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Radiation and Chemical Reaction on unsteady Walter's-B viscoelastic MHD flow past a vertical porous plate

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Abstract: In our current paper, we investigate the unsteady magnetohydrodynamic (MHD) Walter's-B viscoelastic flow past a vertical porous plate located within a porous medium. We have taken into account of chemical reaction changes and radiation effects. The governing PDEs without dimensions describing the field move have been mathematically solved employing a closed analytical method. The resulting profiles for temperature, concentration and velocity, will graphicallybe described and qualitatively discussed.

Keywords: Unsteady, Viscoelastic, MHD, Porous plate, Chemical Reaction.

1) Introduction

From last 2 to 3 years onwards a large number of mathematicians get more informationproperties of mass and heat transport in layer edge flow fields. This is mostly because Newtonian non-fluids have broad applicability in a variety of domains, such as blood oxygenators, mixing mechanisms, dissolving processes, milk processing, and the manufacturing procedures used in the polymer processing sector.

If we observe, there areseveral viscoelastic fluids and related models available to observe the behavior of non-Newtonian fluids, including as Maxwell, Walter's-B, Rivlin Erickson, and micro polar fluids.

Sakiadis [1,2] investigated the (BLP) Boundary Layer Problem assuming a constant velocity at the bounding surface, which laid the groundwork for later work in the field. Moreover, technologies for geothermal energyextractingfrom reservoirs and using porous medium convection difficulties are extensively employed.

Research on boundary layer flows of a Newtonian fluid approaching an elastic sheet under stretch at a velocity is increased the distance covered from the origin was carried out by Crane [3].

Mathematical expectations weretaken out on various facets of free convective flow and transfer mass over vertical porous plates, and a perfect similarity answer was obtained. The phenomena of continuous suction on an unbounded porousplate verticallywasobserved by Waveand Soundalgekar [4].

By freeconvection effects,currents and mass transfer on a vertically oriented plate with an abrupt initiation of motion were investigated by Soundalgekar [5]. In their investigation of the coupled transport of mass and heat in porous media, Kulacki and Lai [6] paid close attention to general convection on a vertical surface. The observations on the impact of free convection currents in through porous mediaoscillations, limited by a smooth surface of constant height, by vertically was also carried out by Patil and Hiremath [7].

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Bychangesthe transfer of mass on flow over a vertical porous plate were examined by Subhashini et al. [8]. Elbashbeshy and Ibrahim [9] investigated the effects of a continuous convection free flow along a plate vertically with changes in thermal and viscosity diffusivity.

Taking into account both diffusion-thermo effects and thermal-diffusion, Williamsand Kafoussias[10] examined the impact of dependent-temperature viscosity in a mixedtransfer of mass withfree-forced convective stable boundary laminar layer flow on a plate vertically. Additionally, Bejan and Nield [11] carried out a thorough examination of studies pertaining to the mechanism of transferheat convective in porous media.

Hayat and Sajid [12] investigated how radiation affected convection mixed flow across an exponentially stretched sheet we analytically analyze the issue.by using the methodof homotopy analysis.The topic of fluctuating mass and heat transport on an unstable free convective MHD flow through a porous media in a moving systemwas studied by Dash et al.Thirteen] These investigations not consider into account the magneto hydrodynamic impact.

The mathematical approach for thisconcept was then given by and Nazar and Bidin [14] and Anwar Beg et al. [15] .

Huang and Tsai [16] looked at the Soret and Dufour changes on the Hiemenz flow over a stretched. immersedsurface in a porous media.Afify[17] looked into theDufourand Soret effects in massand heattransfer in the flow produced by a surface with stretching. Turkyilmazoglu [18] looked into a number of solutions for the heat and mass transfer of viscoelastic fluid over a stretching sheet.The movement of porousvertical plate was studied, Reddy et al.'s [19] by comprising into how chemical radiation and reactions affect MHD flow.

Turkyilmazoglu (20) looked into two distinct types of fluid viscoelastic stretched across a surface and multiple mathematical approach for the mass and heat transfer of MHD slip flow. In order to handle the steady MHDslip flow and convective produced by a moving disk while taking ohmic heating and viscous dissipation effects into account, Erfani [21] andRashidi usedanmathematical approach.

Unsteady MHD dusty fluid Couetteviscoelastic flow was analyzed by Rashidi et al. [22]
Kumar and Sivaraj [23] in the context of anchanging diffusion mass with irregular channel.

Bhaskar Reddyand Poornima conducted a recent investigation [24] on the effects of changes on MHD free convective layer boundary flow of nanofluid over a stretching nonlinear sheet. Comparatively small ideahas given to examining how mass transfer and radiation interact in a sheet with stretchingcontext. Similar to this, Mishra [25] andPrakash et al. [26] examined the flow of an elastic-viscous fluid in a channel vertically. while accounting for the common changes of free convection and mass transfer using the Walters B0 model.

The entropy of an unsteady MHD flow over a permeablestretching surface involving nanofluid was investigated by Abolbashari et al. [27]. For MHD viscoelastic fluid flow over a porous wedge, Rashidi et al. [28] and Benazir et al. [29] investigated the field of mixed heat convective transfer with consideration to thermal radiation.

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Furthermore, in the context of MHD convection free flow over an inclined plate put in a porous medium, Reddy et al. [30] gives the changes of mass and heat transfer.

In the current work, we have examined the chemical radiation and reaction effects on the dynamics of unsteady MHD Walter's-B viscoelastic flow on a vertical porous plate within a porous medium. We have solved the PDEs without dimensions governing the field flow numerically using a closed analytical method. Following, graphical depictions of temperature, concentration, and velocity profiles are shown and qualitatively discussed.

2) Statement of the hypotheses

Here, we examine an irregular flow caused by magneto-hydrodynamic effects in an conductingelectrically incompressible viscoelastic fluid. This flow happens as it passes through an infinite vertical porous plate that is initiated impulsively, accounting for radiation effects, temperature variations, and mass diffusion. We set up a coordinate system with the x-axis parallel to the plate and the y-axis perpendicular to it because the plate is embedded in a porous medium. At the beginning, the fluid's and the plate's temperature and concentration abbreviated T and C, respectivelyare the same.
Inthe x-axis direction, the plate startswhen t=0, moving at a constant velocity of U. It introduces a transverse magnetic field B that is 90^0angleto the direction of flow. Induced magnetic fields are deducted because the applied transverse magnetic field's strength and Reynolds magnetic number are both incredibly small. We take into consideration a first-order changes in chemical and an exponential pattern in the fluid's concentration. The only mappings of t and y are the flow variables under the condition infinite extension along the x-axis. With Bossiness's approximation included, the boundary layer governing equations by these rules can be developed as follows:

$$\frac{\partial v^*}{\partial y^*} = 0 \Rightarrow v* = -v_0(\text{constant}) \tag{1}$$

Momentum equation:

$$\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} = \nu\frac{\partial^2 u^*}{\partial y^{*2}} - \lambda\frac{\partial^3 u^*}{\partial y^{*2}\partial t^*} + g\beta(T^* - T_\infty^*)\cos\alpha + g\beta^*(C^* - C_\infty^*)\cos\alpha - \frac{\sigma B_0^2 u^*}{\rho} - \frac{\nu u^*}{K^*} \tag{2}$$

Energy equation:

$$\rho C_p\left(\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*}\right) = k\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{\partial q_r}{\partial y^*} \tag{3}$$

Equation of continuity for mass transfer:

$$\frac{\partial C^*}{\partial t^*} + v^*\frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - k_r(C^* - C_\infty^*) \tag{4}$$

Here, v stands for kinematic viscosity, k for fluid thermal conductivity, T for dimensional temperature, β represents thermal expansion of the volumetric coefficient and g for gravitational acceleration. Cp is at fixed pressure the specific heat, chemical reaction rate constant represented by Kr,and the diffusion mass coefficient is represented by D.

The corresponding boundary conditions are

$$\begin{cases} t^* \le 0 \;\; u^* = 0, T^* = T_\infty^*, C^* = C_\infty^* \quad \forall y^* \\ t^* > 0 \begin{cases} u^* = u_0, v^* = -v_0, T^* = T_\infty^* + (T_w^* - T_\infty^*)\,e^{At^*}, \quad C^* = C_\infty^* + (C_w^* - C_\infty^*)\,e^{At^*} \quad \text{At } y^* = 0 \\ u^* = 0, T^* \to \infty, C^* \to \infty, \qquad y^* \to \infty, \end{cases} \end{cases} \tag{5}$$

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where, $A=\frac{v_0^2}{\nu}, T_w^*$ and C_w^* are concentration andtemperature of place respectively.

For an optically thick gray fluid, the radioactive heat flux q_r is approximated by the Roseland approximation which is given by

$$q_r = -\frac{4\sigma}{3k_m}\frac{\partial T^{*4}}{\partial y^*} \qquad (6)$$

Here σ and k_m are BoltzmannStefan constant and mean absorption coefficients respectively. We consider that the heatchange within the flow is small enough to be approximated as a linear mapping of temperature. To achieve this, we employ a Taylor series expansion around a reference temperature (let's call it T0) and disregard the higher-order terms.

$$T^{*4} \cong 4T_\infty^{*3}T^* - 3T_\infty^{*4} \quad ---- \quad (7)$$

Using equations (6) and (7 in (3), we get

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \frac{k}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{16\sigma T_\infty^{*2}}{3k_1\rho C_p}\frac{\partial^2 T^*}{\partial y^*} \qquad (8)$$

, By introduce the following variableswithout dimensions, we obtain non-dimensional PDEs as

$$\begin{cases} u=\frac{u^*}{u_0}, y=\frac{y^* v_0}{\nu}, t=\frac{y^* v_0^2}{\nu}, \theta=\frac{T^*-T_\infty^*}{T_w^*-T_\infty^*}, \\ \Gamma=\frac{\lambda v_0^2}{v^2}, C=\frac{C^*-C_\infty^*}{C_w^*-C_\infty^*}, Gm=\frac{\nu g\beta^*(C_w^*-C_\infty^*)}{u_0 v_0^2}, Gr=\frac{\nu g\beta(T_w^*-T_\infty^*)}{u_0 v_0^2}, \\ Kr=\frac{kr\lambda}{v_0^2}, K=\frac{v_0^2 K^*}{v^2}, \Pr=\frac{\mu Cp}{k}, M=\frac{\sigma B_0^2 \nu}{\rho v_0^2}, R=\frac{4\sigma T_\infty^{*3}}{k_1 k}, Sc=\frac{\nu}{D} \end{cases} \qquad (9)$$

By virtue of equation (9),we get non-dimensional form of equations (2),(3) and (8) respectively:

$$\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} - \Gamma\frac{\partial^3 u}{\partial y^2 \partial t} + Gr\theta + GmC - (M + \frac{1}{K})u \qquad (10)$$

$$\frac{\partial \theta}{\partial t} - \frac{\partial \theta}{\partial y} = \frac{1}{\Pr}\left(1+\frac{4R}{3}\right)\frac{\partial^2 \theta}{\partial y^2} \qquad (11)$$

$$\frac{\partial C}{\partial t} - \frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 u}{\partial y^2} - KrC \qquad (12)$$

The conditions in non-dimensional form are taken as:

$$\begin{cases} t \le 0 \quad u=0, \theta=0, C=0 \quad \forall y \\ t > 0 \quad u=1, \theta=e^t, C=e^t \quad \text{at } y=0 \\ \qquad u \to 0, \theta \to 0, C \to 0, y \to \infty \end{cases} \qquad (13)$$

Skin friction

The skin-friction at the plate, which is developed in non-dimensional form by, can be obtained by knowing the velocity field.

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$$\tau = -\left(\frac{\partial u}{\partial y}\right)_{y=0}$$

Nusselt number

Knowing the temperature field, the heat transfer rate coefficient can be obtained, which in non –dimensional form is given,

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

Sherwood number

Knowing the concentration field, the rate of mass transfer coefficient can be obtained, which in non –dimensional form,

$$Sh = \left(\frac{\partial C}{\partial y}\right)_{y=0}$$

3) Results and Discussion

Specifically, we study the dynamics of a viscoelastic flow with an unstable MHD Walter's-B on a porous vertical plate in a porous material. The changesof chemical reactions and radiation are considered in this inquiry. We have evaluated the mathematical answer for the non-dimensional temperature, concentration, and velocity, holding all other parameters constant. Figures (1) through (6) show the graphical representations of these mathematical outputs.

The temperature distribution, velocity, and profiles of theconcentrations at the boundary gives as how different parameters affect these variables. Instead, we use an verticalinfiniteplate with finite length and flow to get the solution. The default parameters used in this investigation are Gm=3, Gr=3, K=0.9, R=2; pr=0.71, t=0.2, Sc=0.66, n=1, and M=5.

A chemical reaction's effects on velocity and distribution ofconcentrationare shown in dig (1) and (2). It gives that the chemical reaction increases as the velocity and concentration profiles grow less. This demonstrates how the chemical reaction coefficient has a major impact on the distribution of velocity. The changes of the Schmidt number on the concentration and velocity curves isgiven indig (3) and (4). From that both concentration profiles and the velocity was decrease with Schmidt numberincreasing.

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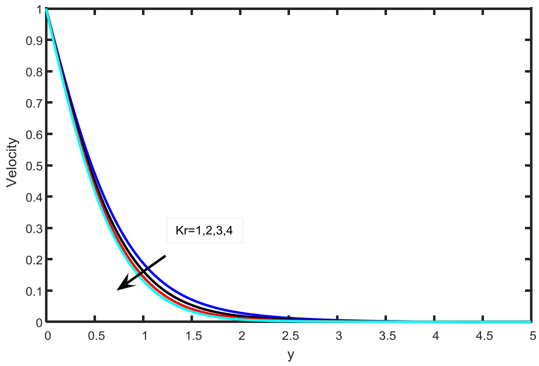
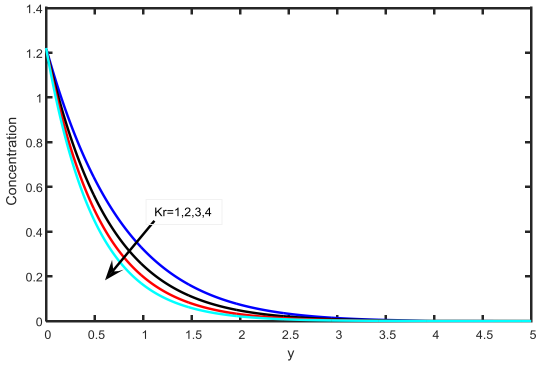
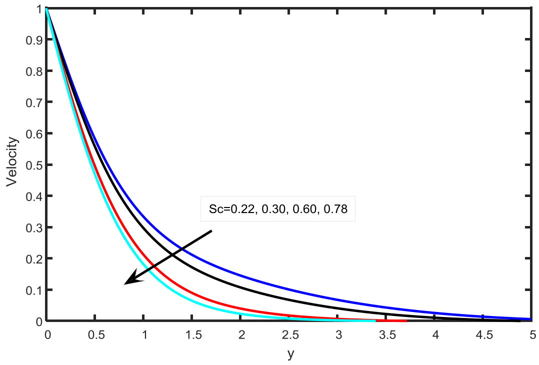


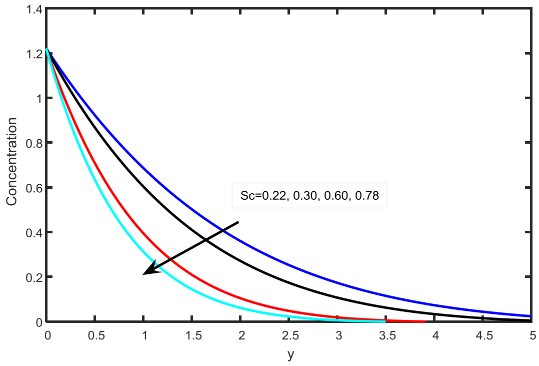
Dig.1. Velocity profiles for a range of chemical reaction parameter (Kr) values



Dig.2. For varies measurements of chemical reaction parameter, the values of (Kr) Concentration profiles



Dig.3. for varies values of Schmidt number (Sc), the values of Velocity profiles.



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Dig.4. For different values of Schmidt number (Sc). Concentration profiles

4) Conclusions:

In this work, we take the changes of radiation and chemical processes in our numerical analysis of Walter's-B viscoelastic MHD flow across a porousvertical plate.

The below observations are derived from the graphic representation of the numerical results:As the values of Kr (permeability parameter), Sc (Schmidt number), R (radiation parameter), and M (magnetic parameter) increase, the velocity decreases.

- At the same time, velocity increases with increases in the values of Pr (Prandtl number), K (permeability parameter), and t (time).
- The temperature decreases, when the raised the R radiation parameter
- In another way,the temperature increases depending on raise the values of t and Pr,

These observations highlight the complex interplay of different observations in the studied flow problem.

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