TWO-DIMENSIONAL UNSTEADY MHD FREE CONVECTIVE FLOW OF A MICROPOLAR FLUID AND MASS TRANSFER THROUGH A POROUS MEDIUM OVER A SEMI- INFINITE MOVING POROUS PLATE IN THE PRESENCE OF HEAT SOURCE WITH CONSTANT HEAT AND MASS FLUX.

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Abstract: The aim of the present paper is to investigate the two-dimensional unsteady free convective flow of a viscous incompressible electrically conducting micropolar fluid and mass transfer through a porous medium over a semi-infinite moving non-conducting porous vertical plate in the presence of heat source, with constant heat and mass flux, under the influence of uniform magnetic field applied normal to the direction of flow. The velocity, temperature and concentration distributions are derived, discussed numerically and their profiles for various values of physical parameters are shown through graphs. Further, the non-dimensional shearing stress in terms of skin-friction coefficient at the plate is derived, discussed and it's numerical values of physical parameters are presented through table.

Key Words: Unsteady, MHD, free-convection, micropolar fluid, mass transfer, porous medium, heat source, heat flux, mass flux.

Introduction : Micropolar fluids contain micro-constituents, which can undergo rotation, the presence of which can affect the hydrodynamics of the flow so that it can be treated distinctly as a non-Newtonian fluid. The theory of this class of fluids was originally formulated by Eringen(1966) in the context of continuum fluid dynamics. Eringen's theory has provided a good model to study a number of complicated fluids, including the flow of low concentration suspensions, liquid crystals, blood and turbulent shear flows. Eringen's theory of microfluids has opened up new areas in research in the physics of fluid flow. According to his theory, a simple microfluid is a fluent medium whose properties and behavior are affected by the local motions of the material particles contained in each of its volume elements; such a fluid possesses local inertia. Microfluids are fluids consisting of randomly oriented particles suspended in a viscous medium[Lukaszewicz(1999)].

The free convection effect on micropolar fluid flow problems is very important in heat transfer studies and hence, has attracted the attention of numerous investigators. The flow arising from the differences in concentration or material constitution and in conjunction with temperature differences have great significance not only for their own interest but also for their applications to aeronautics and geophysics. TheFree convection effects on the oscillatory flow past an infinite, vertical, porous plate with constant suction was investigated by Soundelgekar (1976). The self-similar solution of incompressible micropolar boundary layer flow over a semi- infinite plate was studied by Ahmadi (1976).Jena and Mathur (1982) investigated the free convection in the laminar boundary layer flow of thermomicropolar fluid past a non-isothermal vertical flat plate with suction/injection. Rees and Bassom (1996) presented the Blasius boundary layer flow of micropolar fluids. The Joule heating effects on magnetohydrodynamic free convection flow of micropolar fluid was studied by El-Hakiem et.al.(1999). El-Amin (2001) presented the magnetohydrodynamic free convection and mass transfer flow in micropolar fluid with constant suction. The unsteady convection flow of micropolar fluids past a vertical porous plate embedded in a porous medium was investigated by Kim (2001). Kumar et al. (2002) studied the unsteady oscillatory laminar free convection flow of an electrically conducting fluid through a porous medium along a porous hot vertical plate with time dependent suction in the presence of heat source/sink. The numerical solution of free convection MHD micrropolar fluid flow between two parallel porous vertical plates was analyzed by Bhargava et al.(2003). Bodosa and Barkakati(2003) discussed the magnetic field effects on the free convection flow through porous medium due to an infinite vertical plate with uniform suction and constant heat flux. Sharma et al.(2004) presented the unsteady MHD flow and heat-transfer over a continuous porous moving horizontal surface in the presence of an oscillating free stream and heat source. The unsteady flow and heat transfer along a porous vertical surface bounded by porous medium was discussed by Sharma and Mishra(2005). Badruddin et al.(2005) investigated the free convection and radiation characteristics for a vertical plate embedded in a porous medium. Sharma and Yadav (2006) investigated the Three-dimensional flow and heat transfer through porous medium bounded by a porous vertical surface. The Effect of oscillatory suction and heat source on heat and mass transfer in MHD flow along a vertical moving porous plate bounded by porous medium was studied by Sharma and Sharma (2007). The heat and mass Transfer of an unsteady MHD natural convection flow of a rotating fluid past a vertical porous plate in the presence of radiative heat transfer was presented by Mbeledogu et al.(2007). The conjugate heat transfer free convection along a vertical plate fin was studied by Haiso (2010).Murthy,et al.(2011) discovered the thermo diffusion effect on free convection heat and mass transfer in a thermally linearly stratified non Darcy porous media. The effects of radiation, free convection and mass transfer on anunsteady flow of a micropolar fluid over a vertical moving porousplate immersed in a porous medium with time varying suction was studied by Kumar et al. (2012)

Aim of the present paper is to investigate the two-dimensional unsteady free convective flow of a viscous incompressible electrically conducting micropolar fluid and mass transfer through a porous medium over a semi-infinite moving non-conducting porous vertical plate in the presence of heat source, with constant heat and mass flux, under the influence of uniform magnetic field.

Formulation of the Problem

Consider the two-dimensional unsteady laminar flow of a viscous incompressible electrically conducting micropolar fluid over a semi-infinite non-conducting vertical moving porous plate embedded in a porous medium and subjected to a transverse magnetic field in the presence of heat source. The x^*-axis is taken along the porous plate in the upward direction and y^*-axis is normal to it. Flow is fully developed under the following assumptions:(i)There is no applied voltage implies the absence of an electric field.

(ii)The transversely applied magnetic field and magnetic Reynolds number are very small and hence the effect of induced magnetic field is neglected [Cowling (1957)].

It is assumed that the size of the pore of porous plate is significantly larger than a characteristic micropolar length scale of the porous medium. The porous medium is supposed as an assemblage of small identical spherical particles fixed in space [Yamamoto and Iwamura(1976)].As the bounding surface is semi-infinite in length, therefore all the physical variables of fluid are functions of y^* and t^* only.

Within the frame of these assumptions the equations which govern the free convection flow of an MHD micropolar flow in the presence of heat source under usual Boussinesq approximation are

Equation of Continuity

$$\frac{\partial v^*}{\partial y^*} = 0\,, \qquad ....(1)$$

Equation of Linear Momentum

$$\frac{\partial u^*}{\partial t^*} + v^* \frac{\partial u^*}{\partial y^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + (\upsilon + \upsilon_r)\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_f (T^* - T_\infty) + g\beta_c^*(C^* - C_\infty) - \frac{\upsilon u^*}{K^*} - \frac{\sigma}{\rho}B_0^2 u^* + 2\upsilon_r \frac{\partial \omega^*}{\partial y^*}, \qquad ...(2)$$

Equation of Angular Momentum

$$\rho\, J^*\left(\frac{\partial \omega^*}{\partial t^*} + v^* \frac{\partial \omega^*}{\partial y^*}\right) = \gamma \frac{\partial^2 \omega^*}{\partial y^{*2}}\,, \qquad ....(3)$$

Equation of Energy

$$\frac{\partial T^*}{\partial t^*} + v^* \frac{\partial T^*}{\partial y^*} = \alpha \frac{\partial^2 T^*}{\partial y^{*2}} + \frac{Q_0}{\rho C_p}\left(T^* - T_\infty\right), \qquad ....(4)$$

Equation of Mass Transfer

$$\frac{\partial C^*}{\partial t^*} + v^* \frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial y^{*2}}\,, \qquad ....(5)$$

where u^* and v^* are the components of velocity along x^*-axis and y^*-axis respectively, t^* the time, ρ the density of the fluid, ν the kinematic viscosity, ν_r the kinematic rotational viscosity, p^* the pressure, g the acceleration due to gravity, β_f the coefficient of volumetric thermal expansion of the fluid, T^* the fluid temperature, β_c^* the coefficient of volumetric expansion with concentration, C^* concentration in the boundary layer, K^* the permeability of the porous medium, B_o the magnetic field intensity, ω^* component of angular velocity vector normal to the x^*y^* plane, J^* the microinertia density, γ the spin-gradient viscosity, α the effective fluid thermal diffusivity, C_p the specific heat at constant pressure, D the coefficient of molecular diffusivity, σ the electrical conductivity of the fluid, T_∞ the free stream temperature , C_∞ the free stream concentration and Q_o is the volumetric rate of heat generation.

The heat due to viscous dissipation is neglected for small velocities and Darcy dissipation term is also neglected because of it is of the same order of magnitude as the viscous dissipation term. The porous plate moves with constant velocity in the longitudinal direction and the free stream velocity follows an exponentially time dependent perturbation law. The boundary conditions are given by

$$y^*=0: \qquad u^*=u_p^*, \qquad \omega^*=-n\frac{\partial u^*}{\partial y^*}, \qquad \frac{\partial T^*}{\partial y^*}=-\frac{q^*}{\kappa}, \qquad \frac{\partial C^*}{\partial y^*}=-\frac{m^*}{D};$$

$$y^*\to\infty: \qquad u^*\to U(t^*)=U_\infty\left(1+\in e^{\delta^* t^*}\right), \qquad T^*\to T_\infty, \qquad \omega^*\to 0, \qquad C^*\to C_\infty, \qquad \text{....(6)}$$

where n is the positive number, q^* the heat flux per unit area, κ the thermal conductivity, m^* the mass flux per unit area, U_∞ the mean free stream velocity and $\in$ and δ^* are small positive parameters such that $0<\in, \delta^*<<1$.

The boundary conditions for microrotation variable ω^* describes its relationship with the surface stress. The parameter n is a number lying between 0 and 1 that relates the microgyration vector to shear stress. The value n=0 corresponds to the case when the particle density is sufficiently large so that microelements close to the wall are unable to rotate. The value n=0.5 indicates weak concentration and n=1 represents turbulent boundary layer flow [Rees and Bassom(1996)].

From the continuity equation (1), the suction velocity normal to the porous plate can be written in the following form

$$v^*=-V_0\left(1+\in A\, e^{\delta^* t^*}\right), \qquad \text{....(7)}$$

where A is a real positive constant and $\in A$ is small less than unity(i.e. $\in A$ <<1) and V_o is the mean suction velocity. Out side the boundary layer, the equation (2) becomes

$$-\frac{1}{\rho}\frac{dp^*}{dx^*}=\frac{dU^*}{dt^*}+\frac{\nu}{K^*}U^*+\frac{\sigma}{\rho}B_0^2\,U^* \qquad \text{....(8)}$$

From equation (2) and equation (8), we have

$$\frac{\partial u^*}{\partial t^*}+v^*\frac{\partial u^*}{\partial y^*}=\frac{dU^*}{dt^*}-\frac{\upsilon}{K^*}\left(u^*-U_\infty\right)-\frac{\sigma B_0^2}{\rho}\left(\left(u^*-U_\infty\right)\right)B_0^2\,U_\infty^*+(\upsilon+\upsilon_r)\frac{\partial^2 u^*}{\partial y^{*2}}+g\beta_f(T^*-T_\infty)+$$
$$g\beta_c^*(C^*-C_\infty)+2\upsilon_r\frac{\partial\omega^*}{\partial y^*}. \qquad \text{....(9)}$$

Introducing the following dimensionless quantities

$$u=\frac{u^*}{U_\infty}, \quad v=\frac{v^*}{V_0}, \quad y=\frac{V_0 y^*}{\upsilon}, \; U(t)=\frac{U(t^*)}{U_\infty}, \; u_p=\frac{u_p^*}{U_\infty}, \; \omega=\frac{\upsilon\omega^*}{U_0 v_0}, \; t=\frac{t^* V_0^2}{\upsilon},$$

$$\theta=\frac{T^*-T_\infty}{q^*\upsilon/\kappa V_0}, \; C=\frac{C^*-C_\infty}{m^*\upsilon/V_0 D}, \; \delta=\frac{\upsilon\delta^*}{V_0^2}, \; K=\frac{K^* v_0^2}{\upsilon^2}, \; j=\frac{J^* V_0^2}{\upsilon^2}, \quad M=\frac{\sigma B_0^2\,\upsilon}{\rho V_0^2},$$

$$Gr=\frac{g\,\beta_f\,q^*\,\upsilon^2}{V_0^3\,U_\infty\,\kappa}, \quad Gc=\frac{g\,\beta_c\,m^*\,\upsilon^2}{V_0^3\,U_\infty\,D}, \quad Pr=\frac{\upsilon}{\alpha}, \quad Sc=\frac{\upsilon}{D}, \quad \eta=\frac{\mu J^*}{\gamma}, \quad Q=\frac{Q_0\,\upsilon}{\rho C_p\,V_0^2}, \qquad \text{....(10)}$$

and the spin-gradient viscosity γ which gives some relationship between the coefficients of viscosity and microinertia, as given below

$$\gamma=\left(\mu+\frac{1}{2}\Lambda\right)J^*=\mu J^*\left(\mu+\frac{1}{2}\beta\right), \qquad \beta=\frac{\Lambda}{\mu}, \qquad \text{...(11)}$$

Into the equations (3) to (5) and (9), and using the equation (7), we have

$$\frac{\partial u}{\partial t}-\left(1+\in Ae^{\delta t}\right)\frac{\partial u}{\partial y} = \frac{dU(t)}{dt}+ (1+\beta)\frac{\partial^2 u}{\partial y^2}+ Gr\,\theta + Gc\,C + N\left(U_\infty - u\right) + 2\beta\frac{\partial \omega}{\partial y}, \quad ...(12)$$

$$\frac{\partial \omega}{\partial t}-\left(1+\in Ae^{\delta t}\right)\frac{\partial \omega}{\partial y} = \frac{1}{\eta}\frac{\partial^2 \omega}{\partial y^2}, \quad ...(13)$$

$$\frac{\partial \theta}{\partial t}-\left(1+\in Ae^{\delta t}\right)\frac{\partial \theta}{\partial y} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2}+Q\theta, \quad ...(14)$$

$$\frac{\partial C}{\partial t}-\left(1+\in Ae^{\delta t}\right)\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}, \quad ...(15)$$

where β is the dimensionless viscosity ratio, Λ the coefficient of gyro-viscosity(or vertex viscosity), M the Hartmann number, Gr the Grashof number for heat transfer, Gc the Grashof number for mass transfer, Pr the Prandtl number, Sc the Schmidt number, Q the volumetric rate of heat generation (heat source)parameter and

$$N=\left(M+\frac{1}{K}\right), \eta=\frac{\mu J^*}{\gamma}=\frac{2}{2+\beta}.$$

The boundary conditions (6) are reduced to

$$y=0: \quad u=u_p, \quad \omega=-n\frac{\partial u}{\partial y}, \quad \frac{\partial \theta}{\partial y}=-1, \quad \frac{\partial C}{\partial y}=-1;$$

$$y\to\infty: \quad u\to U(t)=\left(1+\in e^{\delta t}\right), \quad \omega\to 0, \quad \theta\to 0, \quad C\to 0. \quad ....(16)$$

Method of Solution : Since the equations (12) to (15) are non-linear coupled differential equations, therefore using the perturbation technique to solve them under the boundary conditions (16), as given below

$$u=u_0(y)+\in e^{\delta t}u_1(y)+O(\in^2),$$

$$\omega=\omega_0(y)+\in e^{\delta t}\omega_1(y)+O(\in^2), \theta=\theta_0(y)+\in e^{\delta t}\theta_1(y)+O(\in^2), C=C_0(y)+\in e^{\delta t}C_1(y)+O(\in^2). \quad .... (17)$$

Substituting (17) into the equations (12) to (15), and equating the coefficients of like powers of $\in$, we have

$$(1+\beta)\frac{\partial^2 u_0}{\partial y^2}+\frac{\partial u_0}{\partial y}-Nu_0=-N-Gr\,\theta_0-Gc\,C_0-2\beta\frac{\partial \omega_0}{\partial y}, \quad ....(18)$$

$$(1+\beta)\frac{\partial^2 u_1}{\partial y^2}+\frac{\partial u_1}{\partial y}-(N+\delta)u_1=-Gr\,\theta_1-Gc\,C_1-2\beta\frac{\partial \omega_1}{\partial y}-A\frac{\partial u_0}{\partial y}-(N+\delta), \quad ....(19)$$

$$\frac{\partial^2 \omega_0}{\partial y^2}+\eta\frac{\partial \omega_0}{\partial y}=0, \quad ....(20)$$

$$\frac{\partial^2 \omega_1}{\partial y^2}+\eta\frac{\partial \omega_1}{\partial y}-\eta\delta\,\omega_1=-\eta A\frac{\partial \omega_0}{\partial y}, \quad ....(21)$$

$$\frac{\partial^2 \theta_0}{\partial y^2}+Pr\frac{\partial \theta_0}{\partial y}+Q\theta_0=0, \quad ....(22)$$

$$\frac{\partial^2 \theta_1}{\partial y^2}+Pr\frac{\partial \theta_1}{\partial y}+Pr\,(Q-\delta)\theta_1=-A\,Pr\frac{\partial \theta_0}{\partial y}, \quad ....(23)$$

$$\frac{\partial^2 C_0}{\partial y^2}+Sc\frac{\partial C_0}{\partial y}=0, \quad ....(24)$$

$$\frac{\partial^2 C_1}{\partial y^2}+Sc\frac{\partial C_1}{\partial y}-Sc\,\delta\,C_1=-A\,Sc\frac{\partial C_0}{\partial y}. \quad ....(25)$$

$y=0:\quad u_0=u_p,\quad u_1=0,\quad \omega_0=-n\frac{\partial u_0}{\partial y},\quad \omega_1=-n\frac{\partial u_1}{\partial y},\quad \frac{\partial\theta_0}{\partial y}=-1,\quad \frac{\partial\theta_1}{\partial y}=0,$

$\frac{\partial C_0}{\partial y}=-1,\ \frac{\partial C_1}{\partial y}=0;$

$y\to\infty:\quad u_0\to 1,\quad u_1\to 1,\quad \omega_0\to 0,\quad \omega_1\to 0,\quad \theta_0\to 0,\quad \theta_1\to 0,\quad C_0\to 0,$

$C_1\to 0$ ....(26)

Now, the equations (18) and (25) are ordinary linear coupled differential equations with constant coefficients and solved under the boundary conditions (26). Through, straight forward calculations their solutions are of $u_o(y)$, $u_1(y)$, $\omega_o(y)$, $\omega_1(y)$, $\theta_o(y)$, $\theta_1(y)$, $C_o(y)$ and $C_1(y)$ are known but not given here due to sake of brevity.

Skin-Friction Coefficient

Coefficient of the skin-friction at the porous plate is given by

$$C_f=\frac{2\tau_w}{\rho U_\infty V_0}=(\mu+\Lambda)\left(\frac{\partial u^*}{\partial y^*}\right)_{y^*=0}+\Lambda(\omega^*)_{y^*=0}\ =\ 2[1+\beta(1-\eta)]\left(\frac{\partial u}{\partial y}\right)_{y=0}, \quad ....(27)$$

Results and Discussion

The translational velocity, microrotation velocity, temperature and concentration distributions are derived and discussed numerically across the boundary layer for various values of the physical parameters along with t=1, δ=0.01 and ∈ = 0.01.

Fig.1 depicts that the magnitude of velocity decreases with an increase of viscosity ratio near the plate, while different behavior is observed for free stream.

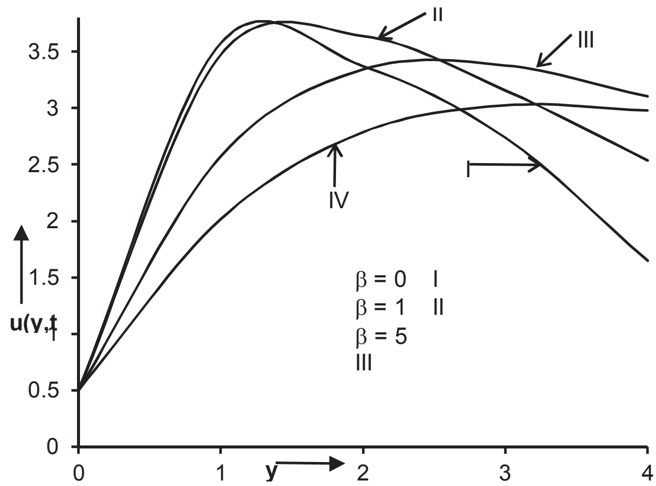

Fig.1. Velocity distribution versus y when n =0.5, Sc=0.2, M=2, Gr=2, Gc=2, K=2, Pr=3,

It is noticed from Fig.2 that microrotation of the fluid near the plate increases with the increase of viscosity ratio, while across the boundary layer the microrotation distribution do not show consistent variation.

The fluid velocity increases with the increase of n as observed from Fig.3. Fig.4 shows that the magnitude of microrotation velocity decreases due to increase of n. It is noticed from Fig.5 that velocity of the fluid decreases with an increase of Hartmann number.

The microrotation velocity increases with an increase of Hartmann number as seen in Fig.6.

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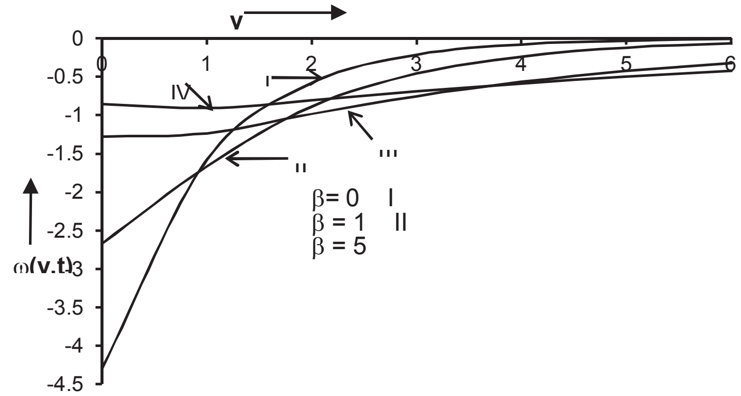

Fig.2. Microrotation velocity distribution versus y when n =0.5,

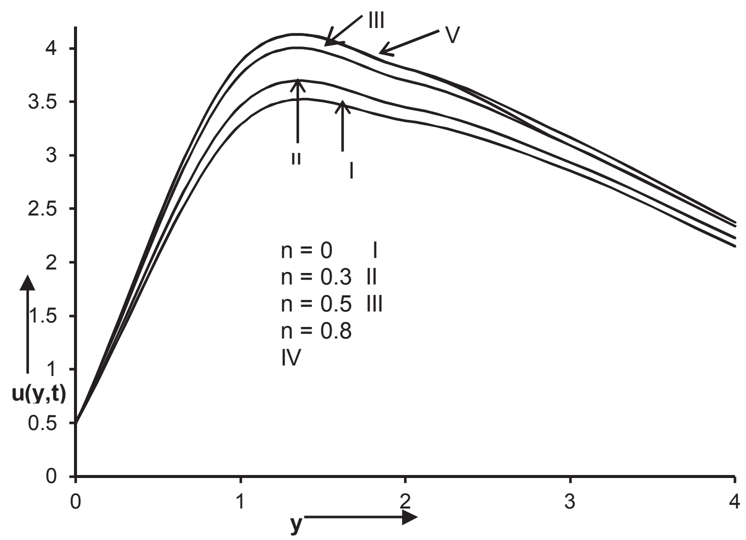

Fig.3. Velocity distribution versus y when β =0.5, Sc=0.2, M=2,

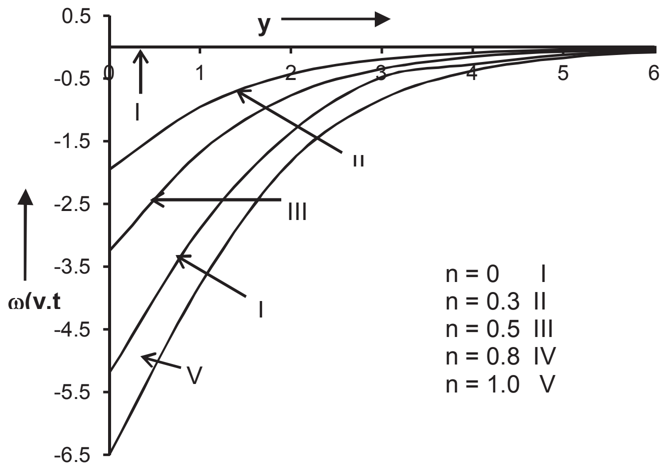

Fig.4. Microrotation velocity distribution versus y when β=0.5, Sc=0.2, M=2, Gr=2,

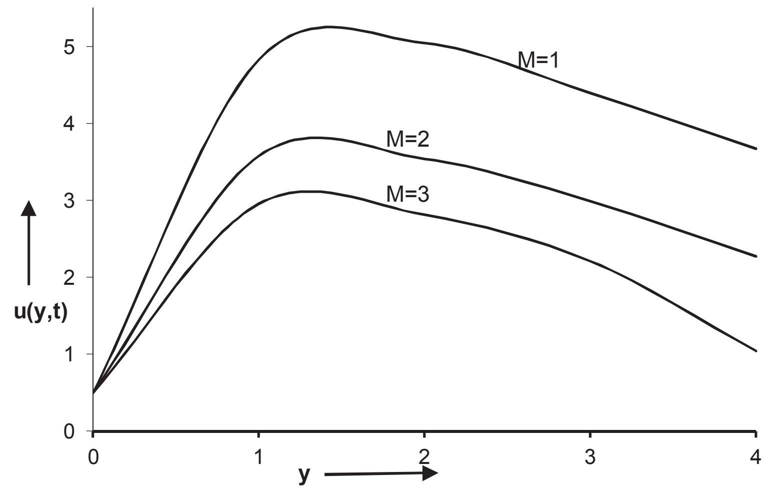

Fig.5. Velocity distribution versus y when β =0.5, Sc=0.2, n=0.5, Gr=2, Gc=2, K=2, Pr=3,

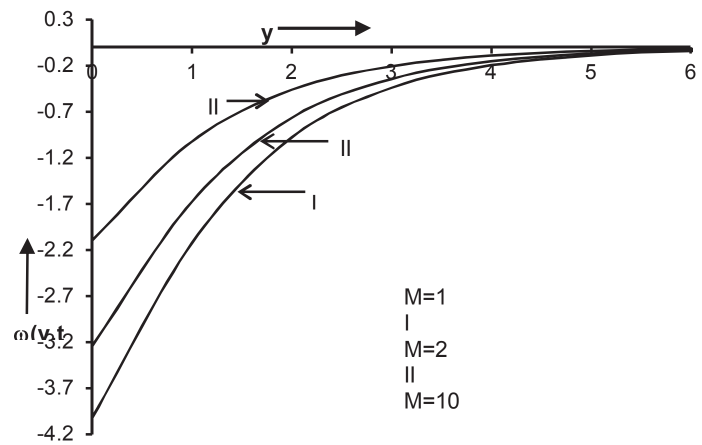

Fig.6. Microrotation velocity distribution versus y when β=0.5,

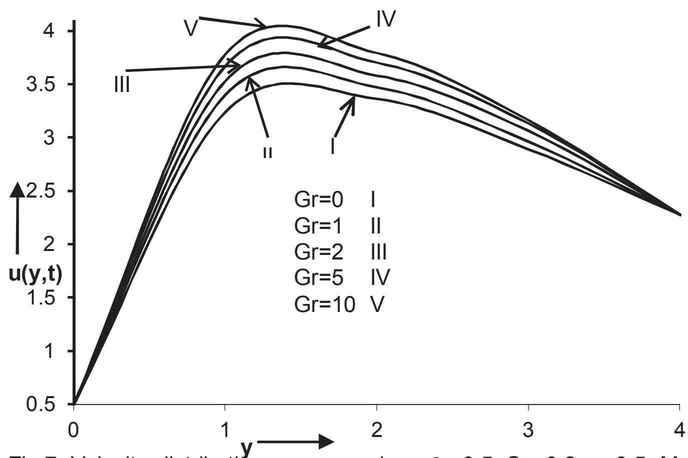

Fig.7. Velocity distribution versus y when β =0.5, Sc=0.2, n=0.5, M=2,

Fig.7 depicts that the fluid velocity increases with the increase of Grashof number for heat transfer, while microrotation velocity of the fluid decreases with the increase of Grashof number for heat transfer as seen from Fig.8

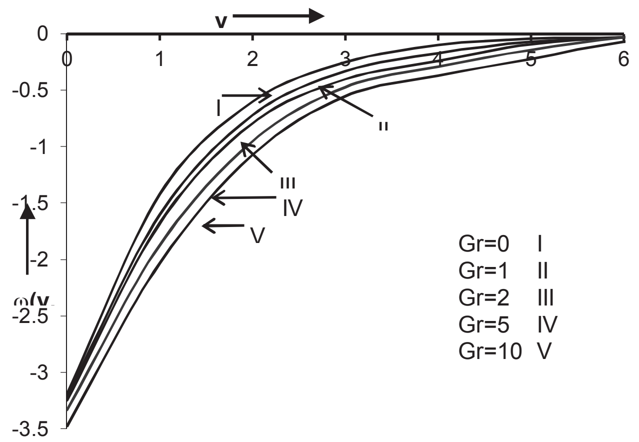

Fig.8. Microrotation distribution versus y when β=0.5,

Fig.9illustrates that the fluid velocity increases with the increase of modified Grashof number for mass transfer and the peak value of the velocity increases rapidly near the plate as modified Grashof number increases.
Fig.10 describes that the microrotation velocity of the fluid decreases with the increase of modified Grashof number in the neighborhood of the porous plate.

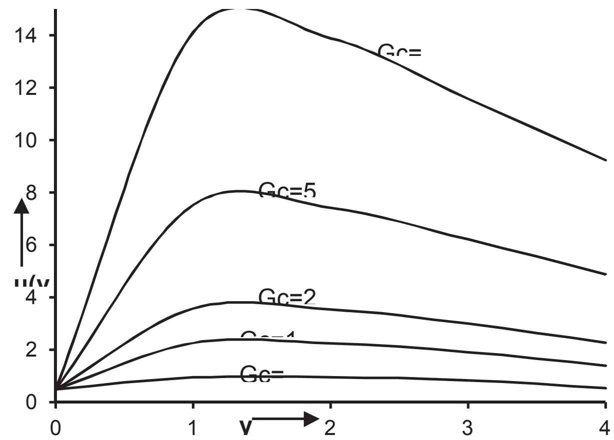

Fig.9. Velocity distribution versus y when β =0.5,

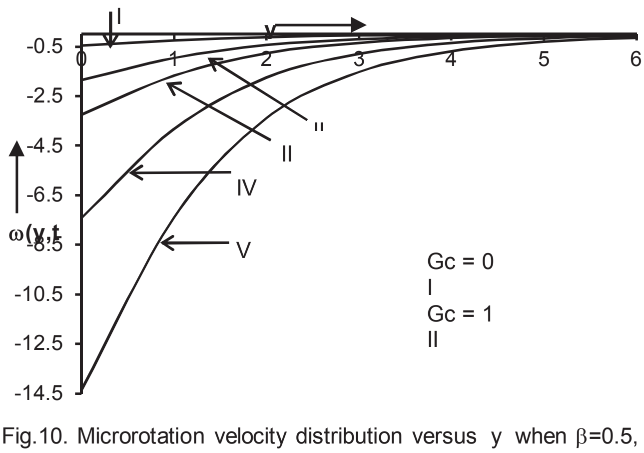

Fig.10. Microrotation velocity distribution versus y when β=0.5,

Fig.11 depicts that the fluid velocity increases with the increase of permeability parameter, while microrotation velocity of the fluid decreases with the increase of permeability parameter at the porous plate as noted from Fig.12.

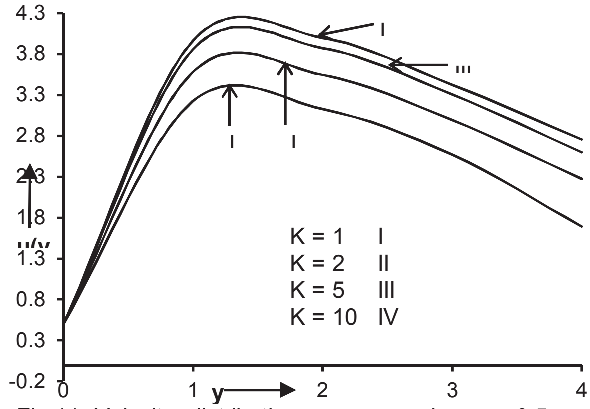

Fig.11. Velocity distribution versus y when β =0.5,

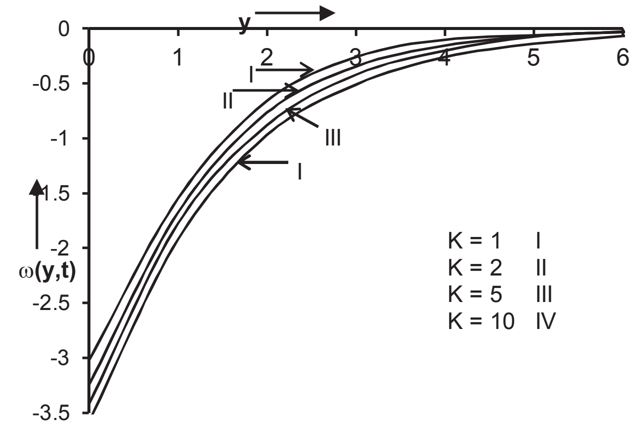

Fig.12. Microrotation Velocity distribution versus y when

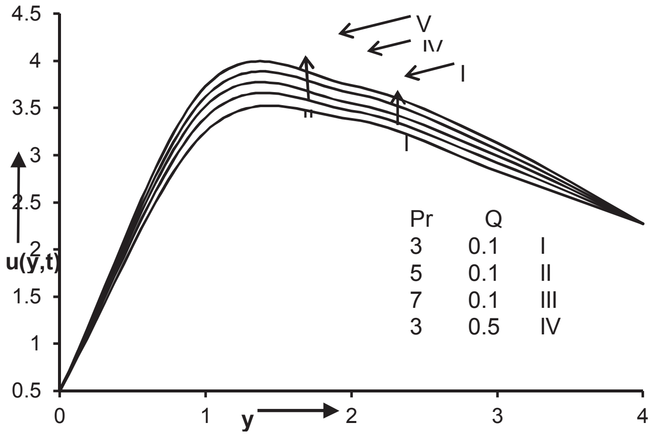

Fig.13. Velocity distribution versus y when β =0.5, Sc=0.2,

Fig.13 describes that the fluid velocity decreases with the increase of Prandtl number, while it increases with the increase of heat source parameter. Fig.14 illustrates that the microrotation velocity of the fluid increases with the increase of Prandtl number, while it decreases with the increase of heat source parameter.

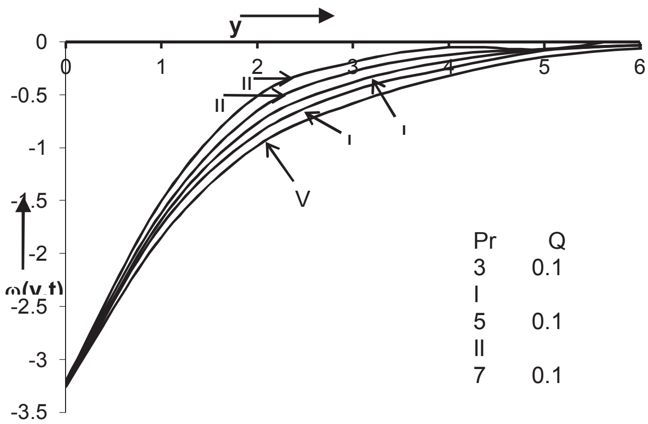

Fig.14. Microrotation Velocity distribution versus y when β=0.5,

Fig.15 shows that the fluid velocity increases with the increase of plate velocity near the plate and then approaches to the free stream boundary layer condition. Fig.16 depicts that the microrotation of the fluid increases with the increase of plate velocity near the plate and then approached to the free stream velocity.

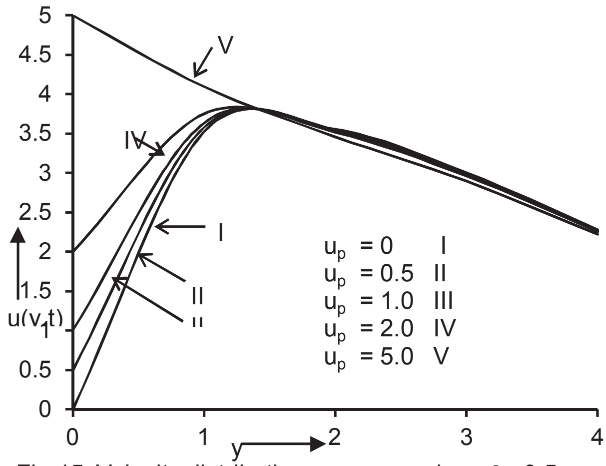

Fig.15. Velocity distribution versus y when β =0.5,

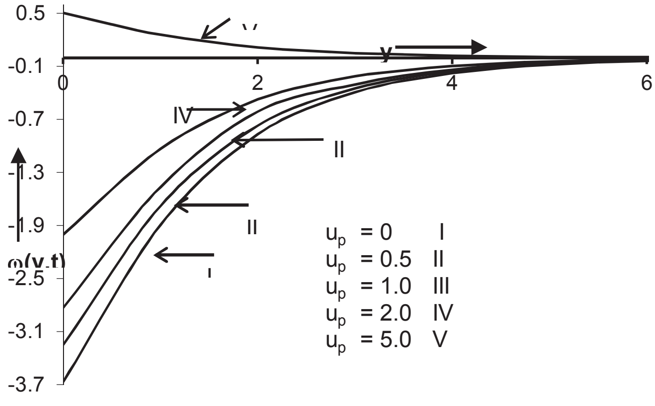

Fig.16. Microrotation Velocity distribution versus y when

Fig.17 illustrates that the fluid velocity decreases with the increase of Schimdt number across the boundary layer. Fig.18 shows that the microrotation velocity of the fluid increases with the increase of Schimdt number near the plate.

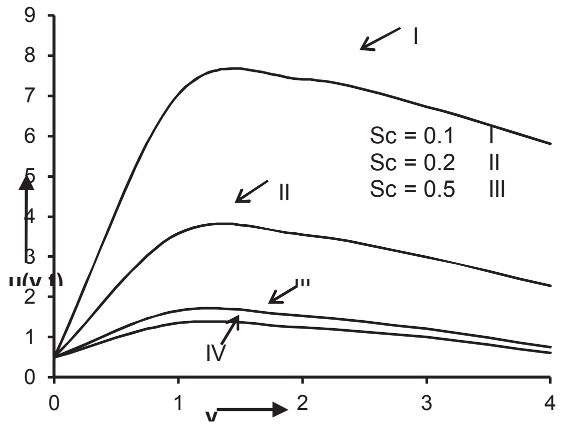

Fig.17. Velocity distribution versus y when β =0.5,

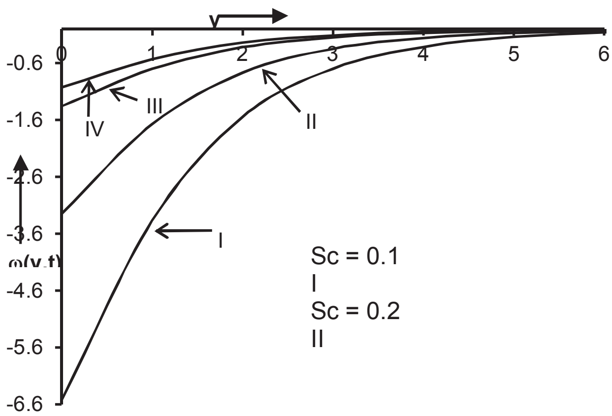

Fig.18. Microrotation velocity distribution versus y when

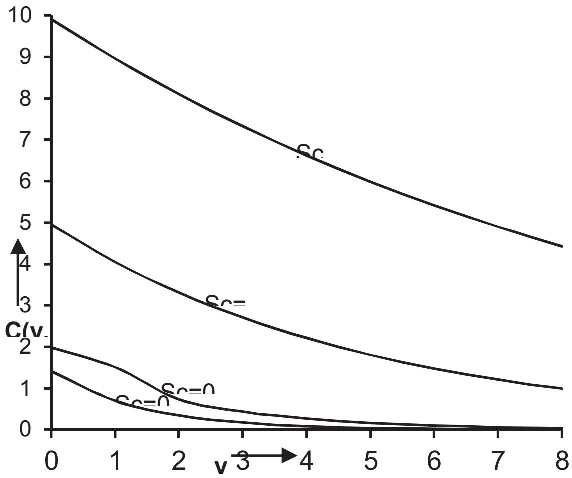

Fig.19. Concentration distribution versus y when

It is observed from Fig.19 that the fluid concentration decreases with the increase of Schimdt number near the plate and then approaches to the boundary condition. Fig.20 shows that the fluid temperature decreases with the increase of Prandtl number, while it increases with the increase of heat source parameter.

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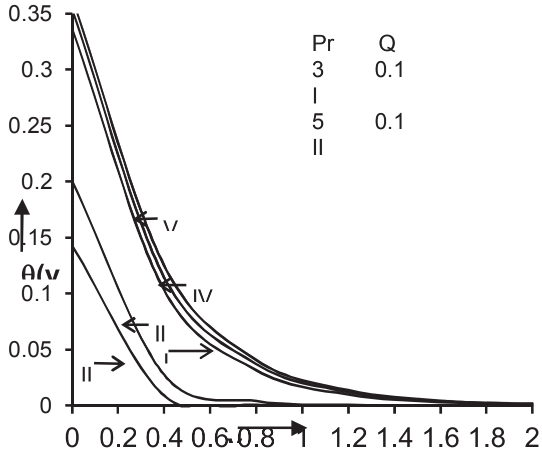

Fig.20. Temperature distribution versus y when

It is inferred from Table-1 that skin-friction coefficient increases with the increase of Grashof number for heat transfer, modified Grashof number for mass transfer, permeability parameter or heat source parameter, while it decreases with the increase of viscosity ratio, Prandtl number, plate velocity, Schimdt number, Hartmann number or n.

Table-1. Numerical values of skin-friction coefficient at the plate for various values of physical parameters when t=1, δ=0.01 and ε =0.01 .

β	n	M	Gr	Gc	K	Pr	Q	u_p	Sc	C_f
0.5	0.5	2	2	2	2	3	0.1	0.5	0.2	16.230228
1.0	0.5	2	2	2	2	3	0.1	0.5	0.2	16.018721
0.5	1.0	2	2	2	2	3	0.1	0.5	0.2	12.984183
0.5	0.5	3	2	2	2	3	0.1	0.5	0.2	14.261558
0.5	0.5	2	5	2	2	3	0.1	0.5	0.2	16.6555214
0.5	0.5	2	2	3	2	3	0.1	0.5	0.2	23.17467
0.5	0.5	2	2	2	5	3	0.1	0.5	0.2	17.096701
0.5	0.5	2	2	2	2	7	0.1	0.5	0.2	16.006660
0.5	0.5	2	2	2	2	3	0.5	0.5	0.2	16.255793
0.5	0.5	2	2	2	2	3	0.1	1.0	0.2	14.146896
0.5	0.5	2	2	2	2	3	0.1	0.5	0.5	6.785786

Conclusions: The problem of magnetohydrodynamic free convection flow with radiative heat transfer in porous media with constant heat and mass flux subject to time dependent suction of an incompressible and optically transparent medium has been solved making fairly realistic assumption. For a small time dependent perturbation of the fluid velocity and temperature the non-linear problem is tackled by asymptotic approximation giving solutions for steady flow on which a first order transient component is superimposed. The non-dimensional coefficient of shearing stress and the rate of heat transfer in terms of Nusselt number at the plate are obtained.

The following conclusions are made as given below:

(i) The magnitude of fluid velocity increases as the cooling of the plate increases, while magnitude of microrotation velocity decreases as the cooling of the plate increases.

(ii) The fluid velocity increases as the permeability of the porous medium increases, while microrotation velocity decreases with the increase of permeability of the porous medium.

(iii) The magnitude of fluid velocity increases with the increase of volumetric rate of heat generation, while microrotation velocity decreases as volumetric rate of heat generation increases.

(iv) The fluid velocity decreases with the increase of applied magnetic field, while reverse behavior is observed for microrotation velocity.

(v) The fluid velocity increases with the increase of molecular diffusivity and microrotation velocity decreases as the molecular diffusivity increases.

(vi)The fluid temperature increases as the volumetric rate of heat generation increases.

(vii) The magnitude of fluid concentration increases as the molecular diffusivity increases

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