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Effect of viscous dissipation of a magneto hydrodynamic micropolar fluid with momentum and temperature dependent slip flow

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Abstract: In this paper, MHD flow and heat transfer of electrically conducting micro polar fluid over a permeable stretching surface with slip flow in the existence of viscous dissipation and temperature dependent slip flow are investigated. With the help of similarity transformations, the fundamental equations have been altered into a system of ordinary differential equations. It is difficult to solve these equations methodically. That's why we used bvp4c MATLAB solver. We found the Numerical values for the wall couple stress, skin-friction coefficient, and the local Nusselt number in addition to the micro rotation, velocity, and temperature reports for diverse values of the principal parameters like thermal slip parameter, material parameter, magnetic parameter, heat generation/absorption parameter, velocity slip parameter and Eckert number. It is observed that the values of suction/injection parameters rise corresponding to the lessening in the values of velocity, angular velocity, and temperature. Moreover, the change in the values of the Eckert number is opposite to the change in the values of the local Nusselt number.

1. Introduction

Many research scholars are attracted by versatile applications of MHD flow and heat transfer over a stretching surface in the industry. For instance, in the extrusion of a polymer sheet from a die, the sheet is every so often lengthened. Throughout this progression, the quality of the ultimate yield is based on the tempo of cooling. By placing such sheet in an electrically conducting fluid exposed to a magnetic field, the rate of cooling can be restricted and the concluding invention can be attained with preferred uniqueness. Boundary layer flow of a fluid which is subjected to both the electric field and uniform transverse magnetic field along stretching elastic surface was studied by Pavlov [1]. In addition to Pavlov's work, heat transfer of fluid flow along a stretching surface in the presence of uniform suction was studied by Chakrabarti and Gupta [2]. Laminar Boundary layer flow of incompressible power-law fluid which is subjected to the electric field and magnetic field orthogonal to the flow along a stretching sheet is studied by Zhang and Wang [3]. Dutta [4] investigated the decrease in temperature of a stretching sheet when it is placed in a fluid which is subjected to both electric and



magnetic fields. Mahapatra and Gupta [5] investigated the two-dimensional stagnation-point flow of an incompressible viscous electrically conducting fluid over a plane deformable sheet when the sheet is lengthened in its own plane with a velocity balanced to the space from the stagnation-point and fulfilled that velocity at a point also declines or rises with rising in the magnetic field when the free stream velocity is fewer or extra than the stretching velocity. Mahapatra et al. [6] investigated the stagnation-point flow of a power $-$ law fluid which is deal with the electric field and passed over a stretching surface which is stretched with the velocity relative to the distance from the stagnation point. Mostafa and Mahmoud [7] studied the transfer of heat and mass by laminar type flow of Newtonian, viscous fluid which is subjected to the electric field over an exponentially enlarged permeable sheet by means of variable heat and mass fluxes in the company of non-homogeneous magnetic range.

Somand co [8] analyzed MHD boundary layer slip flow of an incompressible fluid over a stretching sheet in Darcy-Forchheimer permeable ambience in the presence of thermal radiation and ohmic dissipation and concluded so as to the rise of velocity slip as well as thermal slip constraints reduces the momentum boundary layer width as well as also enhances the temperature transport from the plate. Hayat et al. [9] investigated the magnetohydrodynamic (MHD) flow and temperature transport features for the boundary layer flow above a porous extending sheet with velocity and thermal slip circumstances. Sharma and co [10] considered the boundary layer flow and heat transport of a nanofluid over extending sheet in the company of velocity slip and concluded that the velocity slip parameter reduces the tempo of heat transport. Sheikholeslami and co [11] investigated the MHD stream in the midst of 2 flat plates in a revolving structure, where the lower plate is an elongating sheet along with the superior is a permeable solid plate in the company of viscous dissipation and concluded that the increasing Prandtl number in the company of viscous indulgence directs to hotness growing among the plates, as in lack of viscous dissipation, the variations are opposite. Rohana Abdul Hamid et al. [12] studied the outcomes of the Joule heating and viscous dissipation on the magnetohydrodynamics (MHD) Marangoni convection boundary layer flow and finished that the collective results of the Joule heating and viscous dissipation have considerably motivated the surface temperature change. Khilap Singh and Manoj Kumar [13] investigated the report of heat and mass transport features of the free convection on a perpendicular plate during permeable medium through inconsistent wall temperature and cluster in a double stratified and viscous dissipating micropolar fluid in the company of chemical reaction, heat generation, and Ohmic heating. Kumar [14] analyzed the MHD flow of a micropolar fluid which is subjected to ohmic heating, viscous dissipation and radiation on a chemically reacting porous plate with stable heat change. Hakiem [15] has obtained a study for the result of thermal spreading, viscous and Joule heating on the flow of an electrically conducting and viscous incompressible micropolar fluid over a semi-infinite plate whose temperature differs linearly with the distance as of the priming the company of consistent transverse magnetic field. Kabir et al. [16] investigated the effects of the viscous dissipation on MHD natural convection flow over a homogeneously heated perpendicular curved surface with heat production. Gangadhar [17] concluded with the aim of the local skin friction parameter increases and local Nusselt number coefficient decreases in the company of viscous dissipation. Bharathi Devi and Gangadhar [18] studied the Flakner-Skan boundary layer flow above a motionless Wedge with thermal slip plus momentum boundary conditions and the temperature needy thermal conductivity in the company of permeable medium along with viscous dissipation. Gangadhar [19] investigated the effects of radiation, heat generation, magnetohydrodynamic along with viscous dissipation on the laminar boundary layer on a flat plate in a consistent flow of fluid (Blasius flow), and on a moving plate in an inactive ambient fluid (Sakiadis flow) together under a convective surface boundary condition. Rashad [20] investigated the radiative consequence on free convection flows in the permeable medium in the company of stress work and viscous dissipation. Mahmoud and Waheed [21] investigated the consequences of slip velocity on the flow plus heat transfer for an electrically conducting micropolar fluid above a porous extending surface through inconsistent heat change in the company of heat production and a transverse magnetic field.

In this paper, MHD flow, as well as heat transport for an electrically, carry out micropolar fluid past a porous extending surface with slip flow in the company of viscous dissipation as well as a temperature dependent slip flow is investigated. With the help of the similarity transformations, the principal equations have been changed into a set of ordinary differential equations, which are nonlinear and cannot be worked out analytically, as a result, bvp4c MATLAB solver has been utilized to get the solution. The effects of velocity, microrotation, and temperature functions are carried out for the broad collection of significant factors specifically; magnetic parameter, momentum slip parameter, thermal slip parameter, Eckert number, material parameter and heat production/inclusion parameter. The skin friction, the wall couple stress and the tempo of heat transport have also been worked out.

2. Mathematical formulation

Now we examine the two-dimensional stream of an incompressible micro polar fluid which is subjected to the electrical field and having viscous dissipation over a stretching exterior and that coincides for the level surface $y = 0$, the stream being in the area x -axis. The abscissa is in use along the extending surface towards motion. A homogeneous magnetic domain B_0 is enforced along the ordinate, and that is perpendicular to the surface. The physical representation of the present problem is shown in figure 1.

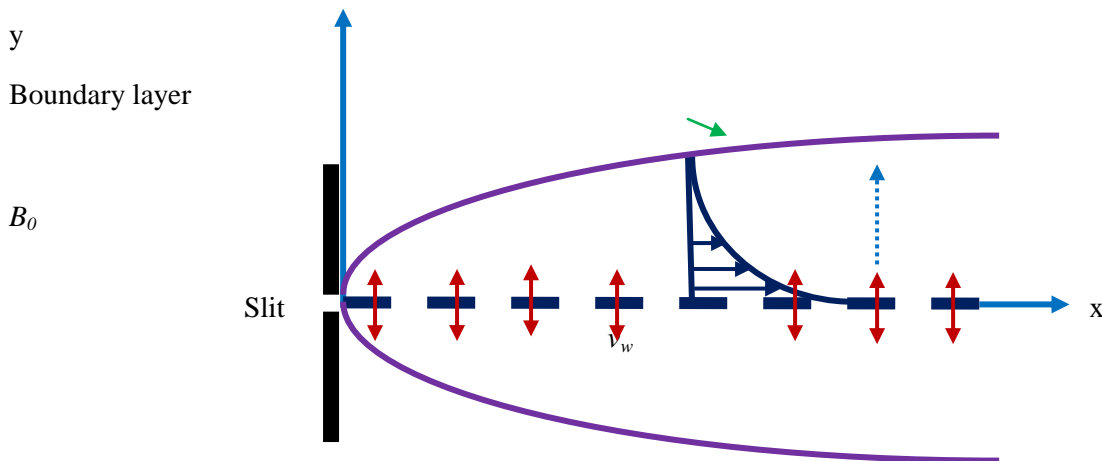


Figure 1. Schematic diagram of the physical problem

It is supposed so as to the variable surface heat flux to be $q_w(x) = b x^m$ (where b, m be in variables and x computes the space from the top edge by the side of the exterior of the plate). (u, v, θ) as well as (θ, θ, N) is taken as the velocity as well as micro-rotation constituents in that order, subject to the customary boundary layer approximation, the governing qualities are

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{2.1}$$

Linear momentum equation

$$u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \left(\frac{\mu + k}{\rho} \right) \frac{\partial^2 u}{\partial y^2} - \frac{\sigma B_0^2}{\rho} u + \frac{k}{\rho} \frac{\partial N}{\partial y} \tag{2.2}$$

Angular momentum equation

$$G_1 \frac{\partial^2 N}{\partial y^2} - \left(2N + \frac{\partial u}{\partial y} \right) = 0 \quad (2.3)$$

Energy equation

$$u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \frac{\kappa}{\rho c_p} \frac{\partial^2 T}{\partial y^2} + \left(\frac{\mu + k}{\rho c_p} \right) \left(\frac{\partial u}{\partial y} \right)^2 + \frac{Q_0}{\rho c_p} (T - T_\infty) \quad (2.4)$$

The boundary conditions designed for the velocity, Angular Velocity as well as temperature fields are

$$u = u_w + \alpha^* \left[(\mu + k) \frac{\partial u}{\partial y} + kN \right] = ax \alpha^* \left[(\mu + k) \frac{\partial u}{\partial y} + kN \right] \text{ at } y = 0$$

$$v = v_w, \quad N = 0, \quad T = T_w + D_1 \frac{\partial T}{\partial y}$$

$$u \rightarrow 0, \quad N \rightarrow 0, \quad T \rightarrow T_\infty \text{ as } y \rightarrow \infty \quad (2.5)$$

Where u and v are taken as velocity constituents in the abscissa and ordinate directions in that order. N is the micro-rotation or the angular velocity, σ is the electrical conductivity, B_0 is the magnetic field strength, $G_1 = \frac{\gamma}{k}$ is the microrotation constant, D_1 is Thermal slip coefficient, α^* is the momentum slip coefficient and m is the heat flux exponent. Here $m=0$ represents uniform surface heat flux.

The stream function $\psi(x, y)$ fulfils the equation (2.1) is

$$u = \frac{\partial \psi}{\partial y} \text{ and } v = -\frac{\partial \psi}{\partial x} \quad (2.6)$$

The equations (2.2) to (2.5) are transformed into a system of ordinary differential equations with the help of subsequent similarity transformations [21]. In addition to that we introduce dimensionless variables are as follows

$$\eta = \sqrt{a/\nu} y, \quad \psi = \sqrt{av} x f(\eta), \quad N = ax \sqrt{a/\nu} h(\eta), \quad T = T_\infty + \frac{q_w(x)}{\kappa} \theta(\eta)$$

$$M = \frac{\sigma B_0^2}{a\rho}, \quad \lambda = \alpha^* \mu \sqrt{a/\nu}, \quad K = k/\mu, \quad G = \frac{G_1 a}{\nu}, \quad Pr = \frac{\mu c_p}{\kappa}, \quad \gamma = \frac{Q_0}{a\rho c_p}$$

$$f_w = -(av)^{1/2} v_w, \quad Ec = \frac{u_w^2}{c_p(T_w - T_\infty)}, \quad \beta = D_1 \sqrt{\frac{a}{\nu}} \quad (2.7)$$

where $f, \theta, \eta, M, \lambda, K, G, Pr, Ec$ and β represent the dimensionless stream function, dimensionless temperature, similarity variable, magnetic parameter, velocity slip parameter, material parameter, microrotation parameter, Prandtl number, Eckert number and β is the thermal slip parameter. γ is the heat generation (>0) or absorption (<0) parameter, f_w is the suction (>0) or injection (<0) parameter,

By using the equalities (2.6) and (2.7), the equalities (2.2) to (2.5) are transformed as

$$(1 + K)f''' + ff'' - f'^2 + Kh' - Mf' = 0 \quad (2.8)$$

$$Gh'' - (2h + f'') = 0 \quad (2.9)$$

$$\frac{1}{Pr} \theta'' + f\theta' - mf'\theta + \gamma\theta + Ec(1 + K)f'' = 0 \quad (2.10)$$

The corresponding boundary conditions are

$$\begin{aligned} f(0) &= f_w, f'(0) = 1 + \lambda(1 + K)f''(0), h(0) = 0, \theta(0) = 1 + \beta\theta'(0) \\ f' = h = \theta &= 0 \text{ as } \eta \rightarrow \infty \end{aligned} \quad (2.11)$$

Where the primes represent differentiation with respect to η .

Now we define the physical quantities namely skin friction coefficient C_{fx} , the local wall couple stress M_{wx} and the local Nusselt number Nu_x as

$$\begin{aligned} C_{fx} &= \frac{2\tau_w}{\rho(ax)^2} \\ M_x &= \frac{m_w}{\rho avx^3} \\ Nu_x &= \frac{xq_w}{\kappa(T_w - T_\infty)} \end{aligned} \quad (2.12)$$

Where the local wall shear stress, the wall couple stress m_w and the heat transfer from the plate q_w are formulated as

$$\begin{aligned} \tau_w &= - \left[(\mu + k) \frac{\partial u}{\partial y} + kN \right]_{y=0} \\ m_w &= \gamma_0 \left[\frac{\partial N}{\partial y} \right]_{y=0} \\ q_w &= - \left[\kappa \frac{\partial T}{\partial y} \right]_{y=0} \end{aligned} \quad (2.13)$$

With the help of similarity variables, we obtain

$$\begin{aligned} \frac{1}{2} C_{fx} \text{Re}_x^{1/2} &= -(1 + K) f''(0) \\ M_x \text{Re}_x &= KG h'(0) \\ Nu_x \text{Re}_x^{-1/2} &= \frac{1}{\theta(0)} \end{aligned} \quad (2.14)$$

Where, local Reynolds number is defined as $\text{Re}_x = \frac{u_w x}{\nu}$. In case of Newtonian fluids $K=0$.

3. Solution of the problem

The system of equalities (2.8) to (2.10) is changed to a set of differential equations of order one and we solved the equations with the help of bvp4c MATLAB solver. The bvp4c MATLAB solver solves equations of the form $y' = f(x, y, p)$, $a \leq x \leq b$, by applying a collocation technique exposed to nonlinear, two-point boundary conditions $g(y(a), y(b), p)$. Here p represents a vector of strange constraint. Boundary value problems (BVPs) happen in most dissimilar structures. To find the solution with the help of bvp4c solver, we first change the existing differential equations into differential equations of order one with the help of some considerations. The detailed form of the bvp4c method is mentioned in Shampine and Kierzenka [22].

4. Results and Discussion

We integrate the differential equations (2.8) - (2.10) subject to the conditions (2.11) as mentioned earlier. So as to acquire a lucid approaching into the physical problem, the velocity, temperature, and angular velocity are argued by giving numerical values to the parameters discussed in the problem.

Numerical results for $\frac{1}{2}C_{fx} Re_x^{-1/2}, Nu_x Re_x^{1/2}$ computed by bvp4cMATLAB solver are in good agreement with the values obtained by Mahmoud and Waheed [21] as shown in the first Table.

Table 1. Comparison for the values of $\frac{1}{2}C_{fx} Re_x^{-1/2}, Nu_x Re_x^{1/2}$ for $K=\lambda=Ec=\beta=0, m=2, Pr=0.72, fw=0.2$ and different numerical values of M and γ with Mahmoud and Waheed [21].

M	γ	$\frac{1}{2}C_{fx} Re_x^{-1/2}$	$\frac{1}{2}C_{fx} Re_x^{-1/2}$	$Nu_x Re_x^{1/2}$	$Nu_x Re_x^{1/2}$
		Mahmoud and Waheed [21]	Present study	Mahmoud and Waheed [21]	Present study
0.5	0.1	1.32881	1.328821	1.02958	1.029614
1	0.1	1.51773	1.517745	0.969776	0.969819
1.5	0.1	1.68426	1.684298	0.91750	0.917570
0.5	0.0	1.32881	1.328821	1.08952	1.089562
0.5	-0.1	1.32881	1.328821	1.13991	1.139958

The numerical results for $f'(0), -f''(0)$ computed by bvp4cMATLAB solver are additionally benchmarked with those reported by Andersson [23], Mahmoud [24] and Mahmoud and Waheed [21] as presented in Table 2.

Table 2. Comparison of the numerical values of $f'(0), -f''(0)$ for $K=M=fw=0$ and different numerical values of λ with Andersson [23], Mahmoud [24] and Mahmoud and Waheed [21].

λ	$f'(0)$				$-f''(0)$			
	Andersson [23]	Mahmoud [24]	Mahmoud and Waheed [21]	Present study	Andersson [23]	Mahmoud [24]	Mahmoud and Waheed [21]	Present study
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
0.1	0.9128	0.91279	0.91279	0.912791	0.04500	0.87208	0.87209	0.872092
0.2	0.8447	0.84473	0.84472	0.844722	0.7764	0.77637	0.77639	0.776389
0.5	0.7044	0.70440	0.70440	0.704395	0.5912	0.59119	0.59121	0.591211
1	0.5698	0.56984	0.56982	0.569820	0.4302	0.43016	0.43018	0.430180
2	0.4320	0.43204	0.43199	0.431990	0.2840	0.28398	0.28400	0.284005
5	0.2758	0.27579	0.27579	0.275643	0.1448	0.14484	0.14481	0.144871
10	0.1876	0.18758	0.18759	0.187263	0.0812	0.08124	0.08123	0.081274
20	0.1242	0.12423	0.12420	0.123667	0.0438	0.04378	0.04381	0.043817
50	0.0702	0.07019	0.07019	0.069167	0.0186	0.01859	0.01860	0.018617
100	0.0450	0.04501	0.04500	0.043593	0.0095	0.00955	0.00951	0.009564

The numerical results for $-f''(0), h'(0)$ and $1/\theta(0)$ computed by bvp4cMATLAB solver are matched with the values obtained by Mahmoud and Waheed [21] as presented in Table 3.

Table 3. Assessment of the numerical values of $-f''(0)$, $h'(0)$ and $1/\theta(0)$ for $K=1.2$, $G=2$, $\lambda=0.1$, $Pr=0.72$, $Ec=\beta=0$ and different numerical values of M , f_w , γ and m with Mahmoud and Waheed [21].

M	f_w	γ	m	Mahmoud and Waheed[21]	Present study	Mahmoud and Waheed[21]	Present study	Mahmoud and Waheed[21]	Present study
				$-f''(0)$	$-f''(0)$	$h'(0)$	$h'(0)$	$1/\theta(0)$	$1/\theta(0)$
0.5	0.2	0.1	2	0.68093	0.680930	0.194661	0.194661	1.06836	1.068361
1.0	0.2	0.1	2	0.77032	0.770323	0.204439	0.204439	1.01252	1.012524
1.5	0.2	0.1	2	0.84625	0.846252	0.211354	0.211354	0.96228	0.963388
0.5	-0.2	0.1	2	0.61652	0.616522	0.185523	0.185523	0.93455	0.934552
1.0	-0.2	0.1	2	0.70862	0.708617	0.197264	0.197264	0.87108	0.871085
1.5	-0.2	0.1	2	0.78681	0.786812	0.205568	0.205568	0.81090	0.810907
0.5	0.2	0.2	2	0.68093	0.680930	0.194661	0.194661	1.01481	1.014809
0.5	0.2	0.1	2	0.68093	0.680930	0.194661	0.194661	1.06836	1.068361
0.5	0.2	0	2	0.68093	0.680930	0.194661	0.194661	1.11476	1.114764
0.5	0.2	-0.1	2	0.68093	0.680930	0.194661	0.194661	1.15698	1.156986
0.5	0.2	-0.2	2	0.68093	0.680930	0.194661	0.194661	1.19629	1.196294
0.5	-0.2	0.2	2	0.61652	0.616522	0.185523	0.185523	0.87554	0.875538
0.5	-0.2	0.1	2	0.61652	0.616522	0.185523	0.185523	0.93455	0.934552
0.5	-0.2	0	2	0.61652	0.616522	0.185523	0.185523	0.98216	0.982164
0.5	-0.2	-0.1	2	0.61652	0.616522	0.185523	0.185523	1.02466	1.024655
0.5	-0.2	-0.2	2	0.61652	0.616522	0.185523	0.185523	1.06393	1.063932
0.5	0.2	0.1	0	0.68093	0.680930	0.194661	0.194661	0.460672	0.460669
0.5	0.2	0.1	0.5	0.68093	0.680930	0.194661	0.194661	0.641341	0.641341
0.5	0.2	0.1	1	0.68093	0.680930	0.194661	0.194661	0.799354	0.799354
0.5	0.2	0.1	2	0.68093	0.680930	0.194661	0.194661	1.06836	1.068361
0.5	-0.2	0.1	0	0.61652	0.616522	0.185523	0.185523	0.247212	0.247212
0.5	-0.2	0.1	0.5	0.61652	0.616522	0.185523	0.185523	0.463184	0.463184
0.5	-0.2	0.1	1	0.61652	0.616522	0.185523	0.185523	0.642564	0.642565
0.5	-0.2	0.1	2	0.61652	0.616522	0.185523	0.185523	0.934552	0.934552

In all the above cases we have observed that our values are very close to the previously published values. This gives us a great confidence in the accuracy of the bvp4c Mat lab solver.

Figures 1, 2 and 3 exhibit the consequences of suction/injection parameter f_w on velocity, angular velocity, and temperature profiles. Velocity, angular velocity as well as temperature are found to reduce with the increasing suction/injection parameter.

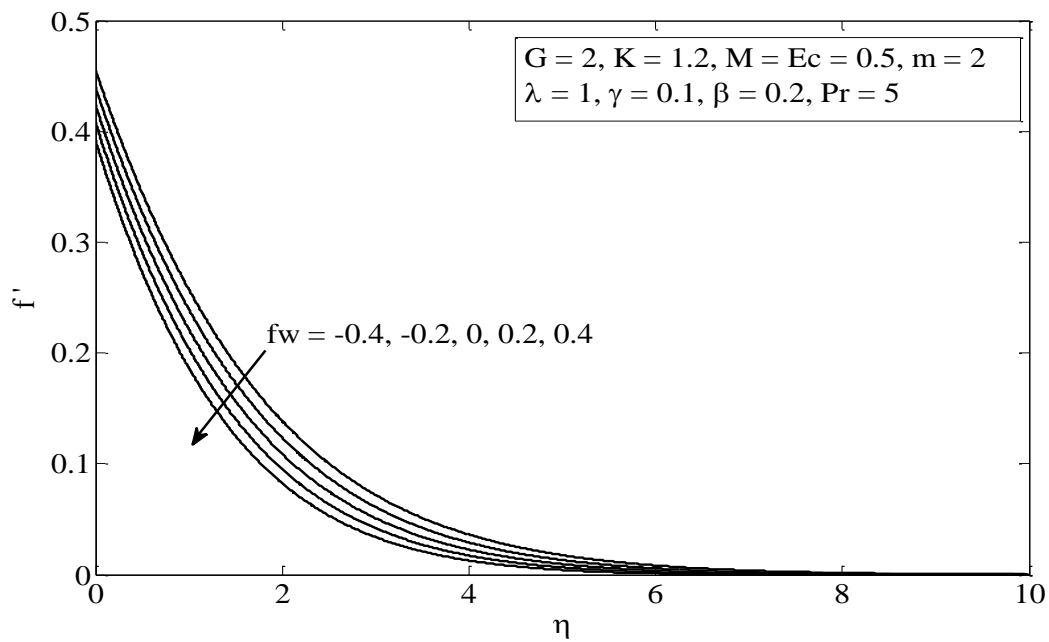


Figure 1. Velocity for various numerical values of fw

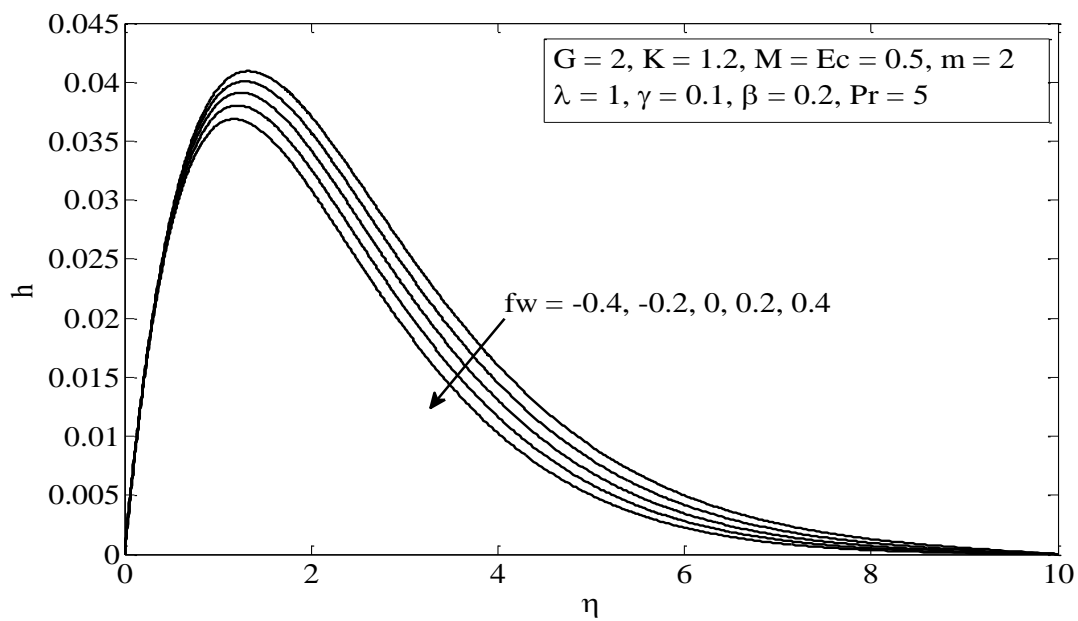


Figure 2. Angular velocity for various numerical values of fw

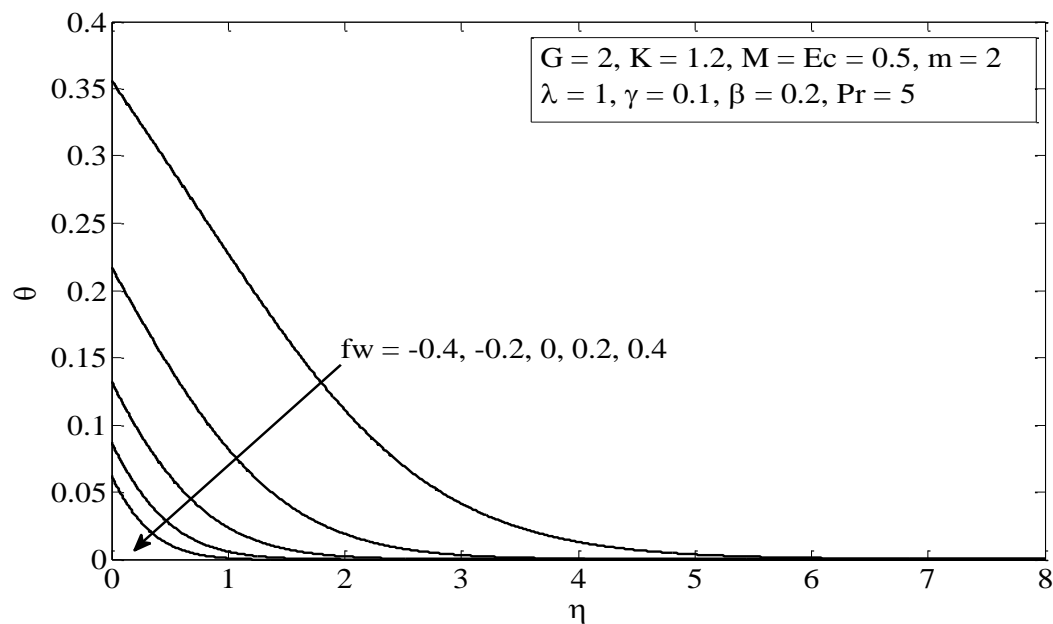


Figure 3. Temperature for different values of fw

Figures.4-6 exhibit the consequence of Magnetic parameter (M) on velocity, angular velocity as well as temperature reports. Velocity is found to decrease with the increasing Magnetic parameters (figure. 4). The Magnetic parameter is observed to slow down the velocity at every position of the flow field. Why because the appliance of transverse magnetic field creates an opposing force (Lorentz force) which causes to oppose the fluid flow. Therefore fluid velocity is decreased. The angular velocity of the fluid reduces the influence of magnetic field (figure. 5). The temperature of the fluid reduces near the sheet and then increases distances of the sheet with increasing the magnetic parameter (Figure.6).

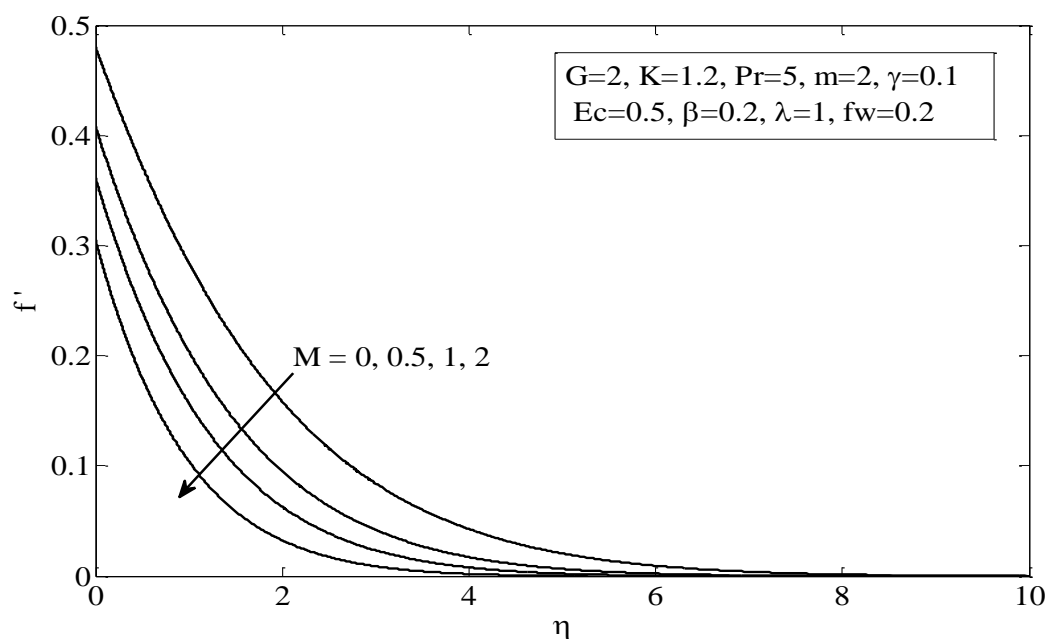


Figure 4. Velocity for various numerical values of M

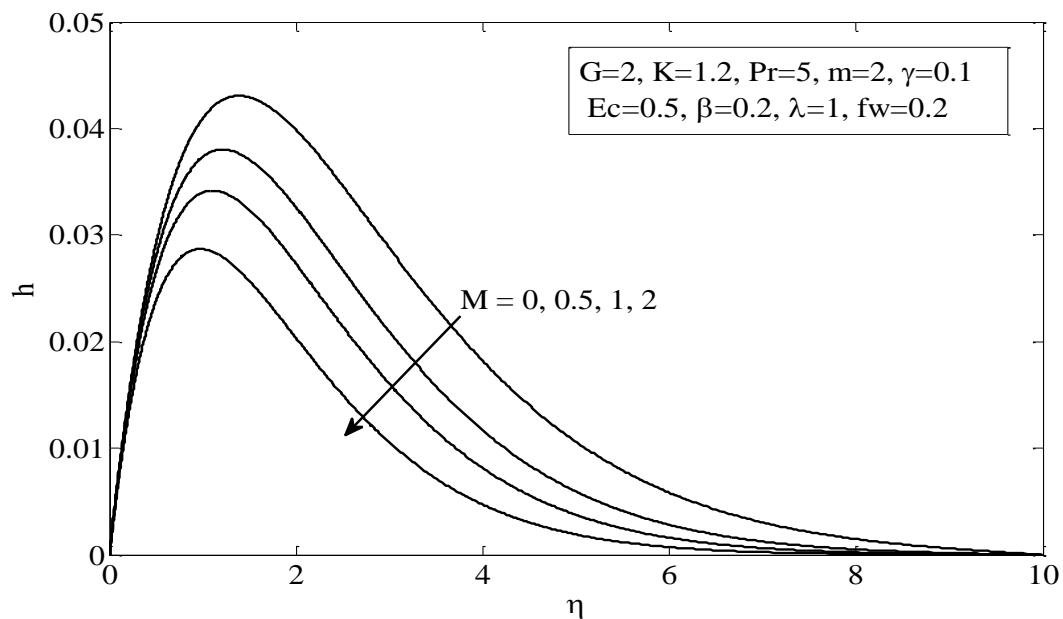


Figure 5. Angular velocity corresponding to different numerical values of M

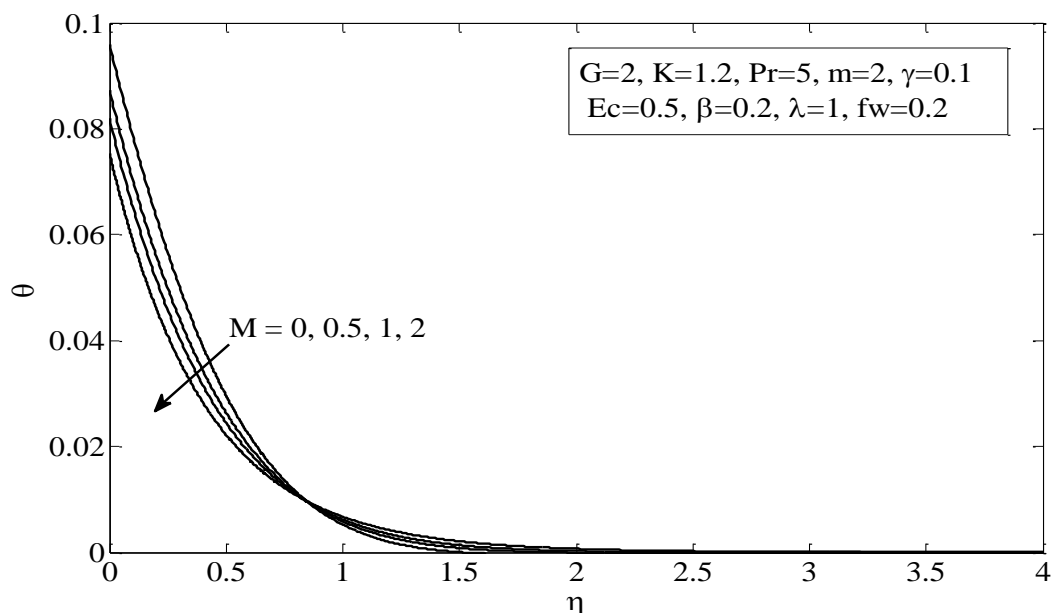


Figure 6. Temperature values Vs various numerical values of M

Figures 7,8 and 9 show the consequence of material parameter (K) on velocity, angular velocity as well as temperature respectively. Fluid's velocity reduces close to the sheet and then raises distant from the sheet with an increasing K (Figure 7). The angular velocity decreases from the sheet and increases away from the sheet with increases in K (figure.8). The fluid's temperature enhances corresponding to the influence of material parameter (Figure.9).

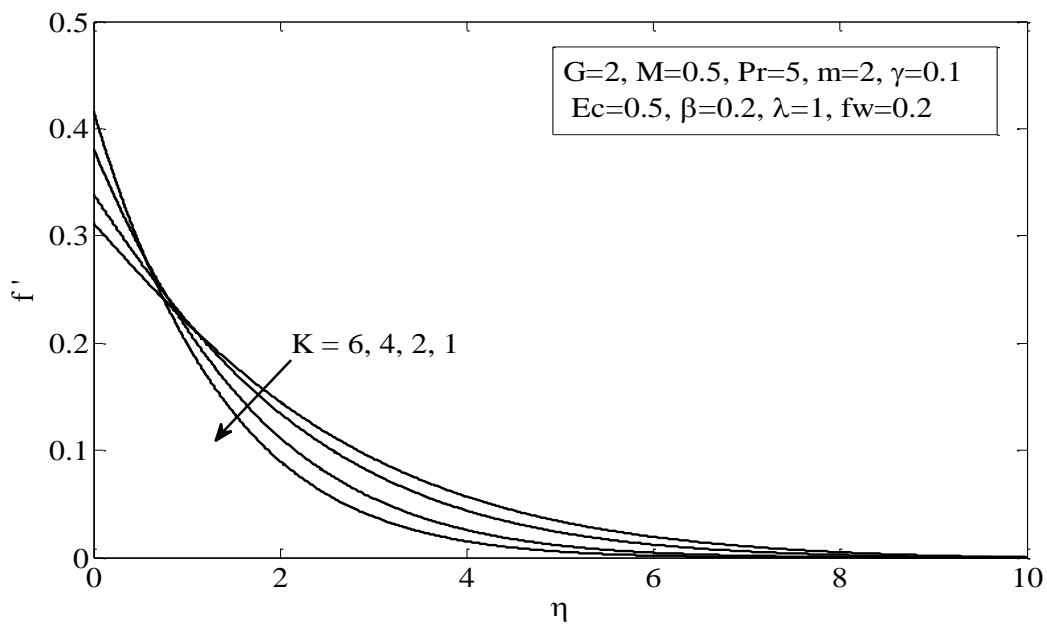


Figure 7.Velocity for various numerical values of K

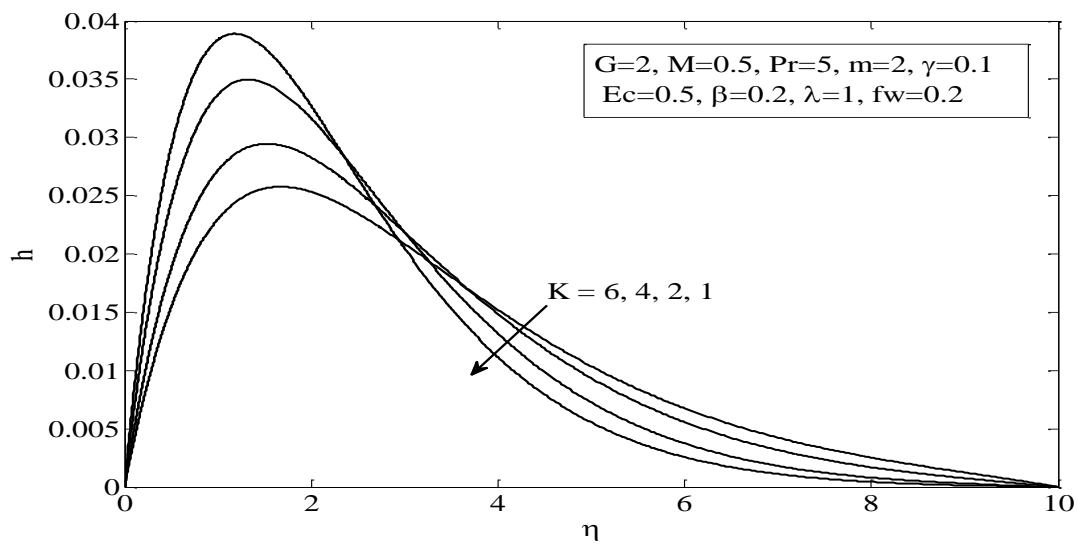


Figure 8.Angular velocity for various numerical values of K

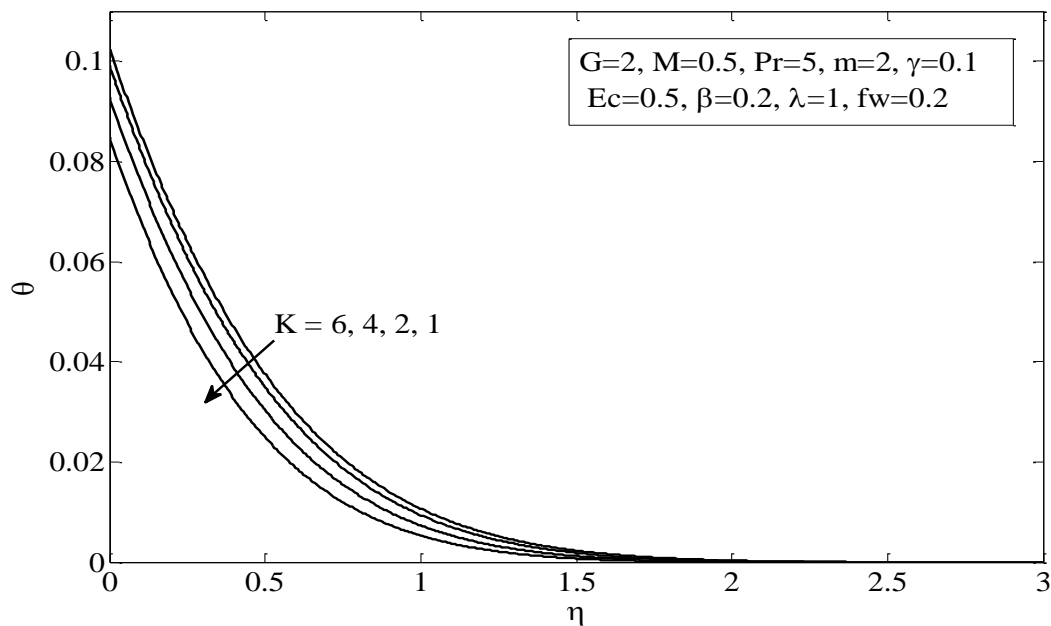


Figure 9. Numerical values of Temperature Vs various numerical values of K

Figures 10 and 12 show the consequences of momentum slip parameter λ over the velocity as well as temperature profiles respectively. Velocity and angular velocity distribution along the boundary layer are found to decrease with increasing momentum slip parameter (see figures 10 & 11), but the temperature of the fluid increases with increasing λ (see figure 12).

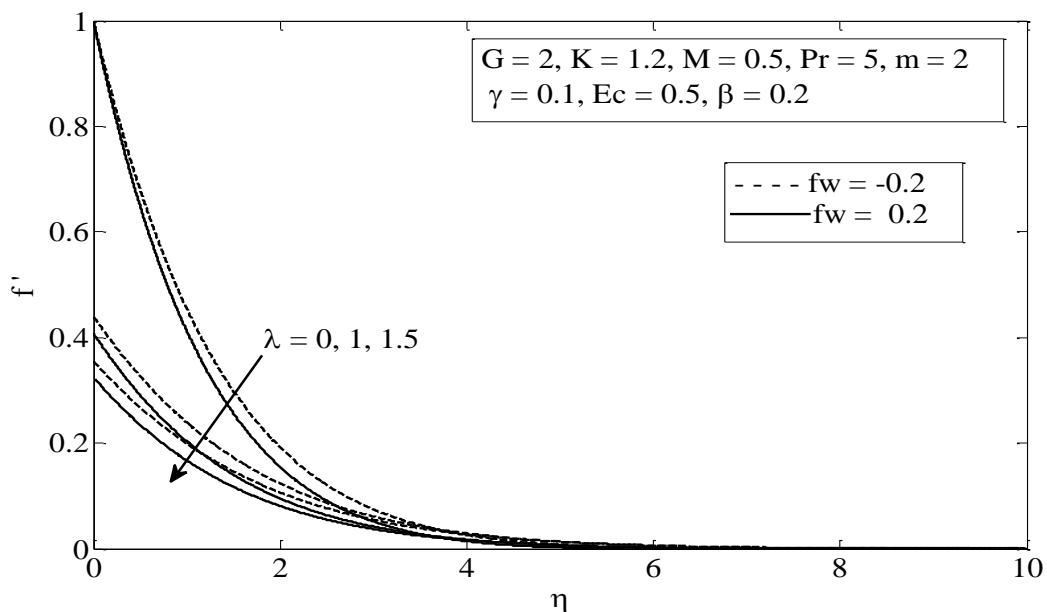


Figure 10. Velocity for various numerical values of λ

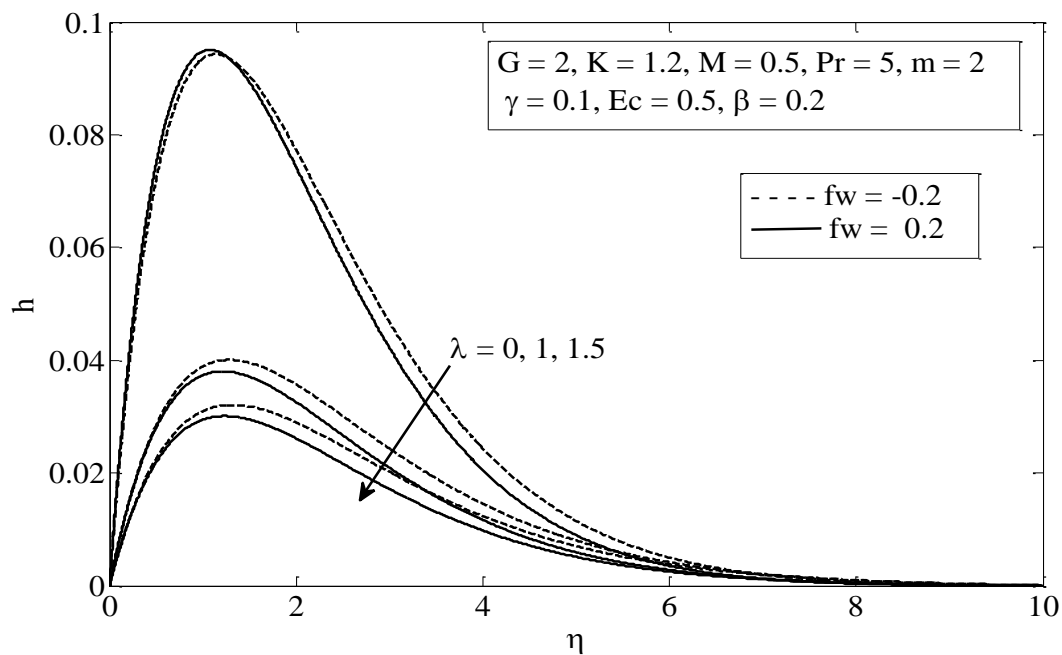


Figure11.Angular velocity for different numerical values of λ

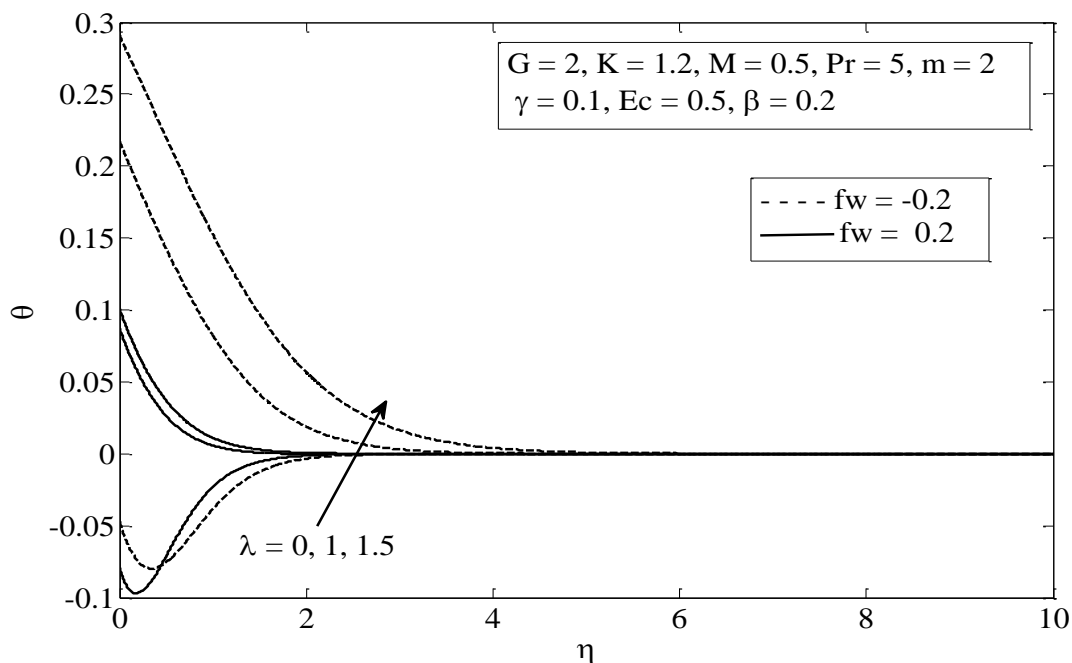


Figure12.Temperature Vs various numerical values of λ

Figures 13, 14 and 15 depict the consequence of the thermal slip parameter (β), Eckert number (Ec), heat generation/absorption parameter (γ) on temperature respectively. We observed the value of temperature rises corresponding to the influence of thermal slip parameter, Eckert number whereastemperature decreases with increases in the heat generation/absorption parameter (figure 15).

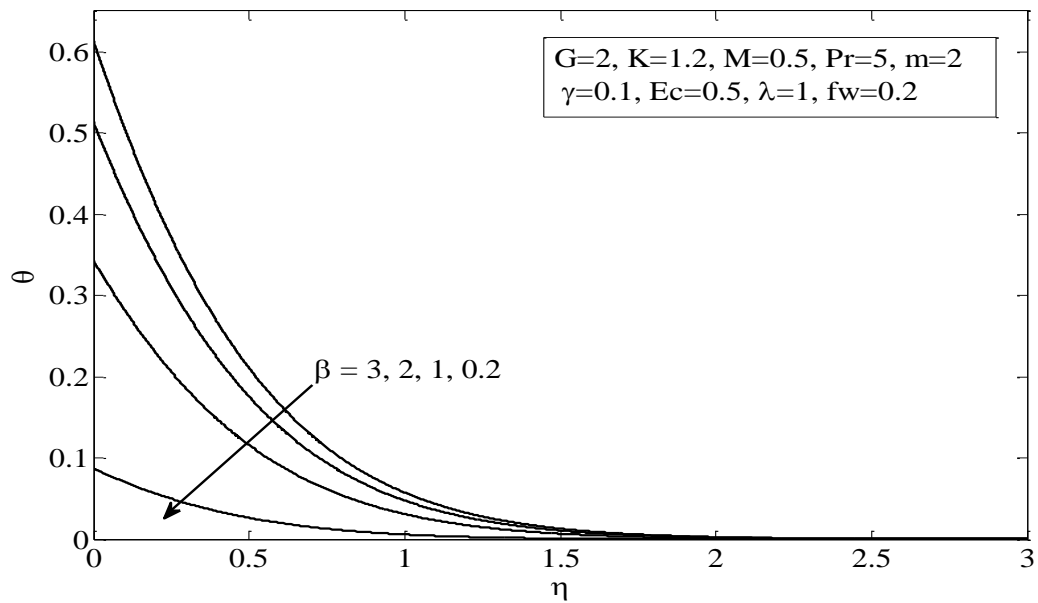


Figure 13.Temperature for various numerical values of β

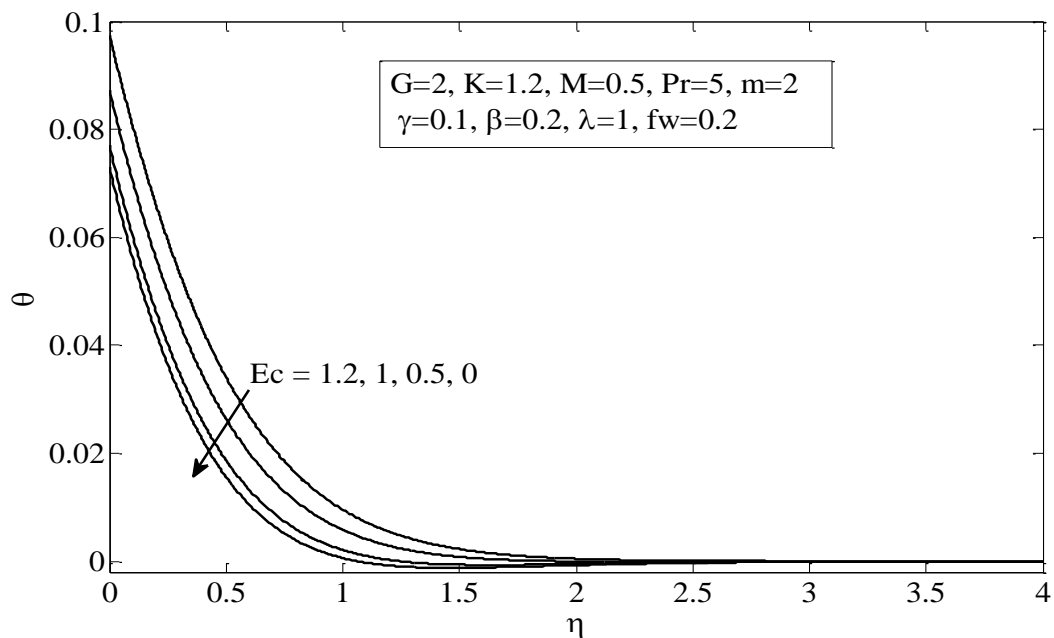


Figure 14.Temperature for various numerical values of Ec .

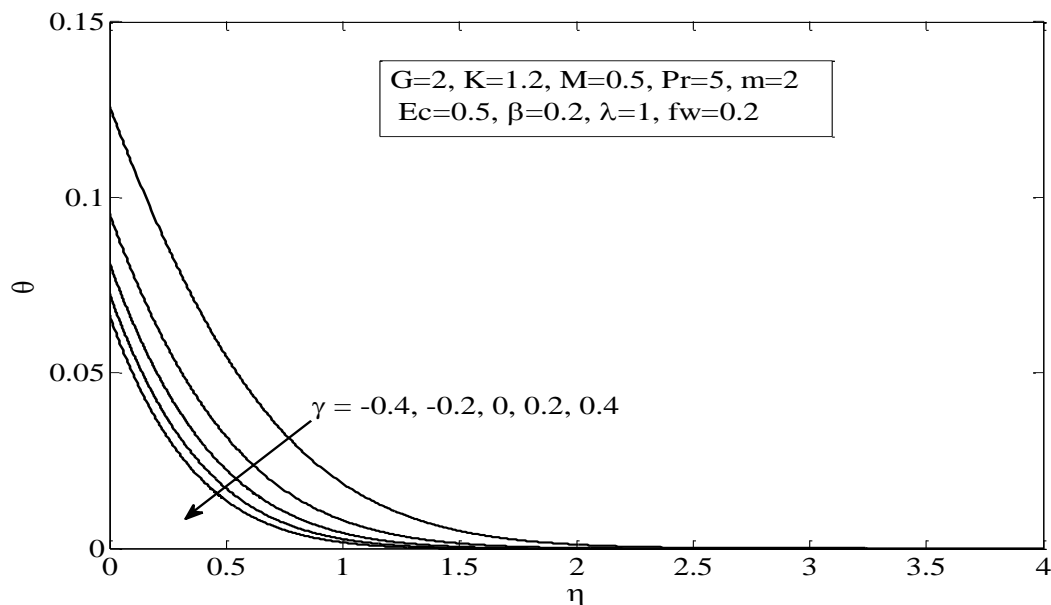


Figure 15.Temperature for various numerical values of γ

Effect of Prandtl number on temperature is shown in figure.16. We observed that the temperature of the fluid decreases with an increasing Pr. Physically at room temperature Pr=0.67 is Argon, Pr=0.69 is Helium, Pr=0.71 is air and Pr=0.76 are Carbon Dioxide.

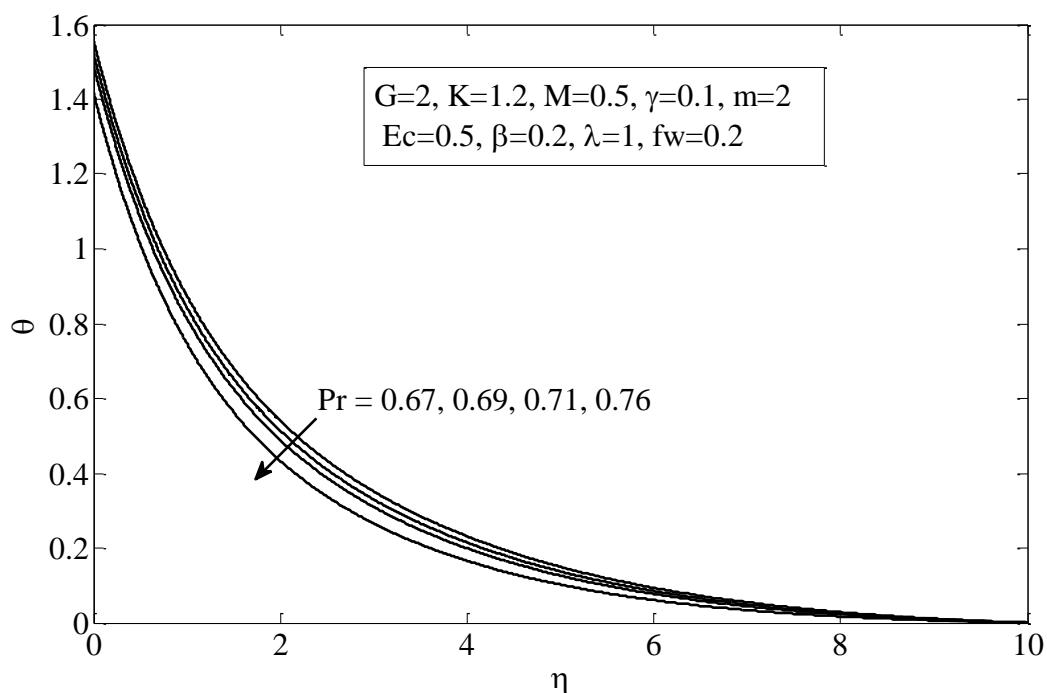


Figure 16.Temperature for different numerical values of Pr

The consequences of suction/injection parameter, magnetic parameter as well as momentum slip parameter on skin friction are exposed in the figure. 17. It is found that skin friction coefficient reduces corresponding to increasing λ , whereas skin friction increases with an increasing orfw.

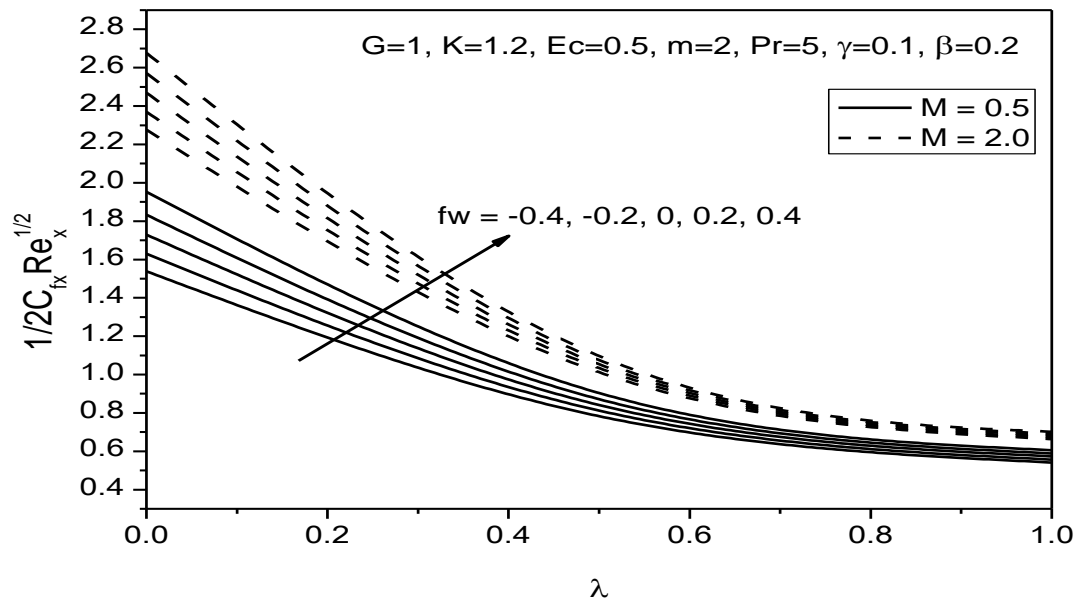


Figure 17. Local Skin-friction for diverse numerical values of M, fw, and λ

Figure 18 illustrates the consequences of suction/injection parameter, magnetic parameter and momentum slip parameter on couple wall stress. It is observed that the couple wall stress rises with raising orfw whereas it decreases with an increasing λ .

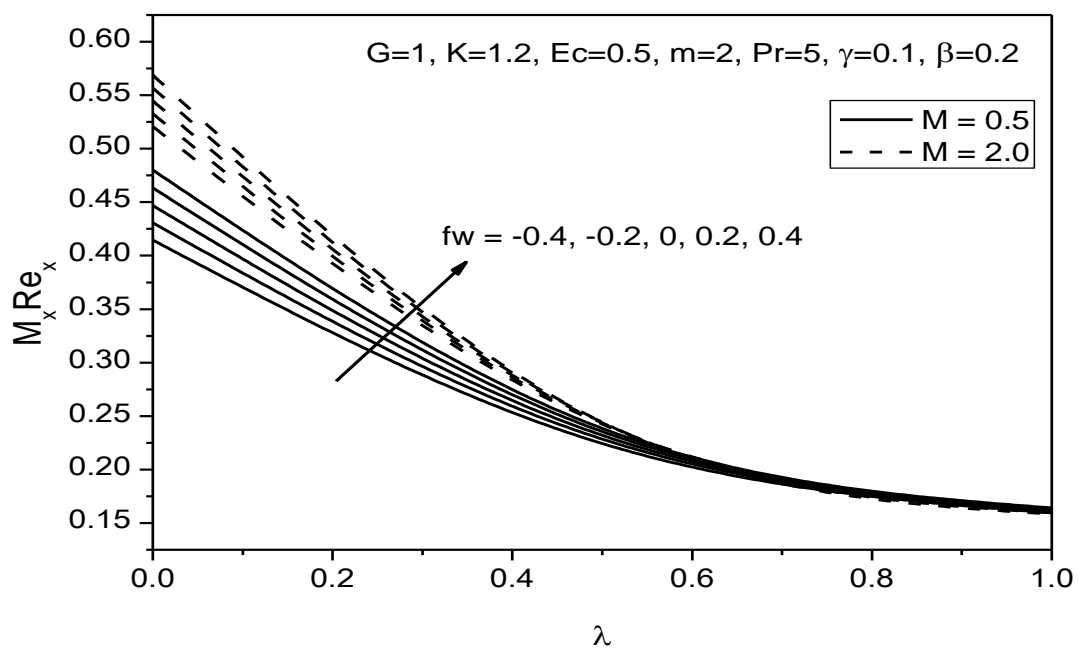
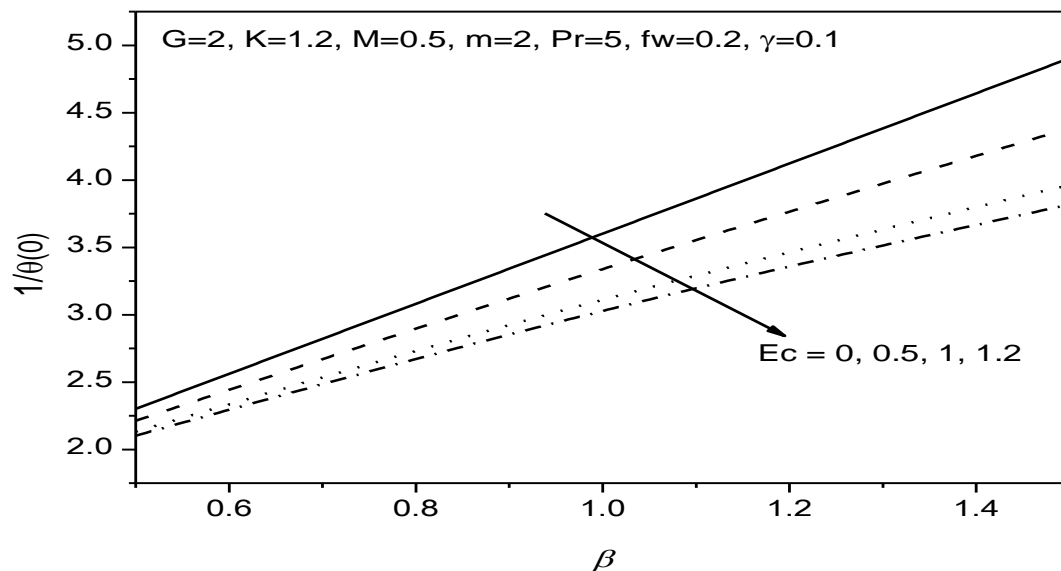


Figure 18. couple wall stress for various values of M , f_w and λ

The consequences of Eckert number and thermal slip parameter on the Local Nusselt number are exposed in the figure. 19. We observed that Local Nusselt number enhances corresponding to the influence of β , whereas it decreases with raising Ec .

**Figure 19.** Local Nusselt number for different numerical values of Ec and β

5. Conclusions

In the current paper, MHD flow, as well as heat transmission for an electrically conducting micro polar fluid past a porous elongating surface including slip flow in the company of viscous dissipation and temperature dependent slip flow, are investigated. The governing equations are accurate to a scheme of ordinary differential equations of degree greater than one with the help of similarity conversion. Numerical computations are implemented for diverse values of the dimensionless parameters of the question. It has been found that

1. The velocity and angular velocity in addition to temperature decreases raise in the suction/injection parameter
2. Momentum slip parameter reduces the velocity as well as angular velocity, and hysteresis in the temperature.
3. Thermal slip parameter or Eckert number enhances the temperature, whereas reduces the temperature with an increase in the heat production or inclusion parameter or Prandtl number.
4. The skin friction as well as couple stress reduce rising the momentum slip parameter and skin friction and couple wall stress enhance by raising the suction/injection parameter or the magnetic parameter.
5. Local Nusselt number reduces with raising the Eckert number and Local Nusselt number enhances by raising the thermal slip parameter.

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