Effect of Non-linear Radiation on MHD Mixed Convection Flow of a Micropolar fluid Over an Unsteady Stretching Sheet

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Abstract: The current analysis explores the results of non-linear radiation on an unsteady stretching mixed Micropolar fluid. Issue modelling leads to a framework of PDE, reworked by transformations into non-linear ODEs. The Homotopy analysis methodology is applied to resolve the matter. The diagrams address the impact of the Magnetic parameter, unsteadiness parameter, Eckert number, Micropolar parameters, buoyancy parameters, Radiation parameter, Temperature ratio and Schmidt number on velocity, temperature, and concentration gradients. Amount of Nusselt number will increase in massive Prandtl number values, within the case of the high values of the unsteadiness parameter skin friction, wall couple stress and Sherwood decrease.

Keywords: Micropolar fluid, Mixed convection, HAM, Nonlinear radiation.

1. Introduction:
Non-Newtonian fluids have overwhelmed in recent decades by their relationship with applied science and industry. Non-Newtonian fluid motion plays an especially important part in theory and many of the manufacturing phases. It does not comply with Newton’s principle of conservation of mass; the fluid in hydraulic motors and power steering can move from a liquid to a solid. During a variety of industrial processes, such as drawing compound layers or continuously stripped filaments out of a mould, cooling of the metal sheet during a bath, mechanical extraction of plastic layers, rolls, rinsing, boundary layer flow and heating transfer, powered by an endless stretch sheet during a calming Newton and non-Newtonian fluid.

The effects of the heat produced by radiation on an electrically charged fluid have been studied by Sheikholeslami et al. [1]. Kataria and Mittal [2] study the effects of an optically thick nanofluid on an unstable MHD flow over a vertical plate based on radiation parameters and a set of physical parameters. In a natural fluid past a vertical platform, Ostrach [4] solved the conventional problem of a gravitational convection. Siegel [4] is likely to be the first to look in a semi-infinite integral layer for free convective transient flows. El-Amin [5] was studied in the Micropolar fluid with continuous suction for magneto hydrodynamic free convection. Zhi xiong Li et al. [6] has researched the migration of nano fluids in the presence of Lorentz forces and the properties of the nanofluid are predicted in view of the Brownian motion. The MHD boundary layer nanofluid flow and heat transfer was introduced by Das [7] via a vertical stretching sheet. Mittal and Patel [8] developed MHD Casson fluid Flows through porous medium with the effect of nonlinear thermal radiation, chemical reactions, and heat generation. Mittal and Kataria [9] have studied in detail the Brownian motion, the fraction in nanoparticles’ volumes and the suspension effect of nano-fluid mixing. A group of Researchers Nadeem et al. [10] proposed a theoretical structure solution for the MHD boundary layer physics and they applied their theory to the laboratory with the aid of computers. Kataria and Mittal [11] are
included in the mathematical simulation on the flow and heat transmission by means of the vertical oscillator panel. Sheikholeslami et al. [12] observed magnetohydrodynamic, unstable radiant, electrically conducive nano-fluid in an ostentatious vertical plate with thermal diffusion and heat production. Kataria et al. [13] investigated the effect, when asymmetric and symmetrical wall heating/cooling is involved, of the macro-material and viscosity parameters on natural convective flows along vertical wall lines. Kataria and Patel [14] investigated the effect of the parabolic motion, heat generation and heat absorption, heating diffusion on free convective MHD radioactive flux and chemically sensible second grade fluids near the infinite vertical plate.

To address the problem of the slowness and the inefficiency involved in adjusting the pace, temperature and the concentration of the material in an oscillating vertical plate, Kataria and Patel [15] used the Laplace transformation used to convey velocity, temperature and concentration for the Casson natural convective fluid. Kataria and Patel [16] examine on exponentially accelerated vertical plate fitted into porous heat/absorption media and chemical reactive effect in the presence of thermal and chemical radiation on the unstable magnetohydrodynamics Casson fluid flow. Kataria and Patel [17] has researched that the heat and thermal diffusion effects on MHD Casson fluid flow over an oscillating vertical plate. Liao [18] For the purpose of solving the nonlinear governing equations, the Homotopy analysis method (HAM) was established.

In this analysis, we tend to analyze the impact of nonlinear radiation on the mixed convection flow of a Micropolar fluid over an unsteady stretching sheet. The solution to the problem encountered by using the method of Homotopy analysis.

**Nomenclature**

| Symbol | Description |
|--------|-------------|
| $A$    | Unsteadiness parameter |
| $B_0$  | Uniform strength of magnetic field |
| $a, b, c$ | Constants |
| $C$   | Solutal concentration |
| $c_p$ | Consistent temperature specific heat |
| $C_\infty$ | Ambient concentration |
| $C_w$ | Fluid concentration by the wall |
| $C_f$ | The coefficient of skin friction |
| $D$ | Diffusiveness of chemical molecular |
| $g$  | Gravity acceleration |
| $h$ | Dimensionless angular velocity |
| $j$ | Unit weight microinertia |
| $u$ | $x$-direction velocity component |
| $v$ | $y$-direction velocity component |
| $N$ | Microrotation/angular velocity |
| $q_r$ | Radiothermal heat flux |
| $M$ | Magnetic parameter |
| $R$  | Parameter for thermal radiation |
| $T$  | Temperature of fluid |
| $T_\infty$ | Ambient temperature |
| $T_w$ | The wall’s temperature |
| $f$ | Role of stream without dimensions |
| $Pr$ | Prandtl number |
| $Ec$ | Eckert number |
| $\alpha$ | Positive constant |
| $\kappa_0$ | Thermal conductivity |
| $\beta_t$ | Thermal expansion coefficient |
| $\beta_c$ | Concentration expansion coefficient |
| $\rho$ | Density of fluids |
| \( \nu \) | Kinematic viscosity |
| \( \kappa \) | Viscosity of the vortex |
| \( \sigma \) | Electrical conductivity |
| \( \lambda_1 \) | Temperature gradient buoyancy parameters |
| \( \lambda_2 \) | Concentration gradient buoyancy parameters |
| \( \lambda_3, \Delta, B \) | Micropolar parameters without dimension |
| \( \mu \) | Dynamic Viscosity |
| \( \psi \) | Stream function |
| \( \gamma \) | Viscosity of the spin gradient |
| \( Sc \) | Schmidt Number |
| \( K \) | Parameter for chemical reaction |

2. Mathematical model

A thermal convection of the viscous, Micropolar fluid through a stretched, vertical elastic layer of conjugated sheets of fluid subjects the material to the flow patterns from different directions. The plate is to come vertically upwards from a narrow slot at pace

\[
U_w(x,t) = \frac{ax}{1-\alpha t},
\]

where \( \alpha \) and \( \alpha \) are positive unit dimensional constants. The positive \( x \) direction of the slots is determined by using the slots as their source. The positive \( y \)-coordinate is responsive to the mat for the fluid to be borne by the mainstream of the fluid. The \( T_w \) and \( C_w \) depending on the distance \( x \) from the cover, the surface temperature of the lining is different

\[
T_w(x,t) = T_\infty + \frac{bx}{(1-\alpha t)^2},
\]

\[
C_w(x,t) = C_\infty + \frac{cx}{(1-\alpha t)^2}.
\]

It is important to remember that the terms \( U_w(x,t), T_w(x,t), \) and \( C_w(x,t) \) are only true for the \( t < \alpha^{-1} \). We also note that using an \( x \)-drive force and an efficient deformation rate \( \frac{a}{1-\alpha t} \) the elastic sheet fixed to your origin is extended with an original power. From \( T_\infty \) and \( C_\infty \) at the sheet in proportion to \( x, \) temperature and concentration of the sheet increase(decrease) if \( b \) and \( c \) are positive(negative) respectively.

The radiation effect in the sample is presumed to be important. With the exception of changes in density, the fluid properties with temperature and concentration are believed to be stable. Under the two-dimensional equations of the boundary layer, these assumptions, and approximations by Boussinesq are:

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0,
\]

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \left( \frac{\mu+k}{\rho} \right) \frac{\partial^2 u}{\partial y^2} + \frac{k}{\rho} \frac{\partial N}{\partial y} + g \beta_t (T - T_\infty) + g \beta_c (C - C_\infty) - \frac{\sigma \beta_2 u}{\rho},
\]

\[
\frac{\partial N}{\partial t} + u \frac{\partial N}{\partial x} + v \frac{\partial N}{\partial y} = \gamma \frac{\partial^2 N}{\partial y^2} - \frac{k}{\rho_j} \left( 2N + \frac{\partial u}{\partial y} \right),
\]

\[
\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \alpha_0 \left( \frac{\partial^2 T}{\partial y^2} \right) - \frac{1}{\rho c_p} \frac{\partial \alpha}{\partial y} + \left( \frac{\mu+k}{\rho} \right) \left( \frac{\partial u}{\partial y} \right)^2.
\]

\[
\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} = D_\theta \left( \frac{\partial^2 C}{\partial y^2} \right) + \kappa_c (C - C_\infty).
\]

With the appropriate boundary conditions:

\[
u = U_w(x,t), \quad v = 0, \quad N = 0, \quad T = T_w(x,t), \quad C = C_w(x,t) \text{ at } y = 0,\]

\[
u \rightarrow 0, \quad N \rightarrow 0, \quad T \rightarrow T_\infty, \quad C \rightarrow C_\infty \text{ as } y \rightarrow \infty.
\]
The radiative heat flux \( q_r \) after the Roseland approximation [19] given as
\[
q_r = \frac{4 \sigma^* T^4}{3 \kappa_1 \partial y},
\]
(10)

Where \( \sigma^* \) is Stefan-Boltzman constant and \( \kappa_1 \) is the mean absorption coefficient.

We recommend similarity variables reconstruct the governing equations (3)-(7) into the system of ordinary differential equations,
\[
\eta = \sqrt{\frac{a}{\nu(1-at)}} y, \quad u = \frac{ax}{1-at} f'(n),
\]
\[
v = -\frac{a}{\nu(1-at)} f(\eta), \quad N = \frac{a^3}{\nu(1-at)^3} x h(\eta),
\]
\[
T = T_\infty + \frac{bx}{(1-at)^2} \theta(\eta), \quad C = C_\infty + \frac{cx}{(1-at)^2} \phi(\eta),
\]
(11)

We get
\[
(1 + \Delta) f'''' + f'''' - (f'')^2 - \frac{\Delta}{2} (2f' + \eta f''') + \Delta h' + \lambda 1 \theta + \lambda 2 \phi - M^2 f' = 0,
\]
(12)
\[
\lambda 3 h'' + f h' - f'h - \frac{\Delta}{2} (3h + \eta h') - \Delta B (2h + f''') = 0,
\]
(13)
\[
\frac{1}{Pr} \left( \left( 1 + \frac{4}{3} R \left( \theta - 1 \right) + 1 \right)^3 \right) \theta'' + 4R \left( \left( \theta - 1 \right) + 1 \right)^2 \left( \left( \theta - 1 \right) \theta'^2 \right) + f \theta' - f' \theta
\]
\[
- \frac{A}{2} (4 \theta + \eta \theta') + Ec (1 + \Delta) (f'')^2 = 0,
\]
(14)
\[
\frac{1}{Sc} \phi'' + f \phi' - f' \phi - K \phi - \frac{\Delta}{2} (4 \phi + \eta \phi') = 0,
\]
(15)
The required limit requirements shall be: The following
\[
f(0) = 0, \quad f'(0) = 1, \quad h(0) = 0, \quad \theta(0) = 1, \quad \phi(0) = 1,
\]
\[
f'(\infty) = 0, \quad h(\infty) = 0, \quad \theta(\infty) = 0, \quad \phi(\infty) = 0,
\]
(16)
The great interest of researchers in the present study are Coefficient of skin friction \( C_f \), Stress of the local wall pair \( MW \), Number of local Nusselt \( Nu \), Local number of Sherwood \( Sh \).

In the existing study, the great attention of researchers is coefficient of skin friction \( C_f \), wall couple stress \( MW \), Nusselt Number \( Nu \) and Sherwood number \( Sh \).

These quantities are specified accordingly
\[
Re_x^1 C_f = \frac{2}{\rho U^2} \left[ \left( \mu + \kappa \right) \frac{\partial u}{\partial y} \right]_{y=0} + \kappa N \mid_{y=0} = 2 (1 + \Delta) f''(0),
\]
(17)
\[
Re_x^1 MW = \frac{\nu^* \frac{\partial N}{\partial y}}{\nu} \mid_{y=0} = h'(0),
\]
(18)
\[
Re_x^{-1/2} Nu = \frac{x}{T_w - T_\infty} \left( \frac{\partial \theta}{\partial y} \right) \mid_{y=0} = -\theta'(0),
\]
(19)
\[
Re_x^{-1/2} Sh = -\frac{x}{\xi_w - T_\infty} \left( \frac{\partial \phi}{\partial y} \right) \mid_{y=0} = -\phi'(0),
\]
(20)
Where unsteadiness parameter $A$, Micropolar parameter $\Delta$, due to temperature gradient the buoyancy parameter $\lambda_1$, due to concentration gradient the buoyancy parameter $\lambda_2$, Micropolar parameters $\lambda_3, B$, Eckert number $E_c$, Schmidt number $S_c$, Radiation parameter $R$ and temperature ratio $\theta_w$ are given as respectively

$$ A = \frac{a}{a'}, \Delta = \frac{k}{\mu}, \lambda_1 = \frac{\partial \eta}{\partial a^2}, \lambda_2 = \frac{\partial \eta}{\partial a^2}, \lambda_3 = \frac{\gamma'}{\mu j}, B = \frac{\nu(1-\sigma)}{\sigma j}, E_c = \frac{\sigma \gamma}{\nu \mu}, S_c = v/D, R = \frac{4\sigma \gamma}{\kappa k}, $$

$$ \theta_w = \frac{\tau_w}{\tau_{\infty}}. $$

3. Homotopy analysis method

There is also great flexibility concerning the Homotopy analysis approach, the latest newly development problems were studied by Loganthan et al. [20-25]. The initial supposition and the auxiliary linear operator $f_0(\eta), h_0(\eta), \theta_0(\eta)$ and $\phi_0(\eta)$ and linear operators $L_f, L_h, L_\theta$ and, $L_\phi$ are so taken as to satisfy boundary conditions of the given in equations (8)-(9).

Initial guess is:

$$ f_0(\eta) = 1 - e^{-\eta}, \quad h_0(\eta) = 0, \quad \theta_0(\eta) = e^{-\eta}, \quad \phi_0(\eta) = e^{-\eta}, $$

With auxiliary linear operator:

$$ L_f = \frac{\partial^2 f}{\partial \eta^2} - \frac{\partial f}{\partial \eta}, \quad L_h = \frac{\partial^2 h}{\partial \eta^2} - h, \quad L_\theta = \frac{\partial^2 \theta}{\partial \eta^2} - \theta, \quad L_\phi = \frac{\partial^2 \phi}{\partial \eta^2} - \phi, $$

Satisfying

$$ L_f(C_1 + C_2 e^\eta + C_3 e^{-\eta}) = 0, \quad L_h (C_4 e^\eta + C_5 e^{-\eta}) = 0, $$

$$ L_\theta (C_6 e^\eta + C_7 e^{-\eta}) = 0, \quad L_\phi (C_8 e^\eta + C_9 e^{-\eta}) = 0 $$

Where arbitrary constants are $C_i, \ (i = 1, 2, ... , 9)$.

3.1 Convergence of the series:

Their HAM solutions converge significantly with the parameter values $h_f, h_h, h_\theta$ and $h_\phi$. The necessary curves are shown in the plots for this purpose. In this case, a HAM approximation is used to draw $h-$curves. Fig. (1) - (4) imply range: $-1.6 \leq h_f \leq -0.4$ for the auxiliary parameter $h_f, -3.2 \leq h_h \leq -0.5$ for the auxiliary parameter $h_h, -1.5 \leq h_\theta \leq -0.5$ for the auxiliary parameter $h_\theta$ and $-0.35 \leq h_\phi \leq -0.1$ for the auxiliary parameter $h_\phi$ respectively.

4. Results and Graphs

The solutions are obtained in this section using applicable Mathematica codes. With the support of graphs, the results obtained are clarified. This section discusses the behaviour of several emerging parameters, i.e., unsteadiness parameter $A$, Micropolar parameter $\Delta$, due to temperature gradient buoyancy parameter $\lambda_1$, due to concentration gradient buoyancy parameter $\lambda_2$, Micropolar parameters $\lambda_3, B$, Eckert number $E_c$, Schmidt number $S_c$, Radiation parameter $R$ and temperature ratio $\theta_w$ on axial and angular velocity profiles, temperature profile and concentration profile.

Fig.(5) emphasizes the change in the profile of the axial velocity due to the variance in the Magnetic Parameter $M$. For large values of the magnet parameter $M$, the axial velocity profile has been found to decline. Since Magnetic parameter $M$ generates large Lorentz force values that flip fluid motion to the direction of flow and gradient axial velocity gradient $f'(\eta)$. The effect on the axial velocity of the Micropolar parameter $\Delta$ is shown in Fig. (6). In this figure, we note that the axial velocity $f'(\eta)$ improves with an improvement in Micropolar parameter $\Delta$. In the Fig. (7) we can see the axial velocity profile exerted by Eckert number. In this figure, we note that the axial velocity profile $f'(\eta)$ increases as the Eckert number increases. The dragging force between the fluid particles means that viscous dissipation creates heat, and then this more fluid heat increases the boosting force, creating an increment in the fluid axial velocity profile.
In Fig. (8), the effect on the axial velocity profile \( f'(\eta) \) of unsteadiness parameter \( A \) is shown. We observe that the axial velocity profile for \( A \) slows down as it goes down. The region of high speed in the atmosphere increases when the maximum rate of change and maximum speed increase simultaneously. Therefore, mechanically, we concluded that the layer extending can be used to stabilize the transition from laminar to turbulent lows of liquid. Fig. (9) designates the influence of the unsteadiness parameter \( A \) on angular velocity profile \( h(\eta) \), we note that the angular velocity profile declines as \( A \) increases. The angular velocity is also considerably impacted by the increased value of the unsteadiness parameter \( A \). The angular velocity profile increases from zero to a peak and gradually dies to zero for any instability value to increase the value of the unsteadiness parameter.

Fig. (10) displays the Micropolar parameter \( B \) effect on the angular velocity profile \( h(\eta) \). We watch in the Fig. (10) the angular velocity profile is reduced with large amount of Micropolar parameter \( B \). However, lowering microinertia density values means that the values of \( B \) are rising. This in turn raises the angular velocity from zero to a peak, until it slowly passes to the free-flowing angular velocity. In Fig. (11), the influence on angular velocity \( h(\eta) \) of the thermal buoyancy parameter \( \lambda_1 \) is shown. The outcome of thermal buoyancy parameter in the event of forced pure convection is to minimize velocity relative to the effect (alternative to pure forced convection), the impact of \( \lambda_1 \) is recognized in this figure. Physically, the positive \( \lambda_1 \) produced a positive pressure gradient, which improves the fluid flow in the frontier and the negative layer \( \lambda_1 \), which then slows the fluid movement. It is important to retrieve that the axial rate at the moving rate of the sheet overruns at the wall with a high value of \( \lambda_1 \) (\( \lambda_1 > 5 \)).

The angular velocity \( h(\eta) \) influenced by Micropolar parameter \( \Delta \) is exhibited in Fig. (12). \( h(\eta) \) is raised in this figure. Owing to the importance of the vortex viscosity, the angular velocity enhances considerably. In Fig. (13) on the temperature profile \( \theta(\eta) \), the influence of the Magnetic parameter \( M \) is encountered. A drag force called a Lorentz force is generated by employing a magnetic field that is perpendicular to a flux. With Magnetic parameter values the temperature profile improvements. Thus, with the transfer of more heat energy from the wall to the flow system the fluid temperature rises. The influence of Micropolar parameter \( \Delta \) is exhibited in the Fig. (14) on the fluid temperature profile \( \theta(\eta) \). Temperature profile decreases to increase of \( \Delta \) in this figure. Fig. (15) reflects the difference of the Radiation parameter \( R \) on temperature profile. It shows that the temperature improvement by the advances Radiation parameter Physically, driven by the growing thermal radiation parameter, heat is generated by the flow of fluid, which plays an essential role in the transfer of heat.

Fig. (16) Temperature ratio \( \theta_w \) enhance on profile of temperature \( \theta(\eta) \). It designates that the temperature profile declines with the high values \( \theta_w \). Fig. (17) represents the effect on the concentration profile \( \phi(\eta) \) of the unsteadiness parameter \( A \). One of the critical parameters of the solution gradually decays with the unsteadiness parameter \( A \). Fig. (18) exhibits the influence of the Magnetic parameter \( M \) on concentration profile \( \phi(\eta) \). With extended \( M \), \( \phi(\eta) \) rise. Fig. (19) the impression of Schmidt number \( Sc \) on concentration profile \( \phi(\eta) \) is designated. We recognize the concentration profile declines with large number of \( Sc \). Schmidt number reveals the apparent ease of momentum transfer and mass transfer and is of great importance when the binary mass transfer of multiphase flows is estimated.

In Fig. (20), the influence on the concentration \( \phi(\eta) \) of the thermal buoyancy parameter \( \lambda_1 \) is displayed. Fluid concentration, with rising thermal buoyancy parameter, are reduced anywhere other than on the wall. Fig. (21) indicates skin friction changes with increased unsteadiness parameter \( A \). Skin friction declines for large values of parameter \( A \). In the Fig. (22) In wall couple stress we found the effects of unsteadiness parameter \( A \), wall couple stress decreases, for large values of unsteadiness parameter \( A \). Fig. (23) has an impact of Prandtl Number \( Pr \) at Nusselt Number, and Nusselt increases with Prandtl Number \( Pr \) increasing values. From the Fig. (24) The effect of the Sherwood number unsteadiness parameter \( A \) is evident. With increased levels of the unsteadiness parameter \( A \), the amount of Sherwood increases.
The influences of the different boundaries on the coefficient of friction of the skin are included in Table 1. Accelerates the coefficient of friction of the skin by improving the values of $\Delta, \lambda_1$ and $\lambda_2$. Reduces the coefficient of friction of the skin by enhancing values of $A$. By raising the values of $A$ and $\lambda_3$, wall couple stress reduces and by enhancing the values of $\Delta, B$, the coefficient of wall couple stress raises. Nusselt number improves for raising $\Delta, Pr$ and reducing for raising $A$ and $\theta_w$. Significance of $A$, $\Delta$ and Sc on Sherwood number can be found, Sherwood number grows for the broad values of $A$, $\Delta$ and decreases for the broad values of Sc.

Table : 1 Comparative analysis of $Re_x^2 cf_x$ for the varying values of $\Delta, A, \lambda_1, \lambda_2$.

| $\Delta$ | $A$ | $\lambda_1$ | $\lambda_2$ | $2(1 + \Delta)f''(0)$ |
|----------|-----|-------------|-------------|------------------------|
| 0.5      |     |             |             | 0.7665378485           |
| 0.6      |     |             |             | 0.7415552839           |
| 0.7      | 0.2 |             |             | 0.7167598465           |
|          | 0.3 |             |             | 0.7665378485           |
|          | 0.4 |             |             | 0.8020618485           |
|          |     | 0.5         |             | 0.8374066051           |
|          |     | 0.6         |             | 0.765378485            |
|          |     | 0.7         |             | 0.755122646            |
|          |     | 0.5         |             | 0.7437066807           |
|          | 0.6 |             |             | 0.7355561117           |
|          | 0.7 |             |             | 0.7045714748           |

Table : 2 Comparative analysis of $Re_x^2 M_{wx}$ for the varying values of $\Delta, A, \lambda_1, \lambda_2$.

| $\Delta$ | $A$ | $\lambda_3$ | $B$ | $h'(0)$ |
|----------|-----|-------------|-----|---------|
| 0.5      |     |             |     | 0.1376752720 |
| 0.6      |     |             |     | 0.1464666317 |
| 0.7      |     | 0.2         |     | 0.1490100931 |
|          | 0.3 |             |     | 0.1376752720 |
|          | 0.4 |             |     | 0.1193869354 |
|          |     | 0.5         |     | 0.1010985988 |
|          |     | 0.6         |     | 0.1376752720 |
|          |     | 0.7         |     | 0.0985279579 |
|          | 0.5 |             |     | 0.0593806439 |
|          | 0.6 |             |     | 0.1376752720 |
|          | 0.7 |             |     | 0.1495514008 |
|          | 0.7 |             |     | 0.1562078877 |

Table : 3 Comparative analysis of $Re_x^{1/2} Nu_x$ for the varying values of $\Delta, A, Pr, \theta_w$.

| $\Delta$ | $A$ | $Pr$ | $\theta_w$ | $-\theta'(0)$ |
|----------|-----|------|-------------|----------------|
| 0.5      |     |      |             | 3.0572785904   |
| 0.6      |     |      |             | 3.0630279065   |
| 0.7      |     |      |             | 3.0693224878   |
|          |     | 0.2  |             | 3.0572785904   |
|          |     | 0.3  |             | 3.0674985287   |
|          |     | 0.4  |             | 3.0095087390   |
Table 4 Comparative analysis of $Re_x^{-1/2}Sh_x$ for the varying values of $\Delta, A, Sc$.

| $\Delta$ | $A$ | $Sc$ | $-\phi'(0)$ |
|----------|-----|------|-------------|
| 0.5      |     |      | 1.5570938002|
| 0.6      |     |      | 1.5579306614|
| 0.7      |     |      | 1.5587675226|
| 0.2      |     |      | 1.5570938002|
| 0.3      |     |      | 1.5616934214|
| 0.4      |     |      | 1.5658360226|
| 0.08     | 0.08|      | 1.5570938002|
| 0.10     | 0.10|      | 0.9529594685|
| 0.12     | 0.12|      | 0.7122670553|

Fig. 1 $h$-Curve for $f''(0)$

Fig. 2 $h$-Curve for $h'(0)$

Fig. 3 $h$-Curve for $\theta'(0)$

Fig. 4 $h$-Curve for $\phi'(0)$
Fig. 5 $f'(\eta)$ for a range of $M$

Fig. 6 $f'(\eta)$ for a range of $\Delta$.

Fig. 7 $f'(\eta)$ for a range of $Ec$

Fig. 8 $f'(\eta)$ for a range of $A$

Fig. 9 $h(\eta)$ for a range of $A$

Fig. 10 $h(\eta)$ for a range of $B$

Fig. 11 $h(\eta)$ for a range of $\lambda_1$

Fig. 12 $h(\eta)$ for a range of $\Delta$. 
Fig. 13 $\theta(\eta)$ for a range of $M$

Fig. 14 $\theta(\eta)$ for a range of $\Delta$

Fig. 15 $\theta(\eta)$ for a range of $R$

Fig. 16 $\theta(\eta)$ for a range of $\theta_w$

Fig. 17 $\phi(\eta)$ for a range of $A$

Fig. 18 $\phi(\eta)$ for a range of $M$

Fig. 19 $\phi(\eta)$ for a range of $Sc$

Fig. 20 $\phi(\eta)$ for a range of $\lambda_1$
Conclusion:
This paper examines the effects of non-linear radiation on MHD mixed convection flow of Micropolar fluid over unsteady stretching sheet accurately. By applying the method of Homotopy analysis, the dimensionless governing equations are solved. By drawing the so-called $\eta$ -curve the convergence region of series solutions by HAM is achieved. We thought of Micropolar fluid. The results for axial velocity, angular velocity, temperature, and concentration are obtained and are graphical. The key results of this study are:

- Axial velocity profile of the Micropolar fluid declines for large values in Magnetic Parameter $M$ and unsteadiness parameter $A$.
- Micropolar fluid axial velocity profile enhances for Eckert numbers $Ec$ and Micropolar parameter $\Delta$.
- The Micropolar fluid angular velocity profile enhances for broad values of Micropolar parameter $\Delta, B$ and declines with high values of unsteadiness parameter $A$ and buoyancy parameter $\lambda_1$.
- The temperature profile of the Micropolar fluid declines for high values Micropolar parameter $\Delta$ and Temperature ratio $\theta_{\infty}$.
- The temperature of the object changes as it's subjected to a great magnetic field and exposure to radiation.
- For the large values of unsteadiness parameter $A$, buoyancy parameter $\lambda_1$ and Schmidt number $Sc$ decreases concentration profile of the Micropolar fluid.
- For large values of Magnetic parameter $M$, concentration profile increases.
- Skin friction, Wall couple stress and number of Sherwood decreases for the broad unsteadiness parameter $A$ values.
- Nusselt number increases with large amount of Prandtl number $Pr$. 
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