Thermal conductivity and Heat generation parameter analysis on micropload nanofluid flows.

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Abstract: In this paper, it deals that the numerical study of variable thermal conductivity and radiation on the flow and heat transfer of an electrically conducting micropolar nanofluid over a continuously stretching surface with varying temperature in the presence of a magnetic field and heat source/sink. The governing conservation equations of Angular momentum, energy, momentum and mass are converted into a system of non-linear ordinary differential equations by means of similarity transformation. The resulting coupled system non-linear ordinary differential equations are solved by implicit finite difference method along with the Thomas algorithm. The results are analyzed for the effect of different physical parameters on velocity, angular velocity, temperature and concentration fields are presented through graphs. Physical quantities such as $-f''(0)$, $\theta'(0)$, $\phi'(0)$ are also computed and are shown in table.

Keywords: MHD, microrotation parameter, radiation parameter, Eckert number, thermal conductivity parameter, Thermophoresis parameter, heat source/sink.

1. Introduction: The nanofluid is changed with the thermal conductivity has attracted the interest of many scientists and researchers. The survey of convective heat transfer in nanofluid by Buongiorno[1]. He showed that the fluid characteristics are changed with the nanoparticles because thermal conductivity of these particles was higher than convectional fluids. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. Micropolar fluids are subset of the micromorphic fluid theory introduced in a pioneering paper by Eringen[2]. Micropolar fluids are those fluids consisting of randomly oriented particles suspended in a viscous medium, which can undergo a rotation that can affect the hydrodynamics of the flow, making it a distinctly non-Newtonian fluid. They constitute an important branch of non-Newtonian fluid dynamics where microrotation effects as well as microinertia are exhibited. Eringen's theory has provided a good model for studying a number of complicated fluids, such as colloidal fluids, polymeric fluids and blood. Srinivas Maripla and Kishan Naikoti[3] studied the MHD mixed convective heat and mass transfer through a Stratified nanofluid flow over a thermal radiative stretching cylinder.

The heat source/sink effects in thermal convection, are significant where there may exist a high temperature differences between the surface (e.g. space craft body) and the ambient fluid. Heat Generation is also important in the context of exothermic or endothermic chemical reaction. Sparrow and Cess [4] provided one of the earliest studies using a similarity approach for stagnation point flow with heat source/sink which vary in time. Pop and Soundalgekar [5] studied unsteady free convection flow past an infinite plate with constant suction and heat source. Srinivas Maripala and Kishan Naikoti [6] studied, MHD convection slip flow of a thermosolutal nanofluid in a saturated porous media over a radiating stretching sheet with heat source/sink. Rahman and Sattar [7] studied magnetohydrodynamic convective flow of a micropolar fluid past a vertical porous plate in the presence of heat generation/absorption. Lin et al. [8] studied the marangoni convection flow and heat transfer in pseudoplastic non-newtonian nanofluids with radiation effects and heat generation or absorption effects. Recently, Srinivas Maripala and Kishan Naikoti[13] MHD effects on micropolar nanofluid flow over a radiative stretching surface with thermal conductivity absence of heat source/sink.

2. Basic equations:

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A transverse magnetic field over a steady two-dimensional micropolar nanofluid over a semi-infinite stretching plate of an incompressible, electrically conducting flow with variable temperature in the presence of radiation. The X-axis is directed along the continuous stretching plate and points in the direction of motion. The X-axis and Y-axis are perpendicular to each other and to the direction of the slot (the Z-axis), so the continuous stretching plate issues. The induced magnetic field and the Jole heating are neglected is assumed. It is assumed that the fluid properties are constant, except for the fluid thermal conductivity which is taken as a linear function of temperature profiles. Then the governing equations under the usual boundary layer approximations for the problem can be written as follows [9]:

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

$$\overline{u}\frac{\partial \overline{u}}{\partial x} + \overline{v}\frac{\partial \overline{u}}{\partial y} = \overline{v}\frac{\partial^2 \overline{u}}{\partial y^2} + K_1 \frac{\partial \sigma}{\partial y} - \frac{\sigma B_0^2}{\rho}\overline{u} \tag{2}$$

$$G_1 \frac{\partial^2 \sigma}{\partial y^2} - 2\sigma - \frac{\partial \overline{u}}{\partial y} = 0 \tag{3}$$

$$\rho c_p \left(\overline{u}\frac{\partial T}{\partial x} + \overline{v}\frac{\partial T}{\partial y}\right) = \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y}\right) + \mu\left(\frac{\partial \overline{u}}{\partial y}\right)^2 - \frac{\partial q_r}{\partial y} + \tau\left[D_B \frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] + \frac{Q_0}{(\rho c)_f}(T - T_\infty) \tag{4}$$

$$\frac{\partial C}{\partial t} + \overline{u}\frac{\partial C}{\partial x} + \overline{v}\frac{\partial C}{\partial y} = D_B \frac{\partial^2 C}{\partial y^2} + \frac{D_T}{T_\infty}\frac{\partial^2 T}{\partial y^2} \tag{5}$$

where $\overline{v} = (\mu + S)/\rho$ (kinematic viscosity), μ (dynamic viscosity), σ (microrotation component), $K_1 = S/\rho (> 0)$ (coupling constant), $G_1 (> 0)$ (microrotation constant), ρ (fluid density), u is the velocity along x- axis and v is along y- axis. T, T_∞, T_w are the temperature of the fluid in the boundary layer, far away from the plate, and plate, respectively. k –(thermal conductivity), c_p (specific heat), σ_0 (electric conductivity), B_0 (magnetic field), q_r (radiative heat flux), D_B – (Brownian diffusion coefficient), D_T -(thermophoresis coefficient) , Q_0 (heat generation/ absorption), $(\rho C)_p$ – (heat capacitance of the nanoparticles), $(\rho C)_f$- (heat capacitance of the base fluid), and $\tau = (\rho C)_p/(\rho C)_f$ is the ratio between the effective heat capacity of the nanoparticles material and heat capacity of the fluid. Boundary conditions of the problem are given by

$$y = 0, \quad \overline{u} = \propto x, \overline{v} = 0, T = T_w(x), \quad \sigma = 0,$$

$$y \to \infty, \ \overline{u} \to 0, \quad T \to T_\infty, \quad \sigma \to 0 \tag{6}$$

$T_w - T_\infty = \beta x^\gamma$ (where β and γ are constants) ,according to the power law (7)

Here the temperature of the wall is changing along the plate.

$\frac{k - k_\infty}{b[(T - T_\infty)]} = k_\infty$ is the liner function of temperature of thermal conductivity in the fluid [10] (8)

where k_∞ (ambient thermal conductivity).

Using Rosselant approximation [11] there is $q_r = (-4\sigma^*/3k^*)\frac{\partial T^4}{\partial y}$ (9)

where σ^* (Stefan Boltzmann constant) and k^* (mean absorption coefficient). Here, consider the temperature differences within the flow are sufficiently small. Expanding T^4in a Taylor series about T_∞ and neglecting higher order terms [10], we have

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \tag{10}$$

Using Eq.(8), Eq.(4) becomes

$$\rho c_p \left(\overline{u}\frac{\partial T}{\partial x} + \overline{v}\frac{\partial T}{\partial y}\right) = \frac{\partial}{\partial y}\left(k \frac{\partial T}{\partial y}\right) + \mu\left(\frac{\partial \overline{u}}{\partial y}\right)^2 + \frac{16\sigma^* T_\infty^3}{3k^*}\frac{\partial^2 T}{\partial y^2} + \tau\left[D_B \frac{\partial C}{\partial y}\frac{\partial T}{\partial y} + \frac{D_T}{T_\infty}\left(\frac{\partial T}{\partial y}\right)^2\right] + Q\theta \tag{11}$$

The following transformations are used to

$$\eta = \sqrt{(\alpha/v)}\, y \ , \quad \psi = \sqrt{(\alpha v)}\, x\, f(\eta),$$

$$\overline{u} = \frac{\partial \psi}{\partial y}, \quad \overline{v} = -\frac{\partial \psi}{\partial x}, \quad \sigma = (\alpha^3/v)^{1/2} x g(\eta), \ \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \ k = k_\infty(1 + S\theta) \qquad (12)$$

Equation(12) substitute into equations(1)-(3) and (10), then

$$\frac{1}{G_1}[\, f''' + ff'' - f'^2 - Mf'] = -g' \qquad (13)$$

$$g'' - (2/G)g) = (1/G)f'' \qquad (14)$$

$$\left(\frac{-1}{Pr}\right)\{[4 + 3F(1 + S\theta)]\theta'' + Q\theta\} = 3F[f\theta' - \gamma f'\theta + Ec(\, f'')^2 + 3FS(\theta'')^2 + [Nb\, \theta'\varphi' + Nt\, \theta'^2] \qquad (15)$$

$$\left(\frac{1}{Le}\right)\varphi'' - \, f\varphi' = -(\frac{1}{Le})\frac{Nt}{\mathrm{Nb}}\theta'' \qquad (16)$$

And boundary conditions are transformed to

$$f(0) = f'(\infty) = g(0) = g(\infty) = \theta(\infty) = 0, f'(0) = \theta(0) = 1, \qquad (17)$$

Where, M(magnetic parameter), $G_1 -$ (coupling constant), $P_r -$ (Prandtl number) G(microrotation parameter), F(Radiation parameter), Ec (Eckert number), S (thermal conductivity parameter), Nb (Brownian motion parameter), Nt(Thermophoresis parameter), Le (Lewies number), γ (Surface temperature parameter).

From the velocity field we can study the wall shear stress, τ_w as given by [12]:

$$\text{At } y{=}0, \tau_w = -|\ (\mu + S)\frac{du}{dy} + S\sigma\ | \ \text{ and } c_f = -2R_{ex}^{-1/2} f''(0) \qquad (18)$$

where $R_{ex} = \alpha x/v$ is the local Reynolds number. Eq. (20) shows the skin friction coefficient does not contain the microrotation term in an explicitly way.

$$at \ \ y = 0 \ , \ \ q_{w\,=} - k\left(\frac{\partial T}{\partial y}\right) at \ \ y = 0 \quad (\text{ rate of heat transfer }) \qquad (20)$$

$$(T_w - T_\infty\ )\, h(x) = q_w\,, N_{ux} = -R_{ex}^{\frac{1}{2}}\theta'(0)\ , m_{w=}\ R_{ex}\left(\frac{G_1\alpha}{x}\right) g'(0) \qquad (21)$$

3. Results and discussion:

The governing equations (13) to (16) under the boundary conditions (17) are solved numerically using the implicit finite difference scheme of Crank-Nicklson type has been employed. The computations have been carried out for various flow parameters on the velocity, angular velocity, temperature and concentration fields are presented through graphs.

Figure 1(a)-1(d), it is observed that an increase in magnetic parameter *M* leads to a decrease in velocity profiles and angular velocity. It is observed from the Fig.1(c), that an increase in magnetic parameter causes the temperature to increase for both the cases S is present and absent. Similarly, from Fig.1 (d), when the magnetic parameter is increased, the concentration of the fluid also increases. The effect of Brownian motion parameter *Nb* on velocity, temperature and concentration profiles are shown in figures 2(a) - 2(c). From the Fig.2(a), the Brownian motion parameter *Nb* which is often neglected causes a rise in velocity of the fluid. The velocity near the wall rises rapidly and descends gradually to zero as its distance from the plate increases. From Figure 2(b), it is observed that the increase in the Brownion motion parameter Nb increases the temperature. From the figure2(c) it is clear that , Brownian motion serves to warm the boundary layer and simultaneously increases particle displacement away from the fluid regime, thereby accounting for the reduced concentration magnitudes. The larger values of Brownian motion parameter Nb , it reduces the nanoparticle concentration. Figures 3(a)-3(c), it is observed that an increase in the thermophoretic parameter Nt leads to increase in fluid temperature, nanoparticle concentrations and velocity profiles. Velocity and angular velocity profiles are explained for various values of microrotation parameter *G* in Fig.4(a) and Fig.4(b) respectively. From these,angular velocity distribution profiles are increased

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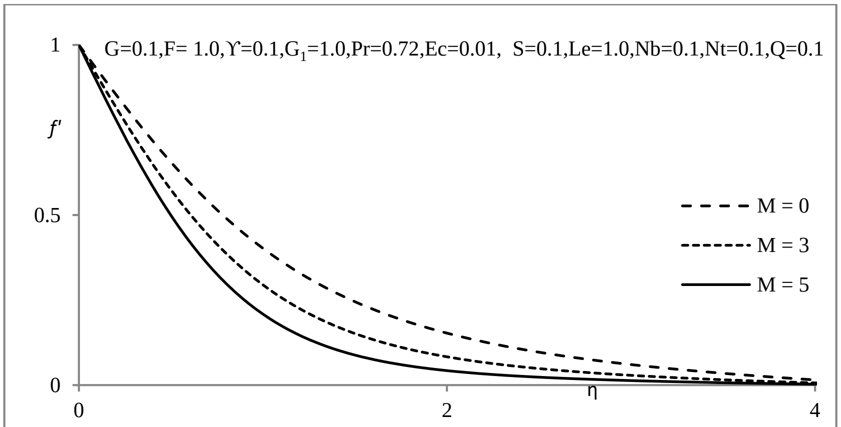
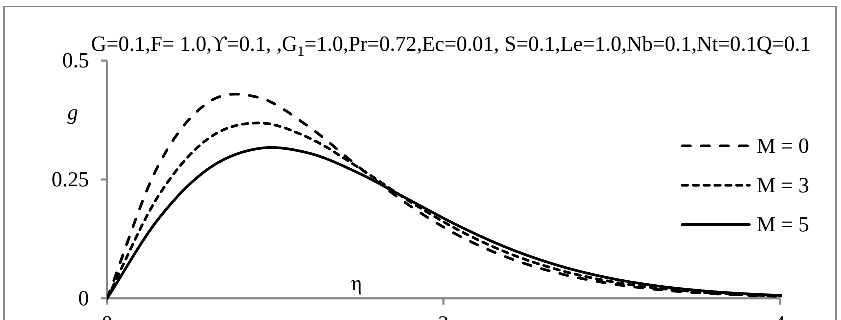
when microroatation parameter *G* increases and from Fig.4(b), reverse phenomena is observed. Figures 5(a) and 5(b) depict temperature profile θ and concentration profile φ, for different values of Prandtl number *Pr*, temperature of nanofluid particles (θ) and concentration profiles(ϕ) decreases with the increase in *Pr*. The thermal conductivity parameter (*S*)are shown in Fig.6,on the temperature profiles, it is noticed that the temperature profiles are decreased with the increasing of *S*. Fig.7 and Fig.8 explain the temperature profiles for different values of radiation parameter *F* and surface temperature parameter *γ*. It is observed that, temperature profiles are increased with the increase of radiation parameter *F* and θ decrees with the increase of surface temperature parameter *γ*. Figure 9 illustrates that concentration profile decrease with the increase of Lewies number *Le*. Figures 10 illustrate the temperature and concentration profiles for different values of heat source/sink parameter Q. From figure 10, it revel that with the effect of heat source/sink parameter (Q<0), the temperature profiles decreases and the temperature profiles increase with heat source (Q>0) and the effect of heat source/sink parameter *Q*, on concentration profiles. The concentration profiles increase in case of heat source/sink *Q<0*, while the concentration profiles decreases with heat source/sink parameter Q>0.

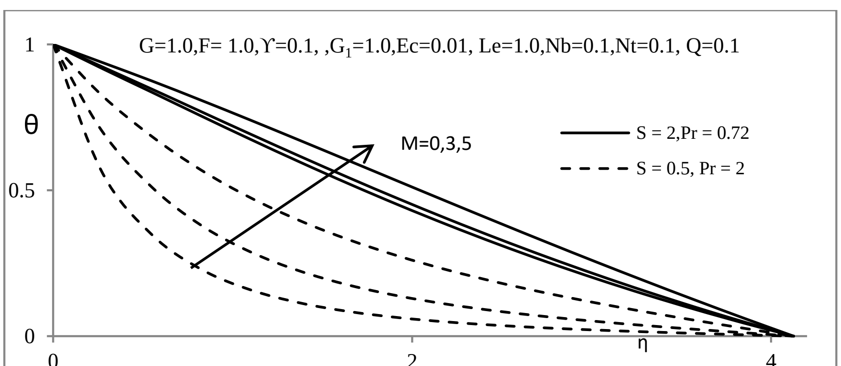
4.Graphs:



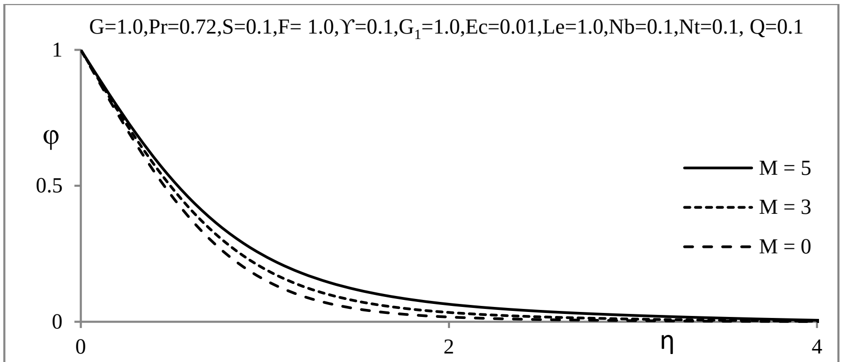
1(a). Velocity distribution for various values of M



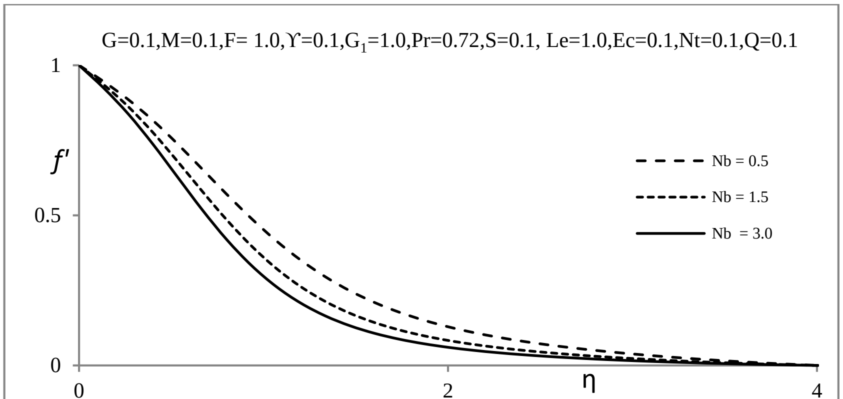
1(b). Angular velocity distribution for various values of M



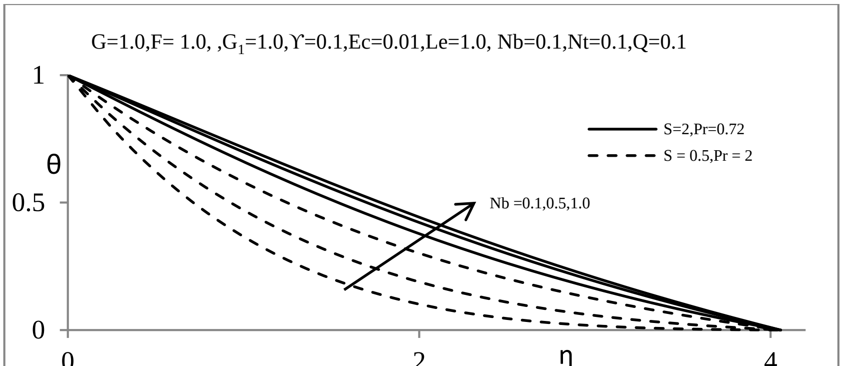
1(c). Temparature distribution for various values of M



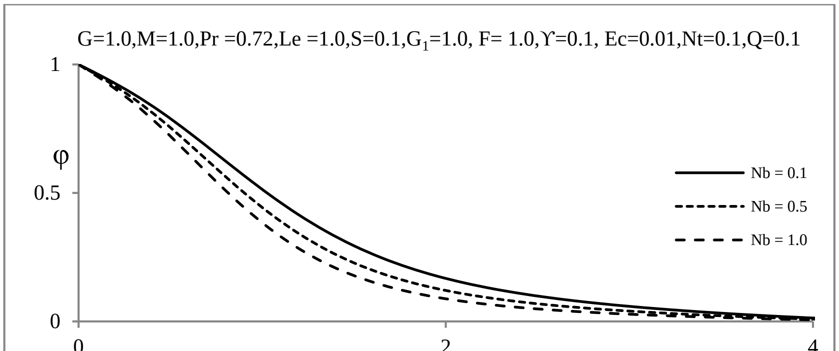
1(d). Concentration distribution for various values of M



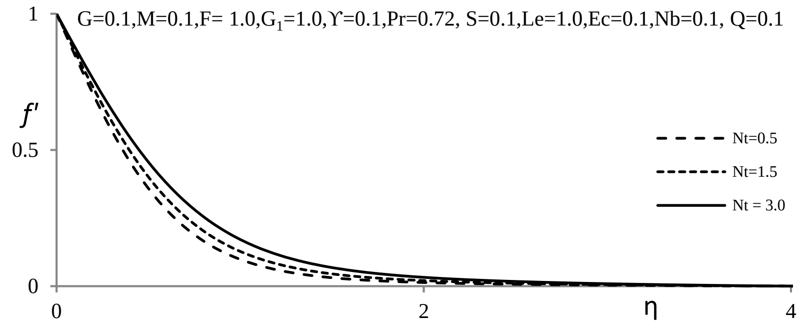
2(a). Velocity distribution for various values of Nb



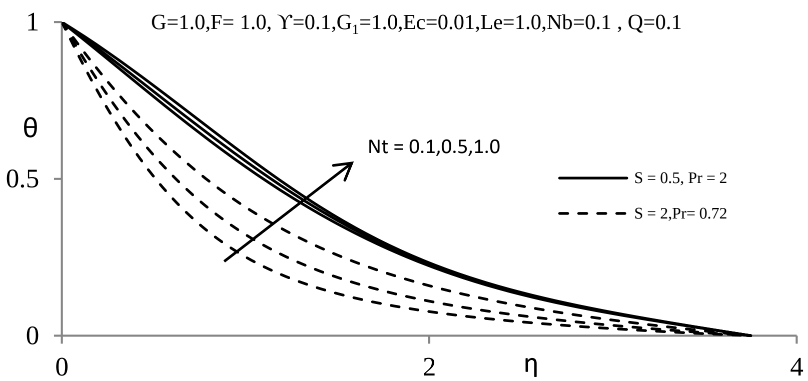
2(b).Temparature distribution for various values of Nb



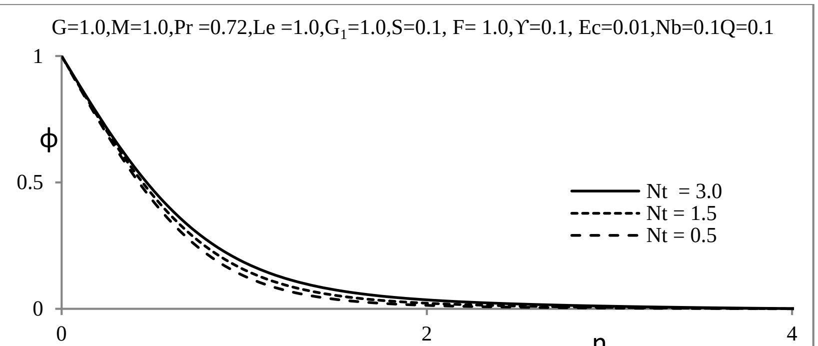
2(c).Concentration distribution for various values of Nb



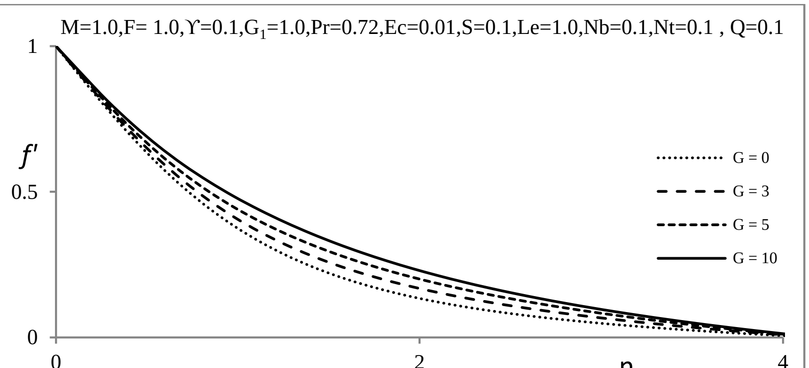
3(a) .Velocity distribution for various values of Nt



3(b). Temparature distribution for various values of Nt



3(c). Concentration distribution for various values of Nt



4(a). Velocity distribution for various values of G

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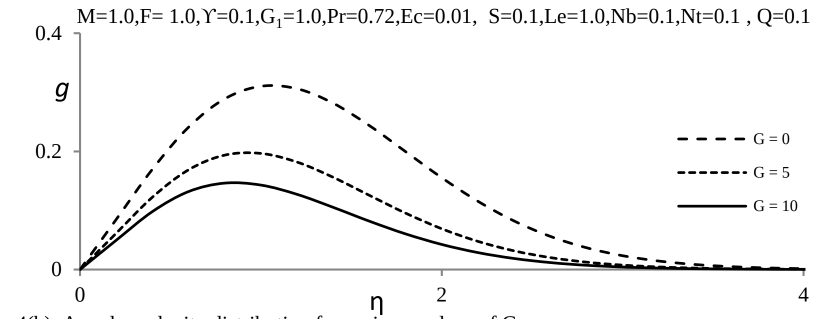
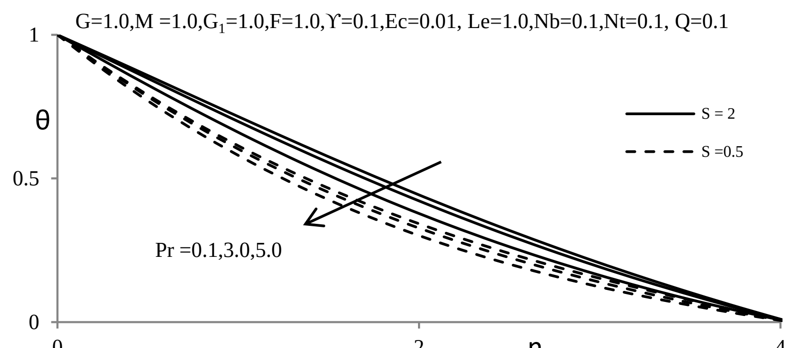
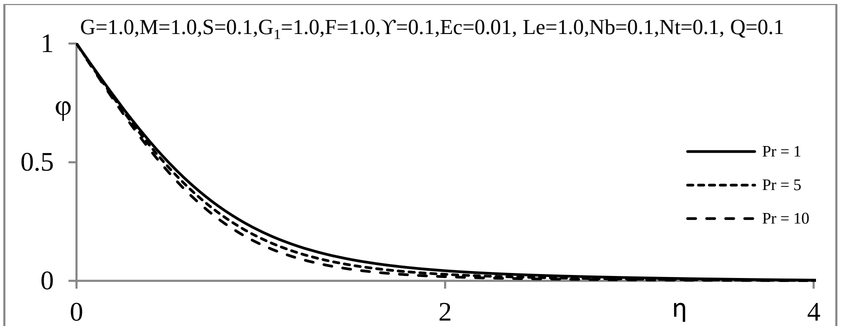


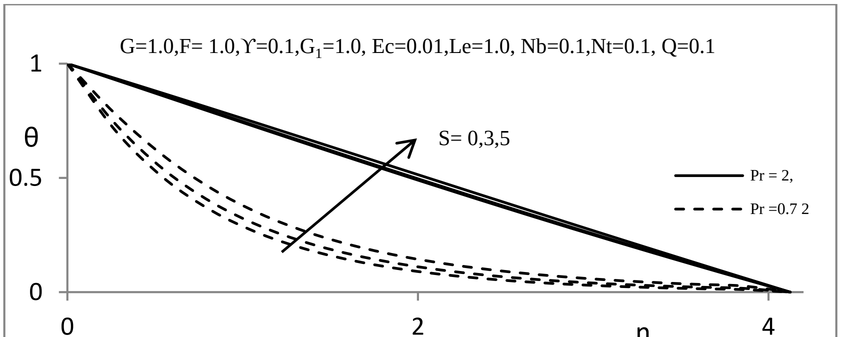
4(b). Angular velocity distribution for various values of G



5(a).Temparature distribution for various values of Pr



5(b). Concentration distribution for various values of Pr



6). Temparature distribution for various values of S

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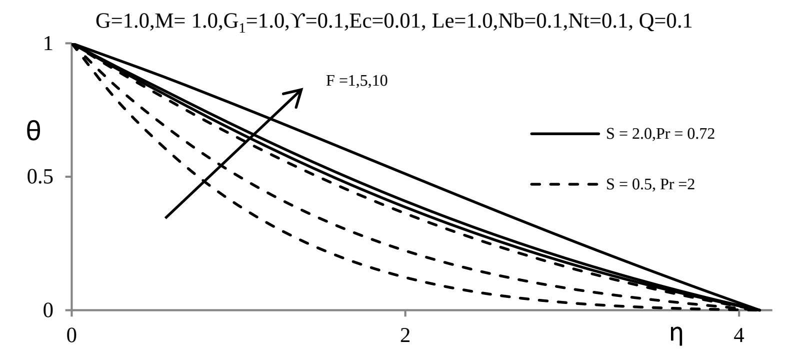
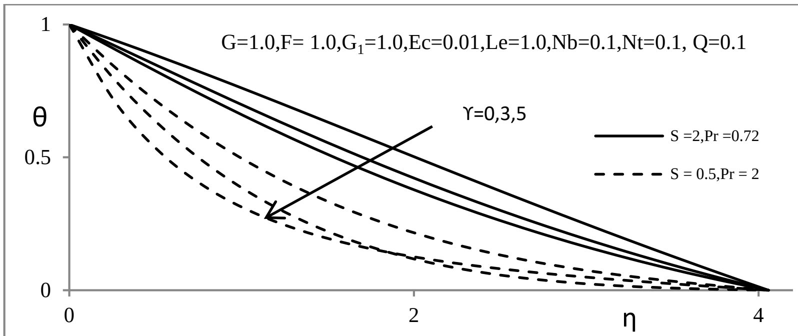
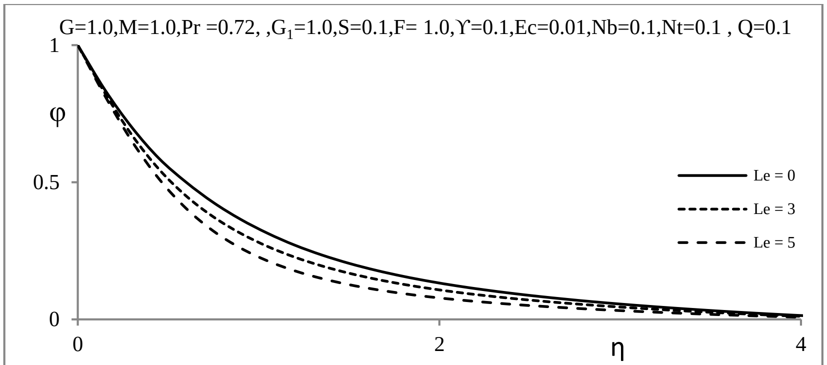


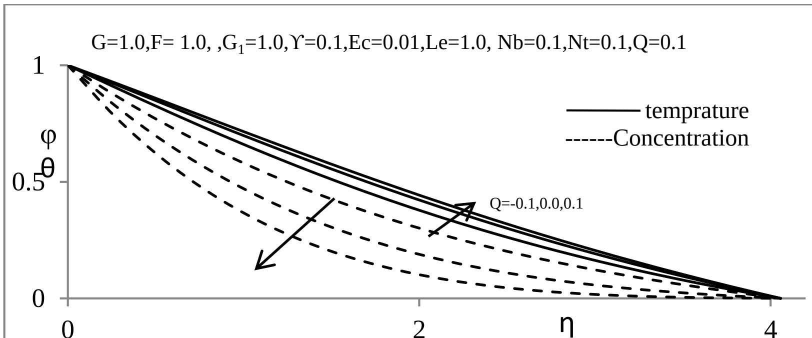
7). Temparature distribution for various values of F



8).Temparature distribution for various values of ϒ



9). Concentration distribution for various values of Le



10.Temparature and Concentrationdistribution for various values of Q

Table 1: Skin friction coefficient $-f''(0)$, Couple stress $g'(0)$, Local Nusselet number $-\theta'(0)$ values with G = 0.1, ,Q=0.1, Pr 0.72, Ec=0.5, G =3.0, Le=0.1, Nb=0.1, Nt=0.1.

F=0.2, γ =0.15, S=0.21 then $-f''(0)$ = 1.1128, $g'(0)$ = 0.22615,$-\theta'(0)$=0.336984,$-\varphi'(0)$=0.33529
F=0.2, γ =0.15, S=0.21 then $-f''(0)$ = 1.5529, $g'(0)$ = 0.229412,$-\theta'(0)$=0.22914,$-\varphi'(0)$=0.229124
F=0.2, γ =0.15, S=0.21 then $-f''(0)$ = 2.3301, $g'(0)$ = 0.335169,$-\theta'(0)$= 0.224311,$-\varphi'(0)$= 0.2243

From the above table, For fixed Q,F,γ,S are increase the $-f''(0)$, and $-g'(0)$,and at the same time decreases the local nusselet number $\theta'(0)$ and Sherwood parameter $\varphi'(0)$.

5. Conclusion:

In this effort, the effect of heat source/sink and thermal conductivity on the micropolr nanofluid flow and heat transfer over a continuously stretching surface is studied. The numerical values are carried out by the implicit finite difference scheme. Magnetic parameter M leads to a decrease in velocity and angular velocity profiles. The increase in the Brownian motion parameter and thermophoresis parameter guides to the escalation the thermal boundary layer thickness. Angular velocity profiles are increased when micro-rotation parameter G increases.

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