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Computational Analysis of Viscous Dissipation on Radiative MHD Maxwell Nanofluid Flow over a Stretching Sheet with Heat Source and Chemical Reaction

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Abstract: The present study examine the influence of chemical reaction and thermal radiation on MHD boundary layer flow of a Maxwell nanofluids past over a stretching sheet. Viscous dissipation effects are also taken into consideration. The governing physical problem is presented using traditional Navier-Stokes theory. By means of scaling group of transformation, consequential system of equations is transformed into a set of nonlinear ordinary differential equations, which are then solved numerically by using the Runge– Kutta–Fehlberg fourth–fifth order method along shooting technique. The working fluid is examined for several sundry parameters graphically and in tabular form. It is noticed that with an increase in magnetic parameter, velocity profile decreases while temperature and nanoparticle fraction enhances. Eckert number enhances flow temperature whereas it decreases heat transfer rate. Rheological fluid parameter contributes increase velocity, but decreases the temperature and nanoparticle fraction. A good agreement of the present results has been observed by comparing with the existing literature results.

Keywords: Maxwell fluid, Thermal radiation, Viscous dissipation, Chemical reaction, Nanoparticle, Heat source

I. INTRODUCTION

The solar power is considered important in getting heat, power and water. Solar power is a renewable source of energy which never consumes. Sustainable energy generation is very serious issue facing society now days. Recent engineers and scientists show interest to research on various sources for sustainable energy generation. Solar energy offers a solution, with the hourly solar flux incident on the earth's surface being greater than all of the human consumption of energy in a year. In fact the researchers utilize solar radiation directly by converting it into useful heat or electricity. The world eventually turning to the renewable energy sources, solar energy in particular, is inevitable, expected and wise. Beside these the boundary layer flows of non-Newtonian fluids have been given considerable attention due to increasing engineering applications. In order to obtain a through cognition of non-Newtonian fluids and their various applications, it is necessary to study their flow behaviors. It is well known that the mechanics of non-Newtonian fluids present a special challenge to researcher.

The nonlinearity can manifest itself in a variety of ways in many fields, such as bio-engineering, drilling operations and food processing. In view of various rheological properties of non-Newtonian fluids in nature, there are no single constitutive relationships between stress and rate of strain by which all the non-Newtonian fluids can be analyzed. Therefore, several models of non-Newtonian fluids have been suggested. Amongst there is a simplest subclass of the rate type fluids known as the Maxwell model. This fluid model represents a rheology different from the Newtonian fluid. The mathematical model of Maxwell fluid has been used as a simplified description of dilute polymeric solutions.

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Mathematical Analysis

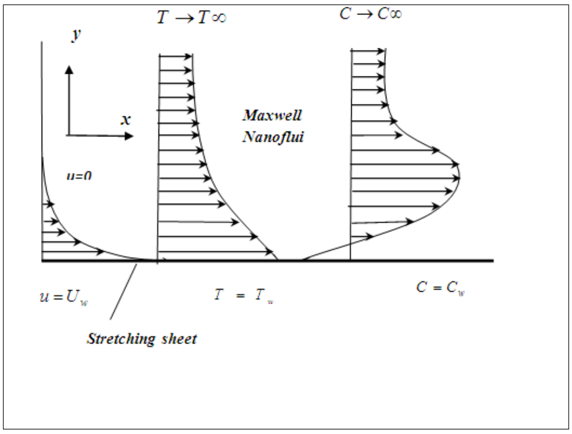

Fig. 1. Physical model of the problem.

We consider a two-dimensional steady incompressible Maxwell Nanofluid flow over a stretching sheet. The sheet is coinciding with the plane y = 0, with the flow being confined to y>0. Here we assume that the sheet is stretched with the linear velocity *u(x) = bx*, where b>0 is constant and x-axis is measured along the stretching surface. A uniform magnetic field of strength B_0 is applied in y-direction. The magnetic Reynolds number is small and so induced magnetic field is neglected. The surface of the plate is maintained at uniform temperature and concentration T_w and C_w, respectively, an these values are assumed to be greater than the ambient temperature and concentration, T_∞ and C_∞, respectively (Fig. 1). Moreover, it is assumed that both the fluid phase and nanoparticles are in thermal equilibrium state. The thermo-physical properties of the Nanofluid are assumed to be constant.
Under foregoing assumptions, the basic two dimensional boundary layer equations of continuity, momentum, energy and concentration with usual notations can be written as:

(1)

$$= \nu \frac{\partial^2 u}{\partial y^2} + k_0 \left(u^2 \frac{\partial^2 u}{\partial x^2} + v^2 \frac{\partial^2 u}{\partial y^2} + 2uv \frac{\partial^2 u}{\partial x \partial y} \right) - \frac{\sigma B_0^2}{\rho_f} \left(u + k_0 v \frac{\partial u}{\partial y} \right) \qquad (2)$$

(3)

(4)

Here u and v denote the velocities in the *x*- and *y*-directions, respectively, σ is the electrical conductivity, k_0 is the relaxation time of the UCM fluid, *T* is the temperature of fluid, *C* is the nanoparticle fraction, D_B is the Brownian

specifically pointed out in the approximate graphs and tables. Figs. 2 to 21 are plotted to visualize velocity $f'(\xi)$, temperature $\theta(\xi)$, nanoparticle fraction $\phi(\xi)$, skin friction factor $-f''(0)$, Nusselt number $-\theta'(0)$ and Sherwood number $-\phi'(0)$ profile of system.

Figs. 2-4 display the impact of the magnetic parameter on velocity $f'(\xi)$, temperature $\theta(\xi)$ and nanoparticle fraction $\phi(\xi)$, while the values of remainder of the parameters are taken to be fixed. It is noticed from the figures that both temperature and nanoparticle fraction demonstrated an increasing behavior for increasing the values of magnetic parameter M. However, the velocity profile decreasing behavior for increasing values of magnetic parameter M. physically, magnetic parameter M is normal to the fluid, so for enhance the values of magnetic parameter M, it increases the temperature and the nanoparticle fraction and resists the fluid flow.

Influence of the elastic parameter β on flow, temperature and concentration, is demonstrated in Figs. 5-7. From these figures it is analyzed that fluid flow enhances on growing values of the elastic parameter β. Conversely, the temperature profile and the nanoparticle fraction decreases for grater values of the elastic parameter β. In Figs. 5 and 6, one can notice that an opposite trend is noted for both the velocity profile and the temperature profile for greater values of the elastic parameter β.

Effect of Prandtl number Pr on temperature profile and nanoparticle fraction is presented in Figs. 8 and 9 respectively. As expected, Figs. 8 and 9 display that both the temperature profile and the nanoparticle fraction demonstrate a decreasing function due to the presence of Prandtl number Pr. Consequently, the boundary layer thickness decreases indefinitely with an increase in Prandtl number Pr. This is due to the fact that a higher Pr fluid has relatively low thermal conductivity, which reduces conduction and thereby the thermal boundary layer thickness, and as a result, temperature decreases. It is illustrated in Figs. 10 and 11 that both the temperature and nanoparticle fraction demonstrate the same behavior when compared with Figs. 8 and 9 for greater values of Lewis number Le. Fig. 12 shows the temperature distribution for different value of thermal radiation R. It is found that the fluid temperature increases with the increase of radiation parameter. The reason for that the temperature increases conduction effect of the Nanofluid in the presence of thermal radiation. Therefore higher values of radiation parameter imply higher surface heat flux and so, increase the temperature within the thermal boundary region. It is also observed that the thermal boundary layer thickness increases with increasing the values of the thermal radiation R.

In view of Fig. 13, it depicts that temperature of the fluid increases with heat source parameter Q. Impact of Eckert number Ec on temperature is portrayed through Fig. 14. Eckert number Ec results in increases temperature of the Nanofluid. Heat dissipation effects are also characterized by Eckert number which cause an increase of temperature.
The influence of the chemical reaction parameter on nanoparticle fraction profile is illustrated in Fig. 15. It is noticed that nanoparticle fraction distribution decreases with increase of chemical reaction parameter .

The impact of the thermophoresis and Brownian motion parameter on the temperature profile and nanoparticle fraction are shown in Figs. 16-19. It is observed from these figures, we noticed that, for greater values of both Brownian motion parameter and thermophoresis parameter, temperature profile also increases. Conversely, an opposite behavior for the nanoparticle fraction in case of Brownian motion parameter. But, nanoparticle fraction increases with thermophoresis parameter.

Fig. 20 displays the variation of skin-friction factor for different values of magnetic parameter M and the elastic parameter β. It is noticed that increasing values of magnetic parameter M is to increase the skin-friction factor. But, the opposite behavior can be seen in case of elastic parameter β. The impact of chemical reaction and Lewis number on Sherwood number is shown in Fig. 21. It is clearly conclude that increasing values of Lewis number and chemical reaction are to increases the rate of concentration at the wall.

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Fig. 5. Effects of β on velocity profile.

Fig. 6. Effects of β on temperature profile.

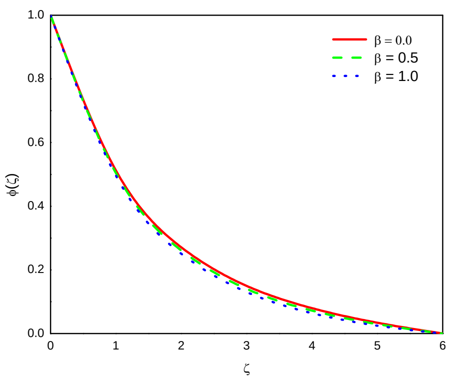

Fig. 7. Effects of β on concentration profile.

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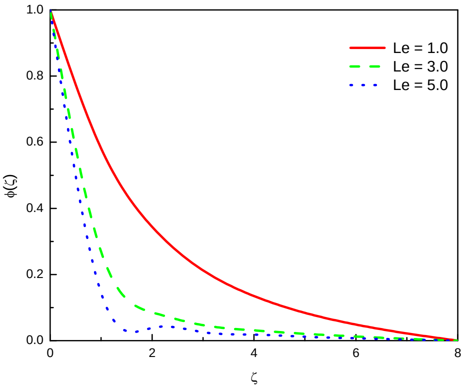

Fig. 11. Effects of *Le* on concentration profile.

Fig. 12. Effects of *R* on temperature profile.

Fig. 13. Effects of *Q* on temperature profile.

Fig. 17. Effects of *Nb* on concentration profile.

Fig. 18. Effects of *Nt* on temperature profile.

Fig. 19. Effects of *Nt* on concentration profile.

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- The magnitude of the local Sherwood numbers increases for greater values of Brownian motion.

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