MHD STEFAN FLOW OF CASSON NANOFLUID THROUGH A POROUS MEDIUM IN THE PRESENCE OF CHEMICAL REACTION WITH THE EFFECT OF THOMPSON AND TROIAN SLIP OVER A PLATE IN THE COMPANY OF RADIATION

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Abstract

In this study, we present the impact of Stefan blowing, Thompson and Troian slip on the behavior of magnetohydrodynamic (MHD) Casson nanofluid past a porous medium in the presence of a chemical reaction. Using a two-phase model for nanofluids, we also investigate the influence of velocity distribution, Joel heat, and radiation parameters. The main Partial Differential Equations (PDEs) can be transformed into Ordinary Differential Equations (ODEs) using similarity transformations. To solve nonlinear equations, MATLAB Shooting and Runge-Kutta techniques can be used. The changes in non-dimensional perimeters reveal how fluid flow, heat, and mass transfer characteristics are affected. It is observed that with the expansion of Stefan blowing parameter S, the skin friction coefficient decreases. The fluid concentration reduces with the increasing values of Thompson and Troian slip parameters. The heat of the fluid increases with the increase of N_t, N_b and k, but the concentration decreases. The outcomes of this examination provide many appealing features that is going to give merits for further study of the problems.

2. Formulation of the problem

Let us think about a forced convective Casson nano liquid flow over a plate of enormously small width and greatly bigger span, fixed in the medium (see, Fig. 1). The $y-$axis is normal to the upward direction plate of $x-$axis. We assume that the applied magnetic field is perpendicular to the plate. The magnetic field is applied to the strength of the transverse magnetic field. Assuming u, v as the velocity apparatuses of parallel and normal to the plate respectively. Based on the above-mentioned conditions, the rheological equations are [33] given by

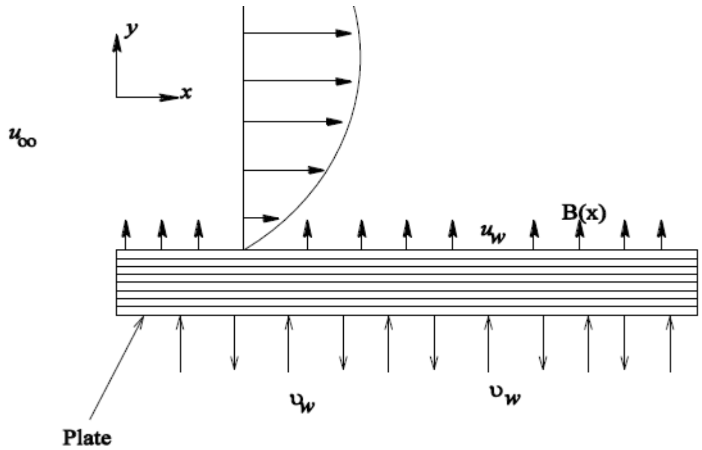

Fig. 1. Sketch of the physical flow problem

The appropriate governing equations of the problem

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon_f\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2}{\rho_f}(u-u_\infty)-\frac{\mu}{k}u \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\frac{(\rho c)_p}{(\rho c)_f}\left[D_B\frac{\partial C}{\partial y}\frac{\partial T}{\partial y}+\frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right]-\frac{1}{(\rho c)_f}\frac{\partial q_r}{\partial y}+\frac{\nu}{(\rho c)_f}\left(1+\frac{1}{\beta}\right)\left(\frac{\partial u}{\partial y}\right)^2 \tag{3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial c}{\partial y}=D_B\frac{\partial^2 C}{\partial y^2}+\frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2}+k_1(C-C_\infty) \tag{4}$$

Here, u and υ are the velocity components in the x and y directions respectively,

The appropriate boundary conditions for this problem are given below as,

$$u=\gamma\left(1-\zeta\frac{\partial u}{\partial y}\right)^{-1/2}\frac{\partial u}{\partial y},\quad v=\frac{-D_B}{(1-C_w)}\frac{\partial C}{\partial y},\quad T=T_\infty,\quad C=C_w \text{ at } y=0 \tag{5a}$$

$u = u_\infty(y) = \beta_1 y$, $T = T_\infty$, $C = C_\infty$ at $y \to \infty$

(5b)

Similarity analysis and solution procedure

We now put the following similarity transformation relations for u, v as

$$u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x} \tag{6}$$

Where, ψ is the stream function. Again, let us introduce the following dimensionless variables,

$$\eta = \frac{y}{L}\left(\frac{x}{L}\right)^{-1/2}, \ \psi = v\left(\frac{x}{L}\right)^{2/3} f(\eta) \quad \text{and} \quad \theta = \frac{T - T_\infty}{T_w - T_\infty}, \ \phi = \frac{C - C_\infty}{C_w - C_\infty} \tag{7}$$

Using the relations (6)–(7) in the boundary layer Eq. (2), energy Eq. (3) and concentration Eq. (4) the following equations are obtained.

$$\left(1 + \frac{1}{\beta}\right) f''' + \frac{2}{3} f f'' - \frac{1}{3}(f')^2 - \left(M + \frac{1}{K}\right) f' = 0 \tag{8}$$

$$\frac{1}{\Pr}\left(1 + \frac{4R}{3}\right)\theta'' + N_b \theta' \phi' + N_t (\theta')^2 + \frac{2}{3} f \theta' + Ec\left[(f')^2 + (f'')^2\right] = 0 \tag{9}$$

$$\phi'' + \frac{N_t}{N_b}\theta'' + Le\left[\frac{2}{3} f \phi' - k\phi\right] = 0 \tag{10}$$

the boundary conditions finally become

$$f = \frac{3S}{2Le}\phi', \ f' = \delta(1 - \beta_1 f''), \ \theta = 1, \ \phi = 1 \text{ at } \eta = 0 \tag{11}$$

$f'' = 1, \theta = 0, \phi = 0$ at $\eta \to \infty$

(12)

Results and Conclusions

Stefan flow of Casson nanofluid over a plate in the presence of shear flow, porous, MHD, and Radiation has been investigated. The effects of the Thompson-Troian slip at the boundary have also been inspected. Numerical solutions have been obtained and a comparison has been made with the available data and found excellent agreement. The following observations are made.

(i)Temperature increases with the augmented values of the thermophoresis parameter N_t and reduction in concentration is noted for mounting values of the Brownian motion parameter N_b.

(ii) Temperature decreases whereas the concentration oscillates with the rising values of chemical reaction parameter k.

(iii) Heat is transported from the plate to the liquid

(iv) Skin friction coefficient reduces with the growing values of Stefan blowing parameter S

(v) Mass transport rate diminishes with the rise in slip parameter δ and critical shear rate β.

References

1. Gupta, P.S., Gupta, A.S. (1997). Heat and mass transfer on a stretching sheet with suction or blowing. The Canadian Journal of Chemical Engineering, 55(6), 744–746.

2. Bhattacharyya, K., Pop, I. (2011). MHD boundary layer flow due to an exponentially shrinking sheet. Magnetohydrodynamics, 47, 337–344.

3. Mahapatra, T.R., Gupta, A.S. (2001). Magnetohydrodynamic stagnation-point flow towards a stretching sheet. Acta Mechanica, 152(1-4), 191–196.

4. Babu, K.S.S., Parandhama, A. Vijaya, R.B. Non-linear MHD convective flow of Carreau nanofluid over an exponentially stretching surface with activation energy and viscous dissipation. SN Appl. Sci. 3, 382 (2021).

5. Ikrom Kulanov, Sneha Latha, Azizbek Uzakboyev, Shakhzoda Burkhanova. Effect of gyrotactic microorganisms on electrically conducting carreau nanofluid flow along an exponentially stretching surface in the presence of chemical reaction. Problems in the textile and light industry in the context of integration of science and industry and

ways to solve them: ptlicisiws-2.4–5 may 2023.Namangan, Uzbekistan.AIP Conf. Proc. 3045, 030066 (2024) https://doi.org/10.1063/5.0197498