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Transient MHD Flows Through an Exponentially Accelerated Isothermal Vertical Plate with Viscous Dissipation and Heat Source Embedded in a Porous Medium

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ABSTRACT

In this article, an unsteady free convection flow of an incompressible viscous fluid past an exponentially accelerated isothermal vertical plate in the presence of the viscous dissipation and heat source is observed. The problem is governed by coupled nonlinear partial differential equations. Dimensionless equations of the problem have been solved numerically by the Galerkin finite element method. The effect of magnetic parameter M, Grashof number Gr, Eckert number Ec, time and an acceleration parameter 'a' on velocity, temperature fields are investigated through graphs. Skin friction coefficient is derived, discussed numerically.

1. Introduction

The heat transfer enhancement is one of the most important technical aims for engineering systems due to its wide applications in electronics, cooling systems, fire and combustion modelling, development of metal waste from spent nuclear fuel, next-generation solar film collectors, heat exchangers technology, applications in the field of nuclear energy and various thermal systems. Magneto-hydrodynamics with mass and heat transfer in the presence of radiation and diffusion has attracted the attention of a large number of scholars due to diverse applications in astrophysics and geophysics. Quick efforts have been made to learn the effects of porous media by both experimentally and theoretically. Simple flow is interested in the flow of water through agricultural engineering, groundwater sources and drainage, marine engineering, natural gas, oil, oil refining and refining processes. For petroleum extraction processes, it is important to stream porous media. In addition to contributing to existing knowledge. Many problems have significant practical significance. Porous materials used due to the efficiency of applied automated engineering, remediation and

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modern applications, as the principle of rolled liquid is very important because it used there are many natural events and a state worthy of being governed by the Coriolis forces directly. The broad areas of Oceanography, Meteorology, and Limnology and Atmospheric science all contain some important and essential features of rotating fluids. The combination of heat and mass transfer with radiation effects and chemical reactions is very important in many processes, so it has received ‘‘great attention in recent years. In processes such as drying, evaporation of the water surface, energy transfer in wet cooling towers and current transfer in desert coolers, heat and mass transfer occur simultaneously. Possible uses for this kind of traffic can be found in many industries. For example, in the power industry, one of the methods’’ to generate electrical energy is to directly extract electrical energy from a moving conductive liquid. Many practical diffusion operations involve one type of molecular diffusion in the presence of chemical reactions within or at the boundary. The effect of radiation on the flow of MHD has important applications in industries related to heat and mass transfer phenomena. Radiation effects play an important role in handling high temperature operations. The combined effects of radiation, chemical reactions and heat transfer are very important to the design of the equipment. Nuclear power plants, gas turbines, missiles and various propulsion devices for aircraft, spacecraft and satellite are examples of such engineering fields. Double diffusive convection in porous media also occurs in many ‘‘geophysical, geothermal and industrial applications, such as the diffusion of chemical pollutants through water-saturated soil and the migration of moisture through’’ the air contained in fibre insulation [1,2]. Some eminent authors discussed the flow of electrically conducting liquids in different configurations [3-7]. The rotating flow of an electrically conducting fluid in the presence of a magnetic fluid is encountered in cosmical, geophysical fluid dynamics. Also, in solar physics involved in the sunspot development, the solar cycle and the structure of rotating magnetic stars. The study of MHD viscous flows with Hall currents has important engineering applications in problems of MHD generators, Hall accelerators as well as in flight magneto hydrodynamics. as in -flight magneto hydrodynamics. The effect of Hall currents on a hydro magnetic flow near an accelerated plate was studied by Pop [8]. Rotation effects on a hydro magnetic free convective flow past an accelerated isothermal vertical plate were studied by Raptis and Singh [9].

Seth and Ansari [10] studied hydro magnetic natural convection flow of a viscous incompressible electrically conducting and heat absorbing fluid past an impulsively moving vertical plate with ramped wall temperature in a porous medium, in the presence of thermal diffusion. Pal and Talukdar [11] studied the interaction of convection and thermal radiation on unsteady hydro magnetic heat and mass transfer flow past a semi-infinite vertical moving plate embedded in a porous medium in the presence of heat absorption and first order chemical reaction. The effects of thermal radiation and heat source on an unsteady MHD free convection flow past an infinite vertical plate with thermal diffusion and diffusion thermo was analyzed by Raju *et al.,* [12] and Prakash *et al.,* [13] examined the effects of diffusion-thermo and radiation on unsteady MHD free convective flow with variable temperature and mass diffusion. In all the above studies, the stationary vertical plate is considered. Ramana Reddy *et al.,*[14] also studied the Soret, radiation and chemical reaction effects on laminar convective flow of a dusty viscous fluid of non-conducting walls in presence of transverse magnetic field. Flow of a conducting dusty fluid due to linearly stretching cylinder immersed in a porous media with the effect of radiation was analyzed by Manjunatha *et al.,* [15]. The influence of heat generation from two vertical plates on the hydro magnetic convective flow of nanofluid was presented by Prakash and Suriyakumar [16]. For the study of the effect of the heat flux and heat source on free convection of nanofluid over an accelerated plate was analyzed by Azhar *et al.,* [17]. The analysis of the effect of Hall current on the convection in Radiative magneto nanofluid is shown by Sharma *et al.,* [18]. Rao *et al.,* [19] have analyzed the effect of chemical reaction on an unsteady MHD free convective flow past an infinite vertical porous plate in the presence of constant suction and heat source. Approximate solutions have been derived for velocity, temperature, concentration profiles, skin friction, rate of heat transfer and rate of mass transfer using finite element method. Reddy [20] discussed chemical reaction effects on transient MHD flow with mass transfer past an impulsively fixed infinite vertical plate in the presence of thermal radiation. Krishna *et al.,* [21] discussed Radiative MHD flow of Casson hybrid nanofluid over an infinite exponentially accelerated vertical porous surface. Ahammad and Krishna [22] analyzed numerical investigation of chemical reaction, Soret and Dufour impacts on MHD free convective gyrating flow through a vertical porous channel. Krishna and Chamkha [23] studied Hall and ion slip effects on MHD rotating boundary layer flow of nano fluid past an infinite vertical plate embedded in a porous medium. Krishna *et al.,* [24] discussed Hall and ion slip effects on MHD rotating flow of ciliary propulsion of microscopic organism through porous media. Krishna and Chamkha [25] analyzed Hall and ion slip effects on MHD rotating flow of elastico-viscous fluid through porous medium. Reddy *et al.,* [26] are discussed 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. Asogwa *et al.,*[27] non-Newtonian electromagnetic fluid flow through a slanted parabolic started Riga surface with ramped energy.

The object of the present paper is to study the unsteady free convection flow of an incompressible viscous fluid past an exponentially accelerated isothermal vertical plate in the presence of the viscous dissipation and heat source. Here the effects of viscous dissipation and heat source effects are studied. Observed that the temperature increases with increase in viscous dissipation, temperature decreases with increase in heat source parameter. The dimensionless governing equations are solved numerically by using Galerkin Finite Element Method.

2. Mathematical Model

Figure 1 shows the geometry of the flow under consideration. Consider the viscosity of an infinite isothermal vertical plate and the transient MHD flow of an incompressible fluid in a three-dimensional coordinate system (x, y, z) in the presence of heat radiation and heat transfer. The x '-axis is taken along the plate in the vertically upward direction and the y ' – axis is taken normal to the plate. In the parallel z'-axis direction, a uniform gradient magnetic field Bo is applied. The plate and fluid rotate uniformly around the ball at a uniform angular velocity ω initially (that is, in time) the fluid is at rest, and when the concentration of all points in the fluid is C'_∞ their temperature is also the same. Their temperature is also the same. In time, the board accelerates exponentially at a prescribed speed on its own plane. It is assumed that rate of heat transfer from the surface is proportional to the local surface temperature T' and the level of concentration near the plate is raised to C'_w. As the plate is infinite in extent, the physical variables are functions of y' and t' only. Applying the Boussinesq approximation, the unsteady flow is governed by the following equation

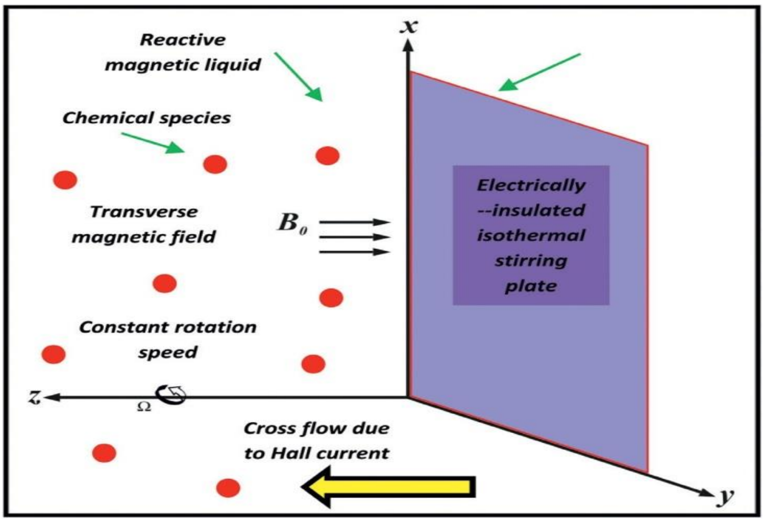

Fig. 1. Geometry of the flow under consideration

The governing equations Megaraju *et al.,* [28] for the exponentially accelerated system in the present problem are considered as follows under the usual boundary conditions.

Equations of Momentum
Primary

$$\frac{\partial u'}{\partial t'} = \upsilon \frac{\partial^2 u'}{\partial z'^2} + 2v'\Omega' - \frac{\sigma B_0^2 (u' + mv')}{\rho(1+m^2)} + g\beta(T' - T'_\infty) + (C' - C'_\infty)\beta^* g - \frac{\upsilon u'}{K'} \tag{1}$$

Secondary

$$\frac{\partial v'}{\partial t'} = \upsilon \frac{\partial^2 v'}{\partial z'^2} - 2\Omega u' + \frac{\sigma B_0^2 (mu' - v')}{\rho(1+m^2)} - \frac{\upsilon v'}{K'} \tag{2}$$

Equation of Energy

$$\rho c_p \frac{\partial T'}{\partial t'} = k\frac{\partial^2 T'}{\partial z'^2} - \frac{\partial q_r}{\partial z'} + \mu\left(\frac{\partial u'}{\partial z'}\right)^2 - Q_0(T' - T'_\infty) \tag{3}$$

Equation of Diffusion

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial z'^2} - K'_r(C' - C'_\infty) \tag{4}$$

U is the axial velocity and v is the lateral velocity. The prescribed initial conditions and boundary conditions are

Boundary Conditions

$$
\begin{aligned}
&u' = 0, v' = 0, T' = T'_\infty, C' = C'_\infty, \quad t' \le 0 \quad \forall z' \\
&u' = u_0 \exp(a' t'), \; v' = 0, \; T' = T'_w, C' = C'_w, \quad t' > 0 \quad at \; z' = 0 \\
&u' \to 0, v' \to 0, T' \to T'_\infty, C' \to C'_\infty, \quad as \quad z' \to \infty
\end{aligned} \tag{5}
$$

The local thermal radiation flux gradient

$$
q_r = -\frac{4\sigma}{3k_1}\frac{\partial T'^4}{\partial y'} \tag{6}
$$

$$
T'^4 \cong 4T'^3_\infty T' - 3T'_\infty \tag{7}
$$

By using Eq. (6) and Eq. (7), Eq. (3) reduces to

$$
\rho C_P \frac{\partial T'}{\partial t'} = k\left(1 + \frac{16\, a^* \sigma v^2 \, T'^3_\infty}{\upsilon \rho Cp\, u_0^2}\right)\frac{\partial^2 T'}{\partial y'^2} + \mu\left(\frac{\partial u'}{\partial y'}\right)^2 - Q_0\left(T' - T'_\infty\right) \tag{8}
$$

To introduce the non-dimensional quantities

$$
\begin{aligned}
&U = \frac{u}{u_0}, V = \frac{v}{u_0}, \; Z = \frac{z u_0}{\upsilon} \; t = \frac{t' \; u_0^2}{\upsilon} \; \Omega = \frac{\Omega' \upsilon}{u_0^{\;2}}, \; S_c = \frac{v}{D} \\
&P_r = \frac{\upsilon \rho \, C_p}{k}, \quad M = \frac{\sigma B_0^2 \, v}{2\rho u_0^2}, \quad K_r = \frac{K_r' \; v}{u_0^2}, \mathrm{n}\, R = \frac{16\, a^* \sigma v^2 \, T'^3_\infty}{\upsilon \rho Cp\, u_0^2}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty} \\
&C = \frac{C' - C'_\infty}{C'_w - C'_\infty} \; Gc = \frac{g\, \beta^* \, v\left(C'_w - C'_\infty\right)}{u_0^3}, \; G_r = \frac{v \; g \; \beta \; \left(T'_w - T'_\infty\right)}{u_0^3}, \; a = \frac{a' \upsilon}{u_0^{\;2}} \\
&S = \frac{Q_0 \upsilon}{\rho \; C_P \; u_0^2}, \; E_c = \frac{\mu u_0^2}{\upsilon \rho C_P \; \left(T'_w - T'_\infty\right)}, \; K_1 = \frac{K' u_0^2}{v^2}
\end{aligned} \tag{9}
$$

Making use of Eq. (9), Eq. (1), Eq. (2), Eq. (4) and Eq. (8), the emerging non-dimensional form of the conservation equations is

$$
\frac{\partial U}{\partial t} = \frac{\partial^2 U}{\partial Z^2} + 2\Omega V - \frac{2M^2(U + mV)}{1 + m^2} + Gr\theta + GcC - \frac{U}{K_1} \tag{10}
$$

$$
\frac{\partial V}{\partial t} = \frac{\partial^2 V}{\partial Z^2} - 2\Omega U + \frac{2M^2(mU - V)}{1 + m^2} - \frac{V}{K_1} \tag{11}
$$

$$
\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial Z^2} + \frac{R\theta}{\Pr} + Ec\left(\frac{\partial U}{\partial Z}\right)^2 - S\theta \tag{12}
$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial Z^2} - KrC \tag{13}$$

Boundary Conditions

$$\begin{aligned} &U = 0, V = 0, \theta = 0,\ C = 0\ \ at\ t \le 0\ \ \ for\ all\ Z \\ &t > 0,\ \ \ U = e^{(at)}, V = 0, \theta = 1,\ C = 1\ at\ Z = 0 \\ &U \to 0, V \to 0, \theta \to 0,\ C \to 0\ \ as\ Z \to \infty \end{aligned} \tag{14}$$

The unsteady boundary value problem defined by Eq. (10) to Eq. (14) is well-posed. A numerical solution is developed and described next

$$Nu = -\left(\frac{\partial \theta}{\partial Z}\right)_{Z=0} \tag{15}$$

$$Sh = -\left(\frac{\partial C}{\partial Z}\right)_{Z=0} \tag{16}$$

3. Method of Solution

Under the given boundary conditions (14), the Galerkin weighted residual numerical method is used to solve the dimensionless partial differential Eq. (10) to Eq. (13).

$$\int_{Z_j}^{Z_k}\left\{N^T\left[\frac{\partial^2 U}{\partial Z^2} - M^*(U + mV) - \frac{\partial U}{\partial t} + Gr\theta + GcC + 2\Omega V - \frac{U}{K}\right]\right\}dZ = 0 \tag{17}$$

where $N^T = [N_j \quad N_k]^T = \begin{bmatrix} N_j \\ N_k \end{bmatrix}$.

Let the linear piecewise approximation solution

$$U^{(e)} = N_j(Z)U_j(t) + N_k(Z)U_k(t) = N_j U_j + N_k U_k$$

where

$$M^* = \frac{2M^2}{1+m^2},\ P = Gr\theta + GcC + 2\Omega V - M^* mV,\ P^* = M^* mU - 2\Omega U,\ Q = E_c\left(\frac{\partial u}{\partial y}\right)^2,$$

where prime and dot denotes differentiation w.r.to ‘Z’ and ‘t’ respectively. Simplifying we get

$$\frac{1}{l^{(e)^2}}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{bmatrix} U_j \\ U_k \end{bmatrix} + \frac{M^*}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} U_j \\ U_k \end{bmatrix} + \frac{1}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} \dot{U}_j \\ \dot{U}_k \end{bmatrix} + \frac{1}{6K}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} U_j \\ U_k \end{bmatrix} = \frac{P}{2}\begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

where $l^{(e)} = Z_k - Z_j = h$.

In order to get the differential equation at the knot x_i, we write the element equations for the elements $Z_{i-1} \le Z \le Z_i$ and $Z_i \le Z \le Z_{i+1}$ assemble two element equations, we obtain

$$\frac{1}{l^{(e)^2}}\begin{bmatrix} 1 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} U_{i-1} \\ U_i \\ U_{i+1} \end{bmatrix} + \left(M^* + \frac{1}{K}\right)\frac{1}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} U_{i-1} \\ U_i \\ U_{i+1} \end{bmatrix} + \frac{1}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} \dot{U}_{i-1} \\ \dot{U}_i \\ \dot{U}_{i+1} \end{bmatrix} = \frac{P}{2}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix}$$

We put the row equation corresponding to the knot $'i'$, is

$$\frac{1}{l^{(e)^2}}\left[-U_{i-1} + 2U_i - U_{i+1}\right] + \left(M^* + \frac{1}{K}\right)\frac{1}{6}\left[U_{i-1} + 4U_i + U_{i+1}\right] + \frac{1}{6}\left[\dot{U}_{i-1} + 4\dot{U}_i + \dot{U}_{i+1}\right] = P$$

Applying Crank-Nicholson method to the above equation then we get

$$A_1 U_{i-1}^{n+1} + A_2 U_i^{n+1} + A_3 U_{i+1}^{n+1} = A_4 U_{i-1}^{n} + A_5 U_i^{n} + A_6 U_{i+1}^{n} + 6Pk$$

where

$$\begin{aligned} &A_1 = -3r + \left(M^* + \frac{1}{K_1}\right)\frac{1}{2}rh^2 + 1 \;\; A_2 = 6r + \left(M^* + \frac{1}{K_1}\right)2rh^2 + 4 \\ &A_3 = -3r + \left(M^* + \frac{1}{K_1}\right)\frac{1}{2}rh^2 + 1 \;\; A_4 = 3r - \left(M^* + \frac{1}{K_1}\right)\frac{1}{2}rh^2 + 1 \\ &A_5 = -6r - \left(M^* + \frac{1}{K_1}\right)2rh^2 + 4 \;\; A_6 = 3r - \left(M^* + \frac{1}{K_1}\right)\frac{1}{2}rh^2 + 1 \end{aligned} \tag{18}$$

Applying similar procedure to Eq. (11), we get

$$B_1 V_{i-1}^{ni1} + B_2 V_i^{n+1} + B_3 V_{i+1}^{n+1} = B_4 V_{i-1}^{n} + B_5 V_i^{n} + B_6 V_{i+1}^{n} + 6kP^*$$

where

$$\begin{aligned} &B_1 = -3r + \left(M^* + \frac{1}{K}\right)\frac{1}{2}rh^2 + 1 \;\; B_2 = 6r + \left(M^* + \frac{1}{K}\right)2rh^2 + 4 \;\; B_3 = -3r + \left(M^* + \frac{1}{K}\right)\frac{1}{2}rh^2 + 1 \\ &B_4 = 3r - \left(M^* + \frac{1}{K}\right)\frac{1}{2}rh^2 + 1, \;\; B_5 = -6r - \left(M^* + \frac{1}{K}\right)2rh^2 + 4 \;\; B_6 = 3r - \left(M^* + \frac{1}{K}\right)\frac{1}{2}rh^2 + 1 \end{aligned} \tag{19}$$

Applying similar procedure to Eq. (12), we get

$$C_1\theta_{i-1}^{n+1}+C_2\theta_i^{n+1}+C_3\theta_{i+1}^{n+1}=C_4\theta_{i-1}^{n}+C_5\theta_i^{n}+C_6\theta_{i+1}^{n}+6kQP_r$$
$$C_1=-3r+\left(\frac{R}{P_r}+S\right)P_r\frac{1}{2}rh^2+P_r,\ C_2=6r+\left(\frac{R}{P_r}+S\right)P_r2rh^2+4P_r$$
$$C_3=-3r+\left(\frac{R}{P_r}+S\right)P_r\frac{1}{2}rh^2+P_r,\ C_4=3r-\left(\frac{R}{P_r}+S\right)P_r\frac{1}{2}rh^2+P_r \tag{20}$$
$$C_5=-6r-\left(\frac{R}{P_r}+S\right)P_r2rh^2+4P_r,\ C_6=3r-\left(\frac{R}{P_r}+S\right)P_r\frac{1}{2}rh^2+P_r$$

Applying similar procedure to Eq. (13), we get

$$D_1C_{i-1}^{n+1}+D_2C_i^{n+1}+D_3C_{i+1}^{n+1}=D_4C_{i-1}^{n}+D_5C_i^{n}+D_6C_{i+1}^{n}$$

where

$$D_1=-3r+S_c+\frac{1}{2}S_cK_rrh^2\ D_2=6r+4S_c+2S_cK_rrh^2\ D_3=-3r+S_c+\frac{1}{2}S_cK_rrh^2$$

$$D_4=3r+S_c-\frac{1}{2}S_cK_rrh^2\ D_5=-6r+4S_c-2S_cK_rrh^2\ D_6=3r+S_c-\frac{1}{2}S_cK_rrh^2$$

All finite element computations are executed in the symbolic software, MATLAB.

4. Validation of Numerical Results

To ensure the accuracy of the numerical results obtained using MATLAB-based finite element codes, Nusselt number and Sherwood number results were compared with the results of previous analyses and studies in the absence of Viscous Dissipation (i.e., Ec = 0). Therefore, confidence in this code is high and the reliability of the results generated subsequently in graphs is established. The computations have adopted the following default parameter values otherwise indicated in the figures Gr = 5.0, Gm = 5.0, M = 0.5, m = 0.5, Ω = 0.1, R = 5.0, Pr = 0.71, Sc = 0.6, Kr = 1.0, a = 0.1 and t = 0.2.

5. Result and Discussion

The main purpose of this paper is to analyse transient MHD flows with viscous dissipation and heat source effects through exponentially accelerated isothermal vertical plate. Extensive computations have been conducted using the validated variation FEM code in MATLAB. The distributions for primary and secondary velocities, temperature and species concentration, for various non-dimensional parameters are visualized in figures. The parameters such as the magnetic parameter - M , radiation parameter - R, Hall parameter- m, chemical reaction parameter- Kr, rotation parameter - Ω and the non-dimensional number such as the Prandtl number- P_r, Schmidt number - S_c, thermal Grashof number - G_r on temperature - θ, Eckert Number - Ec, Heat Source - S, Porous medium - K and concentration - ϕ.

Figure 2 illustrates the effect of Prandtl number on temperature profiles. It observed that there is a decrease in the temperature and temperature boundary layer as the Prandtl number increased. It is clear from this figure that as Prandtl number increases, the temperature profile decreases. This is because the fluid is highly conductive for a small value of Prandtl number. Physically, if Prandtl number increases, the thermal diffusivity decreases, and this phenomenon leads to the decreasing manner of the energy transfer ability that reduces the thermal boundary layer.

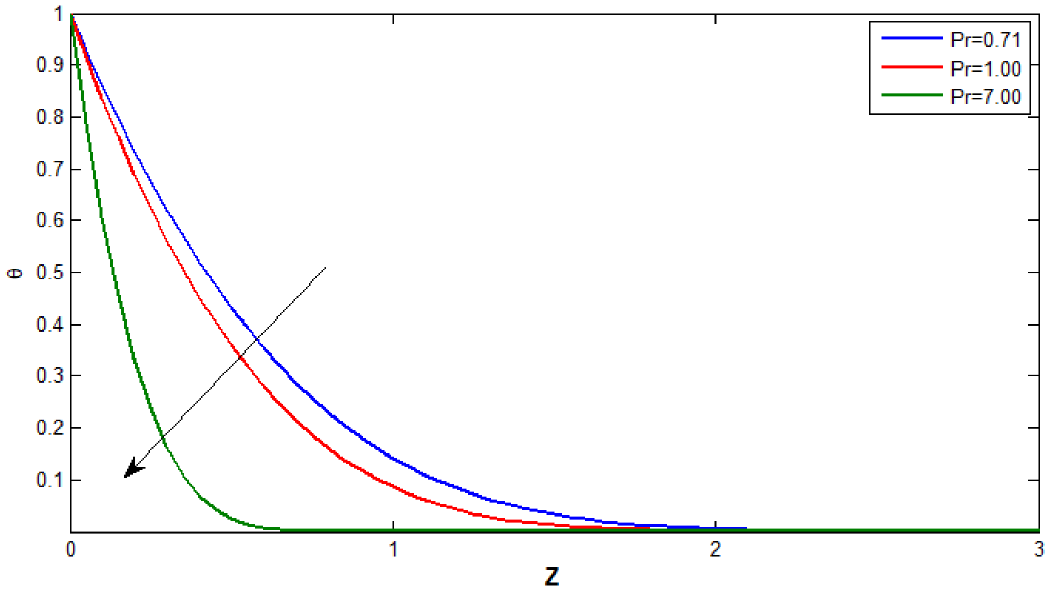

Fig. 2. Temperature profiles for different values of the Prandtl number Pr

Figure 3 illustrates the effect of heat source on temperature profiles. Here temperature of the fluid decreases with the increasing values of heat absorption. Since, when heat absorption is there in boundary layer, it is thickened. So, the fluid temperature declined in the boundary layer. it is Observed that the falls down in the temperature of the fluid.

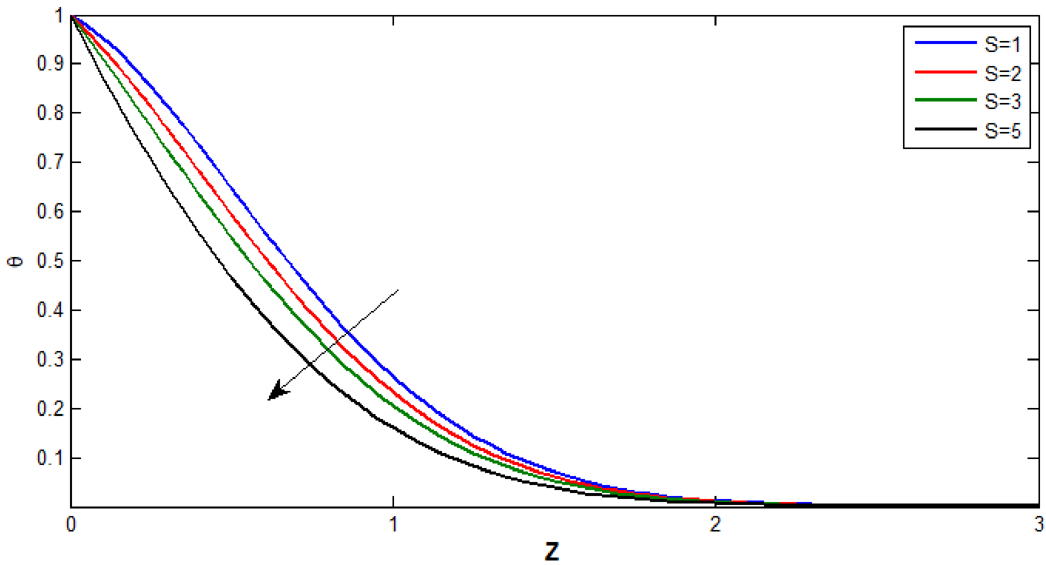

Fig. 3. Temperature profiles for different values of the heat source, *S*

Figure 4 illustrates the effect of Eckert number on temperature profiles. Larger value of Eckert number causes an increase in temperature profile. The Eckert numbers define the ratio between the flow of kinetic energy and enthalpy difference of boundary layer. By the definition of Ec, larger values of Ec on kinetic energy which relases heat energy into the fluid fluid. So there is a increase in temperature.

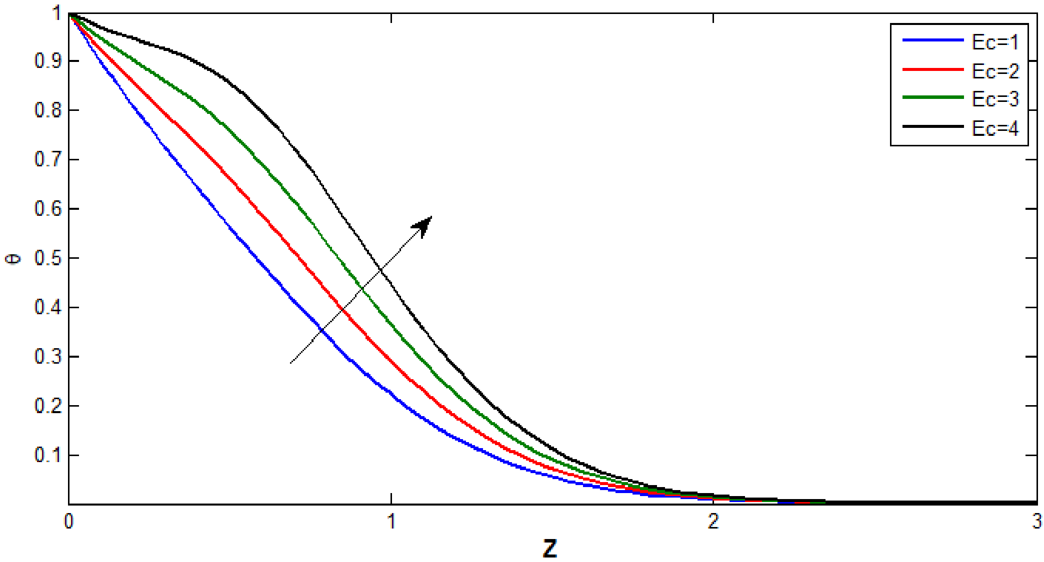

Fig. 4. Temperature profiles for different values of the Eckert number *Ec*

Figure 5 illustrates the effect of radiation on temperature profiles. Larger values of radiation can cause an increase in the thermal boundary layer thickness. This is because radiation typically has a longer reach compared to conduction or convection, allowing heat to be transferred over larger distances. As a result, the temperature gradient across the boundary layer decreases, leading to a thicker thermal boundary layer.

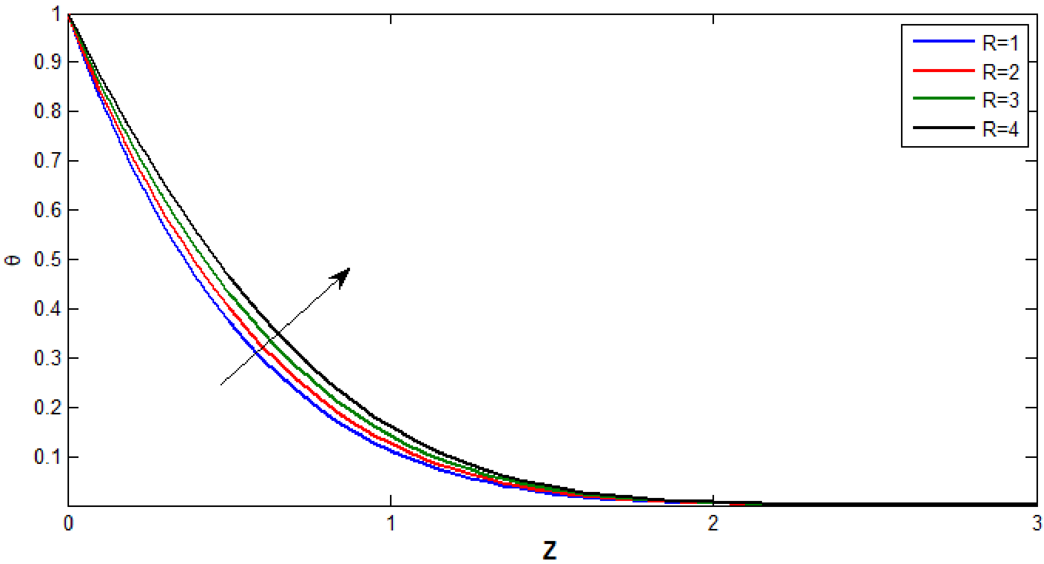

Fig. 5. Temperature profiles for different values of the Radiation paramete, R

Figure 6 illustrates the effect of Schimdt number on concentration profile. A higher Schmidt number leads to a decrease in the rate of molecular diffusion. As a result, the concentration gradients across the fluid flow become steeper, and the concentration profile tends to flatten out. This means that the concentration decreases more rapidly as you move away from the source or reference point.

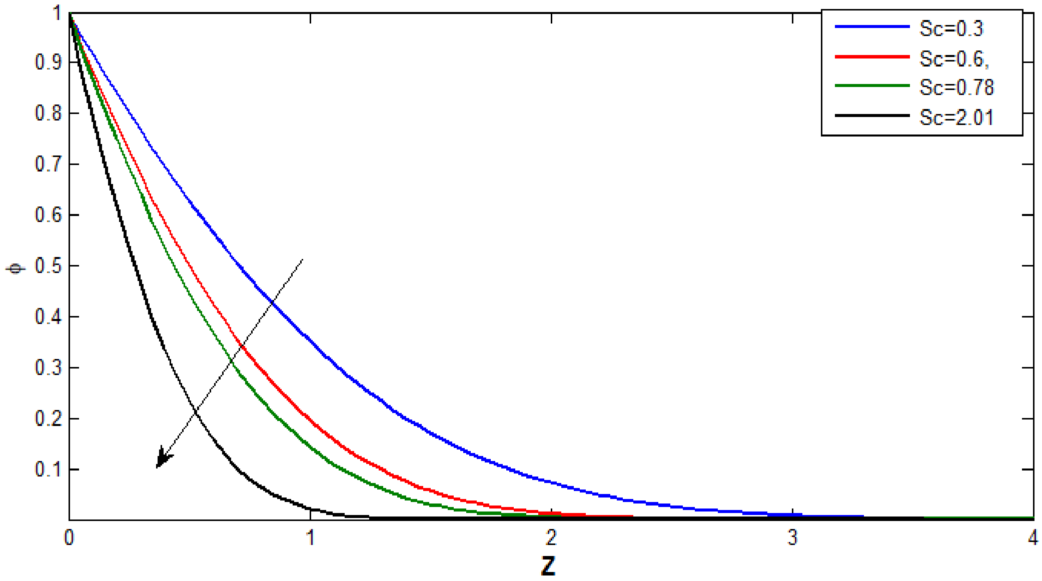

Fig. 6. Concentration profiles for different values of the Schmidt number, S_c

Figure 7 illustrates the effect of chemical reaction on concentration profiles. As the chemical reaction rate increases, more reactant molecules are being consumed, resulting in a decrease in their concentration over time. This is because the reactant molecules are being transformed into products through the chemical reaction.

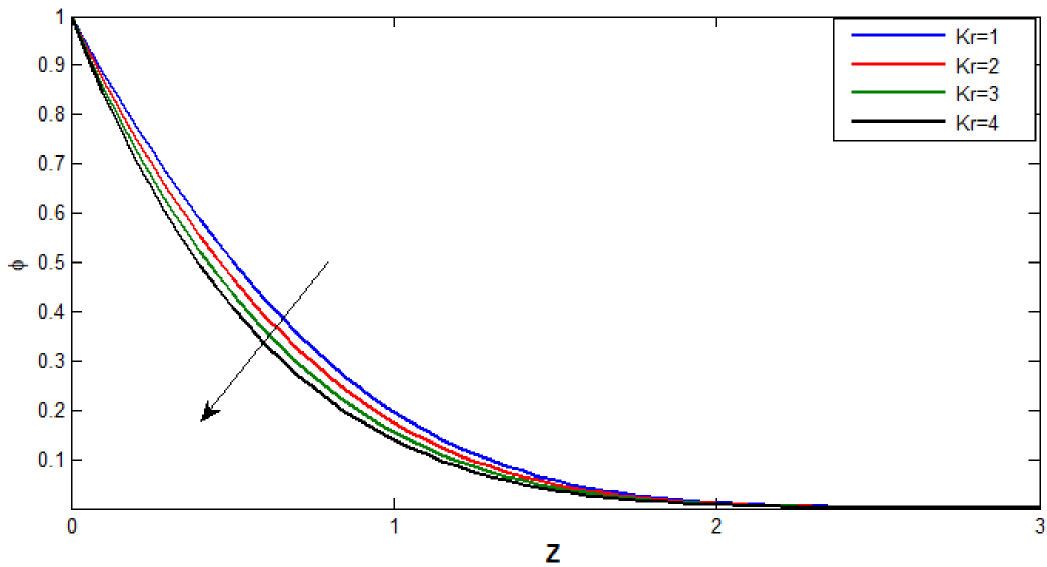

Fig. 7. Concentration profiles for different values of the chemical reaction parameter, K_r

6. Conclusions

The effects on unsteady transient MHD flows through an exponentially accelerated isothermal vertical plate with viscous dissipation and heat source embedded in a porous medium have been quantitatively studied in this paper. The behaviour of regulating parameters for temperature, concentration, and velocity has been displayed to describe the physics of the subject under examination. The Galerkin finite element method was used to solve the converted dimensionless set of equations numerically. The following are the study's main findings

i. The species concentration diminishes with increasing chemical reaction parameter.
ii. The velocity increased with the increase in either the acceleration coefficient 'a'
iii. A growing Eckert number increases temperature of the flow field at all points. The Prandtl number decreases the temperature of the flow field at all points.
iv. Radiation parameter, permeability parameter, rotation parameter tends to raise in the fluid velocity in the boundary layer.
v. The rotation has a tendency to decelerate flow in x- axis and accelerate flow in z- direction for both types of thermal conditions. But rotation tends to raise shearing stress in x and z-directions.
vi. Magnetic parameter tends to retard the primary fluid velocity and opposite effect is observed on the secondary fluid velocity.

Because the magnetic field parameter was taken into account in this study, it will be useful in managing blood turbulence flow. Power pumps, food processing, power accelerators, power generators, heat exchanger design, cooling reactors, and other applications benefit from the MHD characteristics. This research will aid in the treatment of blood cancer using electromagnetic radiation, as well as the regulating of pores in pathological studies.

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