HEAT PROPAGATION MECHANISM AND DYNAMICS OF STRATIFICATION IN MAGNETOHYDRODYNAMIC REACTIVE CARREAU NANOLIQUID FLOW OVER AN ELONGATED SURFACE

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Abstract

The current study is designed to investigate the transport characteristics and heat propagation mechanism across the dynamics of magneto-Carreau fluid over an elongated sheet in the presence of variable viscosity, thermal conductivity with thermal and mass stratification effects. The numerical model incorporates homogeneous first order reaction, inclined magnetic field, Joule heating, nonlinear radiation with thermo-migration and haphazard motion of the tiny particles. Appropriate mathematical model was developed to capture the physical phenomenon, similarity transformation variables were employed to reduce the model from partial to ordinary differential equations. The Runge-Kutta-Gill methodology was used in conjunction with the shooting method and MATLAB bvp4c to obtain the numerical solution. The significant contributions of the emerging physical parameters were communicated through various graphs and tables with appropriate discussion of their trend. And applications. The investigation reveals that, thermal stratification and temperature ratio terms boost heat propagation whereas a hike in the thermophoresis and Brownian motion impedes heat transfer. Also, the material Weissenberg number and the mixed convection parameter cause a reduction in the surface drag force. Furthermore, it has been shown that when stresses grow, viscosity promotes the deformation of fluid components, creating a damping effect in the fluid motion.

Keywords: Brownian motion; Carreau nanoliquid; Heat propagation; Stratification; Thermophoresis.

Introduction

The boundary layer liquid motion along an elongated surface offers a huge industrial and engineering applications as often encountered in the extrusion of plastic sheet, paper and textile production, hot rolling, wire drawing and so on. Crane (1970) pioneered such kind of study with a closed form solution of a two-dimensional flow over a stretching sheet. Thereafter, various researchers have extended such an investigation by considering crucial parameters of engineering interest with various conditions and configurations (see Oahimire and Olajuwon, 2013; Reddy and Krishna, 2018; Fatunmbi and Okoya, 2020). Carreau fluid is a non-Newtonian fluid which manifests a shear thinning and thickening properties. Such attributes are usually utilized in chemical engineering, biological, and industrial processes, as well as in polymer suspensions processes. According to Shamshuddin et al. (2021), Carreau fluid describes an important phenomenon for oil purification research with an emphasis on the dynamic of Carreau conducting fluids over a stretching plate as well as magnetic field interaction. Ahmad et al. (2021) demonstrated that viscosity is significantly dependent on shear rate using a Carreau liquid flow formulation that combined Newtonian and power-law models. Likewise, Jengili et al. (2019) as well as Hassan (2020) reported that temperature variation has significant effect on the viscosity of the fluid and as such, the modelling of constant fluid viscosity may not produce accurate result. Hence, it becomes important to incorporate the non-uniform viscosity that is temperature-dependent. Researchers have also investigated the significance of variable fluid properties as well as the influence of shear thickness/thinness in various flow geometries. Barakat (2004) examined the heat transfer of hydromagnetic temperature-dependent viscosity in an axisymmetric surface. It was discovered that when the temperature distribution grew, the quality of the fluid viscosity reduced with time. Mostafa (2015) studied the influence of viscosity changing characteristics on a conducting electromagnetic fluid in stretchy media. As seen, the material viscosity steadily reduced as heat propagation increased. Salawu et al. (2020) demonstrated the irreversibility and criticality of magneto-couple stress material under Navier slip settings with varying fluid properties. It was discovered that for effective fluid utilization, energy loss may be avoided by rising thermodynamic equilibrium. Pratumwal et al. (2018) used a U-tube viscometer to investigate the effects of the Carreau-Yasuda and power-law models on blood viscosity. Temperature differences, as shown in image scanning, have a considerable impact on blood viscosity. The transient

flow of heat transfer magneto-Carreau fluid via a stenosis artery was studied by Jamalabadi et al. (2018). The Carreau flow was shown to be pulled through the arterial media by the magnetic field. As a result, the impact of varied heat-dependent characteristics on hydromagnetic fluid shear viscosity cannot be overstated. For decades, the need to increase industrial productivity has renewed interest in overcoming the barrier of poor heat convection and heat conduction of fluid materials. Choi (1995) examined the addition of nanometer-sized carbides, oxides, and metal to a base fluid (e.g. ethylene glycol, oil, and water) to enhance fluid heat propagation and conduction. Due to this discovery, researchers interest in nanofluid as a heat transfer fluid has increased. Qayyum et al. (2018) pointed out the usefulness of nanofluids in the cooling of high heat flux machines in welding equipment, (e.g. high power laser diode arrays and microwave tubes), electronic devices such as microprocessors, transportation as well as well as energy generation. Nanofluids have unique features that make them suitable for use in a variety of heat transfer systems, including microelectronics, solar collectors, cancer therapy, fuel cells, household refrigerators, pharmaceutical operations, engine cooling thermal management, hybrid-powered engines, boiler flue gas temperature reduction and heat exchanger and many more (Salawu et al., 2021; Fatunmbi et al., 2021; Khan et al., 2020). Hayat et al. (2019) investigated the motion of electrically conducting second grade nanofluid induced by stretching sheet using the Bungiorno model characterized by Brownian motion and thermophoresis effects. Khan and Alzahrani (2020) performed a numerical simulation for the micropolar nonlinear mixed convective transport via the Bungiorno model with the impact of chemical reaction. Fatunmbi and Adeosun (2020) investigated the features of heat and mass transport in the motion of reactive Eyring-Powell nanoliquid across a vertical Riga device caused by exponential fluctuation of dynamic fluid viscosity, convective wall condition, thermal radiation, and viscous dissipation. Oke et al. (2021) investigated the effect of volume fraction and heat source/sink on the motion of water transporting 47 nm alumina nanomaterials along a uniform surface whereas Kigio et al. (2021) used a numerical technique to investigate hydromagnetic Casson nanofluid flow in a vertical sheet, which included volume fraction analysis and convective heat transfer. None of these studies however incorporated the effect of thermal and solute stratification inspite of such applications. Stratification in fluids often occur due to heat and mass variations as well as density fluctuations.

Inspired by the above literature analysis coupled with the industrial and engineering applications of the various parameters involved, the focus of the current study is to examine heat propagation mechanism, heat and species stratification analysis in magnetohydrodynamic Carreau nanofluid over an elongated surface. The fluid contains tiny nanoparticles in the presence of thermo-migration properties, haphazard motion of the tiny particles, nonlinear thermal radiation and variable fluid properties. Application of this study can be found in the production of electro-conducting lubricant, ecological engineering, bio-microsystems and others in boosting industrial productivity and biotechnology. A numerical model for the problem is set up while computation and simulation are carried out using the MATLAB bvp4c programme. The essential contributions of the various physical terms influencing the flow and heat propagation are displayed in various graphs and tables for better understanding.

2 METHODOLOGY

Assumptions for Problem Formulation

Consider a two-dimensional, incompressible and steady flow of an electro-conducting reactive Carreau fluid conveying tiny particles with thermo-migration and haphazard movement of the tiny particles over a stretchy surface. The presence of variable viscosity, thermal conductivity with nonlinear thermal radiation, thermal and solute stratification are accounted for in the model. The configuration is designed in such a way that the flow dynamics is set up with coordinate (x, y) with (u, v) as corresponding velocity components as depicted in Figure 1. The leading edge is associated with x axis in the vertical region while y axis is perpendicular to it. An external inclined magnetic field of uniform strength B_0 is imposed normal to the leading edge whereas the induced magnetic field is ignored.

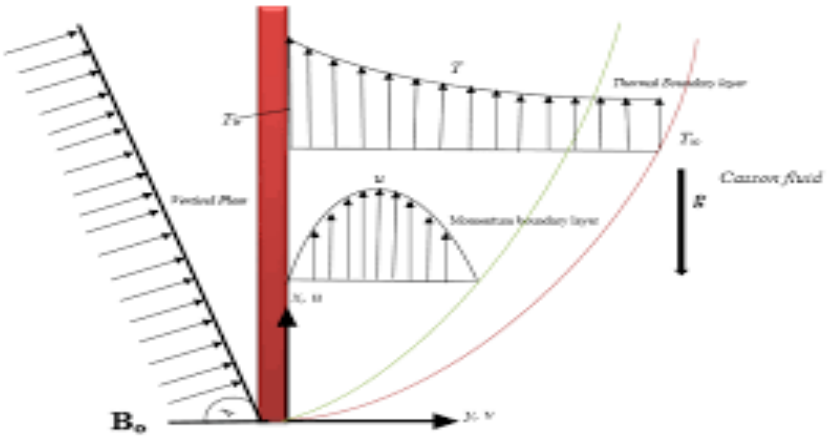


Fig. 1 Flow configuration

The governing equations

Incorporating the above-mentioned assumptions with the usual Boussinesq and boundary layer approximations, the derived governing equations (continuity, momentum energy and reacting species equations) for the model of electro-conducting Carreau fluid containing tiny nanoparticles are stated as follows (Alsaedi et al., 2016; Al-khaled et al. 2020; Muntazir et al, 2021).

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{1}{\rho_{f\infty}}\frac{\partial}{\partial y}\left(\mu_f\frac{\partial u}{\partial y}\right)+\frac{3}{2}(n-1)\Gamma^2\frac{1}{\rho_{f\infty}}\frac{\partial}{\partial y}\left(\mu_f\frac{\partial u}{\partial y}\right)\left(\frac{\partial u}{\partial y}\right)^2-\frac{\sigma B_0^2}{\rho_{f\infty}}\sin^2\alpha u+ \frac{1}{\rho_{f\infty}}\left[(1-\phi_f)\rho_{f\infty}\beta_1(T-T_\infty)g-(\rho_p-\rho_{f\infty})(\phi-\phi_\infty)g\right], \tag{2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{(\rho_\infty c_p)_f}\frac{\partial}{\partial y}\left(k_f\frac{\partial T}{\partial y}\right)+\frac{\sigma B_0^2}{(\rho_\infty c_p)_f}\sin^2\alpha u^2+\frac{16\sigma^*}{3k_*(\rho c_p)_f}\frac{\partial}{\partial y}\left(T^3\frac{\partial T}{\partial y}\right)+\chi\left(\frac{\partial T}{\partial y}\right)\left[\frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)+D_B\left(\frac{\partial C}{\partial y}\right)\right] \tag{3}$$

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

The conditions at the boundary are:

$$u=u_w=ax,\quad v=0,\quad T=T_s(x)=T_0+b_1x,\quad C=C_s(x)=C_0+c_1x,\quad at\quad y=0 \tag{5}$$

$$u\to 0,\quad T\to(T_\infty=T_0+b_2x),\quad C\to(C_\infty=C_0+c_2x),\quad as,\quad y\to\infty. \tag{6}$$

The temperature-dependent viscosity and thermal conductivity as used by Theuri and Makinde (2014) are written in Eq. (7) as $\mu=\mu_\infty e^{-m(T-T_\infty)},\quad k=k_\infty[1+\beta(T-T_\infty)],$ (7)

In the governing equations above, u and v indicate velocity in x and y directions respectively, u_w denotes the stretching velocity whereas T_0 and C_0 are reference temperature and reference concentration of nanoparticles respectively. Similarly, ρ_f symbolizes nanofluid density viscosity, μ_f is the nanofluid viscosity, ν_f describes kinematic viscosity, T describes fluid temperature, $k_\star$ denotes the mean absorption coefficient, $(\rho cp)_f$ is the heat capacity of fluid, μ_∞ indicates the free stream viscosity, k_∞ free stream thermal conductivity, T_∞ indicates the temperature at free stream, ϕ is the nanoparticles volume fraction, k_f is the thermal conductivity, α is the angle of inclination, n is the power law index, C concentration of the fluid, χ denotes ratio of base fluid heat capacity to nanofluid heat capacity, $\square_\square$ describes the rate of chemical reaction whereas D_T and D_B respectively describes

thermophoretic and brownian diffusion coefficients. Using the similarity quantities in Eq. (8) to simplify the governing equations further in order to facilitate computations, Thus, these quantities are introduced as follows.

$$\eta = y\sqrt{\frac{a}{\nu_\infty}}, \psi = \sqrt{a\nu_\infty}xf(\eta), \theta(\eta) = \frac{T-T_\infty}{T_s-T_0}, \phi(\eta) = \frac{C-C_\infty}{C_s-C_0}, Re_x = \frac{a^2x}{\nu_\infty}. \tag{8}$$

On substituting Eq. (8) into the governing Eqs. (1-4) together with the boundary conditions (5-6) and taking cognizance of Eq. (7), the continuity Eq. (1) becomes valid while Eqs. (2-6) result to the underlisted equations:

$$e^{-b\theta}\left(1+\frac{3}{2}(n-1)(We)^2f'^2\right)f''' - b\left(1+\frac{3}{2}(n-1)(We)^2f'^2\right)e^{-b\theta}f''\theta' - M\sin^2\alpha f' + ff'' - f'^2 + \lambda(\theta - Nr\phi - R\xi) = 0, \tag{9}$$

$$\left[1+\varepsilon\theta+Rd\left(1+\left(\frac{\theta}{s+\theta_r}\right)\right)^3\right]\theta'' + \left(\frac{3Rd}{\theta_r+s}\right)\left(1+\left(\frac{\theta}{s+\theta_r}\right)\right)^2\theta'^2 + \varepsilon\theta'^2 + Pr\left(f\theta' - f'\theta - rsf' + MEc\sin^2\alpha f'^2 + NT\theta'^2 + Nb\theta'\phi'\right) = 0, \tag{10}$$

$$\phi'' + Sc(f\phi' - f'\phi - Gf') + \frac{NT}{Nb}\theta'' - \gamma_r Sc\phi = 0, \tag{11}$$

The conditions at the boundary also become:

$$f'(0) = 1, f(0) = 0, \theta(0) = 1-s, \phi(0) = 1-G, \quad f'(\infty) = 0, \theta(\infty) = 0, \phi(\infty) = 0. \tag{12}$$

The emerging physical parameters in Eqs. (9-12) are: Prandtl number, magnetic field term, Schmidt number, Brownian diffusion term, heat stratification term, thermophoresis parameter, Eckert number, viscosity variation term, solute stratification term, chemical reaction parameter, buoyancy ratio parameter, radiation parameter, thermal conductivity term, temperature ratio, mixed convection parameter and Weissenberg number. These are respectively described below:

$$Pr = \frac{\nu_\infty(c_p)_f}{k_\infty}, \ M = \frac{\sigma B_0^2}{a\rho_{f\infty}}, \ Sc = \frac{\nu_\infty}{D_B}, \ Nb = \frac{\chi D_B(C_s-C_0)}{\nu_\infty}, s = \frac{b_2}{b_1}, \quad NT = \frac{\chi D_T(T_s-T_0)}{T_\infty\nu_\infty}, \ Ec = \frac{u_w^2}{(cp)_f(T_w-T_0)}, b = m(T_s-T_0), G = \frac{c_2}{c_1} \quad \gamma_r = \frac{k_r}{a}, Nr = \frac{(\rho_p-\rho_f)(C_w-C_0)}{(1-\phi_\infty)\rho_f\beta_1(T_w-T_0)}, Rd = \frac{16\sigma^*T_\infty^3}{3k^*k_f}, \varepsilon = \beta(T_s-T_0), \quad \theta_r = \frac{T_0}{b_2x}, \ \lambda = \frac{(1-\phi_\infty)g\beta_1(T_w-T_0)}{a^2x}, We = \sqrt{\frac{\Gamma^2a^3x^2}{\nu_\infty}}. \tag{13}$$

Physical Quantities of Engineering Interest

In this study, the physical quantities of engineering interest are the skin friction coefficient C_{fx}, local Nusselt number Nu_x and Sherwood number Sh_x These are respectively defined as:

$$C_{fx} = \frac{\tau_w}{\rho_\infty u_w^2}, Nu_x = \frac{xq_w}{k_\infty(T_w-T_0)}, Sh_x = \frac{xq_m}{D_B(C_w-C_0)}, \tag{14}$$

These quantities are further simplified to obtain

$$C_{fx} = Re_x^{-\frac{1}{2}}\left[f''(0) + \left(\frac{n-1}{2}\right)(We)^2f'^2(0)\right], \tag{15}$$

$$Nu_x = -Re_x^{\frac{1}{2}}\left[1+Rd\left(1+\left(\frac{\theta}{s+\theta_r}\right)\right)^3\right]\theta'(0), \tag{16}$$

$$Sh_x = -Re_x^{\frac{1}{2}}\phi'(0). \tag{17}$$

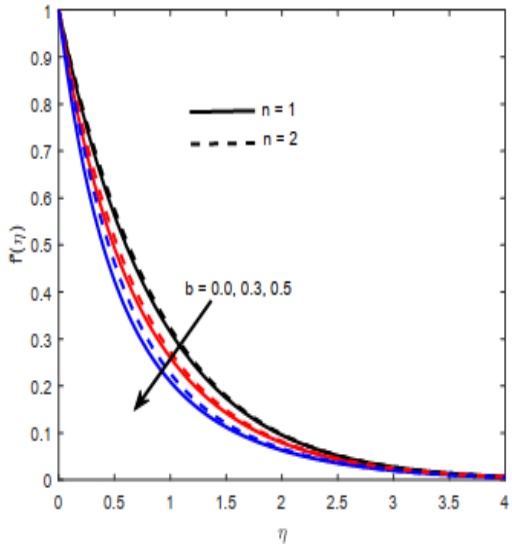
where $\tau_w = \mu_f \left(\frac{\partial u}{\partial y} + \left(\frac{n-1}{2}\right)\Gamma^2 \left(\frac{\partial u}{\partial y}\right)^2\right)\Big|_{y=0}$, $q_w = -\left(k_\infty + \frac{16T^3\sigma^*}{3k^*}\right)\frac{\partial T}{\partial y}\Big|_{y=0}$, $q_m = -D_B \frac{\partial C}{\partial y}\Big|_{y=0}$.

Numerical Method of Solution

Due to the high nonlinearity of the set of equations arrived at in this study, a numerical approach has been sought to provide the needed solution to the governing equations. The nonlinear boundary value equations (9-12) has been solved numerically via Runge-Kutta scheme alongside shooting method by applying the Runge-Kutta-Gill technique in MATLAB bvp4c.

3. RESULTS AND DISCUSSION

In this section, various graphs have been displayed to showcase the effects of the emerging physical parameters on the velocity profiles, heat distribution and concentration profiles. Furthermore, insights into various trends and behaviour of the dimensionless quantities are discussed according to various characteristics of the transport variables for practical application.



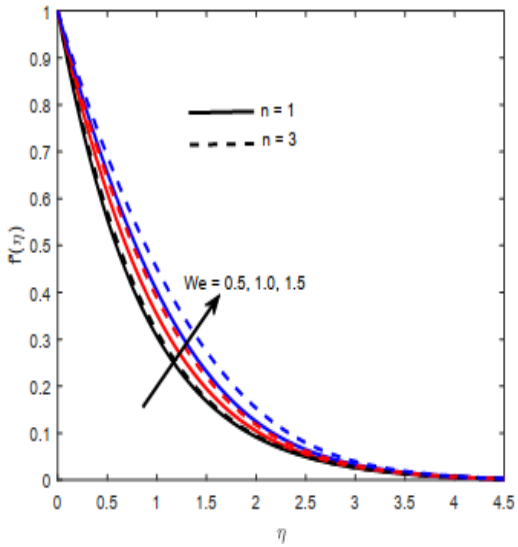
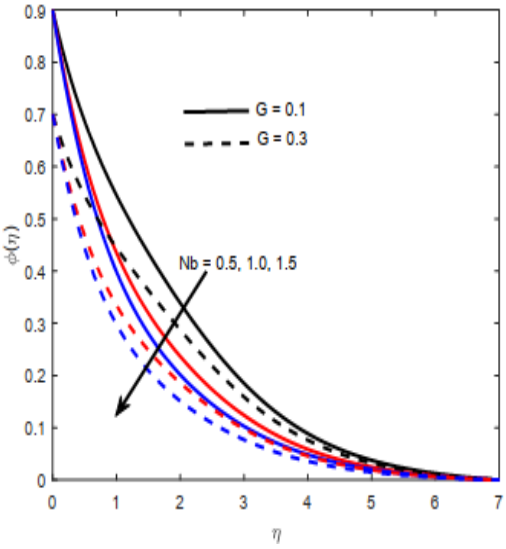


Fig. 2 Velocity profiles for variation in b**Fig. 3** Velocity profiles for variation in We



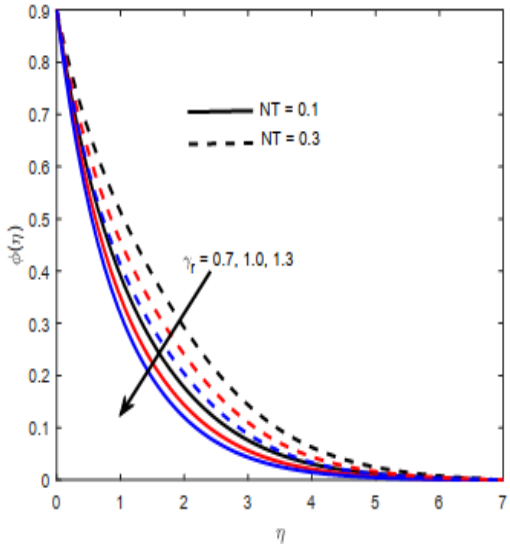
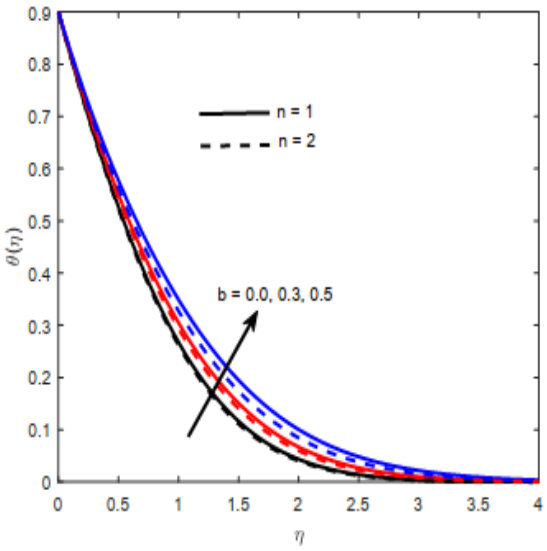


Fig. 4 Concentration profiles for Nb**Fig. 5** Concentration profiles for γ_r

Figure 2 illustrates the impact of the viscosity variation term b on the velocity profiles in the presence of the power law index n. The flow momentum response to a rise in viscosity term b clearly reveal that there is a decrease velocity profiles. The internal friction of the Carreau nanofluid is raised to resist the Carreau nanoparticles free flow as the viscosity is boosted. The bonding force is stimulated to enhance the relative motion of the adjacent fluid layers resulting in a decreasing velocity. Therefore, viscosity causes deformation of fluid materials as the stresses are increased which lead to velocity field damping. However, an increase in n propels a rise in the fluid flow as found in this figure. The flow viscoelastic characteristic is examined with a rising Weissenberg number We in Fig. 3. Weissenberg number describes the ratio of the elastic forces to viscous forces in the study of viscoelastic flows. It is observed that higher magnitude of We boosts the transport of the Carreau nanofluid. The elastic forces of the Carreau nanofluid dominated the viscous forces in the flow dimension and as such, a rising velocity profile occurs. The time rate of the fluid stress relaxation is enhanced owing to the rise in mass reaction of the nanofluid and increasing fluid particles heat conductivity. The impact of increasing physical quantities, Brownian motion Nb and solute stratification parameter G on the concentration profiles are depicted in Fig. 4. It is observed that the concentration profiles is a decreasing function of both terms. Likewise, the influence of chemical reaction term γ_r and the thermophoresis parameter NT on the nanoparticles concentration field are illustrated in Fig. 5. Growing values of γ_r dampens the concentration layer whereas higher magnitudes of NT strengthens the concentration of the Carreau nanofluid curves. Hence, it is noticed that both Nb and γ_r which respectively depicts Brownian motion and chemical reaction damped the volume concentration of the magneto-Carreau fluid reaction leading to a reduced mass distribution. A small random movement of the Carreau nanofluid along the boundless stream is preventing the diffusion of liquid particles as observed in Fig. 4. As such, due to low nanoparticle interaction and heat diffusion, the concentration profile declined as the Brownian motion is raised.



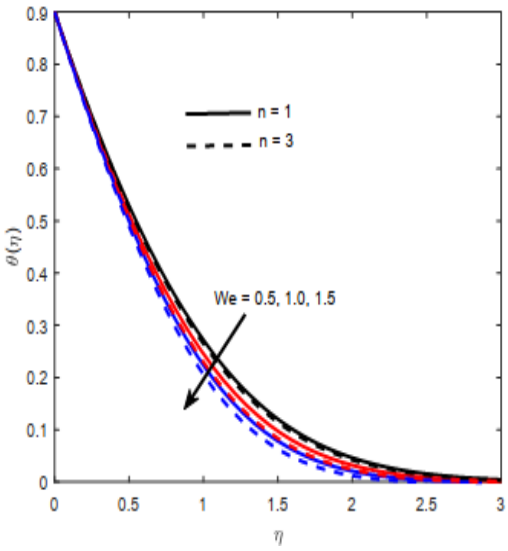
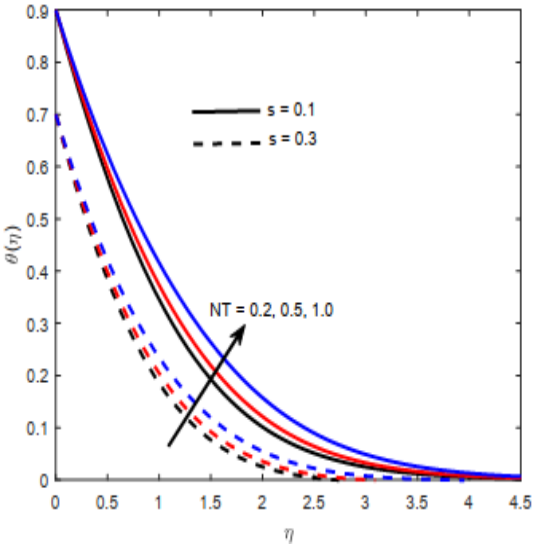


Fig. 6 Temperature profiles for b**Fig. 7** Temperature profiles for We

Also, the Carreau nanofluid reactant mixtures reduces due to high magneto-nanoparticle bonding that discouraged the mass transfer profile. The absence of activation energy and low heat source lead to the fluid species mixtures that causes the fall in solute region as chemical reaction term rises. The thermal profiles is plotted against the streamwise distance η for varying values of viscosity term b and Weissenberg number We in the presence of the power-law exponent as respectively described in Fig. 6 and Fig. 7. Evidently, growth in the viscosity causes an increase in the thermal diffusivity as heat is generated internally to break the Carreau nanoparticle bonding force. Thus, the liquid particles vigorously interact to overcome the dragging effect of the fluid viscosity, and increase nanoparticles heat distribution that thereby encourages heat transfer profile.



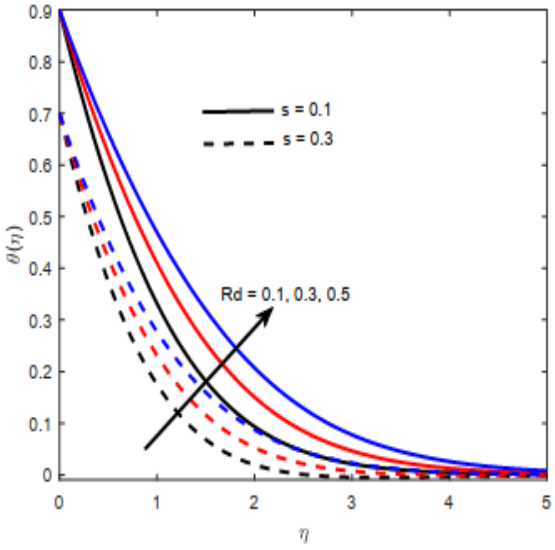


Fig. 8 Temperature profiles for NT**Fig. 9** Temperature profiles for Rd

Conversely, as found in Fig. 7 the thermal profiles response to rising We reveals reducing influence on the surface heat distribution. The viscous forces governed the elastic forces of the fluid mixtures to raise the viscoplastic property of the nanofluid Carreau flow reaction mixtures. As a result, the stress relaxation rate and the heat source are discouraged which leads to decreases reaction rate and temperature propagation profiles. Hence, Carreau flow reaction mixtures can be applied in high-teperature processes to minimize the temperature distribution. Figures 8 and

9 respectively display the impact of thermophoresis parameter NT and thermal radiation term Rd for different values of the heat stratification parameter s. The heat distribution increases for a rise in both dimensionless parameter due to high stimulation of the boundary layer viscosity that discourages ambient heat transfer. Physically, thermophoresis defines thermo-diffusion of mobile particle reaction response to a temperature gradient while radiation is an energy transfer past a material medium. Thus, the terms NT and Rd propel the Carreau nanofluid particles to cause rising heat distribution in the boundless stretchable device. Hence, as NT increases, the heated particles are pulled away from hotter to colder region and as such, the Carreau nanofluid temperature is raised as found in figure 8. Contrarily, growth in the magnitude of s causes the Carreau nanofluid density to fall as found in both figures. As a result, the temperature difference between the heated surface and upstream field reduced which consequently resulted to a reduction in the temperature of the fluid. This trend agrees well with Atif et al. (2019) and Hayat et al. (2018).

Parameter effects on the quantities of engineering interest

The effects of some selected physical terms on the surface drag force C_{fx} and on the Nusselt number Nu_x which corresponds to heat transfer at the surface of the stretching sheet are collated in Tables 1 and 2.

Table 1 Computational values of C_{fx} for variations in $b, We, \alpha, \lambda M$

b	We	α	λ	M	C_{fx}
0.0	0.3	60°	0.1	0.5	1.11827
0.3					1.29734
0.5					1.42032
0.2	0.5				1.19021
	1.0				1.06313
	1.5				0.95854
	0.3	30°			1.12283
		60°			1.23664
		90°			1.28909
		60°	0.1		1.23664
			0.3		1.16955
			0.5		1.10426
			0.1	0.1	1.09839
				0.5	1.23664
				0.7	1.29927

In Table 1, it noticeable that enhancement in the magnitude of viscosity variation term b, angle of inclination α and magnetic field parameter M augment the skin friction coefficient whereas a reduction in the skin friction coefficient C_{fx} is obtained via improving the magnitude of the Weissenberg number We and mixed convection parameter λ. As the fluid becomes more viscous, there is a rise in the friction between the fluid and the stretching material, also, the draglike force (Lorentz force) imposed transversely on the Carreau nanofluid create a frictional force which boost the skin friction coefficient. However, with a rise in We the Carreau nanofluid, the viscosity is reduced and the friction becomes reduced as well. In the like manner, rising values of λ favours the buoyancy force over that of viscous force which then leads to a reduction in the viscous drag. For practical engineering application, it is recommended that the

magnitude of We and λ should be increased to have a better quality of the final product whereas the strength of b, α and M should be reduced.

Table 2 Computational values of Nu_x and Sh_x for variations in $s, \theta r, \varepsilon, NT$ and Nb

s	θ_r	ε	NT	Nb	Nu_x
0.1	1.2	0.2	0.5	0.3	0.70917
0.3					0.73616
0.5					0.74736
0.1	1.2				0.66414
	3.0				0.80015
	5.0				0.83446
	1.5	0.1			0.72932
		0.3			0.69042
		0.5			0.65652
		0.2	0.2		0.75172
			0.5		0.70917
			1.0		0.64856
			0.5	0.5	0.66668
				1.0	0.57212
				1.5	0.49351

The impacts of s, θ_r, ε, Nb parameters on t Nu_x are depicted in Table 2. A rise in s for $0.1 \leq s \leq 0.5$ enhances the Nu_x. Similarly, an increase θ_r improves the heat transfer as noted in this table. However, A rise in ε, NT and Nb depreciates the heat transfer across the stretching surface as noted in Table 2. Thus, for improvement in the heat transfer in the system, the magnitude of s and θ_r should be increased while those of ε, NT and Nb should be decreased in such situations.

5. CONCLUSION

The current study investigated heat propagation and the dynamics of thermal and solute stratification in an electro-conducting Carreau nanoliquid flow over a stretching surface. The Carreau fluid conveying tiny particles in the presence of heat dependent viscosity and thermal conductivity, inclined magnetic field and nonlinear radiative heat propagation. The transport model is built using the Bungiorno model which characterize thermophoresis an Brownian motion effects. Similarity quantities are used to re-structure the flow partial differential equations into ordinary ones while a numerical method is employed via the Runge-Kutta-Gill method alongside the shooting technique on MATLAB bvp4c to solve the problem. Various contributions of the emerging physical terms have been shown graphically for better understanding and real engineering and technology applications. The underlisted points are collated from the main results.

- The heat propagation along the boundless flow stream is boosted for rising terms valu of the thermal stratification an temperature ratio terms whereas thermophoresis, brownian motion and thermal conductivity terms hindered heat propagation.

- The hydrodynamic boundary layer as well as fluid motion enhanced with higher magnitudes of the Wessienberg number but a decelarated flow occur with a rise in viscosity amd magnetic field terms.

- The surface viscous drag effect can be effectively reduced by increasing the strength of the Carreau nanofluid material Wessienberg number and mixed convection term whereas the converse is the case for the viscosity and magntic field terms.

- Carreau nanofluid concentration boundary layer structure and chemical mixtures diminished for an increased values of the chemical reaction and brownian motion terms.

- The thermal field and the surface heat distribution enhanced with the influnce of thermophoresis, temperature-dependent viscosity and radiation terms but fall as sthermal sttratification rises.

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