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Effect of Viscous dissipation on MHD Stagnation point flow of Chemically reacting Nanofluid over a Nonlinear Stretching sheet with Slip conditions

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ABSTRACT:

The objective of the present study is to analyze steady MHD stagnation point flow of a nanofluid over a nonlinear permeable stretching sheet with slip boundary conditions and chemical reaction. Viscous effect is also considered The profiles for the velocity, temperature and nanoparticle concentration depends on the parameters velocity ratio parameter N, suction S, velocity slip A, thermal slip B, concentration slip C, nonlinear stretching parameter n, surface temperature r, Prandtl number Pr, Lewis number Le, Brownian motion Nb, thermophoresis parameter Nt, Eckert number Ec, chemical reaction parameter γ and magnetic parameter M. The governing partial differential equations were transformed into coupled non linear ordinary differential equations using appropriate similarity transformations. The transformed ODE's were then solved by Kellor-Box method. Numerical results and Graphical representation are obtained for distributions of velocity, temperature and concentration, as well as, for the skin friction, local Nusselt number and local Sherwood number for several values of governing parameters.

KEY WORDS:

Nanofluid,Stagnation point, MHD, suction, slip conditions, chemical reaction, nonlinear sheet.

1. Introduction

Nanofluids are fluids having suspension of nano sized metallic or non-metallic particles of which their principal dimension are less than 100 nm. This new type of fluids are called ‘nanofluids’ and are introduced by Choi and Eastman [1]. Comparing with the base fluid, nanofluids have distinctive properties that make them attractive in many applications such as fuel cells, thermal management of electronics, transportation industries, pharmaceuticals processes, boiler flue gas temperature reduction, heat exchangers, etc. [2]. Wang et al [3] investigated the effective thermal conductivity of mixtures of fluids and nanometer sized particles is measured by a steady-state parallel plate technique. In which, the thermal conductivities of nanoparticle fluid mixtures are higher than those of the base fulids. Buongiorno et al [4] examined an explanation for the abnormal convective heat transfer enhancement observed in nanofluids, founding that Brownian diffusion and thermophoresis have been identified as the two more important nanoparticle/base fuild slip mechanism. Kuznetsov et al [5] examined the influence of nanoparticle on a natural boundary layer flow past a vertical plate analytically with the consideration of Brownian motion and thermophoresis in the flow. Gorla and his colleagues [6] studied the natural convection past a non-isothermal vertical plate in a porous medium saturated by a nanofluid. Analysis of the steady mixed convection boundary layer flow of a nanofluid over a vertical permeable surface by taking in to an account the suction/injection was studied by Yasin et al [7] and the problem of laminar boundary layer flow of copper water and alumina water nanofluid over a flat plate was investigated by Devi et al [8]. Steady laminar boundary layer flow of a nanofluid over a convectively heated vertical flat surface was studied numerically by Uddin [9]. Boundary layer flow and heat transfer of nanofluid over a vertical plate with connective surface boundary condition is examined by Ibrahim and Shanker [10].

The study of magnetohydrodynamic (MHD) flow is very importantbecause the influence of a agnetic field on the viscous flow ofelectrically conducting fluid is essential in many industrial processes,such as in magnetic materials processing, purification ofcrude oil, MHD electrical power generation, glass manufacturing,geophysics, and paper production. The MHD parameter is one ofthe important factors by which the cooling rate can be controlledand the product of the desired quality can be achieved. Andersson [11]investigated slip flow past a stretching surface and Pavlov investigated the effect of a magnetic field on viscous flowof an electrically conducting fluid past a stretching sheet. Manyinvestigations were made to examine flow over a stretching sheetunder different aspects of MHD. Some important literature onMHD flow over a stretching sheet can be found in Hayat et al [12], Mahapatra and Gupta[14]Ishaket al [1314] and Mahapatra et al [15].

In addition to this, attention has been paid by the researchers to a flow namely the stagnation-point flow over a stretching surface due to its significant behaviour on numerous technological processes. The stagnation region meets the highest pressure, higher rates of mass and heat transfers. Numerically studies of stagnation-point flow are done by Schlichting and Bussmann [16]. Eckert his team [17] addressed the energyequation, obtained an exact solution for the thermal field.

Another important aspect, which influences heat transfer processes, is effects of injection or suction.It is well-known that the effects of injection on the boundary layer flow are of interest in reducing the drag force. Many of the authors have studied heat transfer by considering uniform and non-uniform heat source/sink effects, which are crucial in controlling the heat transfer.Jalilpour et al [18] presented an theoretical study to analyze the effect of heat generation/absorption on magnetohydrodynamic stagnation point flow and heat transfer over a porous stretching surface, with prescribed surface heat flux. Cao et al [19] have investigated the magnetohydrodynamic (MHD) Maxwell fluid past a stretching plate with suction/injection in the presence of nanoparticles. By considering investigates steady laminar boundary layer flow of power law fluids past a flat surface with suction or injection and magnetic effects Lin et al [20]investigates steady laminar boundary layer flow of power law fluids past a flat surface with suction or injection and magnetic effects.

The no-slip boundary condition is known as the main manifestation of the Navier–Stokes theory of fluid dynamics. But there are situations wherein such condition is not appropriate. Especially no-slip condition is inadequate for most non-Newtonian liquids and nanofluids, as some polymer melt often shows microscopic wall slip and that in general is governed by a non-linear and monotone relation between the slip velocity and the traction. The liquids exhibiting boundary slip find applications in technological problems such as polishing of artificial heart valves and internal cavities. The earlier studies that took into account the slip boundary condition over a stretching sheet were conducted by Andersson [21]. He gave a closed form solution of a full Navier–Stokes equations for a magnetohydrodynamics flow over a stretching sheet. Following Andersson, Wang [22] found the closed form similarity solution of a full Navier–Stoke’s equations for the flow due to a stretching sheet with partial slip. Furthermore, Wang [23] investigated stagnation slip flow and heat transfer on a moving plate. Similarly, Fang et al. [24] studied slip magnetohydrodynamics viscous flow over a stretching sheet analytically. Still further, Hayat et al. [25] expanded the problem of the previous researchers by incorporating thermal slip condition and discussed unsteady magneto hydrodynamic flow and heat transfer over a permeable stretching sheet with slip condition. In a similar way, Aziz [26] studied hydrodynamic and thermal slip boundary layer flow over a flat plate with constant heat flux boundary condition. The above mentioned literature discussed the slip boundary conditions when the first order velocity slip boundary conditions were used. However, Fang et al. [27] found a closed form solution for viscous flow over a shrinking sheet using the second order velocity slip flow model. Similarly, Mahantesh et al. [28] studied flow and heat transfer over a stretching sheet by considering second order velocity slip boundary condition.Recently many authors obtained analytical and numerical solutions for boundary layer flow and heat transfer due to a stretching sheet with slip boundary conditions also many others worked on nanofluids with different conditions [29 30 31 32 33 34 35].

Stimulated by above literature the present paper deals with steady of MHD stagnation point flow of a nanofluid over a nonlinear permeable stretching sheet with slip boundary conditions and chemical reaction.

2. Formulation of the Problem

Consider the steady two-dimensional MHD stagnation point flow of a viscous incompressible nanofluid over a nonlinear stretching sheet coinciding with the plane $y = 0$, with surface temperature T_w and concentration C_w. The fluid occupies the upper half plane ($y > 0$). The sheet is stretched horizontally by applying two equal and opposite forces along x-axis keeping the origin fixed. The stretching velocity of the sheet is $U_w(x) = ax^n$, where the x-component of the velocity varies non-linearly along it, $a > 0$ is constant of proportionality known as stretching rate and n is a power index. Along with these the fluid is permitted by magnetic field and also considered chemical reaction to the flow. The induced magnetic field is assumed to be small compared to the applied magnetic field; so it is neglected. It is also assumed that the ambient fluid i.e. the fluid far away from stretching sheet is moved with velocity $U_\infty(x) = bx^n$ where $b > 0$ is a constant. The ambient temperature and concentration are respectively, $T\infty$ and $C\infty$. T is the temperature and C is the concentration of the nanofluid in the boundary layer.

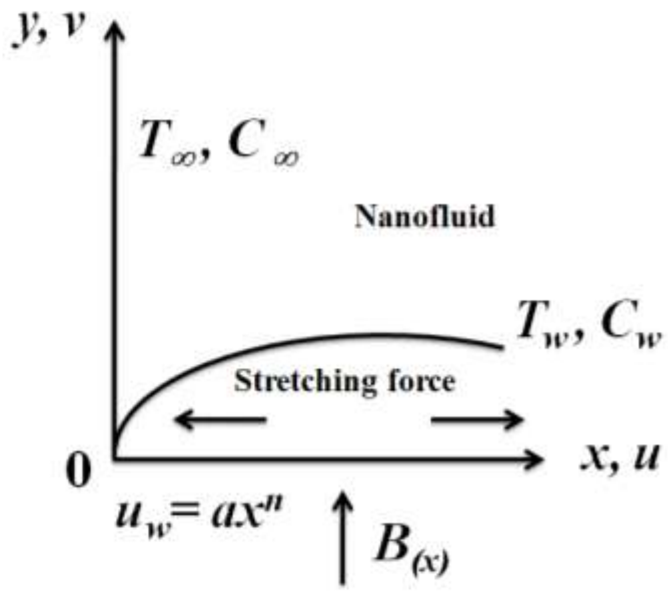

Fig 1.Physical model and co-ordinate system.

Under the above assumptions, the governing equations of the conservation of mass, momentum, energy and concentration in the presence of aligned magnetic field with slip conditions and chemical reaction past a stretching sheet can be expressed as:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad (1)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=U_\infty\frac{\partial u}{\partial y}+\upsilon\frac{\partial^2 u}{\partial y^2}+\sigma\frac{\sigma B_0^2}{\rho_f}(U_\infty-u) \qquad (2)$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}+\tau\left(D_B\frac{\partial c}{\partial y}\frac{\partial T}{\partial y}+\frac{D_T}{T_\infty}\left(\frac{\partial^2 T}{\partial y^2}\right)+\frac{\upsilon}{C_p}\left(\frac{\partial u}{\partial y}\right)^2\right) \qquad (3)$$

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

The boundary conditions corresponding to the problem are as follows.

$$u=\lambda U_w+u_s,\ v=\pm v_w,\ T=T_w+T_s,\ \ C=C_w+C_s \qquad at \quad y=0 \qquad (5)$$

$$U\to U_\infty\ T\to T_\infty,\ C\to C_\infty \quad as \qquad y\to\infty \qquad (6)$$

Where u and v denotes the velocities in the direction of x-and y-respectively, ν is the kinematic viscosity, ρ_f is the density of the base fluid, σ is the electrical conductivity, α is the thermal diffusivity, (ρc)p is the effective heat capacity of the nano particles, $(\rho c)_f$ is the heat capacity of the base fluid, τ is the ratio of the nano particle heat capacity and base fluid heat capacity, D_B is the Brownian motion diffusion coefficient and D_T is the thermophoretic diffusion coefficient.

$K_r(x) = \frac{2k}{a(n+1)(C_W - C_\infty)}$ isthe chemical reaction parameter, with rate constant K_r, where K_r >0 for destructive reaction, K_r < 0 for generative reaction and K_r= 0 for no reaction. We consider that the magnetic field $B(x) = B_0(x)x^{(n-1/2)}$where B_0 is the constant magnetic field.

Let us introducing the following similarity transformations as

$$u = ax^n f'(\eta), \qquad v = -\sqrt{\frac{a\upsilon(n+1)}{2}} x^{\frac{n-1}{2}} \left[f(\eta) + \frac{n-1}{n+1} \eta f'(\eta) \right]$$

$$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \ \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty}, \ \eta = y\sqrt{\frac{a(n+1)}{2\upsilon}} x^{\frac{n-1}{2}},$$

$$v_w = -\sqrt{\frac{a\upsilon(n+1)}{2}} x^{\frac{n-1}{2}} s \qquad (7)$$

ψ represent the stream function and is defined as $u = \frac{\partial \psi}{\partial y}$ and $v = -\frac{\partial \psi}{\partial x}$

so that Eq.(1) is satisfied identically. By employing the similarity transformations (7), the governing equations (2)-(4) reduced to the following ordinary differential equations:

$$f''' + ff'' - \frac{2n}{n+1}(f')^2 + M(N - f') + N^2 = 0 \qquad (8)$$

$$\frac{1}{pr}\theta'' + f\theta' - \left(\frac{2r}{n+1}\right) f'\theta + Nb\theta'\phi' + Nt(\theta')^2 + Ec(f'')^2 = 0 \qquad (9)$$

$$\phi'' + Le\phi' + \frac{Nt}{Nb}\theta'' - \gamma\phi = 0 \qquad (10)$$

By using (7) the transformed boundary conditions are:

$$f'(0) = 1 + Af''(0), \quad f = s, \ \theta(0) = 1 + B\theta'(0), \ \phi(0) = 1 + C\phi'(0) \ \text{at} \quad \eta = 0$$

$$f' \to 0, \ \theta(\infty) = 0, \ \phi(\infty) = 0 \ \text{as} \ \eta \to \infty \qquad (11)$$

The involved physical parameters are defined as follows:

n is the nonlinear parameter, $N = \frac{b}{a}$ is the velocity ratio parameter, r is the is the surface temperatureparameter in the prescribed surface temperature boundarycondition,

$M=\frac{2\sigma B_0^2}{(n+1)a\rho_f}$ is magnetic parameter, $\Pr=\frac{\upsilon}{\alpha}$ is prandtl number, $Nb=\frac{\tau D_B\left(C_w-C_\infty\right)}{\upsilon}$ is the Brownian motion parameter, $Nt=\frac{\tau D_T\left(T_w-T_\infty\right)}{T_\infty \upsilon}$ is the themoporesis parameter, $Ec=\frac{u_w^2}{C_p\left(T_w-T_\infty\right)}$ is Eckert number, $A=L_1\sqrt{\frac{a\left(n+1\right)}{2\nu}}x^{\frac{n-1}{2}}$ is the velocity slip parameter, $B=L_2\sqrt{\frac{a\left(n+1\right)}{2\nu}}x^{\frac{n-1}{2}}$ is the thermal slip parameter, $C=L_3\sqrt{\frac{a\left(n+1\right)}{2}}x^{\frac{n-1}{2}}$ is concentration slip parameter , $Le=\frac{\upsilon}{D_B}$ is Lewis number and $\gamma=\frac{2k}{a(n+1)(C_w-C_\infty)}x^{\frac{n-1}{2}}$ is the chemical reaction parameter.

The Skin friction coefficient, Nusselt number and Sherwood numbers are given by

$$C_f=\frac{\tau_w}{\rho u_w^2},\ Nu_x=\frac{xq_w}{k\left(T_w-T_\infty\right)},\ Sh_x=\frac{xq_m}{D_B\left(C_w-C_\infty\right)} \qquad (12)$$

$$\tau_w=\mu_B(1+\frac{1}{\beta})(\frac{\partial u}{\partial y})_{y=0}\quad q_w=-k\left(\frac{\partial T}{\partial y}\right)_{y=0}\quad q_m=-D_B\left(\frac{\partial C}{\partial y}\right)_{y=0} \qquad (13)$$

q_w *and* q_m are heat flux of the surface and mass flux of the surface where k is thermal conductivity of the nanofluid.

By substituting equation (7) into equations (12)-(13), we will get

$$C_f\,\mathrm{Re}^{\frac{1}{2}}=f''(0),\quad Nu_x\,\mathrm{Re}^{-\frac{1}{2}}=-\theta'(0),\ Sh_x\,\mathrm{Re}^{-\frac{1}{2}}=-\phi'(0) \qquad (14)$$

$\mathrm{Re}=\frac{u_w x(n+1)}{2}$ is the local Reynolds number.

2.1 Numerical method

The higher order ordinary differential equations with the boundary conditions are solved numerically by using of Keller-Box method, the following few steps are involved to achieve the numerical solutions:

- Reduce the above mentioned higher order ordinary differential equations into a system of first order ordinary differential equations;
- Write the finite differences for the first order equations.

- Linearize the algebraic equations by Newton's method, and write them in matrix–vector form; and
- Solving the linear system by the block tri-diagonal elimination technique.
- In order to solve the above differential equations numerically, we adopt Matlab software which is very efficient in using the well known Keller box method.
- Getting the appropriate initial guesses have chosen.

$$f(\eta)=\frac{1}{1+A}\left(1-e^{-\eta}\right), \quad \theta(\eta)=\left(\frac{1}{1+B}\right)e^{-\eta}, \quad \phi(\eta)=\left(\frac{1}{1+C}\right)e^{-\eta} .$$

3. Results and discussion

The Fig 2(a) represent the effect of magnetic field parameter on velocity of the nanofluid. As the magnetic field parameter M increases, it improves the opposite force to the flow of nanofluid direction called 'Lorentz force'. This Lorentz force opposes the motion of the nanofluid as a result the velocity of the fluid decreases. On observing from Fig 2(b), as the M value increases, the temperature profile increases.

Fig 3(a) exhibits the characteristic of velocity profile with respect to the variation in suction parameter S. As the values of 'S' increase the velocity profile results decreases. Fig 3(b) reveals the variation of temperature with suction parameter S. The increased values of suction parameter S, the temperature profile decreases. Moreover, the thermal boundary layer thickness and surface temperature is also decrease. The influence of the suction parameter 'S' on the concentration profile is represented in Fig 3(c). As the values of suction parameter S increase the concentration is observed to decrease and the concentration boundary layer thickness is also decrease.

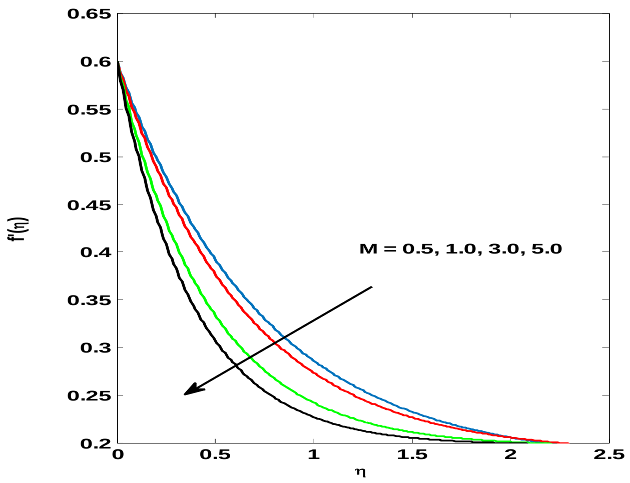

Fig-2(a) Effect of magnetic parameter M on velocity profile

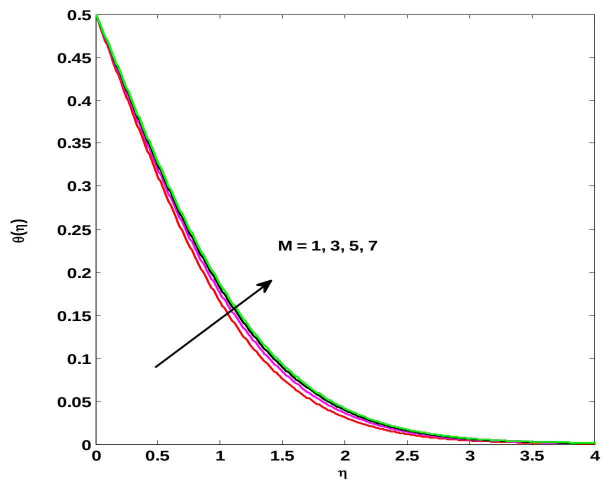

Fig-2(b) Effect of magnetic parameter M on temperature profile

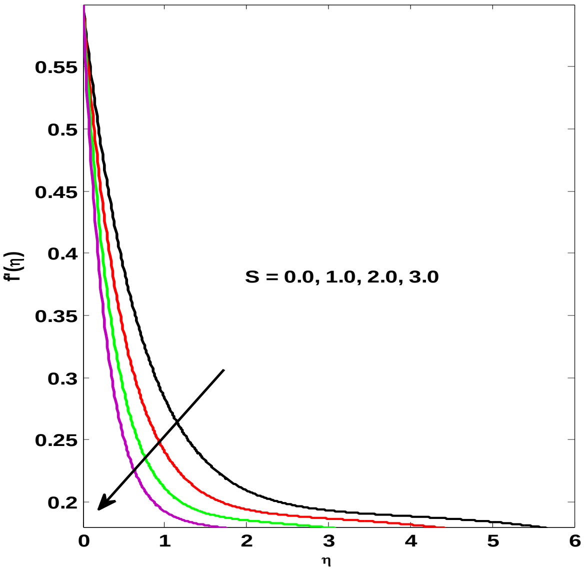

Fig-3(a) Effect of suction parameter S on velocity profile

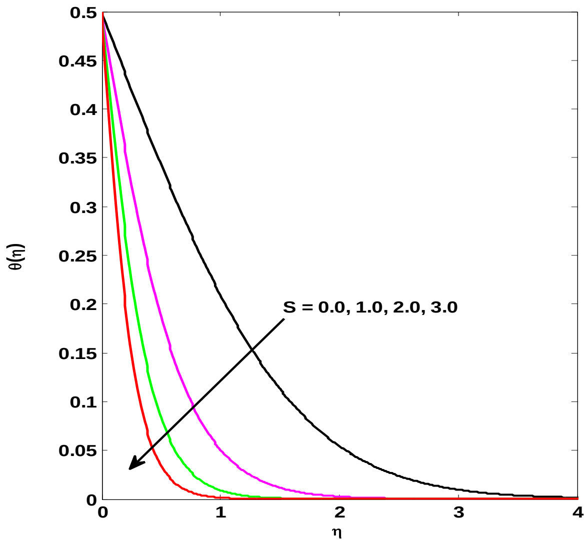

Fig-3(b) Effect of suction parameter S on temperature profile

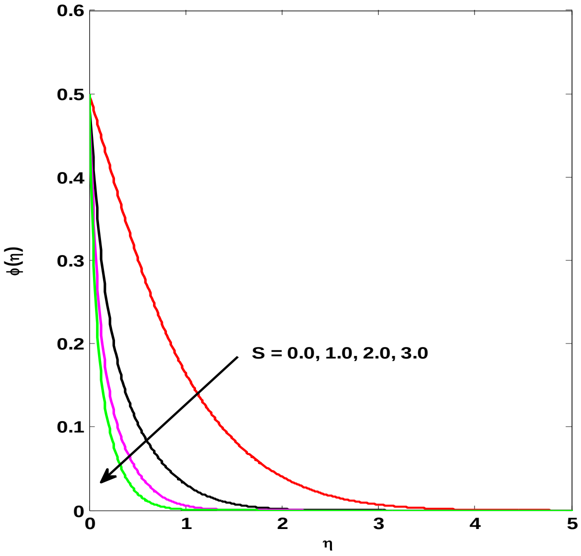

Fig-3(c) Effect of suction parameter S on concentration profile

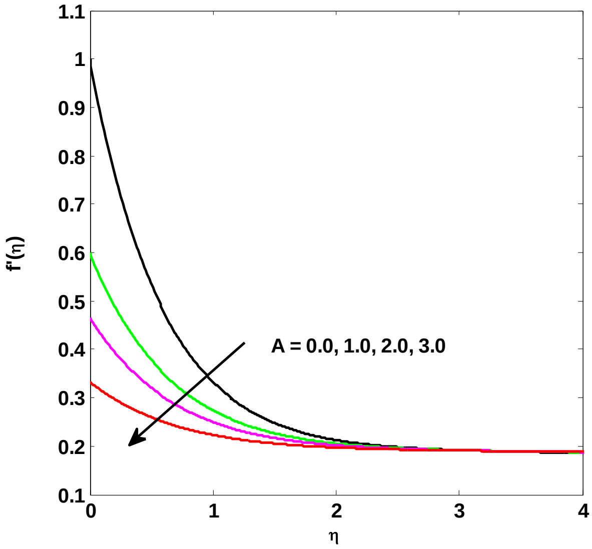

Fig-4(a).Effect of various values of slip parameter A on velocity profile.

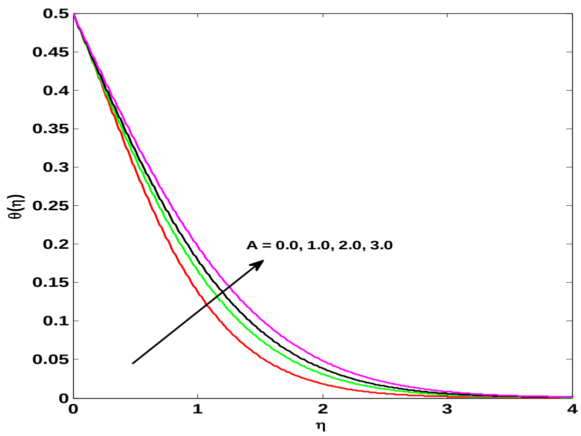

Fig-4(b).Effect of various values of slip parameter A on temperature profile.

The effect of velocity slip parameter on the velocity f ′(η) and temperature θ(η) is depicted in Fig 4(a) and 4(b) respectively. From the Figures it is clearly observed that the velocity is decrease as increase in slip parameter. Velocity distribution is found to decrease along the boundary layer, and is reverse in the case of temperaturei.e. temperature increases with the increase in slip parameter.Due to when increased slip parameter give the generated friction force and is allows more fluid to slip past the sheet and the fluid flow will slows down for distances close to the sheet. The temperature will enhance due to the existence of the forcefor both constant surface temperature and prescribed surfacetemperature.

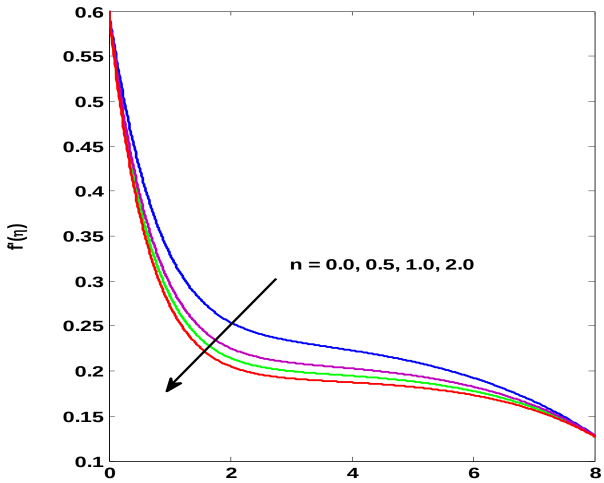

Fig-5(a).Effect of various values of nonlinear parameter'n' on velocity profile.

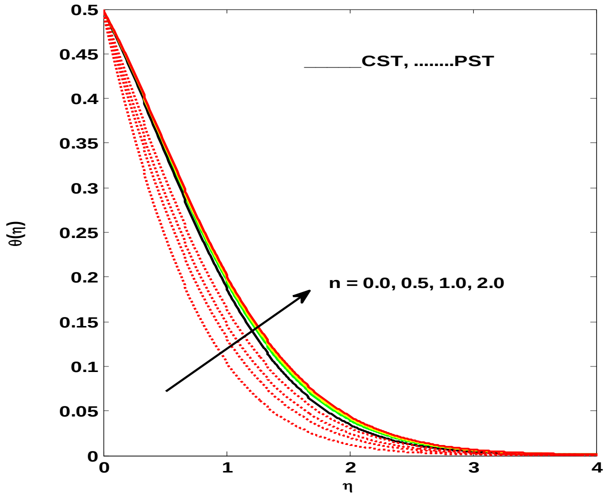

Fig-5(b).Effect of various values of nonlinear parameter n on temperature profile.

On observing from Fig 5(a), as the nonlinear parameter “n” increases, the velocity profile decreases.In case of temperature the result is reversed .i.e. when we increase n values temperature profile increases this fact can be observed from Fig 5(b).

The influence of thermal slip parameters B on the temperature profiles is shown in Fig 6 which describes that the fluid temperature decreases on increasing thermal slip parameter B. From Fig7 we can observe the variation of concentration with respect to solutal slip parameter C. As it can be seen from the graph, increasing in the concentration slip parameter C, the concentration profile is decreasing.

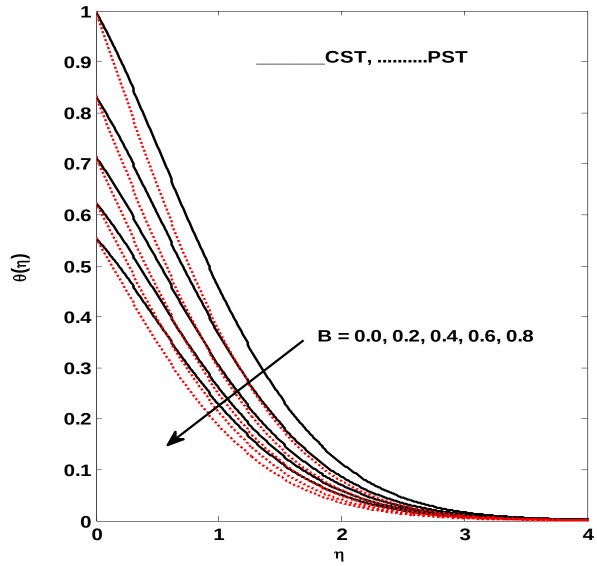

Fig.6.Effect of various values of thermal slip parameter B on temperature profile.

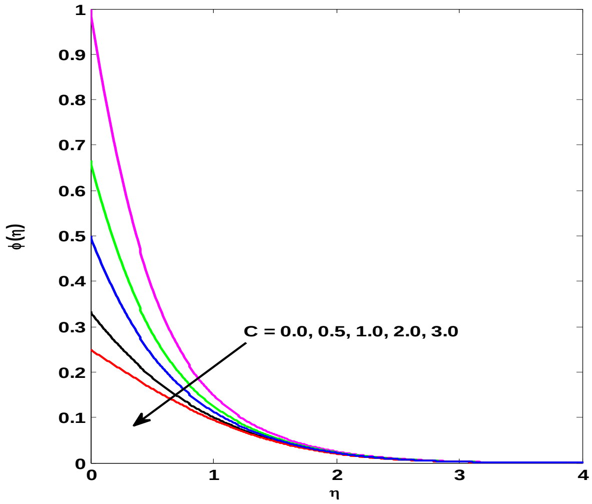

Fig-7.Effect of various values of solutal slip parameter C on concentration profile.

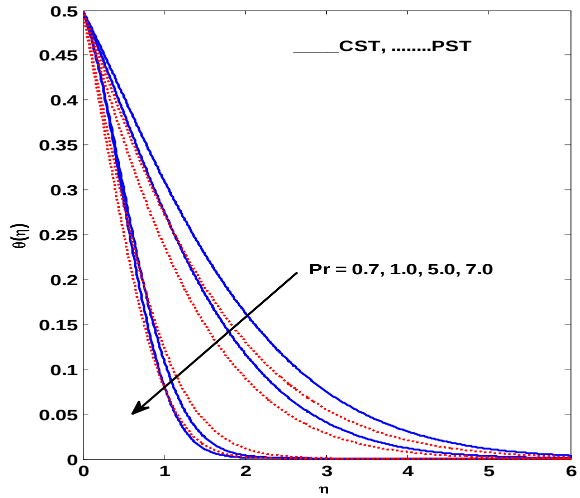

Fig-8.Effect of various values of prandtl number Pr on temperature profile.

The effect of Prandtl number Pr on the heat transfer process is shown by the Fig 8. This figure reveals that as an increase in Prandtl number Pr, the temperature field decreases in both the PST and CST cases. An increase in the values of Pr reduces the thermal diffusivity, because Prandtl number is a dimensionless number which is defined as the ratio of momentum diffusivity to thermal diffusivity, that is $Pr = \upsilon/\alpha$. Increasing the values of Pr implies that momentum diffusivity is higher than thermal diffusivity. Therefore thermal boundary layer thickness is a decreasing function of Pr.The influence of Eckert number Ec is depicted in Fig 9. It illustrates that the temperature increases with an increase in Ec. The viscous dissipation produces heat due to drag between the fluid particles and this extra heat causes an increase of the initial fluid temperature.

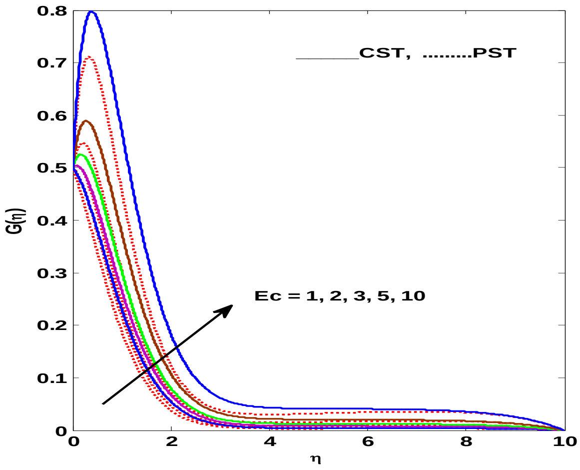

Fig-9.Effect of various values of Ekert number Ec on temperature profile.

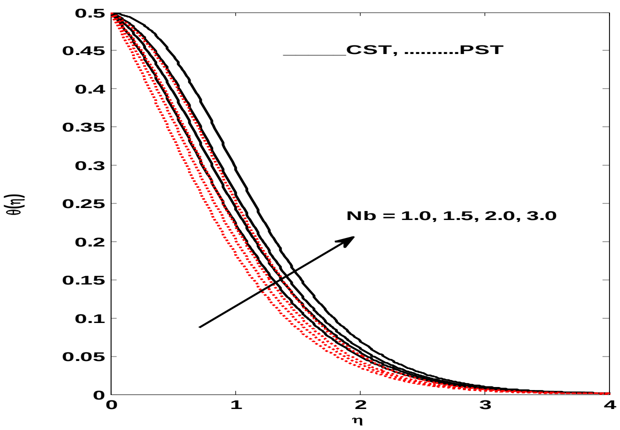

Fig.10(a).Effect of various values of Brownian motion parameter Nb on temperature profile.

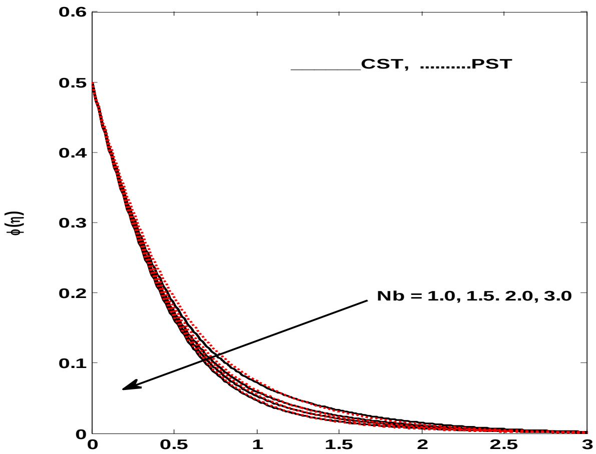

Fig.10(b).Effect of various values of Brownian motion parameter Nb on concentration profile.

The effect of Brownian motion parameter Nb on temperature and concentration are presented in Fig 10(a) and 10(b). The Fig 10(a) represents the variation of temperature with the Brownian motion parameter Nb. Increase in Nb values gives the temperature graph increase and increase in thermal boundary layer thickness. As increase in Nb, due to movement of nanoparticles, results in increase the kinetic energy of the nanoparticle, thus rises the temperaturefor both constantsurface temperature and prescribed surface temperature.But it is reverse in the case of nano particle volume fraction profile, i.e. as the values of Nb increase, the concentration boundary layer thickness decrease. Fig 11(a) and 11(b) shows the impact of thermophoresis parameter Nt on temperature and nanoparticle concentration profile respectively. It is found that an increase in the thermophoresis parameter Nt leads to increase in both temperature and nanoparticle concentrationfor both constantsurface temperature and prescribed surface temperature. As the thermophoretic effect increases, nanoparticles are migrated from the hot surface to cold ambient fluid, as a result the temperature enhanced in the boundary layer.This will helps in the thickening of the thermal boundary layer. Fig 11(b) reveals the variation of concentration profile and it can be seen from the graph concentration profile is increases, as the Nt increases and concentration boundary layer thickness increases.

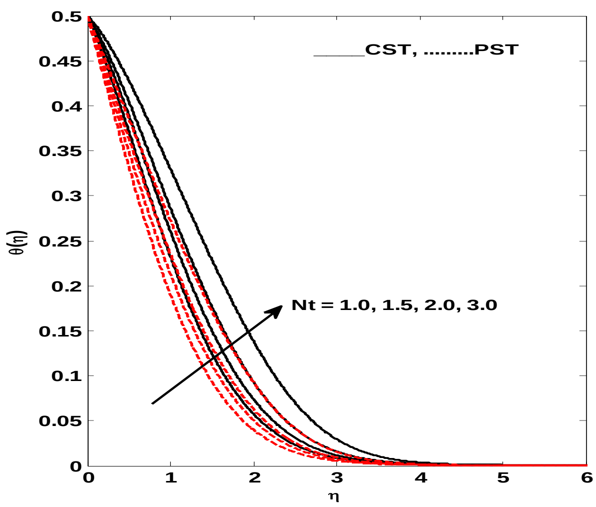

Fig-11(a).Effect of various values of themoporesis parameterNt on temperature profile.

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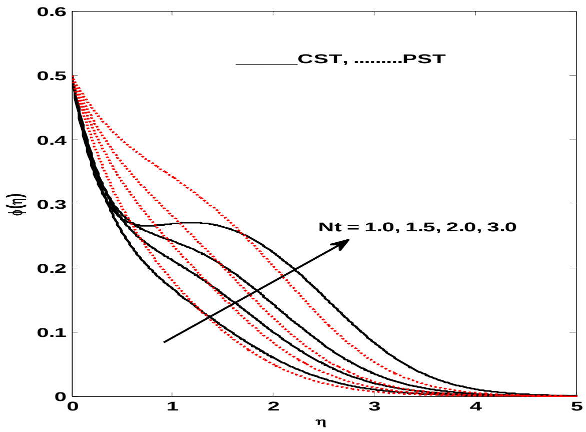

Fig-11(b).Effect of various values of themoporesis parameter Nt on concentration profile.

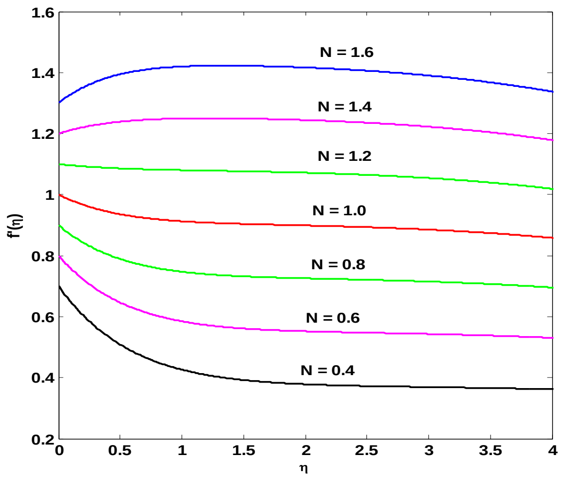

Fig-12(a).Effect of various values of velocity ratio parameter N on velocity profile.

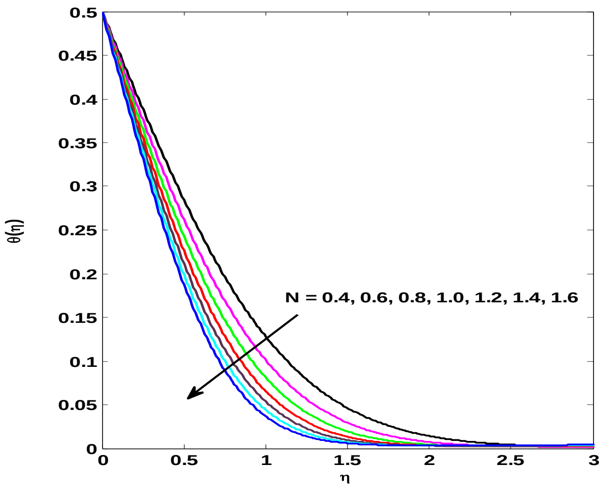

Fig-12(b).Effect of various values of stagnation parameter N on temperature profile.

Fig 12(a) depicts the effect of the velocity ratio parameter on the flow field velocity. It can be observed that for N< 1 i.e., when the stretching velocity of the sheet exceeds the free stream velocity, the velocity of the fluid and the boundary layer thickness increases with an increase in N. Moreover, for N > 1 i.e., when the free stream exceeds the stretching velocity, the flow velocity increases and the boundary layer thickness decreases with an increase in N. If N = 1 i.e., when the stretching and free stream velocities are equal, then there is no boundary layer of fluid flow near the sheet.Fig 12(b) shows the effect of stagnation parameter on temperature. The temperature profile decreases for increasing values of N.

Fig 13 shows the impact of Lewis number Le on concentration profile. Actually, a higher value of Lewis number Le $=\alpha/D_B$ represents a lower nanoparticle diffusivity (Brownian motion) and a higher thermal diffusivity. If Le > 1 the thermal diffusion rate exceeds the Brownian diffusion rate. Lower Brownian diffusion leads to less mass transfer rate, as a result, the nanoparticle volume fraction (concentration) graph and the concentration boundary layer thickness decrease. Fig 14 illustrates the effect of chemical reaction parameter on dimensionless nanoparticle concentration. It is observed that the nanoparticle volume fraction decreases with the increase of chemical reaction parameter whereas the parameter shows no substantial changes on dimensionless velocity and dimensionless temperature profiles.

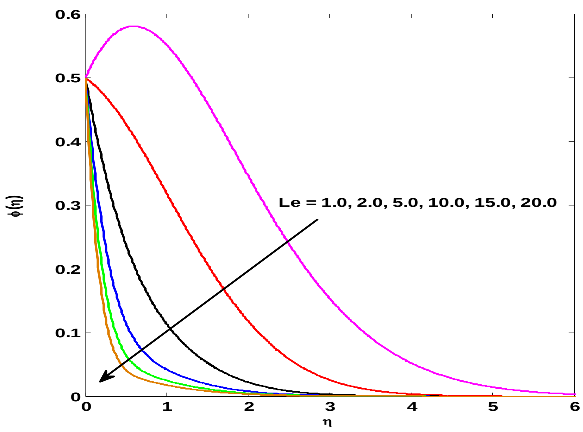

Fig-13.Effect of various values of Lewis number Le on concentration profile.

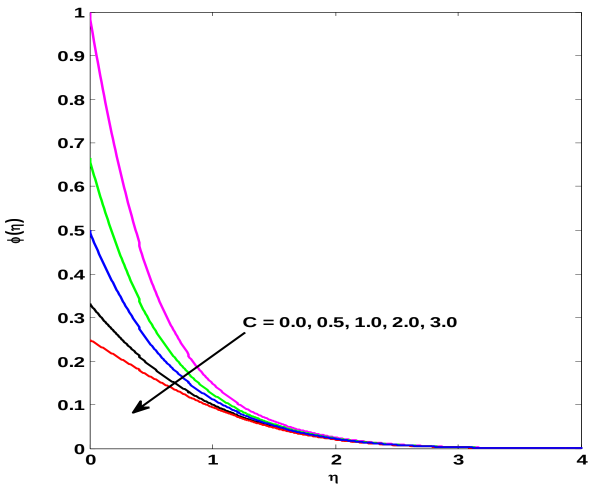

Fig-14.Effect of various values of chemical reaction parameter C on concentration profile.

Table 1. Comparison of the values of $-\theta'(0)$ for various values of n

Pr	N	CortellRana&Bhargava	KalidasDas	Present result	
1.0	0.2	0.610262	0.6113	0.610571	0.6102
	0.5	0.595277	0.5967	0.595719	0.5952
	1.5	0.574537	0.5768	0.574525	0.5748
5.0	0.2	1.607175	1.5910	1.60713	1.6078
	0.5	1.586744	1.5839	1.58619	1.5868
	1.5	1.557463	1.5496	1.55719	1.5577

Table-2. Calculation of skin friction coefficient of various values of M , N ,A, s ,n

M	N	A	S	n	-f''(0)
0					0.4665
0.5					0.4861
1.0					0.5132
	0.8				0.3397

1.0				0.2002
1.2				0.0435
	0.0			1.0079
	1.0			0.5132
	2.0			0.3579
		-1.0		0.3546
		0.0		0.4824
		1.0		0.6539
			0.0	0.0396
			1.0	0.4251
			2.0	0.5132

Table.3 Calculation of Nusselt number and Sherwood number for various values of PrNb Nt B N r

PrNb	Nt	B	N	r	$-\theta'(0)$	$-\phi'(0)$
0.7					0.3265	0.8899
1.0					0.3772	0.8574
2.0					0.4764	0.7918
	1.0				0.3592	0.9670
	1.5				0.2706	1.0165
	2.0				0.2047	1.0360
		1.0			0.4169	0.6367
		1.5			0.3694	0.5431
		2.0			0.3311	0.4887
				0.0	0.8537	0.6192
				0.4	0.6505	0.7083
				0.8	0.5235	0.7686

0.0		0.7865	0.6058
1.0		0.5583	0.7361
2.0		0.4764	0.7918
	0.0	0.3146	0.9277
	1.0	0.4764	0.7918

Table - 4. Calculation of Nusselt number & Sherwood number for various values of Ec Le g c s

Ec	Le	γ	c	s	$-\theta'(0)$	$-\phi'(0)$
0.0					0.4972	0.7733
2.0					0.2879	0.9591
5.0					0.0304	1.2419
	1.0				0.5910	0.1788
	2.0				0.5366	0.1645
	5.0				0.5082	0.4070
		0.1			0.4754	0.8119
		0.3			0.4774	0.7713
		0.5			0.4795	0.7290
			0.0		0.3592	1.9341
			1.0		0.4764	0.7918
			3.0		0.5476	0.2086
				-1.0	0.2013	0.0232
				0.0	0.4131	0.5142
				1.0	0.7954	2.1348

4. Conclusions

In the present work effect of viscous dissipation on MHD stagnation point flow of chemically reacting nanofluid over nonlinear stretching sheet with slip conditions are analyzed.

- The following conclusions were drawn
- As the magnetic parameter M increases, velocity profile decreases and temperature profile increases.

  The suction parameter S values increased the velocity, temperature and concentration profiles are decreases
- The effect of velocity slip parameter ' A' values increases the velocity profile decreases and the temperature profile increases
- The nonlinear parameter n increases, the velocity profile decreases and temperature profile increases.
- The thermal slip parameter B increases, the temperature profile decreases

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