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SLIP EFFECTE ON MAGNETO HYDRO DYNAMICS CASSON FLUID FLOW IN THE INFLUENCE OF THERMAL AND SORET RADIATION

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Abstract

This paper presents in detail the numerical results for the two-dimensional steady and mixed convection motion of numerous slip contributions on MHD Casson liquid with Soret coupled to thermal radiation. Equations for the flow model are D.E.with greater than one independent variable (PDEs), often known as equations for species momentum and energy. Through the use of similarity variables, these model equations are modelled to ODE's. Runge-Kutta Fehlberg is used in conjunction with the shooting method to solve the simplified nonlinear ODEs. Key parameters that affect concentration, skin friction, temperature, velocity, heat rate, and mass movement are described subjectively and visually.

Keywords: Soret radiation, Casson liquid, Thermal radiation

1. Introduction

Given the diverse applications of boundary layer motion, the use of a solid, expanding sheet has provided groundbreaking contributions for several decades. Various fields, such as wire drawing, paper and sheet manufacturing, heat transfer materials, solidification of precious liquids, everyday kitchen products, fiber production, glass processing, and more, have benefited from the utility of expanding surfaces. The introduction of the Casson rheological model, initially proposed by Casson [1], has played a pivotal role in addressing these applications. Researchers like Nazar [4], Mahapatra et al. [3], and Chao [2] have all been captivated by the study of boundary layer motion over stretchable surfaces and stagnation regions. In this context, Nazar et al. [5] specifically investigated the stagnation of micropolar liquid motion over a stretchable sheet.

Ishak et al. [6] introduced convectionmixed layers in the context of stagnation-region motion. Wang [7] examined the stagnation flow of a diminishing sheet. Salleh et al. [8] investigated the behavior in forced convection boundary layer motion.

Nadeem et al. [9] conducted a study to investigate how heat transport affects the stagnation motion of a third-order liquid over a diminishing sheet.

Borrelli et al. [10] examined the oblique stagnation-region motion of a micropolar fluid with the inclusion of Magnetohydrodynamics (MHD). Nadeem et al. [11] demonstrated the flow of a Williamson liquid past a stretchable sheet. Nandy et al. [12] proposed that, in addition to heat generation or absorption, slip plays a significant role in MHD stagnation motion. For a comprehensive understanding of the motion and heat transfer near the stagnation region, Turkyil et al. [13] presented precise analytical results.

In their research, Hamad et al. [14] examined the effects of thermal leap contributions on the boundary layer motion of a Jeffrey liquid as it approaches stagnation motion on a stretchable/shrinking sheet. Their investigation specifically delved into the influence of altering thermal conductivity.To gain deeper insights into the stagnation motion of a Williamson nanoliquid passing over a stretchable/shrinking surface, Halim et al. [15] conducted research that involved both active and passive monitoring techniques.Furthermore, Halim et al. [16] conducted a comprehensive investigation into the active and passive monitoring of nanoparticle motion within the Maxwell stagnation region as it passes over a stretched surface with slip conditions.

The reality of boundary layer motion and the expansion of surfaces is evident and supported by expert analysis, emphasizing their essential role in real-world applications, as highlighted in recent studies [17–23].Raza [24] conducted a study to examine the effects of and slip conditions and thermal radiation on the Magnetohydrodynamics (MHD) stagnation region motion of a Casson liquid as it flows past a convective stretchable sheet.Hasmawani et al. [25] gives the radiation of influence on the MHD stagnation region motion of a Williamson liquid over a stretchable surface.

The primary purpose of this work is to discern how the interaction of MHD, multiple slip conditions in Casson liquid flow, and thermal radiation contributes to the Soret phenomenon. These findings hold significance as the existing literature review reveals a dearth of previous studies on this specific issue.

2. Mathematical Analysis:

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This study concerns the steady-state, two-dimensional motion of an incompressible non-Newtonian liquid flowing through a stretchablenonlinear surface with viscous electrical conductivity. In this analysis, the x-coordinate corresponds to the direction with the stretchable sheet, while the y-coordinate pertains to the direction normal to the sheet, as depicted in Figure 1.

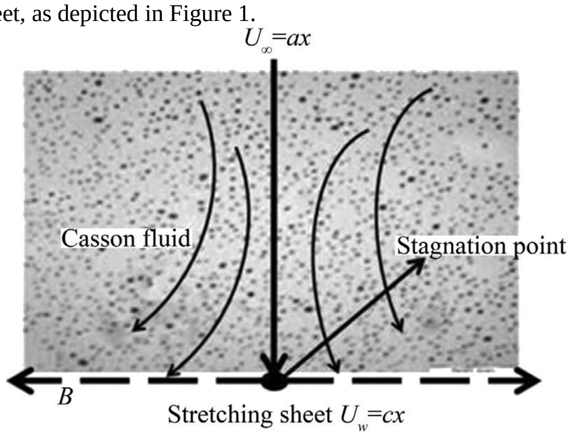

Figure.(1): Physical interpretation of the model under investigation

In the presence of a uniform magnetic field, fluid dynamics play a pivotal role. To elongate the sheet in the direction of its length while maintaining the initial region at rest, two same but opposite forces are applied to the sheet. The ambient velocity of the Casson liquid is also considered. Additionally, while examining the velocity distribution, it gives that the temperature within the boundary layer (T) is significantly wide enough to incorporate radiation effects. Meanwhile, the exterior of the sheet typically experiences convective heating from a hot liquid. This setup is consistent with the heat exchange coefficient and the temperature difference between the surrounding liquid and T.

In the presence of a consistently attractive field, fluid dynamics play a critical role. Two opposing characteristics are applied within the sheet to raise its height while preserving its initial state of rest. Typically, the heat and temperature exchange coefficient from the hot liquid that convectively warms the exterior of the sheet result in a widening gap between the liquid's melting temperature (T) and the temperature inside the boundary layer. This, in turn, leads to the incorporation of radiation effects into the velocity profile.

Moreover, it is recognized that a fractional velocity slip occurs at the robust interface of the liquid. Conversely, in association with this slip, it is possible to neglect the assumed numerical Reynolds number of the liquid to approximate the influence of the attractive field. The outer boundary layer region and the surface concentrations of Casson liquid are independent. The equations governing the properties of the Casson liquid can be expressed as per reference [1].

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

Here, we refer to a viscoelastic non-Newtonian fluid characterized by its liquid yield stress, the square of the constituent deformation rate, and a critical numerical value, which is essential for non-Newtonian analysis

Based on the aforementioned assumptions, the boundary layer conditions that govern the heat, velocity, and species concentration of a Casson liquid, considering incompressibility and the presence of electrically coordinating particles, influenced by radiative heat transfer and a transverse magnetic field, can be expressed as follows:

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

$$U_\infty \frac{dU_\infty}{dx} - \frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\left(1 + \frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2 u}{\rho}\left(U_\infty - u\right) - \frac{\nu}{k}\left(U_\infty - u\right) = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} \tag{3}$$

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$$\alpha_m \frac{\partial^2 T}{\partial y^2} + \frac{16\sigma_e T_\infty^3}{3\rho C_p k^*}\frac{\partial^2 T}{\partial y^2} = u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} \tag{4}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} - D\frac{\partial^2 C}{\partial y^2} + k_1 C = D_T \frac{\partial^2 T}{\partial y^2} \tag{5}$$

here, u, v means velocity factor in x and y direction respectively α_m means liquid thermal diffusivity, v means kinematic viscosity, β signifies Casson term, T means liquid temperature, C signifies concentration field, D signifies mass diffusion, k_1 signifies reaction rate.

The suitable boundary constraints are:

$$u = U_w + L\frac{\partial u}{\partial y} = cx + L\frac{\partial u}{\partial y}, v = 0, -k\frac{\partial T}{\partial y} = h_f\left(T_f - T\right),\ C = C_w \quad \text{at} \quad y = 0,$$

$$u \to U_\infty = ax,\ v \to 0,\ T \to T_\infty,\ C \to C_\infty \ \text{ as } \ y \to \infty$$

(6)

With $U_w = cx$ gives the extending sheet velocity $(C > 0)$, k gives thermal liquid conductivity and $U_\infty = ax(a > 0)$ givesambient liquid velocity.

The stream relations ψ are defined $u = \frac{\partial \psi}{\partial y}, v = -\frac{\partial \psi}{\partial x}$ with (2) satisfied. The relations without dimensions aretaken as:

$$\eta = \sqrt{\frac{a}{v}}y, \psi(x,y) = \sqrt{av}xf(\eta), \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \varphi(\eta) = \frac{C - C_\infty}{C_w - C_\infty} \tag{7}$$

The (3)-(5) equations can be obtained as:

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

$$\left(1 + \frac{4}{3}R\right)\theta'' + \Pr f\theta' = 0, \tag{9}$$

$$\phi'' - Sc(\gamma\phi - f\phi') + S_c So\theta'' = 0 \tag{10}$$

With the constraints:

$$\begin{aligned} &f(0) = 0, \quad f'(0) = \alpha + Af''(0), \theta'(0) = -Bi\left[1 - \theta(0)\right], \ \phi(0) = 1 \\ &f'(\eta) \to 1, \ \theta(\eta) \to 0, \ \phi(\eta) \to 0 \ \text{ as } \ \eta \to \infty \end{aligned} \tag{11}$$

To analyse the surface behaviour of fluid, grades are developed of the physical interest of quantities.

$$C_f = \frac{\left(\mu_B + \frac{P_y}{\sqrt{2\pi_c}}\right)\left(\frac{\partial u}{\partial y}\right)_{y=0}}{\rho u_w^2}, N_u = \frac{-x\left(\frac{\partial T}{\partial y} + \frac{16\sigma_e T_\infty^3}{3\rho C_p k^*}\frac{\partial^2 T}{\partial y^2}\right)_{y=0}}{T_f - T_\infty}, Sh = \frac{-x\left(\frac{\partial c}{\partial y}\right)_{y=0}}{C_w - C_\infty}$$

By using the terms, we got:

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$$C_f\sqrt{\text{Re}} = \left(1+\frac{1}{\beta}\right)f''(0), \frac{N_u}{\sqrt{\text{Re}}} = -\left(1+\frac{4}{3}Rd\right)\theta'(0), \frac{Sh}{\sqrt{\text{Re}}} = -\phi'(0)$$

3. Results and Discussions

This explanation focused on the examination of the combined effects of radiation and slip on Magnetohydrodynamics (MHD) stagnation region over a convective stretchable sheet. It delved into understanding how variations in parameters influenced the obtained results.

Figure (2) displays the velocity profile under the influence of magnetism. It is evident that the magnetic term acts as a source of Lorentz power, causing the fluid's velocity to be inhibited, resulting in a decrease in the velocity profile as the magnetic term's magnitude increases.

In Figure (3), the velocity profile variations with different values of the permeability term (K) are presented. It can be observed that for larger values of the permeability term (K), both the velocity and the boundary layer thickness increase. This suggests that higher values of K lead to reduced resistance within the penetrable channel, accelerating the momentum model of the motion regime and consequently making the velocity profile more comprehensible.

The impact of the radiation term "R" on the dimensionless temperature is illustrated in Figure (4). It is evident from the observation that the radiation term leads to an elevation in temperature. This is primarily due to the influence of surface upsurge, which causes an upward trend in the temperature plot.

Through Figure (5), the variation Prandtl number beyond the dimensionless temperature plot is investigated. Temperature degenerates as numeric Prandtl Pr increases, demonstrating that numeric Prandtl Pr's contribution is to lower magnetism's temperature. Moreover, numeric Prandtl Pr contributes to reducing the thermal layer's thickness.

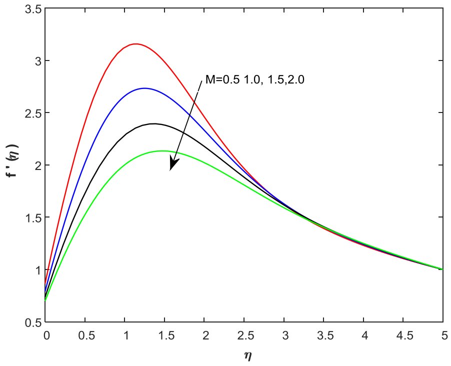

Fig.2. Plots of velocity for various magnetism parameter (M) numbers.

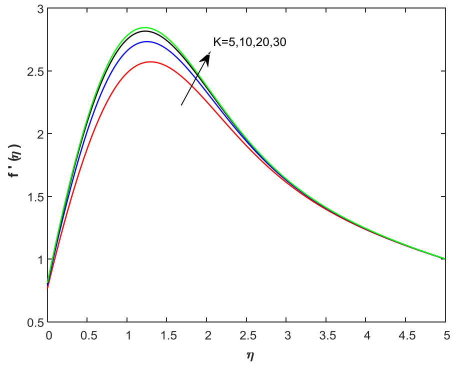

Fig.3. velocity plots for various permeability term (K) numerical values.

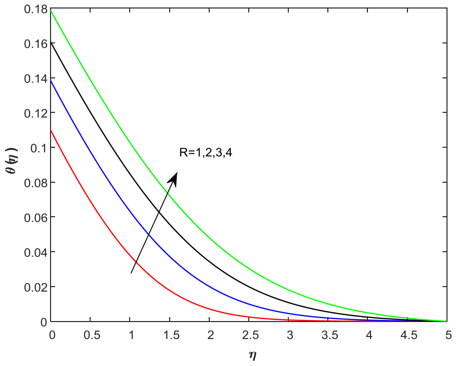

Fig.4. Temperature plots for various radiation term (R) numerical values.

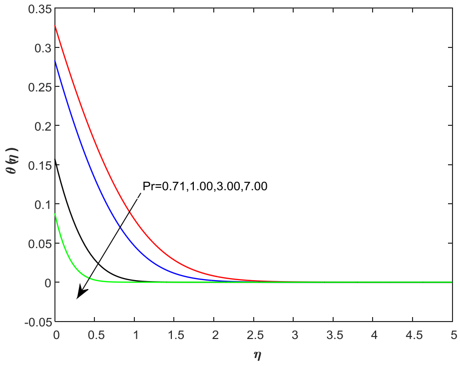

Fig.5. Plots of temperature for various Prandtl number (Pr) numbers.

4.Conclusions

We completed a mathematical investigation of a mathematical model representing fluid dynamics to study the dynamic changes in liquid properties in the context of multiple slip conditions within Magnetohydrodynamics (MHD) Casson motion, considering the influence of Soret diffusion and thermal radiation. We formulated the governing equations and transformed them into a set of coupled, nonlinear ordinary differential equations (ODEs). To solve these equations, we applied the Runge-Kutta Fehlberg numerical method in combination with a systematic shooting approach. Our study systematically explored the effects of different measurements in this scenario. The computational numerical analysis yielded the following key findings:

- The permeability term, Casson fluid parameter, ratio parameter, and velocity slip parameter all increase in tandem with the magnetic term, causing velocity plots to degenerate.
- The Prandtl effect causes the thickness of thermal layer to degenerate, but an opposite trend is seen when the radiation and parameters of Biot number are increased.

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