ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

Buongiorno Model Encompassing Brownian and Thermophoretic Diffusion in the Context of Magnetohydrodynamic Casson Nanofluid Flow over an Inclined Porous Surface.

DR.KOTTAPALLI RAJA SEKHARA PRASAD, Dept of chemistry, Koneru Lakshmaiah Education Foundation, India-522302

Abstract

The primary objective of this study is to investigate the impacts of Brownian motion and thermophoresis dispersion on the behavior of magnetohydrodynamic (MHD) Casson nanofluid boundary layer flow over a non-linear inclined permeable stretching surface. This analysis takes into consideration convective constraints, thermal radiation, and chemical reactions. Nonlinear ordinary differential equations (ODEs) are derived from governing nonlinear partial differential equations (PDEs) using appropriate similarity transformations. The study quantifies various engineering parameters, such as skin friction, Nusselt number, and Sherwood number, while elucidating their influence on the velocity, temperature, and concentration profiles through graphical representations.

Introduction

The exploration of non-Newtonian fluids has garnered considerable attention from researchers, engineers, and scientists, primarily due to their diverse applications, including food production and annealing [1]. These fluids play a pivotal role in various industrial manufacturing processes, encompassing areas such as biological fluids, lubricants, paints, and polymeric suspensions. Numerous models, such as the pseudo-plastic model, Ellis model, power law model, and viscoelastic model, have been scrutinized in the literature, each accompanied by distinct rheological equations and numerical solutions [2]. Non-Newtonian fluids exhibit complexity and nonlinearity, leading researchers to employ various types of rheological equations to characterize their behavior. Of particular interest is the Casson fluid, which stands apart from other non-Newtonian fluids [3]. It showcases shear-thinning characteristics, manifesting indefinite viscosity at zero shear rate and vice versa. Illustrative examples of this behavior can be observed in substances like orange juice, toothpaste, honey, tomato sauce, human blood, and soup [4]. In 2012, Hayat et al. conducted an in-depth analysis of Casson fluid behavior within the context of flow over a stretchable surface. Maboob and Das (2019) investigated the impact of melting on the flow of magnetohydrodynamic (MHD) Casson fluid past a stretchable sheet within a penetrable medium. Kamran et al. (2017) contributed to the understanding of Casson nanofluid MHD flow [5].

This study delves into the domain of free convection MHD radiating flow over an inclined plate confined within a porous medium. Prior research efforts have shed light on various aspects of related phenomena [6]. For instance, R. Nasrin and M.A. Alim (2011) investigated the influence of variable thermal conductivity on the interplay between conduction, Joule heating, and MHD free convection flow along a vertical flat plate [7]. In a similar vein, R. Nasrin and M.A. Alim (2010) examined the combined impact of viscous dissipation and temperature-dependent thermal conductivity on MHD free convection flow featuring conduction and Joule heating along a vertical flat plate [8]. Furthermore, R. Nasrin (2010) provided insights into MHD free convection flow along a vertical flat plate with thermal conductivity and viscosity dependent on temperature. This study seeks to fill gaps overlooked in prior research endeavors [9]. Building upon the aforementioned literature, we present an investigation involving the Buongiorno model integrated with Brownian and thermophoretic diffusion

  UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

phenomena for MHD Casson nanofluid. Our paper offers numerical results pertaining to velocity, concentration, and temperature distributions [10].

Mathematical formulation

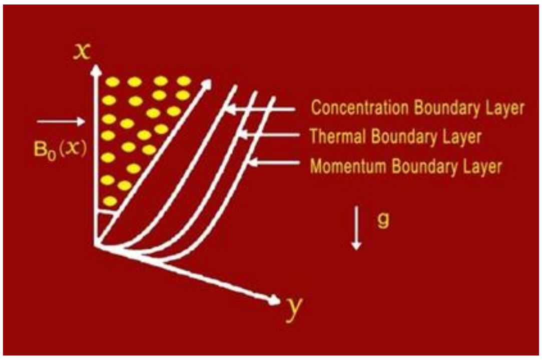

Figure 1: Physical model of the problem

The rheological model of state for an isotropic motion of a Casson liquid can be uttered as:

$$\tau_{ij} = \begin{cases} 2\left(\mu_B + \dfrac{P_y}{\sqrt{2\pi}}\right)e_{ij}, & \pi > \pi_c \\ 2\left(\mu_B + \dfrac{P_y}{\sqrt{2\pi_c}}\right)e_{ij}, & \pi < \pi_c \end{cases} \tag{1}$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{2}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\left(1 + \frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2} + g\left[\beta_T\left(T - T_\infty\right) + \beta_C\left(C - C_\infty\right)\right]\cos\gamma - \frac{\sigma B_0^2(x)}{\rho}u - \frac{\nu}{K}u \tag{3}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{\kappa}{\rho Cp}\frac{\partial^2 T}{\partial y^2} - \frac{1}{(\rho c)_f}\frac{\partial q_r}{\partial y} + \tau\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] \tag{4}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2} - K_r\left(C - C_\infty\right) \tag{5}$$

In this problem the boundary conditions are considered as:

$$\begin{aligned} & u = u_w(x) = ax^m;\ v = 0;\ -k\frac{\partial T}{\partial y} = h_f\left[T_f - T\right];\ C = C_w \text{ at } y = 0 \\ & u \to u_\infty(x) = 0;\ v \to \alpha,\ T \to T_\infty;\ C \to C_\infty \text{ at } y \to \infty \end{aligned} \tag{6}$$

The Roseland flux estimation is expressed as:

$$q_r = \frac{-4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y} \tag{7}$$

$$T^4 = 4T_\infty^3 T - 3T_\infty^4 \tag{8}$$

Using equations (7) and (8), the equation (4) is converted to:

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \left[\alpha + \frac{16\sigma^* T_\infty^3}{3k^*(\rho c)_f}\right]\frac{\partial^2 T}{\partial y^2} - +\tau\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] \tag{9}$$

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

$$u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x} \tag{10}$$

Introducing the similarity transformations as:

$$\psi = \sqrt{\frac{2\upsilon a x^{m+1}}{m+1}} f(\eta);\ \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty};\ \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty};\ \eta = y\sqrt{\frac{(m+1) a x^{m-1}}{2\upsilon}} \tag{11}$$

Results

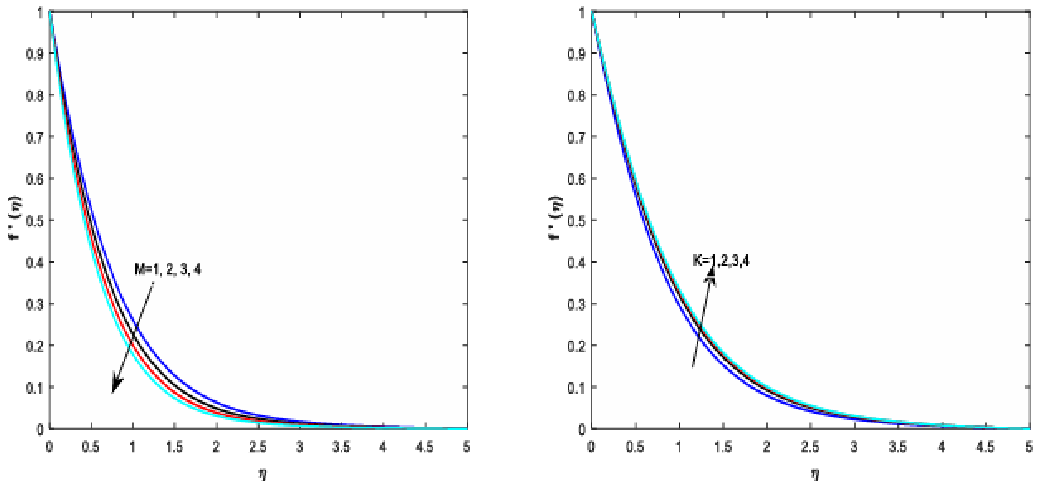

Figure 2: Effect of magnetic parameter (M) and permeability parameter (K) on velocity profile

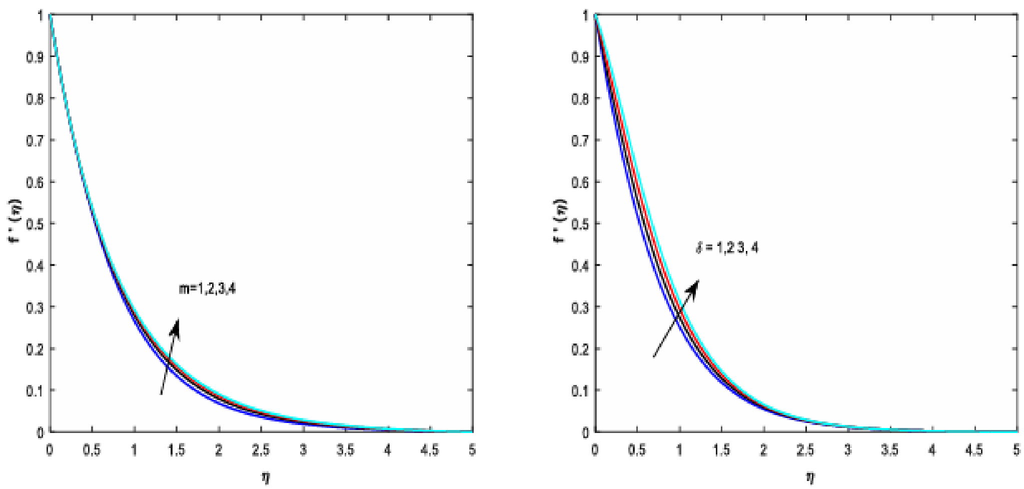

Figure 3: Effect of power index parameter (m) and solutal buoyancy parameter (δ) on velocity profile

Conclusion

The results derived from this study align closely with those presented in previously published research. The primary discoveries from this investigation are as follows:

- An increased value of M leads to a degradation in the velocity profile.

- The velocity profile experiences degradation with higher values of β.

- The Biot number (Bi) exhibits an enhancement in the heat transport coefficient.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper © 2012 IJFANS. All Rights Reserved, UGC CARE Listed (Group -I) Journal Volume 10, Spl Iss 2, 2021

- Higher values of Nb and Nt contribute to the augmentation of the temperature profile.

- All relevant flow parameters have been observed to intensify the rate of heat and mass transport, as evidenced by the rise in the local skin friction coefficient, Nusselt number, and Sherwood number.

References

[1] Hayat, T. Shehzad, S.A. Alsaedi, A. and Alhothuali, M. S. (2012): Mixed convection stagnation point flow of Casson fluid with convective boundary conditions, Chin. Phys. Lett., Vol. 29,114704.

[2] Mabood, F. and Kalidas, D. (2019): Outlining the impact of melting on MHD Casson fluid flow past a stretching sheet in a porous medium with radiation, Heliyon, Vol. 5.

[3] Kamran, S. Hussain, M. Sagheer, N. and Akmal, (2017): A numerical study of magnetohydrodynamics flow in Casson nanofluid combined with Joule heating and slip boundary conditions, Results in Physics, Vol. 7, pp. 3037-3048.

[4] Falodun, B.O. Onwubuoya, C. and AwoniranAlamu F.H. (2018): Magnetohydrodynamics (MHD) Heat and Mass Transfer of Casson Fluid Flow Past a Semi-Infinite Vertical Plate with Thermophoresis Effect: Spectral Relaxation Analysis, Defect and Diffusion Forum, Vol. 389, pp 18-35.

[5] Zahir, S. Abdullah, D. Khan, I. Saeed, I. Dennis, L. C. C. Aurang, Z. and Khan (2019): Cattaneo-Christov model for electrical magnetite micropoler Casson ferrofluid over a stretching/shrinking sheet using effective thermal conductivity model, Case Studies in Thermal Engineering, Vol. 13.

[6] Arshad, K. Dolat, K, Ilyas, K. Farhad, A. Faizan, U. K. and Muhammad, I.(2018): MHD Flow of Sodium

AlginateBased Casson Type Nanofuid Passing Through A Porous Medium With Newtonian Heating,

SCIEnTIFICRePorTS, Vol. 8, pp. 1-12. https://doi.org/10.1038/s41598-018-26994-1

[7] Firas, A. Alwawia, Hamzeh, T. Alkasasbeh, Rashad, A. M. and Ruwaidiah, I. (2020): MHD natural convection of Sodium Alginate Casson nanofluid over a solid sphere, Results in Physics, Vol. 16.

[8] Idowu, A. S. and Falodun, B.O. (2020): Effects of thermophoresis, Soret- Dufour on heat and mass transfer flow of magnetohydrodynamics non-Newtonian nanofluid over an inclined plate, Arab Journal of Basic and Applied Sciences, Vol. 27, pp. 149-165

[9] Hossein, A. SeyedSajad, J. Navid, F. (2018): Analytical approximation of MHD nano-fluid flow induced by a stretching permeable surface using Buongiorno's model, Ain Shams Engineering Journal, Vol. 9, pp. 525-536.

[10] Seethi Reddy, R. PoluBala, A. R. Ali, J. Ch.: Influence of Soret and Dufour effects on unsteady 3D MHD slip flow of Carreau nanofluid over a slandering stretchable sheet with chemical reaction, Nonlinear Analysis: Modelling and Control, Vol. 24, No. 6, 853-869.