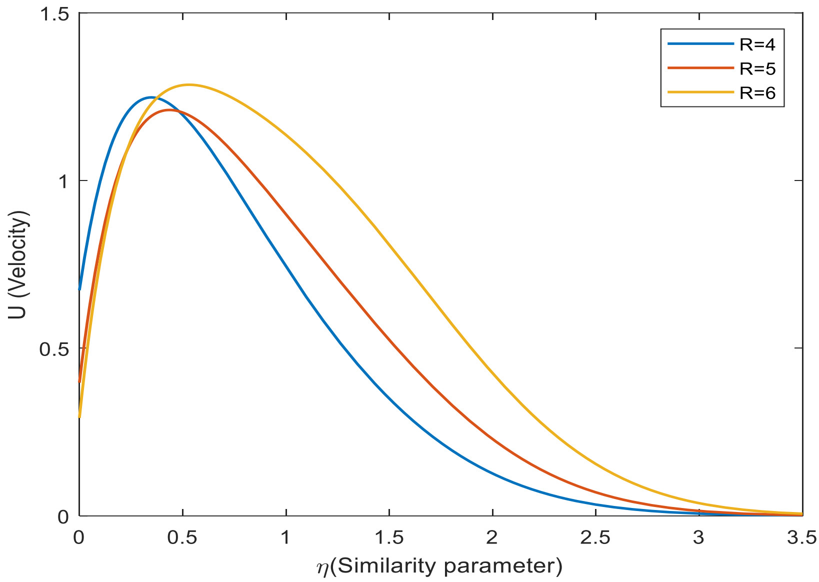

Fig. 13— Velocity profiles for distinct R values with Pr=0.71, Gm=Gr=5,Sc=2.01,R=4, M =0.6, $\lambda = 0.35$,t = 0.4

While radiative heat transfer typically does not directly affect the flow rate of fluids, it can affect the distribution of heat in a system.

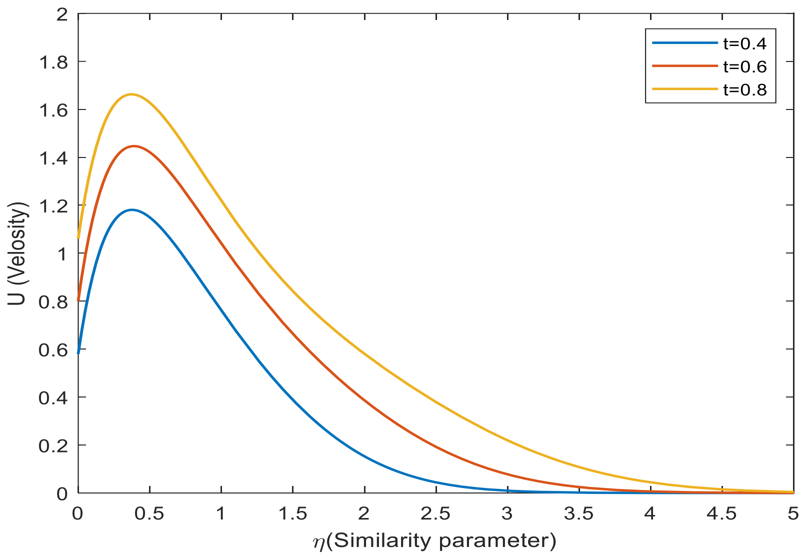

Fig. 14— Velocity profiles for distinct t values with Pr=0.71, Gm=Gr=5, Sc=2.01,R=4, M =0.6, $\lambda = 0.35$

Fig.14 shows how the time parameter t influences the speed U. The velocity profiles become larger as the time parameter t increases.

4. Conclusion

This study examined the free convective MHD flow of a viscous, chemically reactive, electrically conductive, incompressible, and Casson fluid past a parabolically accelerated vertical plate, as well as heat and mass transfer upon incident thermal radiation and mass diffusion. If a transverse constant M is satisfied, the fluid flow through the vertical plate as described above produces precise solutions and numerical results. Temperature and concentration are inferred using the Laplace transform method, which leads to the numerical solution of velocity. In-depth graphic analysis is performed to examine the impacts of time, Pr, Gr, and Gm, among other pertinent parameters. The analytical description of the temperature, velocity, and concentration profiles is as follows

- A temperature increase is induced by increasing the time (t) but a temperature decrease is caused by increasing the thermal radiation (R) parameter.
- A concentration value is deemed high when the Sc falls, the level increases, and the time interval passes
- Gr and Gm rise in tandem with the velocity. Moreover, the velocity decreases as the values of Sc and M rise. The speed increases as Pr are increased.

Nomenclature

Tw	Plate temperature	$\bar{T}_\infty$	fluid temperature far away from the plate
T	Dimensionless fluid Temperature	λ	Casson fluid parameter
Sc	Schmidt number	θ	Inclination angle from the vertical direction
R	Radiation parameter	Q_0	Dimensionless heat source
qr	Radiative heat fluxes in the - y direction	σ	Electric conductivity
Pr	Prandtl number	ρ	Density of the fluid
M	Magnetic field parameter	v	Kinematic viscosity
Gm	Mass Grash of number	μ	Viscosity coefficient
Gr	Thermal Grashof number	Q_0	Dimensionless heat source
B_0	Magnetic field	β	Volumetric coefficients of concentration expansion
g	Acceleration because of gravity	βT	Thermal expansion volumetric coefficient
Cp	Specific heat at constant pressure	k_0	Thermal conductivity of the fluid
$\bar{C}_\infty$	Fluid concentration for away from the plate	$\bar{y}$	Coordinate axis normal to the plate
Cw	Plate Concentration Species	U	Dimensionless velocity
$\overline{k1}$	Porous medium permeability	$\bar{u}$	Velocity fluid in the $\bar{y}$ direction
K1	Permeability parameter	$\bar{t}$	Dimensionless time
$\bar{C}$	concentration	u_0	Velocity of the plate

C	Dimensionless concentration	Y	Dimensionless Coordinate axis normal to the plate

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Appendix

erfc – Complementary error function.

$$L^{-1}\left(\frac{1}{S\sqrt{S+1}}\right) = erfc\left(\sqrt{t}\right), \quad L^{-1}\left(\frac{e^{\frac{s^2}{4}}}{S}\ erfc\ \frac{s}{2}\right) = erfc\left(\sqrt{t}\right).$$

$$m = \left(\frac{1}{1+\lambda}\right),\ n = \frac{(Mk_1+1)}{k_1},\ A_1 = \frac{G_r}{2a(1-mP_r)} \quad A_2 = -A_1e^{at} \quad A_3 = \frac{G_m}{2b(1-mS_c)} \quad A_4 = -A_3e^{bt}$$

$$A_5 = -A_1 \quad A_6 = -A_2 \quad A_7 = -A_3 \quad A_8 = -A_4$$

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