Heat Transfer in Unsteady Squeezing Flow Between Parallel Plates

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Abstract

In this study, we investigated an unsteady MHD flow between parallel plates in the presence of viscous dissipation. The transformed governing equations are solved numerically using bvp5c Matlab package. The impact of different non-dimensional parameters on velocity and temperature profiles along with the local Nusselt number is discussed graphically. It is observed that the Nusselt number is a decreasing function of the radiation parameter and Hartmann number but it is an increasing function of squeeze number and Eckert number.

Keywords:MHD, viscous dissipation, squeeze number, radiation

Introduction

There is a considerable interest among recent researchers in the field of non-Newtonian fluids is applied in many situations in industry such as processing of materials and chemical engineering. The influence of radiation, heat generation and viscous dissipation on magnetohydrodynamic on the laminar boundary layer flow for the flat-plate in a uniform stream of fluid and about a moving plate in a quiescent ambient fluid both under a convective surface boundary condition was studied by Gangadhar [1]. The study of hydromagnetic flow of a viscous incompressible fluid past an oscillating vertical plate embedded in a porous medium with radiation, viscous dissipation and variable heat and mass diffusion was analyzed by Kishore et al. [2]. An unsteady magnetohydrodynamic laminar free convective boundary layer flow of an incompressible Newtonian electrically conducting and radiating fluid past an infinite heated vertical porous plate with heat and mass transfer was analyzed by Ramachandra and Bhaskar Reddy [3]. The effects of radiation on an unsteady magnetohydrodynamic convective flow through a semi-infinite vertical permeable moving plate embedded in a porous medium with viscous dissipation was stated by Murali et al.[4]. The effect of viscous dissipation and radiative heat transfer in nanofluid with the influence of magnetic field over a rotating stretching surface has been investigated by Wahiduzzaman et al. [5]. The influence of inclined magnetic field and radiation on unsteady magnetohydrodynamic convective flow through an moving vertical plate in a porous media was analyzed by Sandeep and Sugunamma [6].Gopi and Jat [7] was stated the effects of radiation and viscous dissipation on MHD through an unsteady stretching surface in the presence of uniform magnetic field in the porous medium. The study of viscous dissipation and thermal radiation on the stagnation point flow of viscous fluid induced by an exponentially stretching surface was discussed by Iqbal et al. [8].The effects of magnetohydrodynamic free convection flow of heat and mass transfer of non-Newtonian fluids along a stretching surface with viscous dissipation has been analyzed by Saha and Samad [9]. The heat transfer characteristics of a viscous Casson thin film flow over an unsteady stretching surface subjected to variable heat flux in the presence of slip velocity condition and viscous dissipation was stated by Megahed [10]. The study of magnetohydrodynamic boundary layer flow of heat transfer through viscoelastic fluid flow over a stretching surface with radiation was studied by Abel and Begaum [11]. Srinivas et al. [12] was investigated the effects of thermal diffusion on magnetohydrodynamic flow of viscous fluid rotating porous medium with viscous dissipation. The effects of viscous dissipation and chemical radiation on magnetohydrodynamic convection flow was experimented by Das et al. [13]. The influence of radiation on magnetohydrodynamic convection from a cylinder with partial slip in a Casson fluid in porous medium was investigated by Makanda et al. [14]. Heat transfer analysis is carried out in the presence of radiation and a viscous dissipation effect has been studied by Hayat et al. [15]. The Effects of radiation absorption and chemical reaction on MHD free convection heat transfer flow over a vertical plate was discussed by Sandeep et al. [16]. The study of magnetohydrodynamic convection flow an infinite vertical plate embedded in a porous media with viscous dissipation was analyzed by Siva and Srinivasa [17]. Heat transfer through micro tubes is conducted using slip velocity and temperature viscous dissipation and axial conduction has been studied by Loussifa and Jamel [18]. Mohan Krishna et al. [19] discussed an unsteady natural convective flow of nanofluid past an infinite vertical plate in presence of radiation effects. Chamka and Issa [20] studied thermophoresis effects of the MHD flow over flat plate with heat source/ sink.

Mathematical Formulation

Consider an unsteady two-dimensional flow of Casson fluid between the infinite parallel plates. The two plates are located at $\ell(1-\gamma t)^{\frac{1}{2}} = h(t)$. when $\gamma < 0$ the two plates are separated and for $\gamma > 0$, the two plates are squeezed. The generation of heat because of friction induced by shear in the flow and the viscous dissipation effect are retained. Thermal radiation is taken into account.

The governing equations for unsteady two-dimensional Casson fluid flow are given by

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0, \quad (1) \qquad \rho_f\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\left(1+\frac{1}{\beta}\right)\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\sigma B_0^2 u, \quad (2)$$

$$\rho_f\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right), \quad (3)$$

$$\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+\frac{\mu}{(\rho c_p)_f}\left(1+\frac{1}{\beta}\right)\left(T_H\left(\frac{\partial u}{\partial y}\right)^2\right)-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}, \quad (4)$$

The corresponding boundary conditions are

$$\left.\begin{array}{l} u=0, v=v_w=\dfrac{dh}{dt}, T=T_H \ at\ y=h(t), \\ v=\dfrac{\partial u}{\partial y}=\dfrac{\partial T}{\partial y}0 \ at\ y=0 \end{array}\right\} \quad (5)$$

To convert the governing equations into a set of nonlinear ordinary differential equations, we introduce the following similarity transformations:

$$\eta=\frac{y}{\left[\ell(1-\gamma t)^{0.5}\right]}, u=\frac{\gamma x}{2(1-\gamma t)}f'(\eta),\ v=-\frac{\gamma \ell}{2(1-\gamma t)^{0.5}}f(\eta), \theta=\frac{T}{T_H}, \quad (6)$$

Substituting (6) into (2) and (3) and then eradicating the pressure gradient from the resulting equations, we get the following nonlinear ordinary differential equation:

$$(1+1/\beta)f^{IV}-S\left(\eta f'''+2f''+f'f''-ff'''\right)-Ha\, f''=0 \quad (7)$$

Substituting (6) into (4), we get the following nonlinear ordinary differential equations:

Substituting (6) into (4), we get the following nonlinear ordinary differential equations:

$$\left(1+Ra\right)\theta''+\Pr S(f\theta'-\eta\theta')+\Pr Ec(1+1/\beta)f''^2=0, \quad (8)$$

The transformed boundary conditions are

$$\left.\begin{array}{l} f(0)=0, f''(0)=0, \theta'(0)=0, \\ f(1)=1, f'(1)=0, \theta(1)=1, \end{array}\right\} \quad (9)$$

Here S, $\Pr$, Ec, Ha, are defined as:

$$S=\frac{\gamma \ell^2}{2\mu},\ \Pr=\frac{\mu}{\rho_f \alpha},\ Ec=\frac{1}{c_p}\left(\frac{\gamma x}{2(1-\gamma t)}\right)^2, Ha=\ell B\sqrt{\frac{\sigma}{\mu}(1-\gamma t)}, \quad (10)$$

Nusselt number Nu is given by

$$Nu=\frac{-\ell k\left(\dfrac{\partial T}{\partial y}\right)_{y=h(t)}}{T_H} \quad (11)$$

By using (7), (13) becomes

$$Nu^*=\sqrt{1-\gamma t}\, Nu=-\theta'(1) \quad (12)$$

Results and Discussion

Equations (7) and (8) with respect to the boundary conditions (9) are solved numerically using bvp5c Matlab package. The results depict the effects of the non-dimensional parameters on the velocity and temperature profiles for both Newtonian and non-Newtonian fluids. In present paper, we have taken the values of non-dimensional parameters as $S=0.5, Ha=1, Ra=1, \Pr=3, Ec=0.5,$. These measures are preserved as fixed except the varied parameters as demonstrated in the respective figures.

Figs. 1-3 show the velocity, temperature and Nusselt number profiles for different values of Squeeze number(S). It observed from the figures that the velocity and temperature profiles of the flow are reduced by increasing values of the Squeeze numbers and increasing the Squeezing number enhances the Nusselt number profiles.

Figs. 4-6 display the influence of radiation parameter (Ra) on temperature, concentration and Nusselt number profiles. It noticed that an increase in the radiation parameter contributes to the decrease in the temperature and Nusselt number profiles and increase the radiation parameter enhances the concentration profiles. Generally, an increase in radiation parameter releases the heat energy to the flow, these causes to develop the thermal boundary layer thickness.

The influence of viscous dissipation parameter (Ec) on temperature, concentration and Nusselt number profiles are shown in Figs.7-9. It is clear that increasing the value of Eckert number enhances the temperature and Nusselt number profiles and increasing the value of Eckert number declined in concentration profiles. This is due to the fact that an increase in the dissipation causes to improve the thermal conductivity of the flow. This helps to enhance the thermal boundary layer thickness.

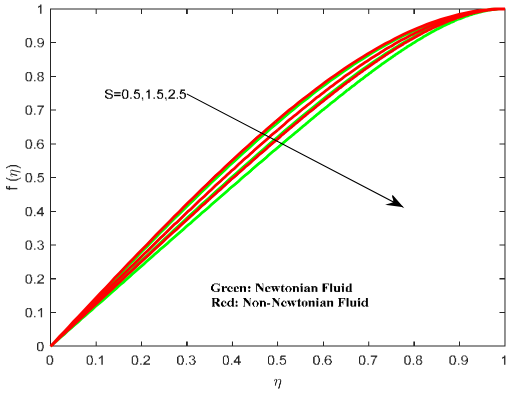


Fig. 1 Velocity profiles for various values of S

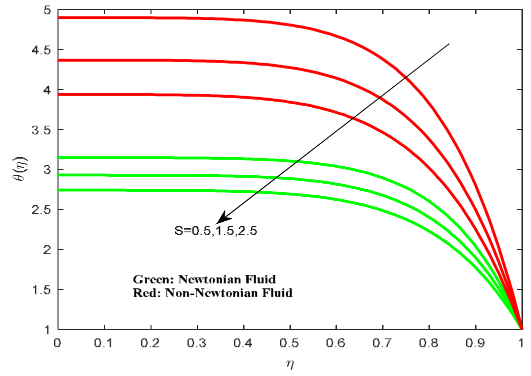


Fig. 2 Temperature profiles for various values of S

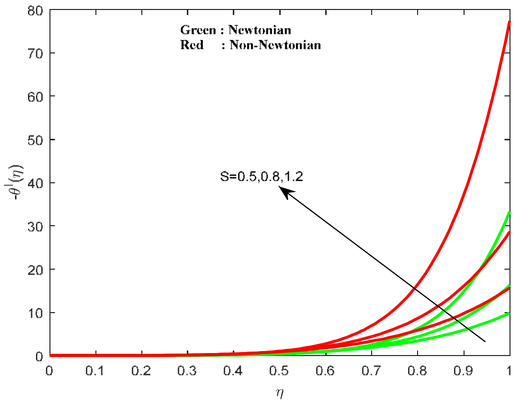


Fig. 3 Nusselt number profiles for various values of S

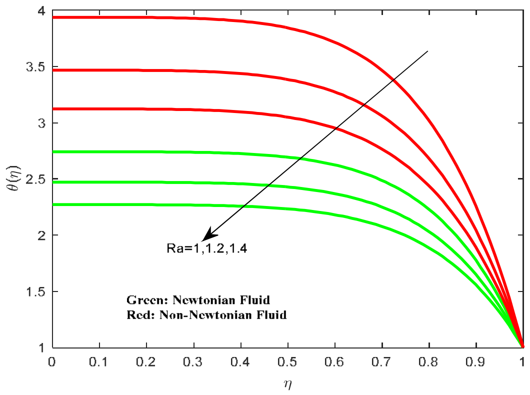


Fig. 4 Temperature profiles for various values of Ra

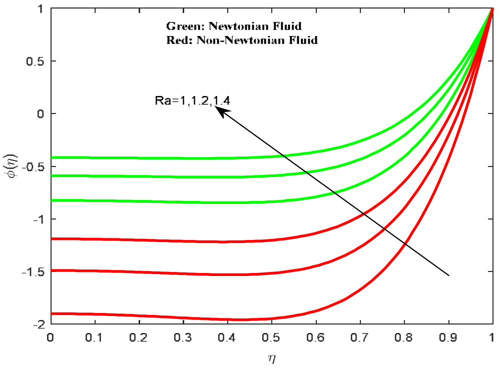


Fig. 5 Concentration profiles for various values of Ra

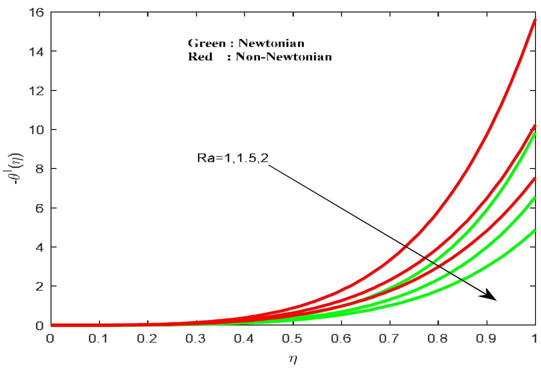
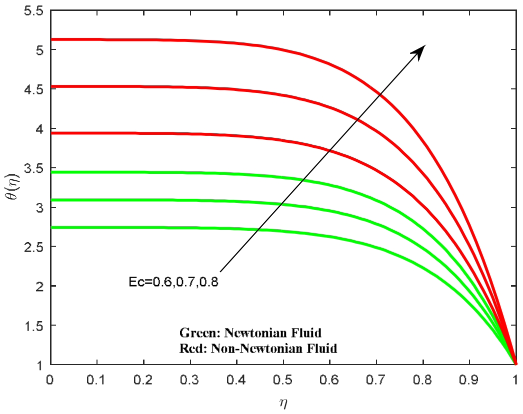


Fig. 6 Nusselt number profiles for various values of Ra



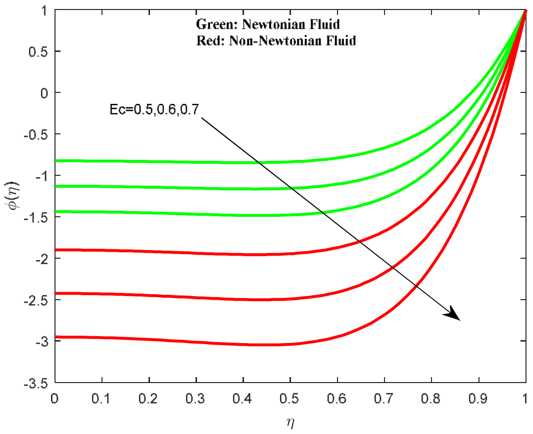


Fig. 7 Temperature profiles for various values of Ec Fig. 8 Concentration profiles for various values of Ec

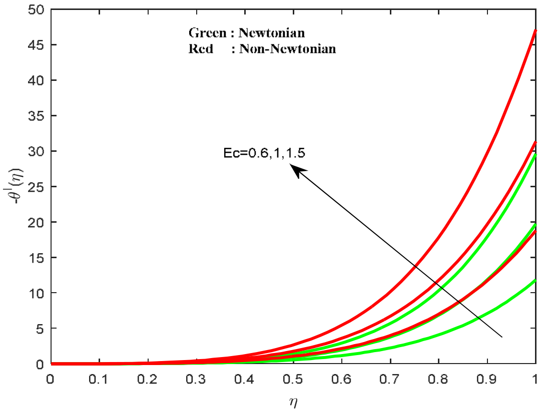


Fig. 9 Nusselt number profiles for various values of Ec

Conclusions

This study presented an unsteady MHD flow between parallel plates in the presence of viscous dissipation. The transformed governing equations are solved numerically using bvp5c Matlab package. The impact of different non-dimensional parameters on velocity and temperature profiles along with the local Nusselt number is discussed graphically. It is observed that the Nusselt number is a decreasing function of the radiation parameter and Hartmann number but it is an increasing function of squeeze number and Eckert number. The conclusions of the present study are made as follows:

- Squeeze number have tendency to decrease both the velocity and temperature profiles.
- An increase in the radiation parameter enhances the concentration profiles.
- An increase in the dissipation parameter enhances the friction factor and thermal boundary layer thickness.

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