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NUMERICAL SOLUTION OF MHD CONVECTIVE IMMISCIBLE MICROPOLAR AND VISCOUS FLUID FLOW IN A VERTICAL CHANNEL WITH VELOCITY SLIP

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Abstract

The present paper deals with Numerical analysis for a coupled nonlinear system of partial differential equations governed by immiscible micropolar and viscous fluid flow in a vertical channel when velocity slip is placed on the left wall subjected to the suitable boundary and interface conditions using Runge-Kutta 6th order with Mathematica application. The variation of pertinent parameters is analyzed on velocity, angular velocity, temperature, and diffusion profiles and presented graphically for easy understanding.The rate of velocity transfer, rate of heat transfer, and rate of mass transfer are tabulated for all the possible variations of governing parameters. It is found that the velocity slip has shown a major effect on velocity, angular velocity, and diffusion. Also, there is a reasonable effect on the transfer rate on both boundaries.

Keywords: Vertical channel, micropolar fluid, velocity slip, R-K Method

1. INTRODUCTION

The study of fluid dynamics is the motion and rest of liquids, gases, blood, and plasmas. There are several applications of fluid mechanics in astronomy, mechanical and chemical engineering, and biological systems [1]. Many different branches of science, engineering, and technology deal with the two-phase flow on regular basis. Oil and gas production, gas-liquid flow in boilers, and aerosol deposition in spray treatment are just a few examples of the remarkable benefits of two-phase flows. Inkjets, clouds, fog, groundwater flow, ocean waves, and pest management, among other things, all exhibit two-phase flows. Several researchers [2-5] examined two-phase flows in different geometries.

Lou et al.[6] used the lattice Lattice-Boltzman technique to investigate a steady two-phase flow in very narrow channels. Chalgeri and jeong[7] investigated two-phase flows in a channel with rectangular walls experimentally. The fluid and particle combination is referred to as particulate flows. Usha et al.[8] studied particle suspension flow in an uneven channel numerically. Chamka and Al-Rashidi [9] performed analytical studies on the flow of hydromagnetic particle suspensions over a channel.Yao et al. [10] convincingly illustrated how fluid and particles travel through a conduit by taking slip effects into consideration. Hatami et al. [11] studied the effects of a magnetic field on the two-phase flow between two parallel plates. Kamel et al. [12] investigated the transport of a fluid-particle suspension in a tube with flexible walls by taking slip effects along the wall into account.. Eldesoky et al. [13] investigated particle suspension in a tube with undulating walls analytically.Kalpana et al. [14]

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used the finite difference method to investigate the buoyancy-driven dusty nanofluids along a non-uniform surface. Dusty free convection Siddiqa et al. [15] investigated Casson fluid using a truncated cone analysis. They discovered that when the thermal radiation parameter rises, the amount of heat transmission increases as well.

The study of MHD has become one of the important subjects, the extensive use of MHD in accelerators, cooling systems with liquid metals, geothermal energy extraction, compacted beds for the chemical industry, MHD power generators, plasma studies, boundary layer control in the field of aerodynamics etc. Asadulla et al. [16]studied hydromagnetic flow in channels with irregular walls. To analyze flow through non-uniform channels under the influence of the magnetic field, Hosseini et al. [17] used the differential transform approach. To examine nanofluid flow analysis in permeable walled channels with the influence of the magnetic field, Hatami and Ganji [18] utilized the weighted residual approach. The heat transfer analysis in communicative channels with non-parallel walls was studied by Erdinc and Yilmaz [19], who found that the heat transfer rate in convergent and divergent channels is much higher than that in channels with parallel walls.

Micropolar fluid is a type of liquid that exhibits specific microscopic effects arising from the regional structure and micro motion of the fluid particles Eringen[20-21]. Bhargava et al. [22] studied that, free convection magnetic hydrodynamics micropolar fluid between two porous vertical plates shows that the velocity decreases with an increase in Hartman number. Airman et al. [23] described the detailed review problem of the matter and its application to the unique characteristics of micropolar fluid mechanics. Micropolar fluids are applicable in the lubrication theory [24], and granular flows [25,26]. The heat transfer process known as thermal radiation involves releasing internal energy. Thermal energy is transformed into electromagnetic energy. Industries like glass manufacturing, polymer manufacturing, and furnace design demonstrate its applicability. processing tech., nuclear power plants, etc.Gerdrood-Bary et al. [27] conducted a numerical examination of thermal radiation's effects on convergent and divergent channels and discovered that the fluid temperature rose along with the radiation parameter. The impact of thermal radiation in non-uniform channels was studied by Asadullah et al. [28] using the A domain decomposition approach. Rashad et al[29] are a numerical investigation of heat and mass transmission in a revolving cone with a thermal radiation effect. Ahmad et al. [30] analysed numerically Jeffrey fluid in convergent and divergent channels with contracting or expanding walls.

The theory of slip effects is unusual, including fluids not adhering to boundaries. There are many uses for the fluid slip at the boundaries, including polishing heart valves and interior cavities, lowering friction and energy conservation, etc. In their study of the effects of slip conditions in a planar channel, Abumandour et al. [31] found that the velocity increases as the slip parameter increase, but that it decreases at higher values of the compressibility parameter when the slip parameter is increased. Analytical magnetohydrodynamics (MHD) flow of particulate suspension flow of Ree-Eyring fluid in a channel with non-uniform walls was explored by Ijaz et al. [32] who found that the magnitude of velocity reduces under the influence of the Hartmann number.Dorrepaal [33] first examined analytically the effects of slip

circumstances in convergent and divergent channels, finding that the slip conditions increase the channel's flow rate.Mohyud-Din et al.[34] used both analytical and numerical methods to investigate the first order velocity and thermal slip effects of ananofluid in non-uniform channels.Khan et al[35] .'s investigation looked at the impact of velocity slip on a Casson fluid in divergent and convergent channels.Farooq et al. [36] investigated flow through a non-uniform permeability channel with the impact of the transverse magnetic field using the Adomian method and found that the magnetic field effect is more significant on fluid flow.Saleem et al. [37] in their study of peristaltic flow in a non-uniform channel, took into account the second-order velocity slip to analyze heat and mass transfer. In a channel with flexible walls, Manjunatha et al. [38] investigated how changing characteristics affected Jeffrey's fluid flow.Andersson [39] and Wang [40] studied the viscous fluid flow with the slip velocity effect across a stretched surface. Mahabaleshwar et al. have performed investigations on the boundary layer flow with slip effect employing Newtonian fluid [41,42].According to Ebaid et al. [43], the slip parameter increased the temperatures of both Cu-water and TiO2-water nanofluids. The velocity profile was also improved by an increase in the velocity slip parameter, according to Bhattacharya et al. [44] and Aziz et al. [45]. Jusoh et al. [46], Jamaludin et al. [47], and Khashi'ie et al. [48] investigated the effect of velocity slip on the three-dimensional stretching/shrinking flow utilizing nanofluid.In heat and mass transfer numerical solution plays a vital role as it produces different set of values for different combinations of all pertinent parameters. Using these values it can be predicted for what set of values the feasibility occurs.

Based on the above criteria and the importance of velocity slip, the present study is on the numerical solution in an immiscible flow containing both micropolar and viscous fluids in a vertical channel with the effect of velocity slip.

2. MATHEMATICAL FORMULATION

Consider two isothermal parallel plates, divided into two regions and placed at y=-h_1& y=h_2.Region-1 is from $-h_1 \leq Y \leq 0$andis filled with micropolar fluid and region -2 is from $0 \leq Y \leq h_2$andis filled with viscous fluid. These two regions are maintained at temperaturesT_1&T_2 respectively. Assuming the fluid flow to be one dimensional, laminar, immersible, Incompressible,and constant transport properties with bouncy effect.The fluid motion is assumed to be fully developed and steady. The walls are isothermal with constant concentration and satisfy the relation $T_1 > T_2, C_1 > C_2$.

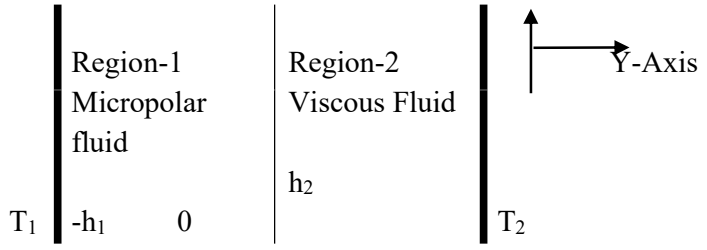

Figure-1:Schematic diagram

The following equations result from the governing equations under the presumptions mentioned above.

Region-1:

$$\frac{\partial U_1}{\partial Y} = 0 \tag{1}$$

$$\rho_1 = \rho_0[1 - \beta_{1T}(T_1 - T_0) - \beta_{1C}(- C_0)] \tag{2}$$

$$\frac{\mu_1 + K}{\rho_1}\frac{\partial^2 U_1}{\partial Y^2} + \frac{K}{\rho_1}\frac{\partial n}{\partial Y} + g\beta_{1T}(T_1 - T_0) + g\beta_{1C}(C_1 - C_0) - \frac{\sigma {B_0}^2 U_1}{\rho_1} = 0 \tag{3}$$

$$\gamma\frac{\partial^2 n}{\partial Y^2} - K\left[2n + \frac{\partial U_1}{\partial Y}\right] = 0 \tag{4}$$

where $\gamma = \left(\mu_1 + \frac{K}{2}\right)j$

$$\frac{k_1}{\rho_1 C_p}\frac{\partial^2 T_1}{\partial Y^2} + \frac{1}{\rho_1 C_p}\left[\mu_1\left(\frac{\partial U_1}{\partial Y}\right)^2 + \frac{\rho_1 D_1 K_{T1}}{C_{S1}}\frac{\partial^2 C_1}{\partial Y^2}\right] = 0 \tag{5}$$

$$D_1\frac{\partial^2 C_1}{\partial Y^2} + \frac{D_1 K_{T1}}{T_M}\frac{\partial^2 T_1}{\partial Y^2} = 0 \tag{6}$$

Region-2:

$$\frac{\partial U_2}{\partial Y} = 0 \tag{7}$$

$$\rho_2 = \rho_0[1 - \beta_{2T}(T_2 - T_0) - \beta_{2C}(- C_0)] \tag{8}$$

$$\frac{\mu_2}{\rho_2}\frac{\partial^2 U_2}{\partial Y^2} + g\beta_{2T}(T_2 - T_0) + g\beta_{2C}(C_2 - C_0) - \frac{\sigma {B_0}^2 U_2}{\rho_2} = 0 \tag{9}$$

$$\frac{k_2}{\rho_2 C_p}\frac{\partial^2 T_2}{\partial Y^2} + \frac{1}{\rho_2 C_p}\left[\mu_2\left(\frac{\partial U_2}{\partial Y}\right)^2 + \frac{\rho_2 D_2 K_{T2}}{C_{S2}}\frac{\partial^2 C_2}{\partial Y^2}\right] = 0 \tag{10}$$

$$D_2\frac{\partial^2 C_2}{\partial Y^2} + \frac{D_2 K_{T2}}{T_M}\frac{\partial^2 T_2}{\partial Y^2} = 0 \tag{11}$$

To solve the above system of equations (1) to (11), we considered the following boundary and interface conditions.

$U_1 = U_0 + S'\frac{\partial U_1}{\partial Y}$,at $Y = -h_1 U_2 = 0$,at $Y = h_2, U_1(0) = U_2(0)$

$T = T_1$ at $Y = -h_1, T = T_2,$ at$atY = h_2, T_1(0) = T_2(0)$,

$C = C_1$ at $Y = -h_1 C = C_2 atY = h_2, C_1(0) = C_2(0)$,

$n = 0 atY = -h_1, (\mu_1 + K)\frac{\partial U_1}{\partial Y} + Kn = \mu_2\frac{\partial U_2}{\partial Y} atY = 0$,

$\frac{\partial n}{\partial Y} = 0 atY = 0, k_1\frac{\partial T_1}{\partial Y} = k_2\frac{\partial T_2}{\partial Y} atY = 0, D_1\frac{\partial C_1}{\partial Y} = D_2\frac{\partial C_2}{\partial Y} atY = 0.$

The system of equations (1) to (11) is transformed into a dimensionless form using the following non-dimensional variables:

$y = \frac{Y}{h_1}$(region-1),$y = \frac{Y}{h_2}$(region-2),$u_1 = \frac{U_1}{U_0}, u_2 = \frac{U_2}{U_0}, \theta_1 = \frac{T_1 - T_0}{\Delta T}, s = \frac{S'}{h_1}$

$C_S = \frac{C_{S1}}{C_{S2}}, K_T = \frac{K_{T1}}{K_{T2}}, D = \frac{D_1}{D_2}, h = \frac{h_1}{h_2}, m = \frac{\mu_1}{\mu_2}, \alpha = \frac{k_1}{k_2}, \rho = \frac{\rho_1}{\rho_2}, b_1 = \frac{\beta_{1T}}{\beta_{2T}}, b_2 = \frac{\beta_{1C}}{\beta_{2C}}, \nu = \frac{\nu_1}{\nu_2}.$

The following are the dimensionless representations of the governing equations:

Region-1:

$$\frac{\partial^2 N}{\partial y^2} - \frac{2K'}{2 + K'}\left(2N + \frac{\partial u_1}{\partial y}\right) = 0 \tag{12}$$

$$(1 + K')\frac{\partial^2 u_1}{\partial y^2} + K'\frac{\partial N}{\partial y} + \frac{Gr}{R}\theta_1 + \frac{Gc}{R}c_1 - Mu_1 = 0 \tag{13}$$

$$\frac{1}{PrPr\,R}\frac{\partial^2\theta_1}{\partial y^2}+\frac{Ec}{R}\left(\frac{\partial u_1}{\partial y}\right)^2+\frac{Du}{R}\frac{\partial^2 c_1}{\partial y^2}=0 \quad (14)$$

$$\frac{1}{ScR}\frac{\partial^2 c_1}{\partial y^2}+Sr\frac{\partial^2\theta_1}{\partial y^2}=0 \quad (15)$$

Region -2

$$\frac{\partial^2 u_2}{\partial y^2}+\frac{m}{b_1\rho h^2}\frac{Gr}{R}\theta_2+\frac{m}{b_2\rho h^2}\frac{Gc}{R}c_2-\frac{mM}{h^2}u_2=0 \quad (16)$$

$$\frac{\rho h}{\alpha}\frac{1}{PrPr\,R}\frac{\partial^2\theta_2}{\partial y^2}+\frac{\rho h}{m}\frac{Ec}{R}\left(\frac{\partial u_2}{\partial y}\right)^2+\frac{c_s h}{DK_T}\frac{D_u}{R}\frac{\partial^2 c_2}{\partial y^2}=0$$

(17)

$$\frac{h}{D}\left(\frac{1}{ScR}\right)\frac{\partial^2 c_2}{\partial y^2}+\frac{h}{K_T D}Sr\frac{\partial^2\theta_2}{\partial y^2}=0 \quad (18)$$

The dimensionless boundary and interface conditions thus formed are:

$u_1=1+s\frac{\partial u}{\partial y}aty=-1u_2=0aty=1,\ u_1(0)=u_2(0),$

$\theta_1=1aty=-1,\theta_2=0aty=1,\ \theta_1(0)=\theta_2(0),$

$c_1=1aty=-1,c_2=0aty=1,\ c_1(0)=c_2(0),$

$N=0aty=-1,$

$\frac{\partial u_1}{\partial y}+\frac{K'}{1+K'}N=\frac{1}{mh(1+K')}\frac{\partial u_2}{\partial y}aty=0,$

$\frac{\partial N}{\partial y}=0aty=0,\frac{\partial\theta_1}{\partial y}=\frac{1}{h\alpha}\frac{\partial\theta_2}{\partial y}aty=0,$

$\frac{\partial c_1}{\partial y}=\frac{1}{hD}\frac{\partial c_2}{\partial y}aty=0.$ (19)

3. SOLUTION OF THE PROBLEM

The system of Non linear equations are solved numerically using Runge-Kutta 6th order method. Numerical calculations have been carried out for different values of governing parameters such as Thermal Grashof number (Gr), Molecular Grashof number (Gc), Reynolds number (R), Magnetic field parameter (M), Material parameter (K'), Dufour number (Du), Schmidt number (Sc), Soret number (Sr) and Eckert number (Ec).The effect governing parameters dimensionless parameters velocity, temperature, concentration are obtained and represented graphically.

4. RESULTS AND DISCUSSIONS

Fig-2 to Fig-7exhibit the effect ofGrashof numbers (Gr) and Molecular grashoff number (Gc) on velocity and angular momentum profiles. It is observed that as Gr increases velocity andangular momentum increases substantially. The fluid velocity increases due to the enhancement of thermal and species buoyancy forces. The effect of Grashof numbers leads to rise in temperature as there is an increment in Gr duo to change in buoyancy .Fig-5 depicts the effect of Grashof numbers (Gr) on Diffusion , slight enhancement in diffusion is recorded as Gr increases.Fig-6 describes the effect of Gc on velocity, due to the enhancement of Bouncy forces velocity increases .Fig-7 reports the effect of Gc on Diffusion. There is a slight increment in diffusion parameter with respect to MolecularGrashof number (Gc).

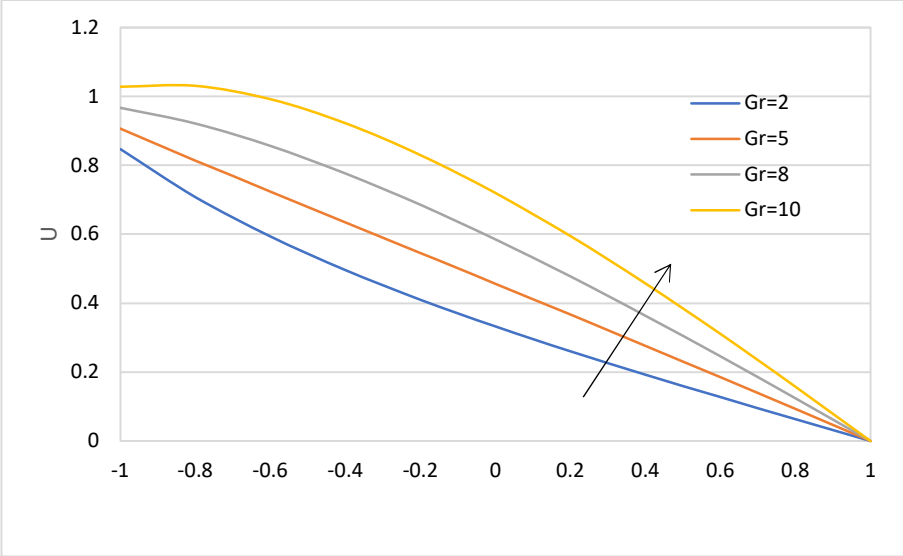

Fig-2:Variation of velocity with Gr

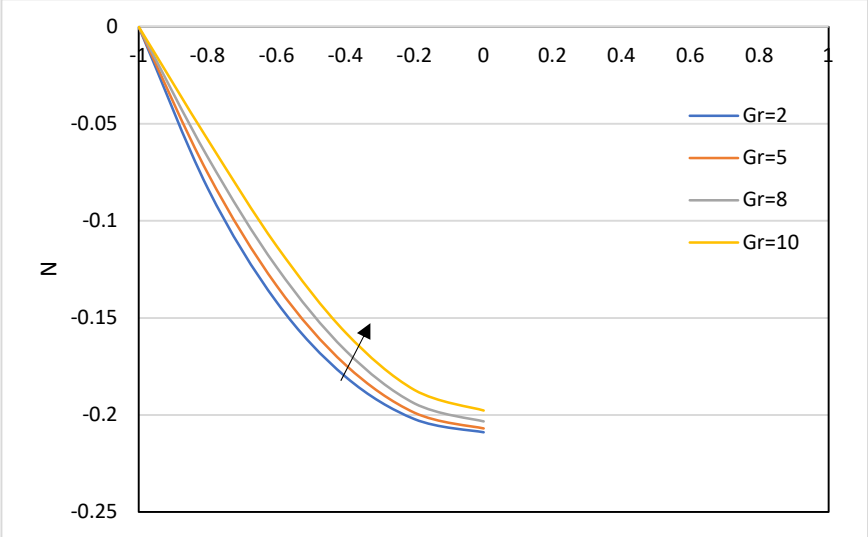

Fig-3: Variation of angular momentum with Gr

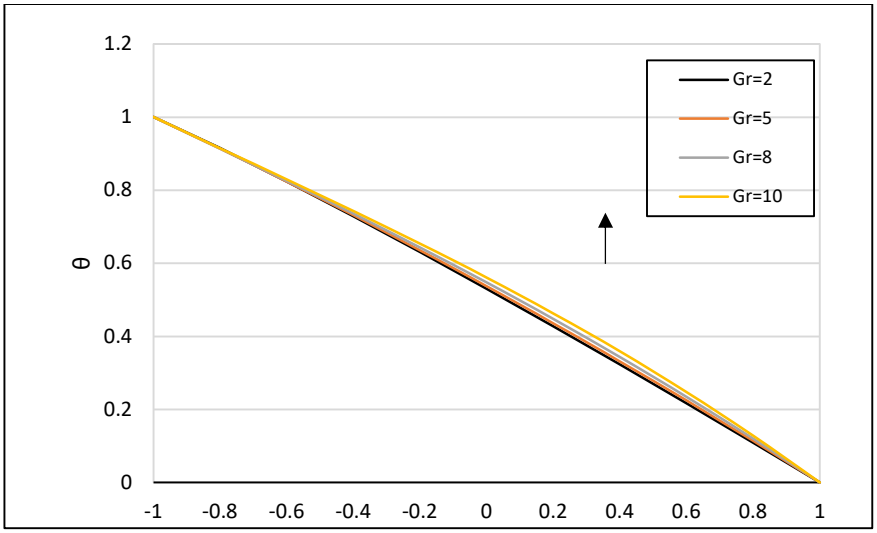

Fig-4: Variation of Temperature with Gr

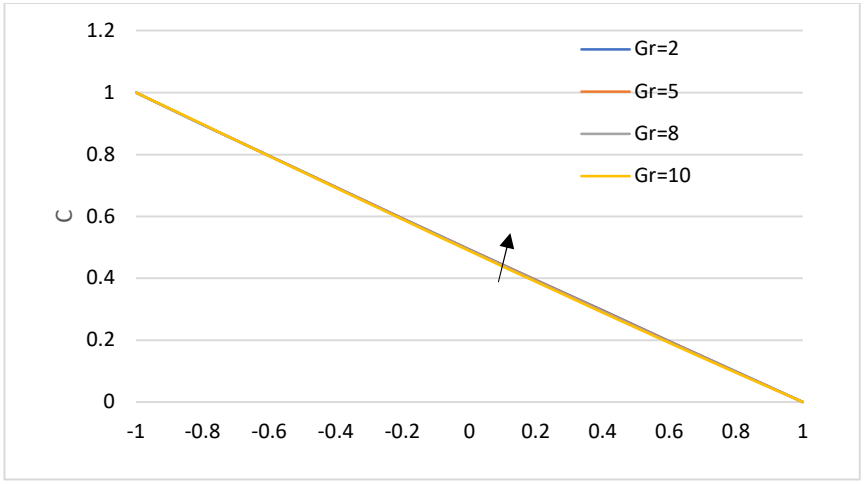

Fig-5: Variation of Diffusion with Gr

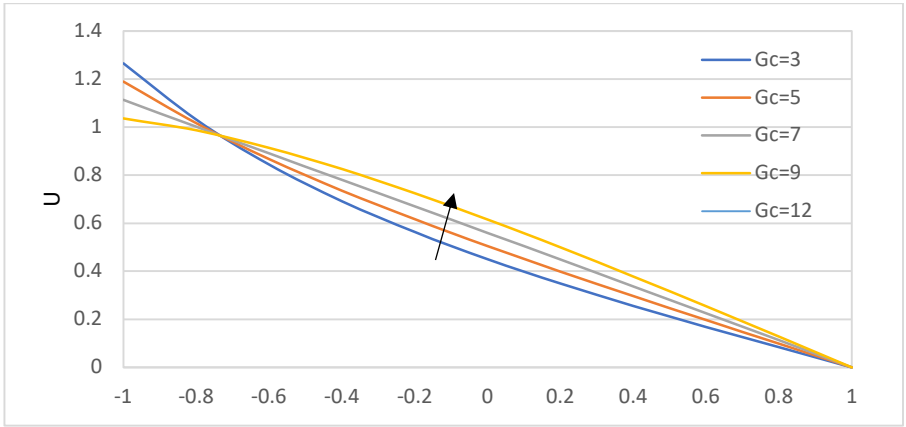

Fig-6: Variation of Velocity with Gc

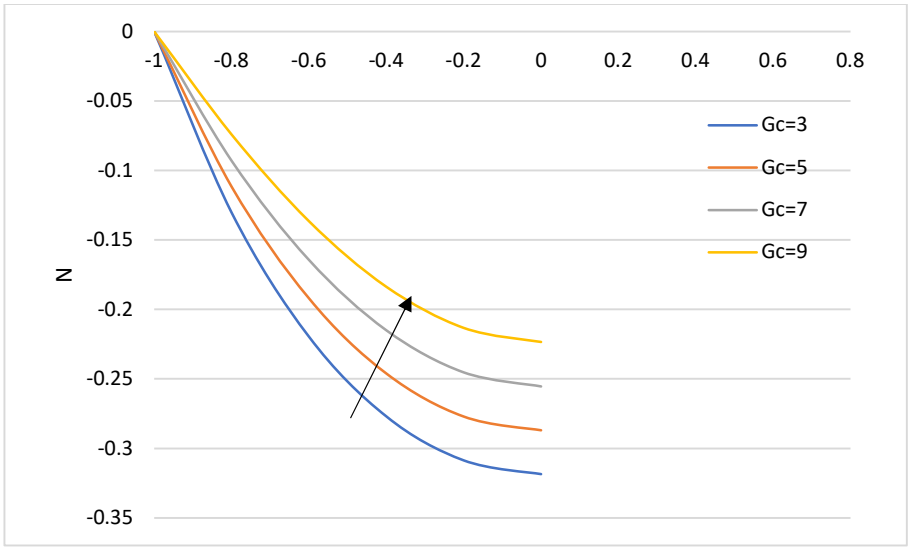

Fig-7: Variation of angular momentum with Gc

Fig-8 to Fig-9illustrates the influence of micro polar parameter,effect on the velocity and diffusion parameter. It is observed that velocity decreases with increase of K' values. It is significant to note that applying a transverse magnetic field acts as a resistive force (Lorentz force) that acts in the opposite direction of fluid motion and resists flow, hence slowing the velocity of the fluid. As the permeability parameter K' increases, it is seen that the velocity profile decreases. Reverse effect is observed in diffusion.Fig-10and Fig-12 describes the effect of radiation parameter R on velocity and angular velocity. An increase in R leads to decreasing the velocity and angular velocity. This is due to the fact that high values of R result in a higher conduction-over-R dominance, which reduces the buoyancy thickness of the momentum boundary layer.Fig-11 depicts the effect ofReynolds number R on temperature. It is observed that there is an enhancement in temperature as R increases. Fig-13Illustrates the effects of R on diffusion. There is a reduction in diffusion as R increases.

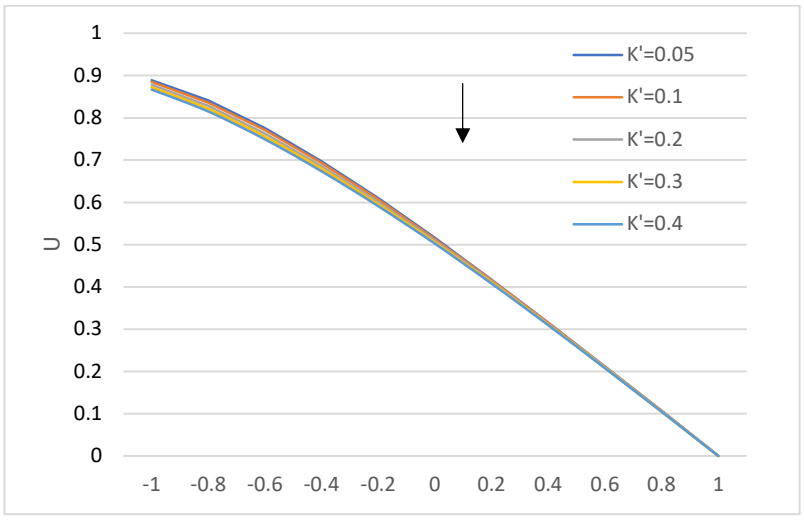

Fig-8: Variation of Velocity with K'

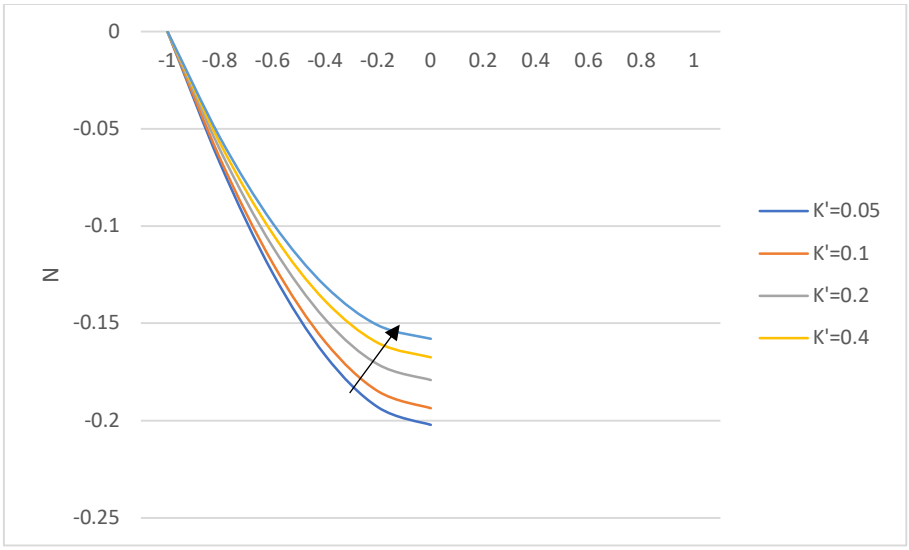

Fig-9: Variation of Diffusion with K'

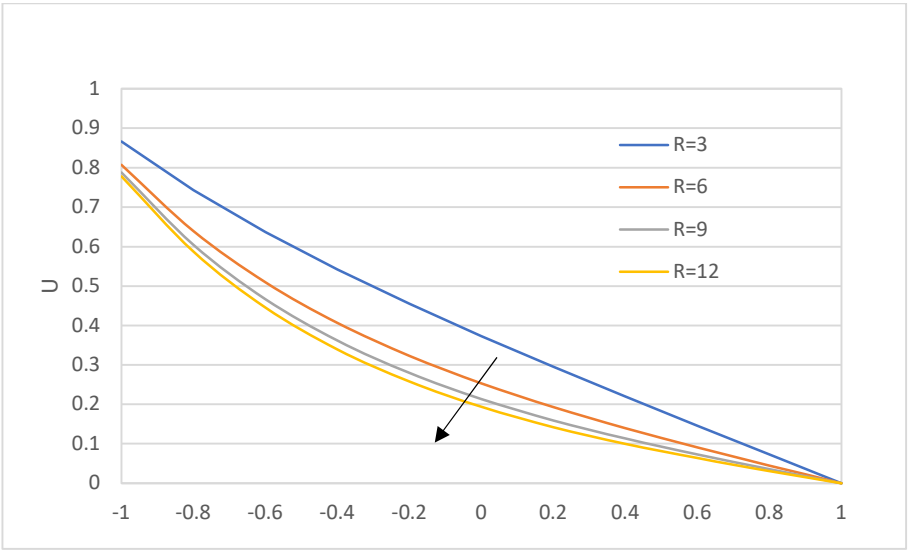

Fig-10:Variation of Velocity with R

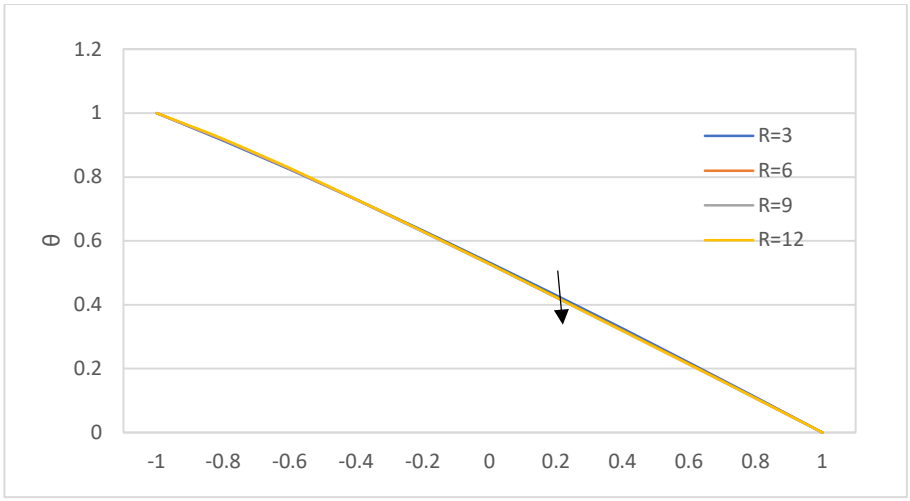

Fig-11:Variation of Temperature with R

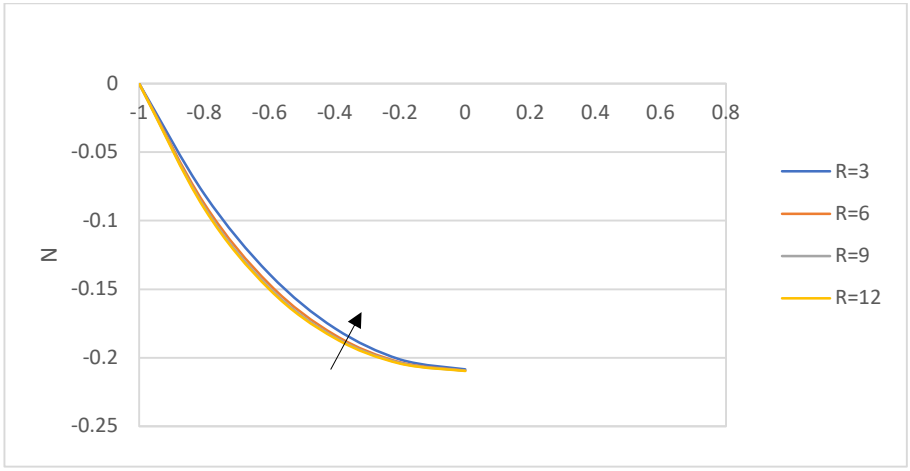

Fig-12:Variation of angular momentum with R

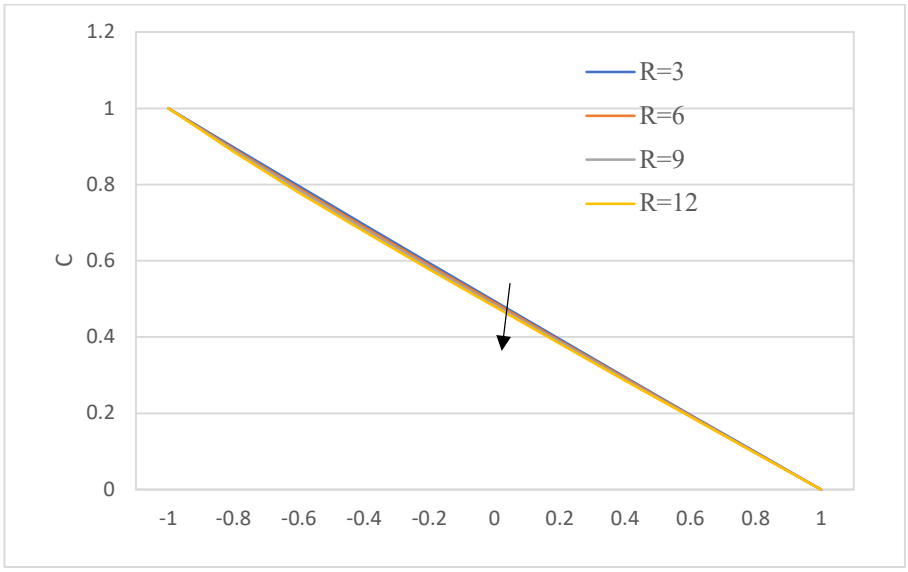

Fig-13Variation of Diffusion with R

As crucx of the work is studying the impact of slip parameter.Many possible values for this are considered when s (velocity slip) is varying as s= -1.2, -0.9, -0.6 ,0, 0.3,0.6,0.9,1.2 there is gradual decay in the velocity which is displayed in Fig-14.Fig-15and Fig-17reports the effect of Slip on temperatureand diffusion profiles at s= -1.2,-0.9,-0.6,-0.3, 0, 0.3, 0.6, 0.9, 1.2. As the slip parameter s is increasing , temperature and diffusion is decreasing.Fig-16 depicts the effect of Slip parameter angular velocity,the effectis observed as similar velocity.

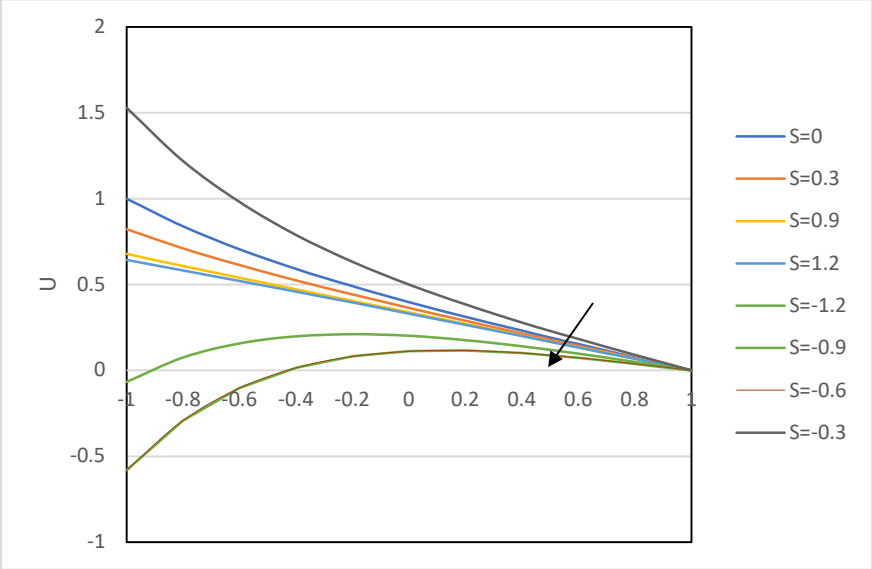

Fig-14:Variation of Velocity with Slip

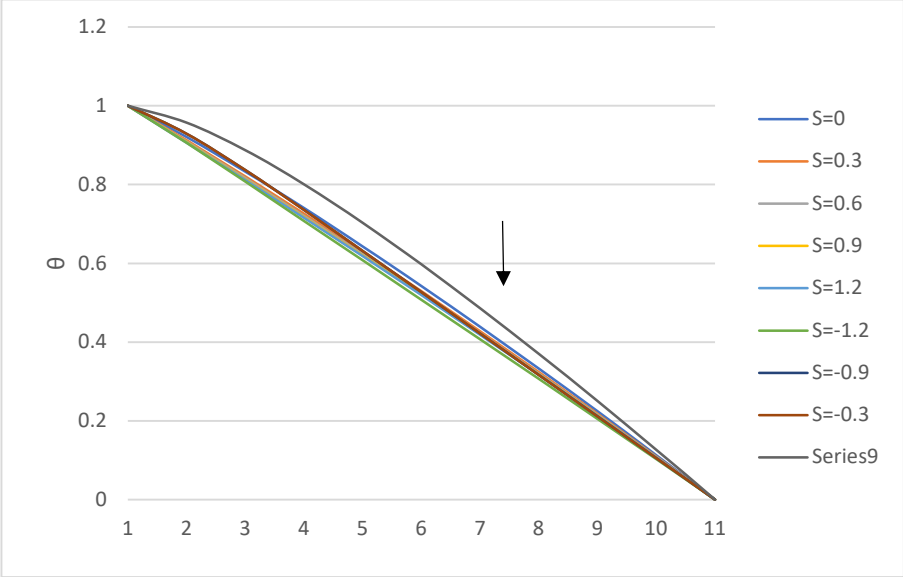

Fig-15:Variation of Temperature with Slip

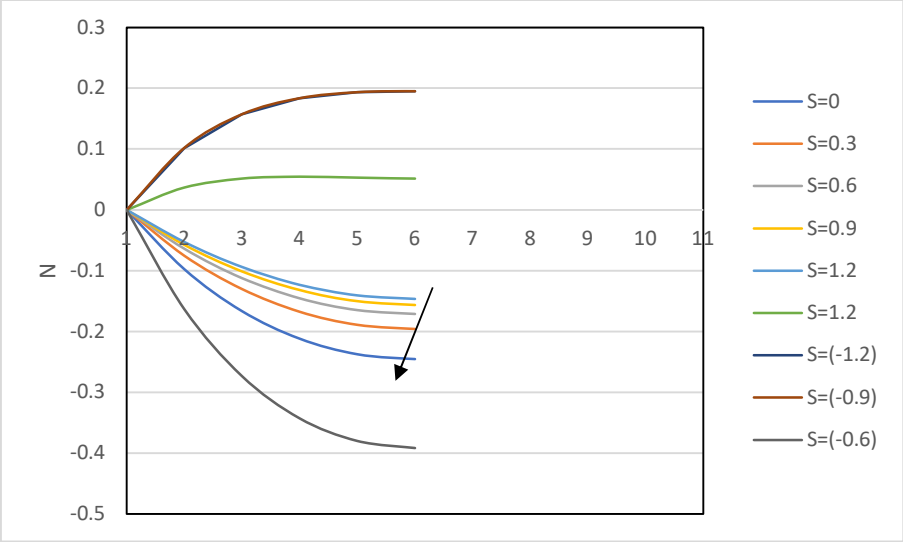

Fig-16:Variation of angular momentumwith slip

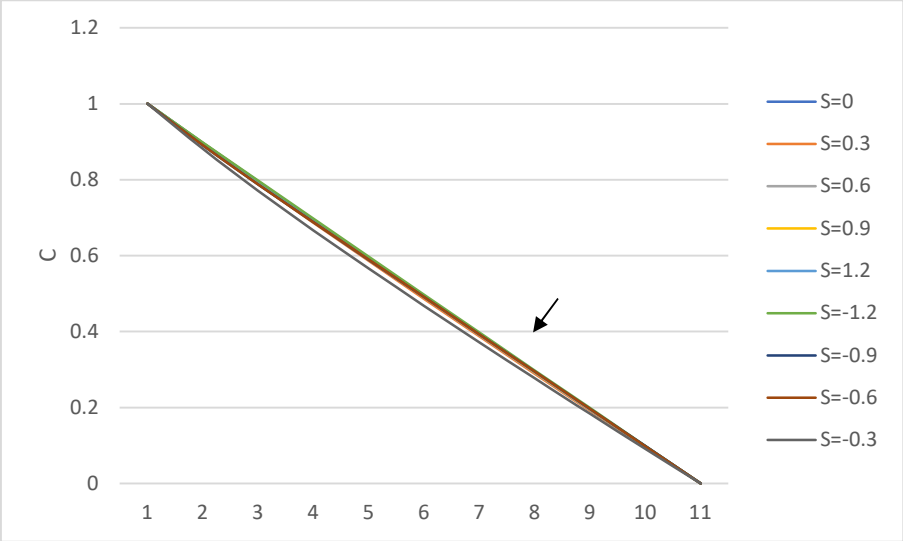

Fig-17: Variation of Diffusion with slip

Gr	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
2	*-0.84173*	*0.2278*	*0.4908*	*0.4872*	*0.6635*	*0.31451*
5	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
8	*-1.60644*	*0.4862*	*0.4906*	*0.4873*	*0.6635*	*0.31443*
10	*-1.86137*	*0.5723*	*0.4905*	*0.4873*	*0.6636*	*0.31439*
Gc	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
2	*-0.87857*	*0.2654*	*0.4908*	*0.4872*	*0.6635*	*0.3145*
5	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*

8	*-1.56958*	*0.4486*	*0.4906*	*0.4872*	*0.6635*	*0.31444*
10	*-1.79991*	*0.5096*	*0.4905*	*0.4873*	*0.6636*	*0.31441*
R	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
1	*-3.76511*	*1.2101*	*0.5003*	*0.4767*	*0.5453*	*0.43269*
2	*-1.85976*	*0.5707*	*0.4961*	*0.4816*	*0.6033*	*0.37467*
3	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
5	*-0.71423*	*0.1847*	*0.4788*	*0.4991*	*0.7908*	*0.18721*
M	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
1	*-1.57481*	*0.621*	*0.4905*	*0.4873*	*0.6636*	*0.31438*
2	*-1.36598*	*0.4578*	*0.4906*	*0.4872*	*0.6635*	*0.31444*
3	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
5	*-1.03872*	*0.2413*	*0.4908*	*0.4872*	*0.6635*	*0.3145*
s	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
0	*-1.26154*	*0.3588*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
0.3	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
0.6	*-1.1571*	*0.3531*	*0.4907*	*0.4872*	*0.6635*	*0.31448*
0.9	*-1.09873*	*0.3491*	*0.4907*	*0.4872*	*0.6635*	*0.31448*
Du	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
0.08	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
0.1	*-1.224*	*0.3569*	*0.4912*	*0.4867*	*0.6632*	*0.31475*
0.3	*-1.22305*	*0.3559*	*0.4971*	*0.4808*	*0.66*	*0.31797*
0.5	*-1.22173*	*0.3546*	*0.5053*	*0.4727*	*0.6555*	*0.32239*
Sr	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
0.05	*-1.25293*	*0.3864*	*0.4991*	*0.4788*	*0.5739*	*0.40405*
0.08	*-1.23581*	*0.3689*	*0.4941*	*0.4838*	*0.6271*	*0.35088*
0.1	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
0.13	*-1.20599*	*0.3385*	*0.4854*	*0.4925*	*0.7196*	*0.25835*
Sc	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
0.22	*-1.26221*	*0.3959*	*0.5018*	*0.476*	*0.5451*	*0.43286*
0.66	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
1.02	*-1.19075*	*0.3229*	*0.481*	*0.4969*	*0.767*	*0.21101*
1.5	*-1.14299*	*0.2742*	*0.467*	*0.5109*	*0.9152*	*0.06279*

Ec	*St-I*	*St-II*	*Nu-I*	*Nu-II*	*Sh-I*	*Sh-II*
0.001	*-1.22408*	*0.357*	*0.4907*	*0.4872*	*0.6635*	*0.31447*
0.002	*-1.22409*	*0.357*	*0.4905*	*0.4873*	*0.6636*	*0.31441*
0.02	*-1.22431*	*0.3571*	*0.4873*	*0.4887*	*0.6644*	*0.31333*
0.05	*-1.22467*	*0.3573*	*0.482*	*0.4911*	*0.6658*	*0.31151*

Table 3.1 Numerical values of shear stress, Nusselt number, Sherwood numbers
[The above values are obtained when the other parameters are fixed as Gr=5, Gc=5, R=3, M=3, K'=0.1, Du=0.08, Sr=0.1, Sc=0.66, Ec=0.001]

Table 1 shows the computed shear stress, Nusselt number, and Sherwood number together with all possible impact on the governing parameters. This table shows that when the buoyancy forces increase close to the borders, there is an increase in the absolute shear stress, which leads to an improvement in shearing outcomes. Shearing stress at the boundary decreases with an increase in the Reynolds number, magnetic field parameter, material parameter, Dufour number, Soret number, and Schmidt number. In the dissipation parameter Ec, the opposite effect is observed.

The Nusselt number, or rate of heat transfer, decreases close to one boundary and increases at the other for the parameters Gr, Gc, R, Sc, and Ec. Significant changes in the Reynolds Number are seen in the rate of heat transfer. The right plate's heat transfer rate is improved by the elevation of the inertial forces, whereas the left plate's is ruined. Reversal of the effect occurs for the parameters M and K'. The relationship between the Nusselt number and the diffusion parameters Du and Sr demonstrates that as Dufour increases, heat transfer to the left plate is enhanced and to the right boundary is reduced. For Sr., it is entirely in opposition.

The Sherwood number, which measures the rate of mass transfer, increases close to the border and decreases at the boundary for the parameters Gr, Gc, R, Sr, Sc, and Ec. Mass transfer increases close to the left border and decreases at the right boundary for the other parameters M, K', and Du, respectively.

5. CONCLUSIONS

The impact of all governing parameters was investigated and displayed graphically. Some of the salient findings are as follows:

- There is a significance effect of Gr, Gc, R, K’ on velocity , angular momentum, temperature and diffusion profiles.
- There is a significant effect of all the parameters on rate of shear stress, rate of heat transfer, rate of mass transfer.
- The velocity slip which is placed on left wall has a significant effect on all profiles.

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