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

Interplay of Brownian Motion, Thermophoretic Diffusion, and Lorenz Force in the Flow of Casson Nanofluid over a Permeable Surface.

K saikumar, Department of ECE, Koneru Lakshmaiah Education Foundation, India-522302,

saikumarkayam4@ieee.org

SK ahammad , Department of ECE, Koneru Lakshmaiah Education Foundation, India-522302,

Abstract

This research aims to investigate the significance of Brownian motion and thermophoresis dispersion on the magnetohydrodynamic (MHD) Casson nanofluid flow over a non-linear slanted permeable stretching surface, considering the influence of convective boundaries and thermal radiation with a synthetic response. Nonlinear ordinary differential equations (ODEs) are derived from managing the nonlinear partial differential equations (PDEs) through suitable similarity transformations. Various quantities related to flow characteristics, such as skin friction, Nusselt number, and Sherwood number, as well as other factors affecting velocity and temperature profiles, are analysed.

Introduction

Non-Newtonian fluids have garnered considerable attention from researchers, engineers, and scientists due to their diverse applications, including food production, annealing, and various industrial manufacturing processes. These fluids find utility in biological applications, lubricants, paints, polymeric suspensions, among others. Researchers have explored several models, such as the pseudoplastic model, Ellis model, power-law model, viscoelastic model, among others, to understand their behaviour through different rheological equations, which have been solved numerically in various studies. Given their intricacy and nonlinearity, authors in the literature have employed diverse types of rheological equations to effectively describe the characteristics of non-Newtonian fluids.

The behaviour of Casson fluids distinguishes them from all other types of non-Newtonian fluids. They exhibit shear-thinning characteristics with an undefined zero viscosity at zero shear rate and vice versa. Everyday examples of fluids displaying this behavior include orange juice, toothpaste, honey, tomato sauce, human blood, and soup. Several studies have explored different aspects of Casson fluid flow: Hayat et al. [1] conducted a critical examination of Casson fluid behavior over a stretchable surface. Ugwah-Oguejiofor et al. [2] investigated the influence of melting on MHD Casson liquid flow past a stretchable permeable sheet. Kamran et al. [3] elucidated the flow of Casson nanofluid in the presence of a magnetic field. They obtained numerical solutions for their flow equations. Reddy and Krishna [4] studied the effects of Soret and Dufour on an MHD micropolar fluid flow over a linearly

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

stretching sheet through a non-Darcy porous medium. They numerically solved their model using the Runge-Kutta method combined with the shooting technique. Shah et al. [5] focused on the model of Cattaneo-Christov for Casson ferrofluids flowing past a stretchable sheet. These studies contribute to a better understanding of the unique behavior of Casson fluids and their applications in various contexts [6-8]. This current study delves into unexplored areas that have not been investigated in prior published works. Building upon the insights from the literature mentioned above, this paper introduces the incorporation of Brownian motion, thermophoretic diffusion movement, and the Buongiorno model for magnetohydrodynamic (MHD) Casson nanoliquid [9-11]. The velocity, concentration, and temperature profiles are depicted through illustrative diagrams, while computational results of engineering significance are presented in tables.

Problem description

Consider an incompressible, Casson nano liquid flow of a nonlinear slanting porous stretchable sheet.

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

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

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}-\tau\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y}+\frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right]=\frac{\kappa}{\rho c_p}\frac{\partial^2 T}{\partial y^2}-\frac{1}{(\rho c_p)_f}\frac{\partial q_r}{\partial y}, \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_B\frac{\partial^2 C}{\partial y^2}+\frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2}-K_r(C-C_\infty). \tag{4}$$

Roseland radiation flux is

$$q_r=\frac{-4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y},\quad \tau=\frac{(\rho c)_p}{(\rho c)_f}. \tag{5}$$

$$T^4=T_\infty^3(4T-3T_\infty). \tag{6}$$

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**

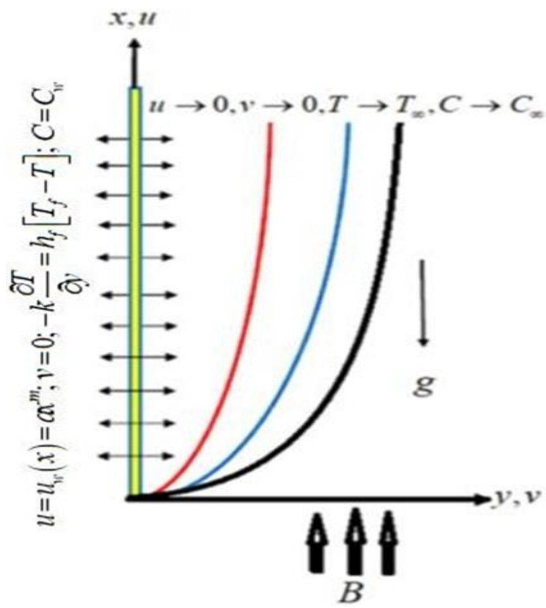

Fig. 1. Physical geometry

Putting Eq. (5) and Eq. (6) in Eq. (3) is simplified to

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\left[\alpha+\frac{16\sigma^{*}T_{\infty}^{3}}{3k^{*}(\rho c)_{f}}\right]\frac{\partial^{2}T}{\partial y^{2}}-+\tau\left[D_{B}\frac{\partial C}{\partial y}\frac{\partial T}{\partial y}+\frac{D_{T}}{T_{\infty}}\left(\frac{\partial T}{\partial y}\right)^{2}\right]. \quad (7)$$

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

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

$$u = u_w(x) = ax^m; v = 0; -k\frac{\partial T}{\partial y} = h_f[T_f - T]; C = C_w \text{ at } y = 0, \quad (8)$$
$$u \to u_\infty(x) = 0; v \to o; T \to T_\infty; C \to C_\infty \text{ at } y \to \infty.$$

The transformations variables are

$$\psi = \sqrt{\frac{2\upsilon a x^{m+1}}{m+1}} f(\eta); \;\; \theta(\eta) = \frac{T-T_\infty}{T_w-T_\infty}; \;\; \phi(\eta) = \frac{C-C_\infty}{C_w-C_\infty}; \;\; \eta = y\sqrt{\frac{(m+1)ax^{m-1}}{2\upsilon}}. \quad (9)$$

Substituting Eq. (9) into Eq. (1) to Eq. (4), the following ordinary differential equations are obtained;

$$\left(1+\frac{1}{\beta}\right) f''' + ff'' - \frac{2m}{m+1}(f')^2 + \frac{2}{m+1}(\lambda\theta + \delta\phi)\cos\alpha - \frac{2}{m+1}\left(M + \frac{1}{K}\right) f' = 0, \quad (10)$$

$$\left(1+\frac{4R}{3}\right)\theta'' + \Pr f\theta' + \Pr Nb\theta'\phi' + \Pr Nb\,(\theta')^2 = 0, \quad (11)$$

$$\phi'' + (Nt/Nb)\theta'' + Lef\phi' - Kr\, Le\,\phi = 0, \quad (12)$$

The transformed boundary constraints are:

$$f(\eta) = 0;\; f'(\eta) = 1;\; \theta'(0) = -Bi\big(1-\theta(0)\big);\; \phi(\eta) = 1 \;\text{ at } \eta = 0, \quad (13)$$
$$f'(\eta) \to 0;\; \theta(\eta) \to 0;\; \phi(\eta) \to 0 \;\text{ as } \eta \to \infty,$$

Results

The Runge-Kutta Fehlberg scheme with shooting technique is employed to investigate the results of the transformed ordinary differential equations of Eq. (10) to (12) with the BCs (13). The main aim is based on the impact of Brownian movement along with thermophoresis on MHD Casson nano liquid limit layer over a nonlinear slanted permeable surface [12-14]. The heat and mass transport problem were set up with thermophoresis, thermal radiation and Brownian motion. The flow model is solved numerically, and the physics of the problem is shown graphically [15].

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**

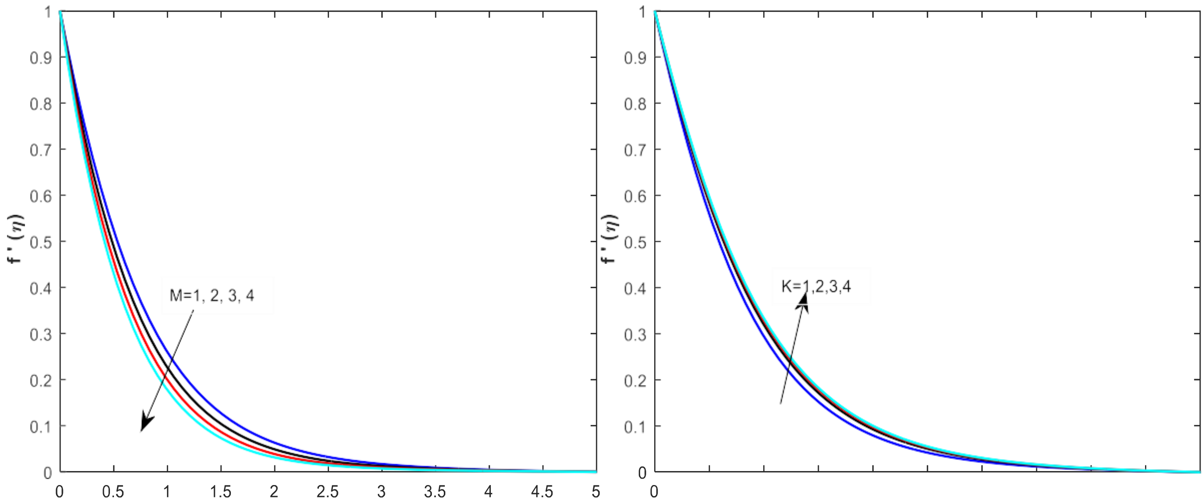

Fig. 2. Velocity profiles with magnetic and permeability parameters

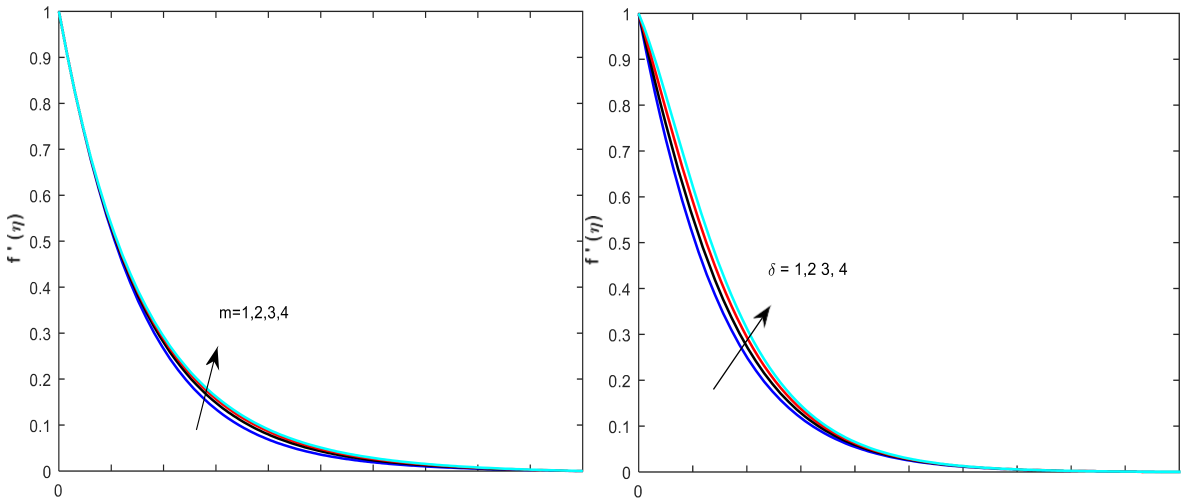

Fig. 3. Velocity profiles with power index and solute buoyancy parameters

References

[1] Hayat, T., S. A. Shehzad, A. Alsaedi, and M. S. Alhothuali. "Mixed convection stagnation point flow of Casson fluid with convective boundary conditions." Chinese Physics Letters 29, no. 11 (2012): 114704.

[2] Ugwah-Oguejiofor, Chinenye Jane, Charles Ogbonna Okoli, Michael Oguejiofor Ugwah, Millicent Ladi Umaru, Chiedozie Smart Ogbulie, Halilu Emmanuel Mshelia, Mohammed Umar, and Anoka Ayembe Njan. "Acute and sub- acute toxicity of aqueous extract of aerial parts of Caralluma dalzielii NE Brown in mice and rats." Heliyon 5, no. 1 (2019): e01179.

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

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**

[4] Reddy, G. V. R., and Y. Hari Krishna. "Soret and dufour effects on MHD micropolar fluid flow over a linearly stretching sheet, through a non-darcy porous medium." International Journal of Applied Mechanics and Engineering 23, no. 2 (2018).

[5] Shah, Zahir, Abdullah Dawar, I. Khan, Saeed Islam, Dennis Ling Chaun Ching, and Aurang Zeb Khan. "Cattaneo- Christov model for electrical magnetite micropoler Casson ferrofluid over a stretching/shrinking sheet using effective thermal conductivity model." Case Studies in Thermal Engineering 13 (2019): 100352.

[6] Khan, Arshad, Dolat Khan, Ilyas Khan, Farhad Ali, and Muhammad Imran. "MHD flow of sodium alginate-based Casson type nanofluid passing through a porous medium with Newtonian heating." Scientific Reports 8, no. 1 (2018): 1-12

[7] Alwawi, Firas A., Hamzeh T. Alkasasbeh, A. M. Rashad, and Ruwaidiah Idris. "MHD natural convection of Sodium Alginate Casson nanofluid over a solid sphere." Results in Physics 16 (2020): 102818.

[8] Sandhya, A., G. V. Ramana Reddy, and V. S. R. G. Deekshitulu. "Heat and mass transfer effects on MHD flow past an inclined porous plate in the presence of chemical reaction." International Journal of Applied Mechanics and Engineering 25, no. 3 (2020). https://doi.org/10.2478/ijame-2020-0036

[9] Dolatabadi, Nader, Ramin Rahmani, Homer Rahnejat, and Colin P. Garner. "Thermal conductivity and molecular heat transport of nanofluids." RSC Advances 9, no. 5 (2019): 2516-2524.

[10] Buongiorno, Jacopo. "Convective transport in nanofluids." Journal of Heat Transfer 128, no. 3 (2006): 240-250.

[11] Buongiorno, Jacopo, Lin-Wen Hu, Sung Joong Kim, Ryan Hannink, B. A. O. Truong, and Eric Forrest. "Nanofluids for enhanced economics and safety of nuclear reactors: an evaluation of the potential features, issues, and research gaps." Nuclear Technology 162, no. 1 (2008): 80-91.

[12] Ajam, Hossein, Seyed Sajad Jafari, and Navid Freidoonimehr. "Analytical approximation of MHD nano-fluid flow induced by a stretching permeable surface using Buongiorno's model." Ain Shams Engineering Journal 9, no. 4 (2018): 525-536.

[13] Reddy, Seethi Reddy Reddisekhar, Polu Bala Anki Reddy, and Ali J. Chamkha. "Influence of Soret and Dufour effects on unsteady 3D MHD slip flow of Carreau nanofluid over a slendering stretchable sheet with chemical reaction." Nonlinear Analysis: Modelling and Control 24, no. 6 (2019): 853-869.

[14] Raju, K., Pilli, S. K., Kumar, G. S. S., Saikumar, K., & Jagan, B. O. L. (2019). Implementation of natural random forest machine learning methods on multi spectral image compression. Journal of Critical Reviews, 6(5), 265-273.

[15] Saba, S. S., Sreelakshmi, D., Kumar, P. S., Kumar, K. S., & Saba, S. R. (2020). Logistic regression machine learning algorithm on MRI brain image for fast and accurate diagnosis. International Journal of Scientific and Technology Research, 9(3), 7076-7081.