Effects of Slip and Thermophoresis on Unsteady Flow and Heat Transfer of (MHD) Bioconvection of Nanofluids over a Stretching Sheet

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Abstract:- Effects of Slip and thermophoresis on Unsteady Flow and Heat Transfer of (MHD) Bioconvection of Nanofluids over a Stretching Sheet was investigated. Similarity transformations are employed to transform a set of nonlinear partial differential equations for momentum, heat and mass transfer, concentration and motile microorganism intoa set of nonlinear ordinary differential equations. These equations are solved using fourth order Runge-Kutta methods with a shooting technique. The effects of velocity slip, temperature slip, thermophoresis and grashof number are examined. While the velocity slip increases the velocity profile and decrease. As the temperature slip parameter increases the temperature profile decreases gradually while heat transfer rate increases.As the thermophoresis parameter increases the temperature profile increases while heat transfer rate initially decreases and then increases. The present numerical results are compared with available data and are found in an excellent agreement. Other results are presented in a table and in graphs.

Keywords: Unsteadiness, Numerical, Boundary layer, Slip, Bioconvection

I. INTRODUCTION

In the recent times, flow, heat and mass transfer of nanofluids have been widely examined by numerous scientists and engineers. Wang and Fan [1] suggested that nanofluids involved macro molecular and micro particles. Sparrow and Gregg [2] reported the examination of the different thermo physical attributes of nanofluids for laminar natural convection past an isothermal perpendicular divider. Brown [3] explored the impacts as regards volumetric development coefficient on convective heat transfer. However, inference of the Boussinesq approximation for fluid found exploited by Gray and Giogini [4]. According to his paper, the author likewise recommended a strategy at breaking down normal convective streams in the fluid with different attributes. Moreover, Clausing and Kempka [5] reported that impacts of different properties on trial premise and the details of convective reduced Nulsset number (Nu) is an element of radiation (Ra) with benchmark temperature is taken as the normal temperature in the system of boundary layer. Unsteadiness exploration of laminar normal stream, progress from laminar to turbulent fluid flow was credited to Gebhart [6]. The bio-nano-designing model was accounted for by Akbar [7]. Karode [8] reported a review on laminar stream in a channel with permeable divider in a slit. He introduced an insightful answer to the strain fall in liquid stream in conferment and tube shaped cylinder in the consistent divider penetrability. Oxarango et al. [9] mentioned one-layered simulation to examine hotness move in laminar progression in fluids. Motsumi and and Makinde [10] accounted for impacts in warm radiation on the thick scattering limit of boundary layer stream of nanofluids on a porous moving sheet. Uddin et al. [11] concentrated on MHD limit layer fluid flow past an upward permeable layer with Newtonian warming limit condition. Raees et al. [12] showed the instance with respect to blended heat and mass transfer in gravity-driven bioconvection. Zen'kovskaya and Simonenko [13] gave the subjective examination as regards the impact of high recurrence frequency convection inception. In the new turn of events, there has been a significant exploration centers around the investigation of vertical frequency impacts on suspensions of different sort of motile cells because of its vibration effects of oil terrains so also drug designs get balanced either agreeably or sub-pleasingly to the attain the recurrence. Bardan and Mojtabi [14] and Bardan [15] investigated a straight strength with feebly non-direct examination for Lapwood [16]. Murthy et al. [17] carried out the convective steam; Wenfei and Xiaojiang [18] and Gang et al. [19]. Repeated perpendicular vibration impacts on a porous limit toward a path corresponding to applied temperature angle and subjective way settles the convection commencement as exhibited Zen'kovskaya and Rogovenko [20]. Jeffrey et al [21] revealed exploratory perceptions of heat transfer in a film limit driven by both warming from beneath and in an upward direction sinusoidal vibrations and saw that convection move pace of delineated nano-liquid immersed with non-Darcy permeable fluid. Rashidi et al. [22] noted that the heat age of progression in magneto nanofluid over the permeable plate. Instruments controlling to warm trade improvement in nanofluids are taken apart in various distributions. Das et al. [21]and Jang et al. [22] recommended utilizing a permeable medium (a careful cotton fleece), which should be adequately penetrable to permit cells to swim through it yet additionally adequately close to moist out bioconvection. Alharbi et al. [24] construed that when growing the value of the appealing field limit, the porosity factor speed profiles decline. The speed profile rises with a climb in the value of couple-stress limit. Qian et al.[25] while doing a molecular dynamical simulation studies found that slipping interaction took place between the liquid and solid surface. He discovered that

Navier boundary exists and is free of shear rate compared to enormous scope of shear rate, thus indicating that there is slip. Interestingly, many researchers have explored the significance of boundary layer, the occurrence of buoyancy and magnetic field in fluid flow but only a very small number of them have considered slip condition. More works on the flow under slip condition will enhance the depth of knowledge on the concept of no slip and slip conditions. Hence, the numerical analysis of combined effects of velocity slip, temperature slip and thermophores of a nanofluid past a stretching sheet with a slip condition will be very significant. Therefore, this investigation is undertaken by these researchers.

II. FORMULATION OF PROBLEM

Consider unsteady two-dimensional flow of water based electrically conducting fluid containing oxytactic microorganisms over a vertical plate with Navier slip keptT_w, $C_w$and $n_w$along plate and T_∞, $C_\infty$and n_∞ away from the plate, where *t* is time, *u* and *v* are the velocity components, *x* and *y* are the Cartesian coordinates, *T* is the temperature, *n* is the density of motile microorganisms, υ is the kinematic viscosity, ρ_f is the density of the fluid, ρ_p is the density of the nanoparticles, $\rho_{m\infty}$ is the microorganism density, δ is the fluid electrical conductivity, B_0 is the strength of magnetic field, *g* is the acceleration due to gravity, β is the volumetric expansion coefficient, γ is the average volume of a micro-organism, *k* is the thermal conductivity, $C_p$is the specific heat at constant pressure, D_T is the thermophoresis diffusion coefficient, D_B is the Brownian diffusion coefficient, D_n is the diffusivity of microorganisms. The presence of nanoparticles is assumed to have no effect on the direction in which microorganisms swim and on their swimming velocity. The Magnetic strength B_0 is constructed parallel to the y-axis and induced magnetic field and the electric polarization charges are negligible. The npresence of nanoparticles is assumed that there is no effect on microorganisms swim and the bio convection takes place in suspension of nanoparticles. Also, the figure shows that a strong magnetic field of strength B_0 is applied in the *y* direction. T_w and n_w are the temperature and the density of the motile microorganisms at the wall, respectively, which are kept constant thereafter, and the nanofluid particle fraction on the boundary is passively rather than actively controlled. T_∞, C_∞ and n_∞ are the ambient values of the temperature, concentration and density of motile microorganisms, respectively, far away from the plate. At knowing that, the plate temperature and the density of motile microorganisms are raised to $T_w > T_\infty$ and $n_w > n_\infty$, at $t > 0$. Base on Oberbeck- Boussinesq approximation, (as used by [28]), the governing equations are given as follows:

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

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2} - \frac{\mu}{k}u + \frac{(1-c_\infty)\rho_{f\infty} g\beta(T_w-T_\infty)\theta}{\rho_f}\{(\rho_f - \rho_{f_\infty})(C - C_\infty) + (n - n_\infty)\gamma\chi(\rho_{m\infty} - \rho_f\}\frac{g}{\rho_f} + \frac{\sigma B^2 u}{\rho} \qquad 2$$

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

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D_B\frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2} \qquad 4$$

$$\frac{\partial n}{\partial t} + u\frac{\partial n}{\partial x} + v\frac{\partial n}{\partial y} = D_n\frac{\partial^2 n}{\partial y^2} - \frac{bW_C}{C_w - C_\infty}\frac{\partial}{\partial y}\left(n\frac{\partial C}{\partial y}\right) \qquad 5$$

[28]

$$f''' + ff'' - (f')^2 - s\left[f' + \frac{1}{2}\eta f''\right] - \frac{1}{Da}f' - Mf' + G_r\theta - N_r\phi - R_b\chi = 0 \qquad 6$$

$$(1+R)\theta'' - \frac{1}{2Pr}\square[\eta\theta' - 3\theta] + 2Prf'\theta + PrNb\theta'\phi + Nt(\theta)^2 \quad = 0 \qquad 7$$

$$\phi'' - \square_c\left[\frac{1}{2}\square(\eta\phi' - 3\phi) - 2f'\phi - f\phi'\right] + \frac{N_t}{N_b}\theta'' \quad = 0 \qquad 8$$

$$\chi'' + \square_{mm}[\square(\eta\chi' - 3\chi) - 2f'\chi - f\chi'] - p_e\left[\phi'\chi' + \phi''(\sigma + \chi)\right] = 0 \qquad 9$$

Boundary conditions are as follows:

$$f'(0) = S + \delta_1 f''(0); f(0) = 0;\ \theta(0) = 1;\ , \phi(0) = 1 \text{ and } \chi(0) = 1 \qquad 10$$

$$f'(\eta) = 0, f(\eta) = 0, \theta(\eta) = 0, \phi(\eta) = 0 \text{and } \chi(\eta) = 0; \qquad 11$$

$$f = 0, f'(0) = S + \delta f''(0);\ \theta(\eta) = 1 + \gamma\theta'(\eta), \chi = 1 \text{ at } \eta = 1 \text{and} N_b\phi' + N_t\theta' = 0 \qquad 12$$

$$f'(\eta) = 0, \Rightarrow f(\eta) = 0, \theta(\eta) = 0, \phi(\eta) = 0 \text{ and } \chi(\eta) = 0 \qquad 13$$

Gammar,$\gamma = \frac{(\alpha v x)^{\frac{1}{2}}}{D_B\left((1-\emptyset_\infty)\beta g \Delta T_f\right)^{\frac{1}{2}}} k_1$–,Unsteadiness parameter $s = \frac{c}{a}$-, Magneticparameter, $M = \frac{\sigma B_0^2 x^2}{\rho a}$ - ,

Grashof number, $G_r = \frac{(1-ct)^2}{a^2 x} \cdot \frac{(1-c_\infty)\rho_{f\infty} g\beta(T_w - T_\infty)\theta}{\rho_f}$, Buoyancy parameter depending on the volumetric co-efficient of thermal expansion,$N_r = \frac{(1-ct)^2 \cdot}{a^2 x} \frac{(\rho_p - \rho_{f\infty})(c - c_\infty)\phi}{\rho_f \beta \Delta T(1-\emptyset_\infty)}$- Buoyancy ratio parameter,$R_b = \frac{(n_w - n_\infty)(\rho_p - \rho_{f\infty}) g\gamma (1-ct)^2}{a^2 x \rho_f}$ - Rayleigh number, $R = \frac{16\sigma T_\infty^3}{3k^* k_0}$ - Radiation parameter, $R_b = \frac{\nu \rho c_p}{k_0}$, Prandtl number as, $P_r = \frac{\nu}{\alpha}$, $N_b = \frac{\tau D_B (C_w - C_\infty)}{\nu}$- Brownian motion coefficient, Thermophoresis parameter, $N_t = \frac{\tau D_B (T_w - T_\infty)}{\nu T_\infty}$- , $S_c = \frac{\nu}{D_B}$-Schimdt number, $S_{mm} = \frac{\nu}{D_n}$- Schmidt number for diffusing motile microorganisms, σ $\frac{n_\infty}{n_w - n_\infty}$, Motile parameter, $p_e = \frac{b w_c}{D_n}$bioconvection peclet number

$D_a = \frac{\mu}{k} \cdot \frac{ax}{1-ct}$ – Darcy, number,$\delta = \frac{N_1 R_a^{1/4}}{x}$ – *Delta*

The physical quatities of engineering interests are the skin friction coefficient , C_{fx} , and local nusselt , Nu_x.

The Skin friction is derived as follows from shear stress given by :

$$\tau_w = \mu \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$$C_{fx} = \left(\frac{\tau_w}{\rho U^2/_2}\right),$$

$$\frac{1}{2} C_{fx} R_x^{\frac{1}{2}} = f''(0) \qquad 14$$

While the Nusselt number follows the surface heat flux given by:

$$q_w = -k \left(\frac{\partial T}{\partial y}\right)_{y=0}$$

$$Nu_x = \frac{x q_w}{\kappa \Delta T}, ,$$

$$Nu_x \Big/ Re_x^{1/2} = -\theta'(0) \qquad 15$$

Where, $q_w = -k \left(\frac{\partial T}{\partial y}\right)_{y=0}$ is surface heat flux; flux. $\tau_w = \mu \left(\frac{\partial u}{\partial y}\right)_{y=0}$ is shear stress 16

Where, the local Reynolds numberRe_x is defined as $Re_x = \frac{U_0}{\nu} x$.

III. METHODOLOGY

Referring to the above couples ODEs, Runge-Kutta scheme with shooting technique was employed. (2)- (5) with initial and boundary conditions (6)–(9) [28].

IV. RESULT AND DISCUSSION

The following dimensionless quantities were set for numerical computation and repeated arranged to evaluate dependent variables. The dimensionless quantities were set as follows: Gr=1; R=2;Pr=6.2; Nb=Rb=Nr=0.3; Pe=0.5;s=1.0; Snm=1; Da=0.1; Sc=0.1

A	Aminreza et al [63]	Wang [25]	Present result
0	1.000000	1.001	1.0013959
0.1	0.872082		0.8734401
0.2	0.776377		0.777700
0.3	0.701548	0.703	0.702841
0.5	0.591195	-	0.592433

Table 1: Comparison of results for the skin friction coefficient when A=0, Nb=0.1,Nt=0.1,Pe=M=Lb= Ec=R=0,Sc=Pr=10 with varying slip

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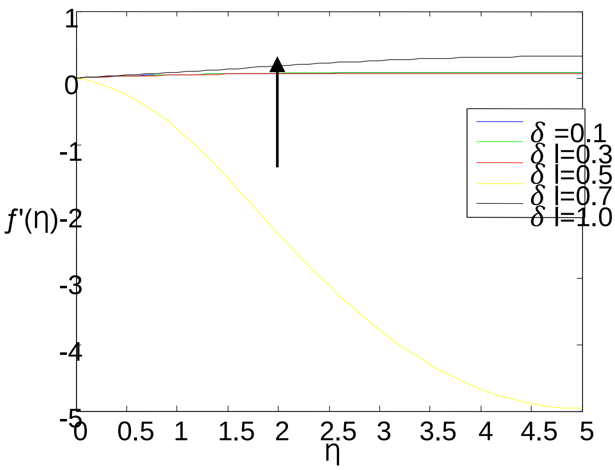

Fig. 1: Effect of δ on velocity profiles R=2;Pr=6.2.0; Nb=Rb=Nr=0.3;

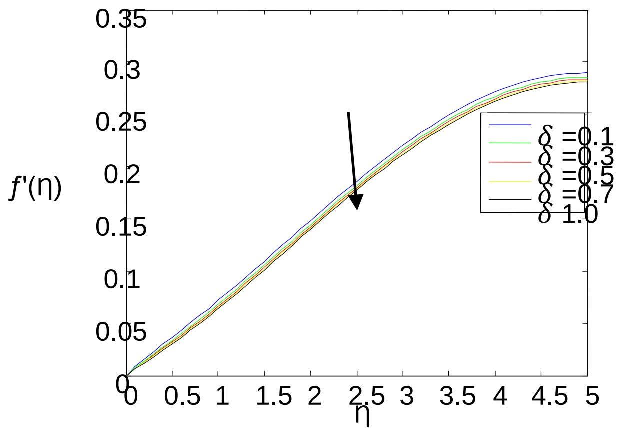

Fig. 2: Effect of δ on velocity profiles R=2;Pr=1.0; Nb=Rb=Nr=0.3;

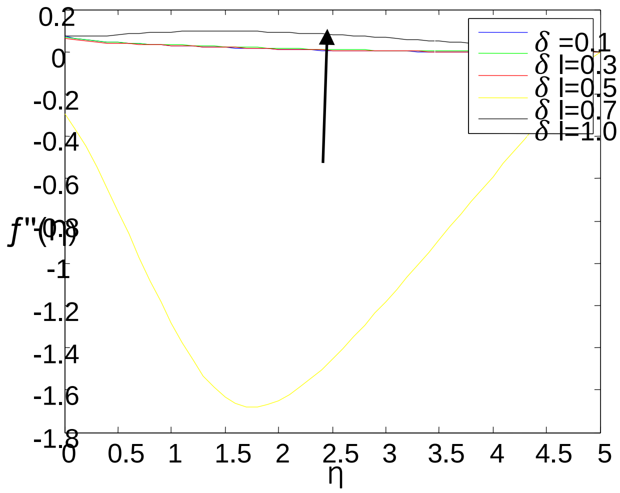

Fig. 3: Effect of δ on velocity profiles R=2;Pr=6.2.0; Nb=Rb=Nr=0.3;

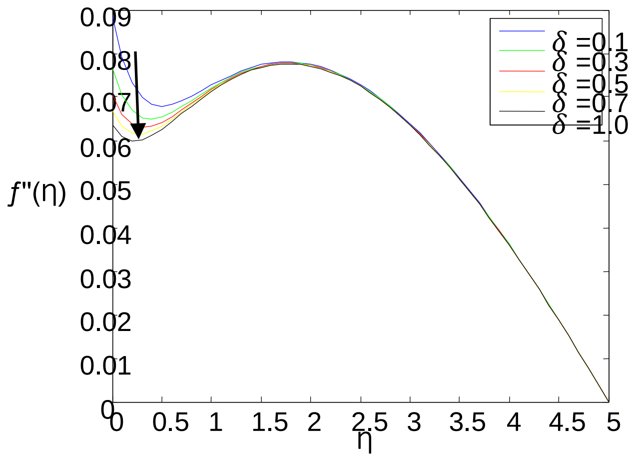

Fig. 4: Effect of δ on Skin Friction : R=2;Pr=1.0.2; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1; Da=0.1;

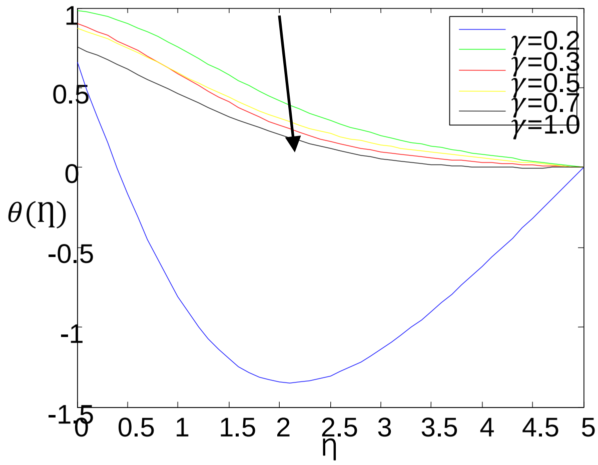

Fig. 5: Effect γ on Temperature profiles R=2;Pr=1.0;Nb=Rb=Nr=0.3;

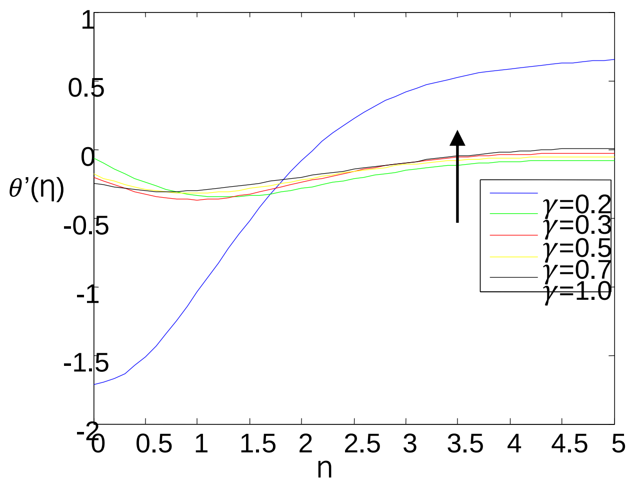

Fig. 6: Effect of γ on heat transfer R=2;Pr=1.0;Nb=Rb=Nr=0.3;

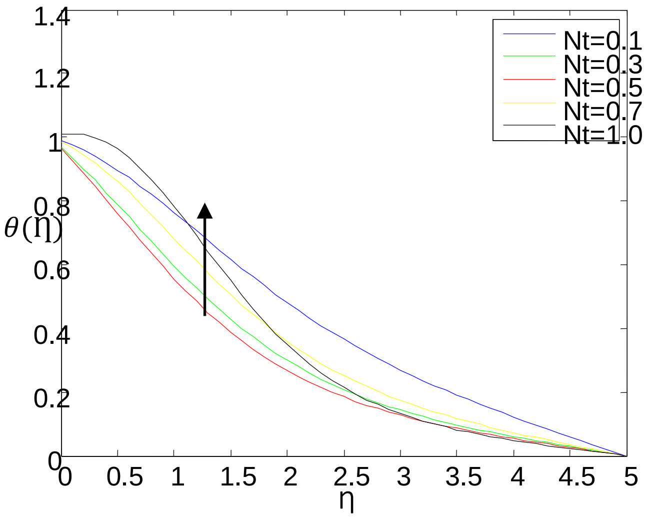

Fig. 7: Effect of thermophoresis on Temperature R=2;Pr=1.0; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1; Da=0.1;

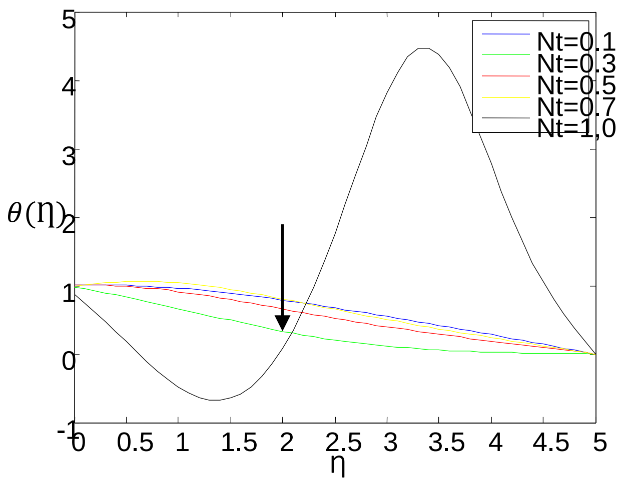

Fig. 8: Effect of thermophoresis on Temperature R=2;Pr=6.2; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1; Da=0.1;

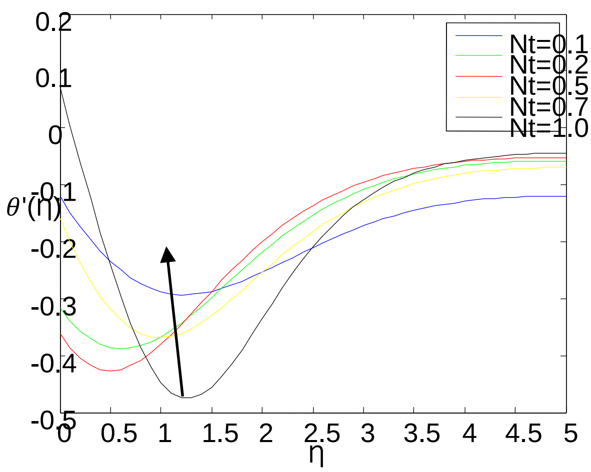

Fig. 9: Effect of Thermopherosis on Heat Transfer R=2;Pr=6.2; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1

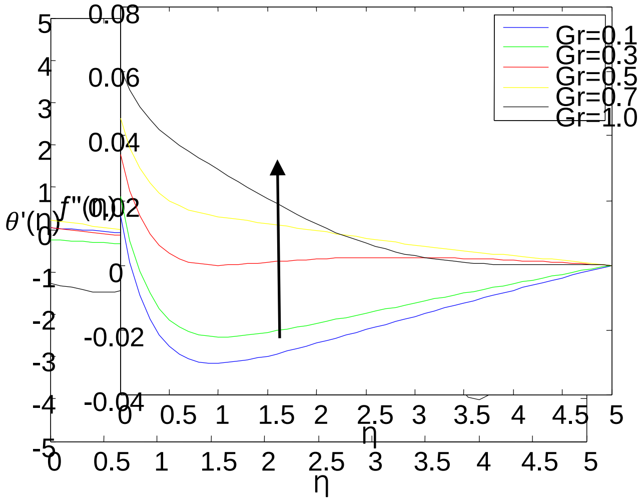

Fig. 10: Effect of Thermopherosis on Heat Transfer R=2;Pr=1.0; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1

Figures 11-14 showed when the grashof number(G_r) is low, the velocity profile increases and when grashof number is high profile decreases. With increase in grashof number the skin friction increases at eta =1, the grashof number increases then skin friction decreases

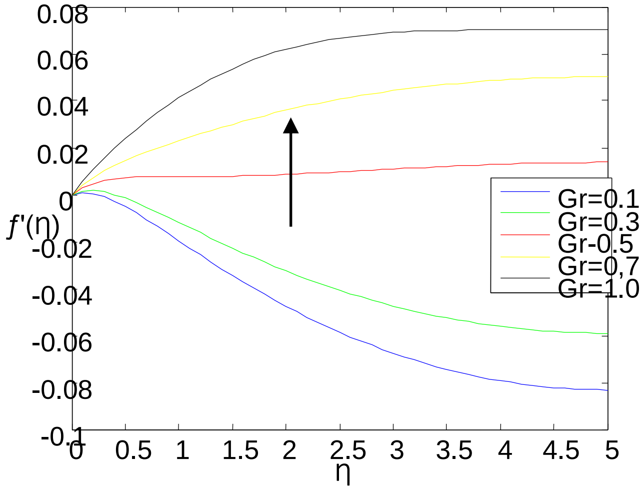

Fig. 11: Effect of Gr on velocity profiles R=2;Pr=6.2.0; Nb=Rb=Nr=0.3;

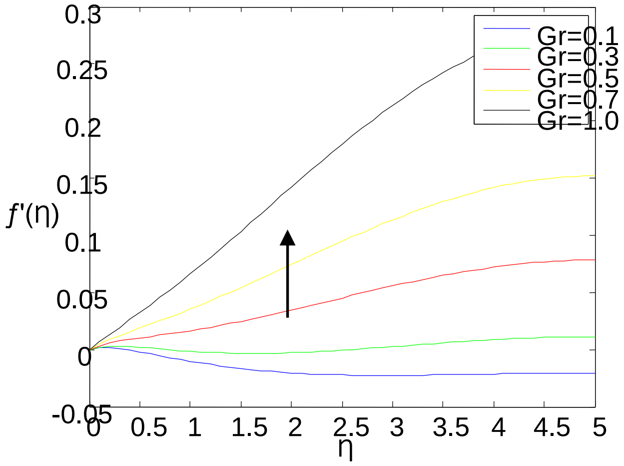

Fig. 12: Effect of Gr on velocity profiles R=2;Pr=1.0; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1

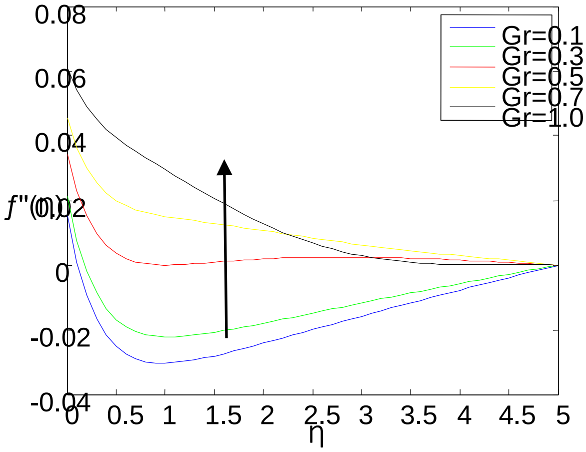

Fig. 13: Effectof Gr on Skin Friction profiles R=2;Pr=6.2; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1

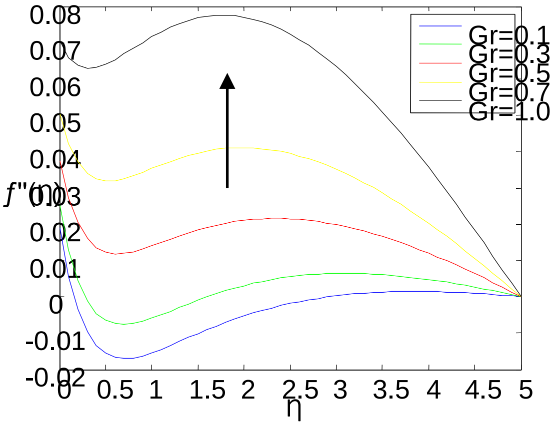

Fig. 14:Effectof Gr on Skin Friction profiles R=2;Pr=1.0; Nb=Rb=Nr=0.3; Pe=0.5; Snm=1

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V. CONCLUSION

The effects of slip and thermophoresis with the grashof number on Unsteady Flow and Heat Transfer of (MHD) Bioconvection of Nanofluids over a Stretching Sheet were investigated in this study.we observed :

- that while the velocity slip increases the velocity profile decreases and decreases .
- As the temperature slip parameter increases the temperature profile decreases gradually while heat transfer rate increases.
- As the thermophoresis parameter increases the temperature profile increases while heat transfer rate initially decreases and then increases.
- The present numerical results are compared with available data and are found in an excellent agreement

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