Effect of the Thermal Gradient Along Electric Magnetic Force Past a Nonlinear Slanted Permeable Extending Surface

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Article Info
Page Number: 13042 - 13048
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: *21 September 2022*
Revised: *24 October 2022*
Accepted: *18 November 2022*
Publication: *13 December 2022*

Abstract

This study aims to test the significance of Brownian movement and thermophoresis dispersion on MHD Casson nano liquid limit layer stream past a nonlinear slanted permeable extending surface, with the impact of convective limits and warm radiation with a synthetic response. Nonlinear ODEs are obtained from overseeing nonlinear PDEs by utilizing good comparability changes. The amounts related to building angles, for example, skin grating, Nusselt, and Sherwood numbers, alongside different effects of factors from the material on the speed and temperature, are outlined. Numerical consequences of the current investigation are acquired through the Runge-Kutta Fehlberg strategy alongside the shooting procedure and, in a constraining sense, are diminished to the distributed outcomes for a precision reason.

Keywords: Thermal gradient, magnetic force, non-Newtonian fluid, slanted surface.

1. Introduction

Many industrial processes depend on fluids especially, non-Newtonian fluids. Few examples are plastic sheet extrusion, paper production, spinning of metals, glass fiber, etc. Maxwell is one of the non-Newtonian models, and he predicts the stress relaxation. The primary principle of MHD is that forces are produced in the fluid when the magnetic field induces a current through a moving conducting fluid. Magnetohydrodynamics has diverse engineering applications.

Several models such as the pseudo plastic model, Ellis model, power-law model, viscoelastic model etc. have been examined with different rheological equations and solved numerically in literature. Due to their complexity alongside nonlinearity, rheological equations of different types have been used by authors in literature to describe non-Newtonian fluids. The present study explored areas that have not been considered by researchers in previously published works. Inspired by the above-aforementioned literature, we hereby present in this paper the Brownian, thermophoretic diffusion movement and Buongiorno model for MHD Casson nanoliquid. The velocity and concentration alongside temperature profiles are illustrated with the aid of diagrams. Tables are used to display the computational findings for quantities of engineering importance.

All fluids in everyday life have viscosity, both liquids and gases. Clear honey is more viscous than water, water more viscous than alcohol; cold water about twice as viscous as hot water. Engine oil is specifically sold in various grades corresponding to its viscosity. Viscosity affects how quickly liquids flow in a given circumstance. Viscosity affects how quickly liquids flow in a given circumstance. Viscosity is a form of internal friction and as such during flow results in energy dissipation as heat.

Fig.1 shows the variation of viscosity for different fluid

Casson fluid behaviour is different from all other types of non-Newtonian fluids. It is a shear-thinning fluid with an indefinite zero viscosity shear rate and vice versa. Examples of fluid that portrays this type of behaviour are orange juice, toothpaste, honey, tomato sauce, human blood and soup. Hayat et al. [1] critically examined Casson fluid behaviour flowing on a stretchable surface. Maboob and Das [2] presented the influence of melting on the MHD Casson liquid flow past a stretchable permeable sheet. Kamran et al. [3] elucidate Casson nanofluid MHD flow. They obtained the solution of their flow equations numerically. Reddy et al [4] pondered the Soret and Dufour effects on an MHD micropolar fluid flow over a linearly stretching sheet, through a non-Darcy porous medium. They numerically solved their model using the method for Runge-Kutta along with shooting technique. Shah et al. [5] studied the model of Cattaneo-Christov for Casson ferrofluids past a stretchable sheet. The outcomes of their flow model were obtained using the homotopy analysis approach. Sodium alginate is another type of Casson liquid that many researchers have recently pondered on because of its applications in pharmaceuticals, textiles as well as cosmetics. Sodium alginate is highly viscous, it has solubility properties and is very safe. It is a type of Casson nano liquid. This type of fluid helps to enhance the fluid thermal properties. Khan et al. [6] explored Sodium alginate MHD Casson nanofluid through a penetrable medium. In recent times, Alwawia et al. [7] illustrated the movement of Sodium alginate Casson nano liquid past a solid sphere under the influence of magnetic force. Sandhya et al. [8] presented the heat and mass transfer effects on MHD flow past an inclined porous plate in the presence of chemical reaction. The researchers [12 – 15] have extended the above mentioned work.

In this paper an analysis is performed to investigate the effect of thermal radiation on the two-dimensional steady flow of an incompressible, upper-convected Maxwells (UCM) fluid. The governing mathematical model in terms of partial differential equations is transformed into a system of coupled nonlinear ordinary differential equations and is solved numerically. Velocity and temperature fields have been computed and shown graphically for various values of physical parameters. The objective of the present work is, to instigate the thermal effects of the proposed fluid.

2. Problem Statement

Following Kigio et al. [9], Oke and Mutuku [10] and Oke [11] in their formulations, the governing equations are

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\nu\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2(x)}{\rho}u-\frac{v}{K}u \tag{2}$$

The present analysis considered the boundary conditions (BCs) as:

$$\begin{aligned} &u=u_w(x)=ax^m; v=0; \text{ at } y=0 \\ &u\rightarrow u_\infty(x)=0; v\rightarrow o; T \text{ as} y\ \rightarrow\infty \end{aligned} \tag{3}$$

The similarity transformations variables are

$$\psi=\sqrt{\frac{2vax^{m+1}}{m+1}}f(\eta);\ \ ;\ \ \eta=y\sqrt{\frac{(m+1)ax^{m-1}}{2v}} \tag{4}$$

Substituting equations (3 and 4) into equation (2), the following ordinary differential equation obtained;

$$\left(1+\frac{1}{\beta}\right)f'''+ff''-\frac{2m}{m+1}(f')^2+\frac{2}{m+1}(\lambda\theta+\delta\phi)\cos\alpha-\frac{2}{m+1}\left(M+\frac{1}{K}\right)f'=0 \tag{5}$$

The transformed boundary constraints are:

$$\begin{aligned} &f(\eta)=0;\ \ f'(\eta)=1;\ \ \text{at}\ \eta=0 \\ &f'(\eta)\rightarrow 0\text{as}\ \ \eta\rightarrow\infty \end{aligned} \tag{6}$$

Where

$$\lambda=\frac{Gr}{Re_x^2};\delta=\frac{Gc}{Re_x^2};M=\frac{\sigma B_0^2(x)x}{\rho u_w};K=\frac{K_1 u_w}{vx}$$

3. Methodology

The governing equations of the model (1-2) with appropriate boundary conditions (3) as mentioned above are first converted into ordinary differential equations (5) and solved the converted ordinary differential equations numerically using Runge-Kutta fourth order algorithm with the shooting technique. The crucial part of the numerical solution is obtained with the help of the tool MATLAB bvp4c package. At employed Newton–Raphson scheme at this to correct the three arbitrary guess values such that the numerical solution will eventually satisfy the required boundary conditions.

The convergence criterion largely depends on fairly good guesses of the initial conditions in the shooting technique. The iterative process is terminated until the relative difference between the current and the previous iterative values matches.

4. Experimentation & Draft Setup

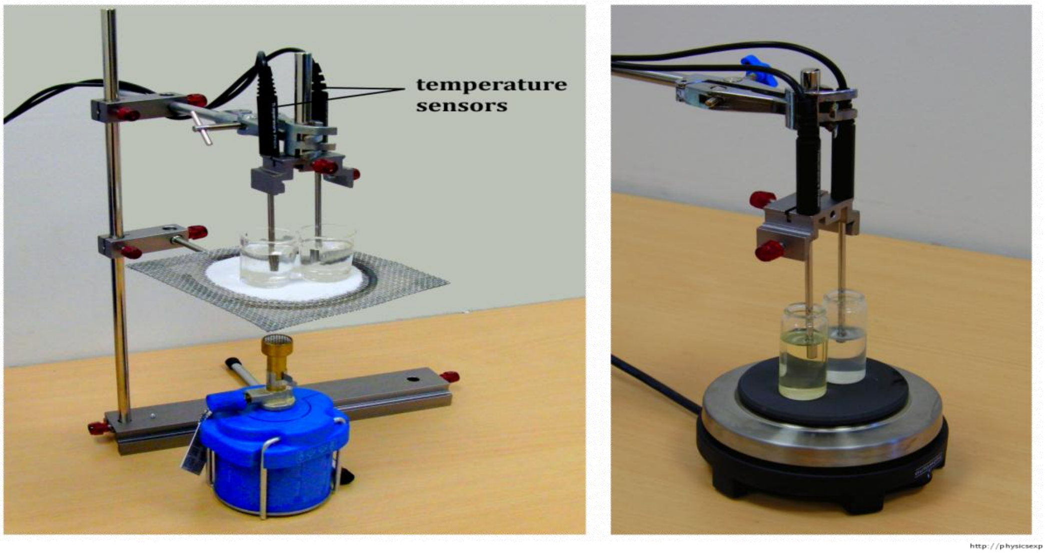

Fig-2: Experimental setup for radiation measurements for two different fluids

Several experiments have shown a huge enhancement in thermal radiation over the blackbody limit when two objects are separated by nanoscale gaps. Although those measurements only demonstrated enhanced radiation between homogeneous materials, theoretical studies now focus on controlling the near-field radiation by tuning surface polaritons supported in nanomaterials. The goal of this experiment is to compare specific heat capacities of sunflower oil and water.

Heat capacity is a physical quantity that determines the heat supplied to (resp. removed from) the body that causes heating (cooling) of the body by 1 K. Specific heat capacity determines the heat supplied to (removed from) the body that causes heating (cooling) of 1 kg of substance by 1 K; it is not a characteristic of a particular subject, but the material itself.

The specific heat capacity expresses a “willingness” of a substance to change its temperature – the lower the value, the more easily the temperature changes. In the sample experiment we used cooking sunflower oil ($c \doteq 2250\ \mathrm{J \cdot kg^{-1} \cdot K^{-1}}$) and two Vernier TMP-BTA temperature sensors. In the sample experiment we used cooking sunflower oil ($c \doteq 2250\ \mathrm{J \cdot kg^{-1} \cdot K^{-1}}$) and two Vernier TMP-BTA temperature sensors. Place the containers above a burner or on a cooker so that they are both supplied with the same amount of heat, i.e. symmetrically around the flame of the burner or in the middle of the cooker plate.

Insert the temperature sensors in both containers. The arrangement of the experiment in different variationsStart the measurement and begin to heat both liquids. Observe the graph plotted by the computer.Once one of the measured temperatures exceeds 80 °C, turn off the heat source and stop the measurement.It is also recommended to ensure that both liquids are of the same temperature before the measurement. This can be obtained by preparing both oil and water in the classroom an hour before the experiment.

5. Results And Discussion

Numerical solution is obtained for magnetohyderodynamic (MHD) flow about a stretching sheet. Similarity transformations are used to convert the highly non-linear governing partial differential equations into ordinary differential form. We adopt the most effective shooting method with fourth order Runge-Kutta integration scheme to solve boundary value problems in different heat transfer cases. The non-linear equations transformed into a system of first order differential equations. Numerical results have been computed for several values of the magnetic parameter M to check the accuracy of the numerical results. The results are presented in tabular form in table 1 for representative values of the magnetic parameter M. Flow parameters are varied and their significance on the flow are shown graphically.

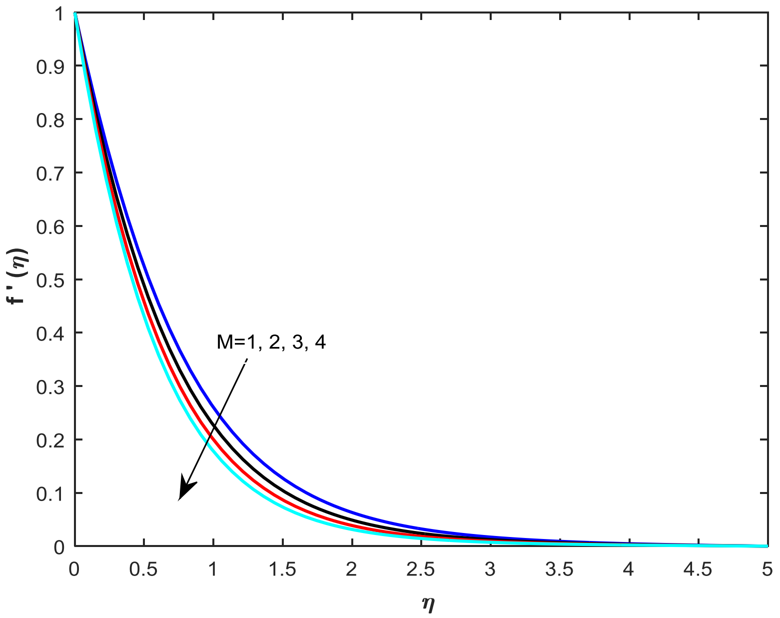

Fig 3. The effect of magnetic parameter M on the velocity profile

Figure 3 represents the magnetic and permeability terms' effects on the velocity plot. The magnetic parameter (M) is noticed to decline the velocity immediately after its value is increased. M has a significant effect on the fluid flow such that when it is applied transversely in the flow direction; it will produce the Lorentz force. In electromagnetism, Lorentz force is useful in engineering applications such as in plasma accelerators, MHD accelerators, hydrodynamic etc. Lorentz force is a phenomenon that slows the flow of an electrically conducting liquid. So, immediately the magnetic parameter increases more, it triggers the Lorentz force to decline the velocity as well as momentum boundary layer thickness.

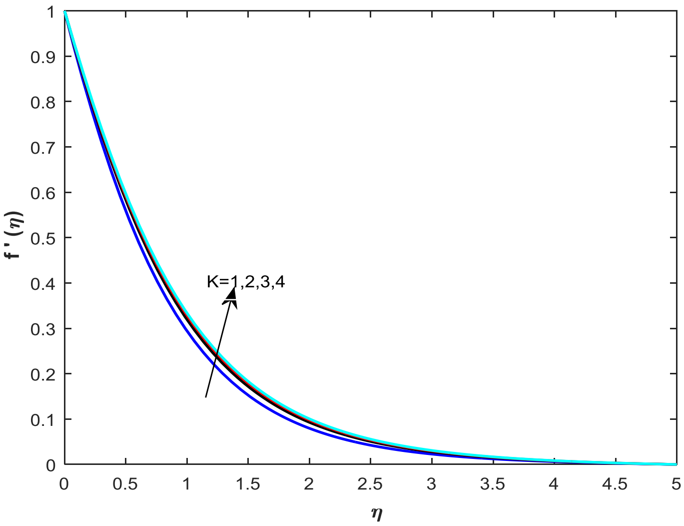

Fig 4. The effect of permeability parameter K on the velocity profile

The effects of large permeability term (K) as shown in figure 2 enhances the velocity profile. The presence of K allows the exchange of fluid particles among regions within the boundary layer. Now, increasing the value of K expands the pore size, hence providing space for more movement of fluid particles.

6. Conclusion

The Runge-Kutta method with the shooting procedure is utilized on the transformed differential equations (5) subject to (3) which describe the Brownian, thermophoretic diffusion and Buongiorno model for MHD Casson nanoliquid flow. The key findings in the present study is the effect of magnetic field on velocity profile. A large value of M is noticed to degenerate the velocity profile within the boundary region.

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