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EFFECTS OF THERMAL RADIATION AND SUCTION/INJECTION ON MAGNETOHYDRODYNAMIC BOUNDARY LAYER FLOW OF A MICROPOLAR FLUID PAST A WEDGE EMBEDDED IN A POROUS STRATUM

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AbstractAn analysis has been carried out to study the effects of thermal radiation and suction or injection on two-dimensional magnetohydrodynamic laminar boundary layer flow of a micropolar fluid past a wedge embedded in a porous stratum. The fluid assuming to be viscous, incompressible and electrically conducting micropolar fluid. The radiative heat flux in the energy equation is described by Rosseland approximation. The governing partial differential equations are derived and transformed using a similarity transformation. The transformed equations are solved using MATLAB bvp4c code. Numerical results are presented graphically for the distribution of velocity, microrotation and temperature profiles with in the boundary layer.

1 Introduction

A boundary layer is a flow of a fluid over a body is an important phenomenon in fluid mechanics. Sakiadis [1] analysed the boundary layer produced by a sheet issuing with constant speed from a slit into a fluid at rest and found that the flow was of Blasius type, in which the boundary layer thickness increased with the distance from the slit. An extension to this problem Lawrence Crane [2] studied the analytical solution to the boundary layer equations for the problem of steady two-dimensional flow over a stretching surface. The flow in this case finds certain similarities with in the Hiemenz [3] boundary layer flow near a stagnation point in which the mainstream velocity is proportional to the distance from the stagnation point. H. Schlitchting and K Gersten [4] explained a few analyses on the boundary layer flow past a wedge with different angles from flat plate at zero incidences to two-dimensional stagnation flows. The study of the boundary layer flow field adjacent to wedge is very important and is an essential part in the area of fluid dynamics. Nowadays, a convectional flow of newtonian and non-newtonian fluid over the wedge becomes important.

The steady two-dimensional incompressible laminar boundary layer flow over a wedge with uniform suction/injection has been carried out by Watanabe et al. [5]. Magnetohydrodynamic is the study of fluid flow in an electrically conducting fluid in the presence of electromagnetic field that affects the fluid flow characteristics. Magnetic fields are used in technological processes such as MHD power generator designs, plasma studies, petroleum industries, MHD pumps, Nuclear reactors cooling etc. Magnetohydrodynamic is significant in the control of boundary layer flow and metallurgical processes. The steady two-dimensional boundary layer flow past a wedge with suction/injection of a newtonian fluid have been investigated by Kafoussias and Nanousis [6], Kandasamy et al. [7, 8], Nanousis [9]. Srinivasacharya et al. [10] analysed the steady laminar magnetohydrodynamic boundary layer flow of a nanofluid past a fixed wedge.

The flow along a porous stratum have a variety of applications such as electronic cooling, packed bed reactors, extraction of crude oil, ground water hydrology, geothermal systems, industrial and agricultural assignment.The steady two-dimensional magnetohydrodynamic boundary layer flow of a viscous fluid over a constant wedge with porous medium has been studied by Ramesh et al. [11]. Baag et al. [12] analysed the magnetohydrodynamic boundary layer flow over a stretching sheet embedded in a porous medium with the transfer of heat. Rashad and Bakier [13] analysed magnetohydrodynamic effects on non-Darcy forced convection boundary layer flow over a permeable wedge embedded in a porous medium with uniform heat flux. Anbuchezhian et al. [14] described the magnetohydrodynamic laminar boundary layer flow past a porous wedge with the effects of variable and temperature in the presence of chemical reaction.

The study of heat transfer in the boundary layer flow of an incompressible newtonian fluid with dependent viscosity temperature past a non-isothermal wedge in the presence of thermal radiation and heat generation/absorption has been analysed by Dulal Pal and Hiranmoy Mondal [15]. Govind Rajput et al. [16] investigated the study of the buoyancy effects on the magnetohydrodynamic flow past a stretching sheet with in porous medium by considering the effect of radiation. Xiaohong Su et al. [17] examined the magnetohydrodynamic mixed convection flow over a permeable stretching wedge in the presence of thermal radiation and ohmic heating and also proposed a new analytical method named DTM-BF. Paresh Vyas and Ashutosh Ranjan [18] carried out the magnetohydrodynamic boundary layer flow over a stretching sheet with the effects of the thermal radiation and heat transfer dissipation in a porous medium.

Over the past decades a great interest in flow of a micropolar fluid has been increased substantially due to phenomenon of these fluids in industrial processes. Eringen [19, 20], pioneering researcher who has formulated the theory of micropolar fluid. This theory describes the effects of microscopic arising from the local structure and micro-motions of the fluid elements and is capable of explain the behaviour of an animal crystals and real fluids with suspensions. Hassan [21] examined the thermal radiation effect on the flow of a micropolar fluid past a continuous moving plate with suction/injection. Uddin and Kumar [22] examined the magnetohydrodynamic boundary layer flow of a micropolar fluid past a wedge by considering viscous dissipation, joule heating, hall and ion-slip effects. Gnaneswara Reddy [23] described the steady thermal boundary layer flow induced by a stretching sheet immersed in an incompressible micropolar fluid in presence of constant surface temperature with the effects of radiation and heat generation. The steady two-dimensional boundary layer flow over a wedge with variable wall temperature and constant wall heat flux has been analysed by Ishak et al. [24, 25]. Uddin and Kumar [27] investigated the magnetohydrodynamic boundary layer flow over a wedge in presence of Joule heating, viscous dissipation and hall and ion-silp effects. Vanita [28] studied the unsteady laminar boundary layer flow of a micropolar fluid due to a moving wedge. Srivasacharya et al. [29] analysed the variable magnetic field effects on magnetohydrodynamic boundary layer flow of nanofluid past a wedge. Alok Kumar Pandey and Manoj Kumar [30] examined the two-dimensional steady magnetohydrodynamic nanofluid flow past a wedge with influence of thermal radiation, chemical reaction and viscous-ohmic dissipation. Wubshet Ibrahim and Ayele Tulu [31] revealed the influence of viscous dissipation on magnetohydrodynamic laminar boundary layer flow through a wedge by heat and mass transfer of nanofluid within a porous media with the effects of Brownian and Thermophoresisi parameters. The magnetohydrodynamic boundary layer flow of a micropolar fluid over continuous moving stretching surface embedded in a non-Darcian porous medium with the effect of radiation has been extensively reviewed by Mostafa et al. [32]. Syam Sundar Majety and Gangadhar [**?**] studied the magnetohydrodynamic boundary layer flow over a wedge embedded in a porous medium with effects of viscous dissipation, heat source, thermal radiation and chemical reaction. Therefore, the objective of this paper is to examine the steady two-dimensional magnetohydrodynamic boundary layer flow of a micropolar fluid past a wedge embedded in a porous stratum with the effects of thermal radiation and suction/injection. In energy equation the Rosseland approximation is considered to describe the radiative heat flux. Hence the contribution of radiation only through the equation of energy. The transformed boundary layer governing equations were solved using MATLAB bvp4c code. The obtained results are presented graphically for velocity, angular velocity and temperature profiles.

2 Analysis

Fig.1 indicates the geometry of the problem under consideration. The following assumptions are made in order to simplify the solution.

(i) the steady, two-dimensional magnetohydrodynamic laminar boundary layer flow of an incompressible electrically conducting micropolar fluid over a wedge as shown in figure 1.

(ii) let x-axis be parallel to the wedge and y-axis be normal to it

(iii) an uniform transverse magnetic field with constant strength B_0 is applied parallel to the y-axis

(iv) the wedge embedded in a porous stratum

(v) the thermal radiation and suction/injection effects are considered.

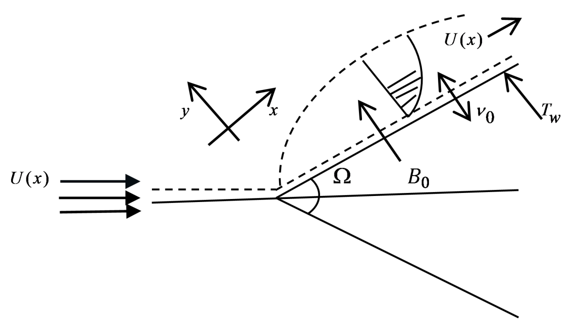

Figure 1. Schematic diagram of the physical flow problem

Under these assumptions, the governing equations for two-dimensional laminar boundary layer flow can be written as ([25, 26]),
conservation of mass:

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

conservation of momentum:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=U\frac{dU}{dx}+\left(\frac{\mu+\kappa}{\rho}\right)\frac{\partial^2 u}{\partial y^2}+\frac{K}{\rho}\frac{\partial N}{\partial y}-\left(\frac{\sigma B_0^2}{\rho}+\frac{\nu}{K^*}\right)u, \tag{2.2}$$

conservation of angular momentum:

$$\rho j\left(u\frac{\partial N}{\partial x}+v\frac{\partial N}{\partial y}\right)=\frac{\partial}{\partial y}\gamma\left(\frac{\partial N}{\partial y}\right)-\kappa\left(2N+\frac{\partial u}{\partial y}\right), \tag{2.3}$$

micro inertia:

$$u\frac{\partial j}{\partial x}+v\frac{\partial j}{\partial y}=0, \tag{2.4}$$

conservation of energy

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{\nu}{P_r}\frac{\partial^2 T}{\partial y^2}+\frac{\sigma B_0^2}{\rho c_p}u^2-\frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}, \tag{2.5}$$

the boundary conditions are,

$$y = 0; \quad u = 0, \qquad v = v_0, \qquad j = 0, \qquad N = -\frac{1}{2}\frac{\partial u}{\partial y}, \qquad T = T_w,$$

$$y \to \infty; \qquad u = U(x), \qquad N \to 0 \qquad j \to 0, \qquad T = T_\infty. \tag{2.6}$$

The radiative heat flux q_r, by using Rosseland approximation as follows,

$$q_r = -\frac{4\sigma_s}{3K_e}\frac{\partial(T^4)}{\partial y}, \tag{2.7}$$

where, σ_s and K_e be the Stefan-Boltzman constant and mean absorption coefficient, respectively. We assume that the term T^4 can be expressed as a linear function of temperature difference within the flow. By expanding T^4 in a Taylor series about terms at free stream T_∞ as :

$$T^4 = T_\infty^4 + 4T_\infty^3(T - T - \infty) + 6T_\infty^2(T - T_\infty)^2 + ...$$

and then neglecting higher order terms beyond the first degree in $(T - T_\infty)$ we get,

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4. \tag{2.8}$$

By applying above approximation to (2.7), we have

$$q_r = -\frac{16\sigma_s T_\infty^3}{3K_e}\frac{\partial T}{\partial y}. \tag{2.9}$$

From equations (2.8) and (2.9) eq.(2.5) can be written as,

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{\nu}{Pr}\frac{\partial^2 T}{\partial y^2} + \frac{\sigma B_0^2}{\rho Cp}u^2 + \frac{1}{\rho Cp}\frac{16\sigma_s T_\infty^3}{3K_e}\frac{\partial^2 T}{\partial y^2}. \tag{2.10}$$

In the above equations u, v are the velocity components along and perpendicular to the wall; U, is the flow velocity at the outer edge of the boundary layer; ν, the kinematic viscosity; v_0, velocity of the suction/injection; T, temperature of the fluid; ρ, density of the fluid; B_0 , the applied magnetic field strength; P_r , Prandtl number; N, angular velocity outside the boundary layer; q_r, radiative heat flux; λ, porosity stratum parameter; κ, the gyro-viscosity; j , micro-inertia density; μ, dynamic viscosity; γ, spin gradient viscosity; T_w, temperature at the wall.
The velocity of the free stream from the wedge is of the form $U(x) = cx^m$ where,$m = \frac{\beta}{2-\beta}$ and β is the Hartree pressure gradient parameter that corresponds to $\beta = \frac{\Omega}{\phi}$ for a total angle Ω of the wedge and c is a positive constant. We have noticed that $0 \leq$ m ≤ 1 with $m = 0$ for the boundary layer flow over a stationary flat plate (Blasius problem) and $m = 1$ for the flow near the stagnation point on an infinite wall.
The spin gradient viscosity γ can be written as

$$\gamma(x, y) = \left(\mu + \frac{\kappa}{2}\right)j(x, y) = \mu\left(1 + \frac{K}{2}\right)j(x, y) \tag{2.11}$$

Where $K = \frac{\kappa}{\mu}$ denotes dimensionless viscosity ratio and is known as material parameter. Equation (2.11) is importuned to allow the field of equations predicts the correct behavior in the limiting case when the microstructure effects become negligible and the total spin N reduces to the angular velocity. It is stated by Ahmadi [34] that for a non-constant microinertia, it is possible using equation (2.11) to find similar and self-similar solutions for a large number of problems of micropolar fluids. We notice that the case $K = 0$ describes the classical Navier-Stokes equation for a viscous and incompressible fluid.
Following dimensionless similarity transformations will be introduced,

$$f(x, \eta) = \left(\frac{2}{m+1}\nu x U\right)^{-1/2}, \qquad \Theta(x, \eta) = \frac{T - T_\infty}{T_w - T_\infty}, \qquad \eta = \left(\frac{m+1}{2}\frac{U}{\nu x}\right)^{1/2} y,$$

$$j(x,y) = \frac{2\nu x}{(m+1)U} i(\eta), \qquad N(x,y) = U\left(\frac{(m+1)U}{2\nu x}\right) h(x,\eta). \tag{2.12}$$

The equation of continuity (2.1) is identically satisfied by the stream function $\psi(x,y)$ can be defined as,

$$u = \frac{\partial \psi}{\partial y} \qquad and \qquad v = -\frac{\partial \psi}{\partial x}. \tag{2.13}$$

The governing partial differential equations (2.2), (2.3), (2.4) and (2.10) becomes,

$$(1+K)\frac{\partial^3 f}{\partial \eta^3} + f\frac{\partial^2 f}{\partial \eta^3} + \frac{2m}{m+1}\left\{1 - \left(\frac{\partial f}{\partial \eta}\right)^2\right\} + K\frac{\partial h}{\partial \eta} = \frac{2}{m+1} x\left\{\frac{\partial^2 f}{\partial x \partial \eta}\frac{\partial f}{\partial \eta} - \frac{\partial f}{\partial x}\frac{\partial^2 f}{\partial \eta^2}\right\}$$

$$+\left(\frac{\sigma B_0^2}{\rho U} + \frac{\nu}{K^*}\right)\frac{2x}{m+1}\frac{\partial f}{\partial \eta}, \tag{2.14}$$

$$\left(1+\frac{K}{2}\right)\left(i\frac{\partial h}{\partial \eta}\right) + i\left(f\frac{\partial h}{\partial \eta} - \left(\frac{3m-1}{1+m}\right)h\frac{\partial f}{\partial \eta}\right) - K\left(2h + \frac{\partial^2 f}{\partial \eta^2}\right) = 0, \tag{2.15}$$

$$(1-m)\frac{\partial f}{\partial \eta} i - \left(\frac{1+m}{2}\right) f\frac{\partial i}{\partial \eta} = 0, \tag{2.16}$$

$$\frac{\partial^2 \theta}{\partial \eta^2} + P_r\frac{2}{m+1}x\left\{\left(\frac{\partial \theta}{\partial x}\frac{\partial f}{\partial \eta} - \frac{\partial f}{\partial \eta}\frac{\partial \theta}{\partial \eta}\right) - \frac{\sigma B_0^2 U(x)}{\rho c_p (T_w - T_\infty)}\left(\frac{\partial f}{\partial \eta}\right)^2\right\} - \frac{1}{\rho c_p}\frac{\partial q_r}{\partial y}, \tag{2.17}$$

The boundary conditions (2.6) becomes

$$\eta = 0;\ \ \frac{\partial f}{\partial \eta} = 0,\ \ \frac{1}{2}f + \frac{1}{2}\frac{x}{U}\frac{dU}{dx}f + x\frac{\partial f}{\partial x} = -v_0\left(\frac{m+1}{2}\frac{x}{U\nu}\right)^{1/2},\ \ i(0) = 0,\ \ h(0) = -\frac{1}{2}f''(0),\ \ \theta(0) = 1,$$

$$\eta \to \infty;\ \ \frac{\partial f}{\partial \eta} \to 1,\ \ h(\infty) \to 0,\ \ \theta(\infty) \to 0. \tag{2.18}$$

By introducing the dimensionless parameters

$$s = -v_0\left(\frac{m+1}{2}\frac{x}{U\nu}\right)^{1/2} = \pm k x^{(1-m)/2} \qquad \text{(suction/injection parameter)}$$

$$M_p = \frac{\sigma B_0^2}{\rho c k^2} \qquad \text{(Magnetic parameter)}$$

$$E_c = \frac{c^2}{c_p (T_w - T_\infty) k^(4m/(1-m))} \qquad \text{(Eckert number)}$$

$$P_r = \frac{\mu c_p}{k} \qquad \text{(Prandtl number)}$$

$$R = \frac{16\sigma_s T_\infty^3}{3kK_e} \qquad \text{(Radiation parameter)}$$

$$\lambda = \frac{\nu}{K^*U} \qquad \text{(Porous stratum parameter)} \tag{2.19}$$

Where v_0 is the velocity of suction or injection, when $v_0 < 0$ and $v_0 > 0$, respectively. The equations (2.14) to (2.17) and boundary conditions (2.18) can be written as,

$$\frac{\partial^3 f}{\partial \eta^3} + \left(f + \frac{1-m}{1+m}\xi\frac{\partial f}{\partial \xi}\right)\frac{\partial^2 f}{\partial \eta^2} - \left(\frac{2}{1+m}(M_p+\lambda)\xi^2 + \frac{1-m}{1+m}\xi\frac{\partial^2 f}{\partial \xi \partial \eta}\right)\frac{\partial f}{\partial \eta}$$

$$+\frac{2m}{m+1}\left\{1-\left(\frac{\partial f}{\partial \eta}\right)^2\right\} + K\frac{\partial h}{\partial \eta} = 0, \tag{2.20}$$

$$\left(1+\frac{K}{2}\right)\left(i\frac{\partial h}{\partial \eta}\right)' + i\left(f\frac{\partial h}{\partial \eta} - \left(\frac{3m-1}{1+m}\right)h\frac{\partial f}{\partial \eta}\right) - K\left(2h + \frac{\partial^2 f}{\partial \eta^2}\right) = 0, \tag{2.21}$$

$$(1-m)\frac{\partial f}{\partial \eta}i - \left(\frac{1+m}{2}\right)f\frac{\partial i}{\partial \eta} = 0, \tag{2.22}$$

$$(1+R)\frac{\partial^2 \theta}{\partial \eta^2} + P_r\left\{\frac{2}{m+1}M_pE_c\xi^{2(1+m/1-m)}\left(\frac{\partial f}{\partial \eta}\right)^2 - \left(\frac{\partial f}{\partial \eta}\right)^2 - \left(\frac{1-m}{1+m}\xi\frac{\partial \theta}{\partial \xi}\right)\frac{\partial f}{\partial \eta}\right\} = 0, \tag{2.23}$$

$$\eta = 0; \qquad \frac{\partial f}{\partial \eta} = 0, \qquad \frac{1+m}{2}f + \frac{1-m}{2}\xi\frac{\partial f}{\partial \xi} = s, \qquad i(0) = 0, \qquad h(0) = -\frac{1}{2}f''(0), \qquad \theta(0) = 1,$$

$$\eta \to \infty; \qquad \frac{\partial f}{\partial \eta}, \qquad h(\infty) \to 0, \qquad \theta(\infty) \to 0. \tag{2.24}$$

Where s is suction ($s > 0$) and injection ($s < 0$) parameter and $\xi = kx^{(1-m)/2}$ is the dimensionless distance along the wedge ($\xi > 0$). In this system of equations $f(\xi, \eta)$ is dimensionless stream function, $\theta(\xi, \eta)$ is the dimensionless temperature and $h(\xi, \eta)$ is the dimensionless microrotation, P_r is the Prandtl number, m is the pressure gradient, s is the suction/injection, M_p is the magnetic parameter, K is the material parameter, E_c is the Eckert number which are defined in equations (2.19).
The parameter ξ denotes the dimensionless distance along the wedge($\xi < 0$) . It is clear that to retain the ξ - derivative terms, it is necessary to employ a numerical scheme suitable for the solution of partial differential equations. In addition, owing to the coupling between adjacent streamwise location through the ξ derivatives, a locally autonomous solution at any given stream wise location, cannot be obtained. Therefore, in such a case an implicit marching numerical solution scheme is usually applied proceeding the solution in the direction of ξ, i.e., calculating unknown profiles at ξ_{i+1} when the same profiles at ξ_i are known. The process starts at $\xi = 0$and solution proceeds from ξ_i to ξ_{i+1} but such a procedure is time consuming.
However, when the terms involving $\frac{\partial f}{\partial \xi}$, $\frac{\partial \theta}{\partial \xi}$ and $\frac{\partial h}{\partial \xi}$ their η derivatives are deleted, the resulting system of equations resembles, in effect a system of ordinary differential equations for the function f, θ and h with ξ as a parameter and the computational task is simplified. Furthermore, a locally autonomous solution for any given ξ can be obtained because the stream wise coupling is served.

Now, by the above mentioned factors, the system of equations (2.20) to (2.23) with boundary conditions (2.24) can also be written as,

$$(1+K)f_{\eta\eta\eta} + ff_{\eta\eta} + \frac{2m}{1+m}(1-(f')^2) - \frac{2}{m+1}M_p\xi^2 f' + Kh' - \frac{2}{1+m}\xi^2(M_p+\lambda)f' = 0, \tag{2.25}$$

$$\left(1+\frac{K}{2}\right)(ih_\eta)_\eta + i\left(fh_\eta - \left(\frac{3m-1}{1+m}\right)hf_\eta\right) - K(2h+f_\eta) = 0, \tag{2.26}$$

$$(1-m)f_\eta i - \left(\frac{1+m}{2}\right)fi_\eta, \tag{2.27}$$

$$(1+R)\theta_{\eta\eta} + P_r f\theta_\eta + P_r\frac{2}{1+m}M_pE_c\xi^{2^{(1+m)/(1-m)}}f_\eta^2 = 0, \tag{2.28}$$

$$\eta = 0; \quad f(0) = \frac{2}{1+m}s, \quad f_\eta(0) = 0, \quad i(0) = 0, \quad h(0) = -\frac{1}{2}f_{\eta\eta}(0), \quad \theta(0) = 1$$

$$\eta \to \infty; \quad f_\eta(\infty) = 1, \quad h(\infty) \to 0, \quad \theta(\infty) \to 0. \tag{2.29}$$

Where prime denotes differentiation with respect to η.
If we integrate equation (2.27) we get

$$i = Af^{2(1-m)/(1+m)}, \tag{2.30}$$

where $h(\eta)$ is dimensionless constant of integration. If $K \neq 0$ but $A = 0$ i.e., $i = 0$ from equation (2.26) we can find,

$$h = -\frac{1}{2}f'', \tag{2.31}$$

i.e., the gyration is identical to the angular velocity. Then equation (2.25) become

$$\left(1+\frac{K}{2}\right)f_{\eta\eta\eta} + ff_{\eta\eta} + \frac{2m}{m+1}(1-(f_\eta)^2) - \frac{2}{1+m}M_p\zeta^2 f_\eta = 0. \tag{2.32}$$

3 Results and Discussion

The non-lnear ordinary differential eqautions (25) to (28) with boundary conditions (29) were solved using MATLAB bvp4c code. The obtained results are presented graphically for different values of material parameter K, suction/injection parameter s, magnetic parameter Mp, pressure gradient parameter m, radiation parameter R, porous stratum parameter λ and Prandtl number Pr, while other parameters were fixed. To get clear interpretation of the results, the numerical values are plotted as shown in figure 2 to 13.
Figure 2 illustrates the results of the variation of the s with fixed Mp, K, m and λ in the boundary layer region of the wedge. It is found that increase in suction/injection causes enhances in velocity along the wedge by the varying suction/injection parameter. Also figure 3 shows the variation of the s for fixed values of Mp, K, m, R and λ on the temperature field. The temperature profile $\theta(\eta)$ suppresses as s increases. Figure 4 indicates the velocity profile $f'(\eta)$ for different values of Mp. From this figure we conclude that for increasing values of Mp suppresses the velocity profile. Figure 5 depicts the effects of Mp on temperature profile $\theta(\eta)$. It is evident that increasing values of Mp there is an enhances in the temperature profile. Figure 6 plotted for the effect of pressure gradient parameter m on velocity profile $f'(\eta)$, when m is increasing there is significantly suppresses in velocity profile. Figure 7 drawn for temperature field for different values of pressure gradient parameter m in presence of some fixed parameter. The temperature profile suppresses as pressure gradient parameter m increases.
Figure 8 describes the variation of material parameter K on velocity in the region of the boundary layer of the wedge.It is inferring that for increasing values of K causes suppresses in velocity profile.
The effect of material parameter K on the temperature profile $\theta(\eta)$ as shown in figure 9. The temperature profile is enhances for incraesing values of K. Figure 10 illustrate the effect of porous stratum parameter λ on velocity profile $f'(\eta)$. It states that the increasing value of λ

suppresses the velocity field. Figure 11 shows the influence of Prandtl number P_r on temperature profile $\theta(\eta)$. From the figure we observe that an increaseing in Prandtl number causes suppresses in thickness and in general, with in boundary layer an average of temperature of fluid is small. In fact, for small values of P_r there is an increase in thermal conductivities and for large values ofP_r the transfer of heat is able to diffuse away from the heated surface more rapidly. So, we conclude that the boundary layer is thicker and the rate heat transfer is reduced for smaller values of P_r .The influence of thermal radiation R on temperature field is plotted in figure 12. It is discovered that for increasing values of R enhances the temperature with in boundary layer flow of the wedge. The radiation parameter R states the relative condition of conduction heat transfer to thermal radiation transfer and effective in the boundary layer flow. Figure 13 plotted for dimensionless microrotation profile for different values of K while other parameters are fixed. It evident that for increasing values of material parameter K microrotation profile suppresses and become zero for away from the surface.

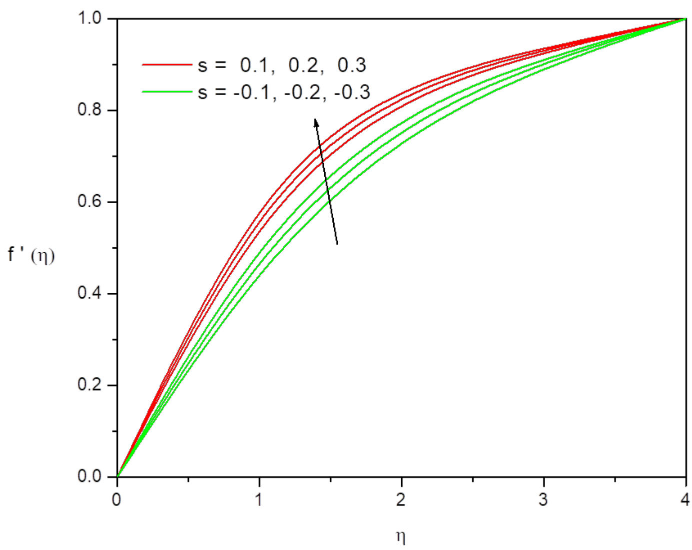

Figure 2. Influence of suction/injection parameter s on velocity profile $f'(\eta)$

4 Conclusion

The problem of steady two-dimensional magnetohydrodynamic laminar boundary layer flow of a micropolar fluid past a wedge embedded in a porous stratum with the effects of thermal radiation and suction/injection was investigated. A transformed set of coupled non-linear ordinary differential equation were solved by MATLAB bvp4c code. Some of the main important results of the present work are as follows,

(i) For increasing values of s the velocity profile enhances and temperature profile suppresses.

(ii) The velocity suppresses for increasing values of M_P, m, K, and λ.

(iii) The temperature profile suppresses for increasing values of m and P_r.

(iv) The temperature profile enhances for increasing values of M_p, K and R.

(v) The microrotation profile suppresses for increasing values of K.

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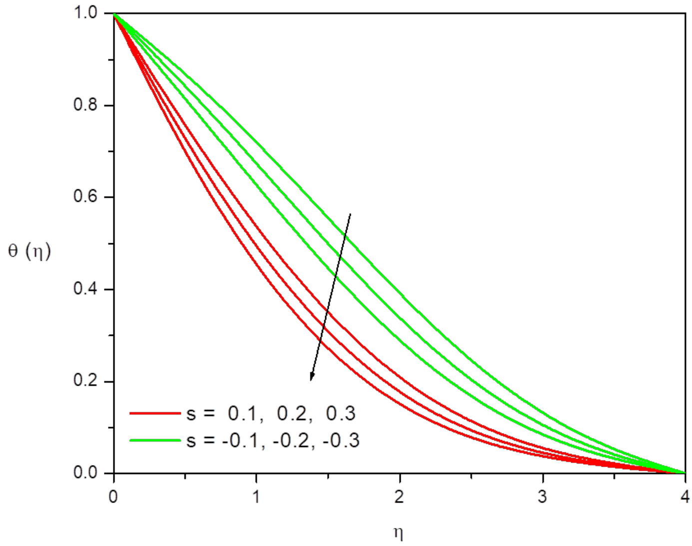

Figure 3. Influence of suction/injection parameter s on temperature profile $\theta(\eta)$

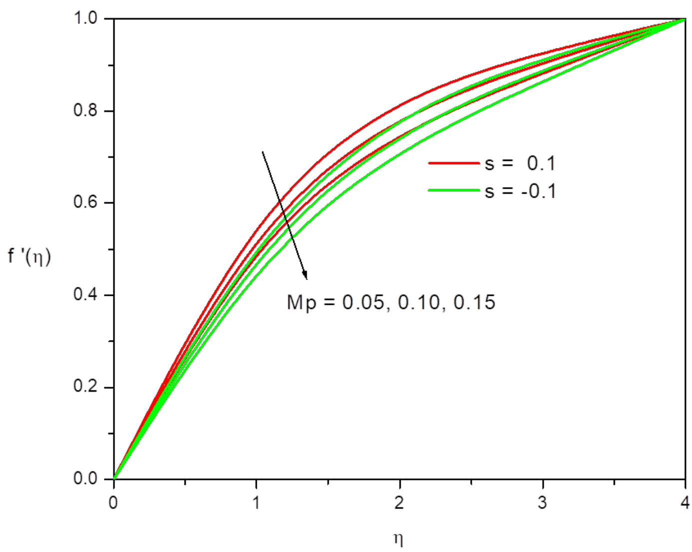

Figure 4. Influence of magnetic parameter Mp on velocity profile $f'(\eta)$

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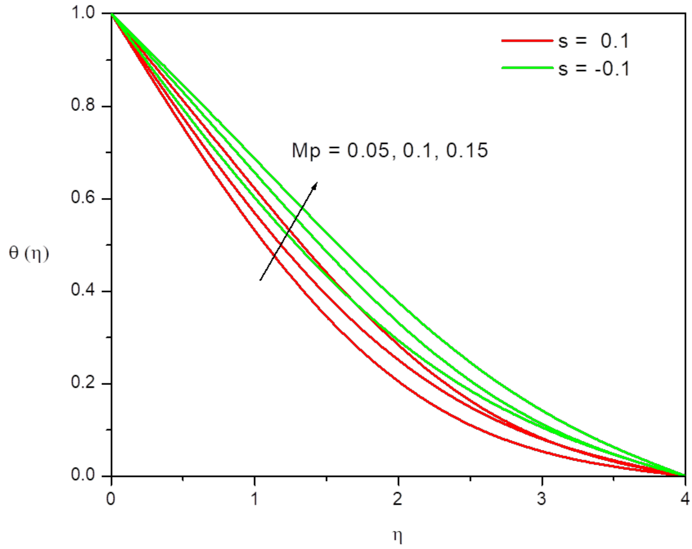

Figure 5. Influence of magnetic parameter Mp on temperature profile $\theta(\eta)$

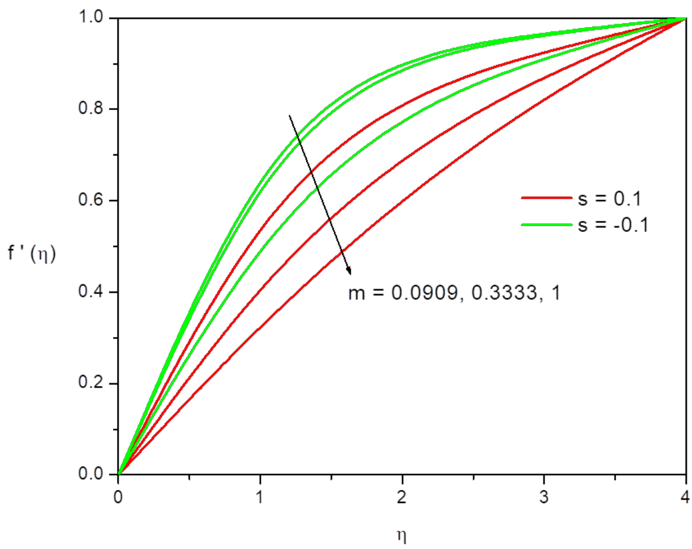

Figure 6. Influence of pressure gradient parameter m on velocity profile $f'(\eta)$

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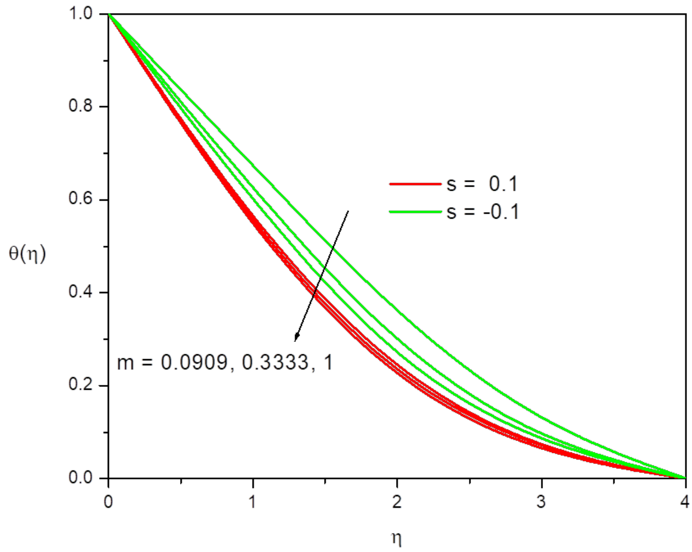

Figure 7. Influence of pressure gradient parameter m on temperature profile $\theta(\eta)$

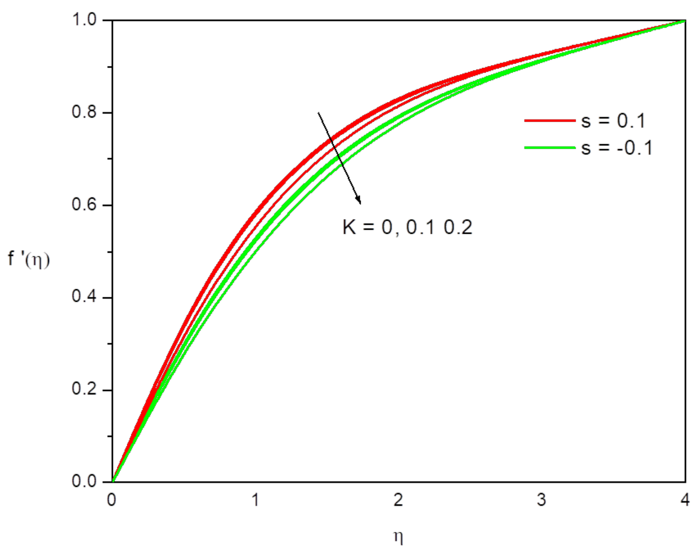

Figure 8. Influence of material parameter K on velocity profile $f'(\eta)$

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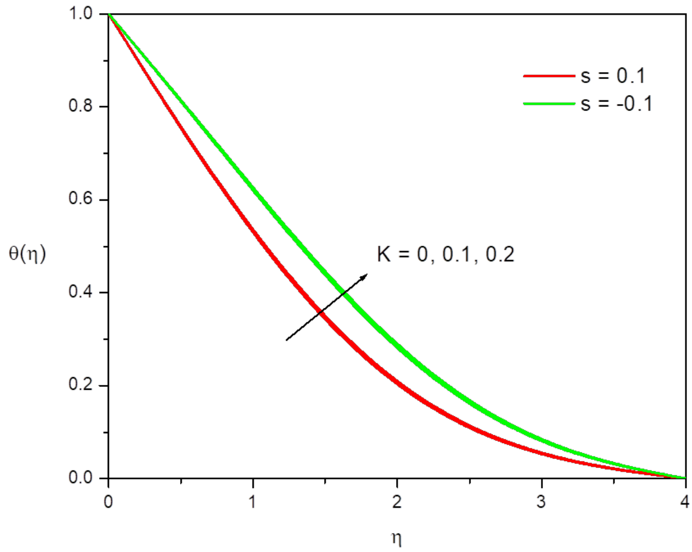

Figure 9. Influence of material parameter K on temperature profile $\theta(\eta)$

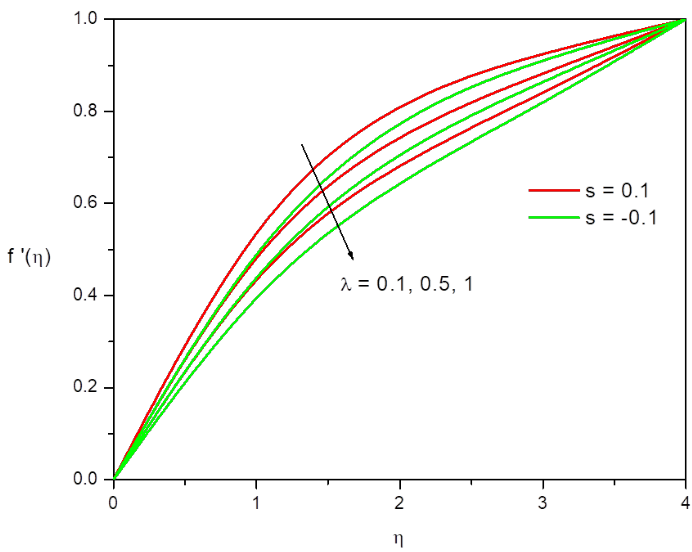

Figure 10. Influence of porous stratum parameter λ on velocity profile $f'(\eta)$

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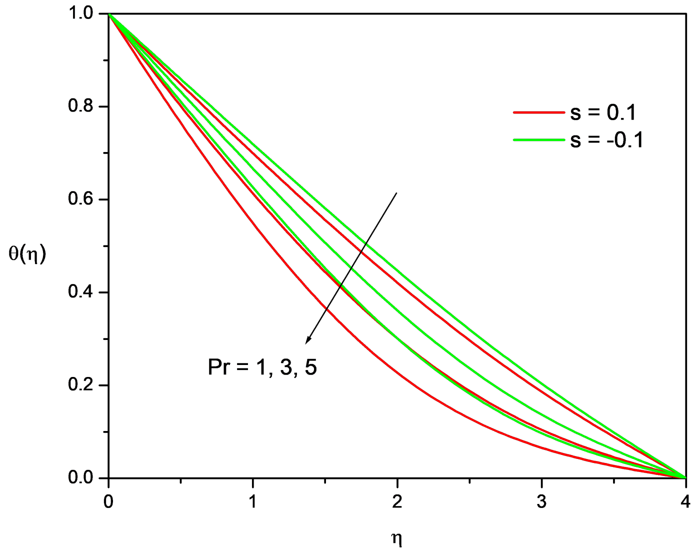

Figure 11. Influence of Prandtl number Pr on velocity profile $\theta(\eta)$

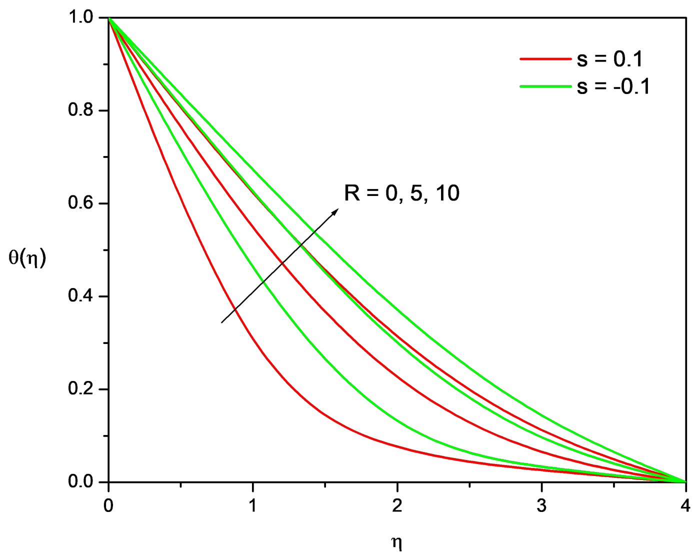

Figure 12. Influence of radiation parameter R on velocity profile $\theta(\eta)$

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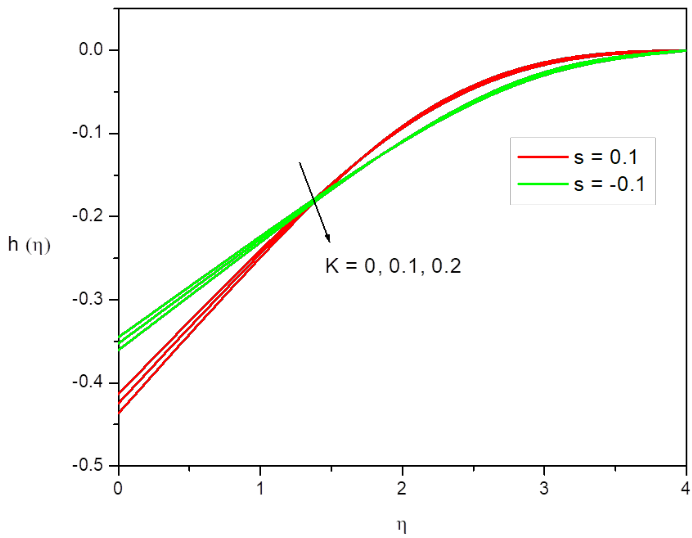

Figure 13. Influence of material parameter K on microrotation profile $h(\eta)$

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