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Effects of Radiation, Free Convection and Mass Transfer on an Unsteady Flow of a Micropolar Fluid Over a Vertical Moving Porous Plate Immersed in a Porous Medium With Time Varying Suction

Navin Kumar*, Tanu Jain** and Sandeep Gupta**

**Department of Mathematics, National Defence Academy, Pune, (MS) India*

***Department of Mathematics, University of Rajasthan, Jaipur, (RJ) India*

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ABSTRACT : In the present paper, an analysis is carried out to study the free convection, thermal radiation and mass transfer effects on an unsteady flow of a viscous incompressible micropolar fluid over a vertical moving porous plate immersed in a porous medium with time varying suction velocity. The plate moves with the constant velocity in the longitudinal direction, and the free stream velocity follows an exponentially small perturbation law. The velocity and temperature distributions are derived, discussed and their profiles shown through graphs. Also, the results of coefficient of skin-friction, the rate of the heat transfer in terms of Nusselt number and the ratio of convective to diffusive mass transport in terms of Sherwood number at the plate are prepared with various values of fluid properties and flow conditions.

Keywords: Micropolar fluid, free convection, radiation, mass transfer, sheerwood number.

I. INTRODUCTION

The micropolar fluids are the fluids with microstructure belonging to a class of fluids with nonsymmetrical stress tensor referred to as polar fluids. Physically, they represent fluids consisting of randomly oriented particles suspended in a viscous medium (Lukaszewicz, [1]), and they are important to Engineers and Scientists working with hydrodynamic–fluid problems. Synovial fluid is a good example of micropolar fluid. The earliest formulation of a general theory of micropolar fluids was given by Eringen [2]. His theory has opened up new ideas in the physics of fluid flow. According to him, a simple micropolar fluid is a fluent medium whose properties and behavior are affected by the local motions of the material particles contains in each of its volume elements; such a fluid possesses local inertia.

Raptis *et.al* [3] discussed the free convection flow through a porous medium bounded by a vertical surface. Heat and mass transfer by natural convection in a porous medium was investigated by Bejan and Khair [4]. Agarwal and Dhanapal [5] studied the numerical solution of free convection micropolar fluid flow between two parallel porous vertical plates. Free convection effects on the flow past a porous medium bounded by a vertical infinite surface with constant suction and constant heat flux was discussed by Sharma [6]. Hooper *et.al*. [7] studied the mixed convection along an isothermal vertical plate in a porous medium. Unsteady free–convection and mass transfer effects on the flow past an infinite, vertical, moving porous plate in the presence of heat source/sink with constant suction and constant heat flux was investigated by Sharma and Kumar [8]. Al–Nimr and Masoud [9] analysed the unsteady free convection flow over a vertical flat plate immersed in a porous medium. Unsteady free convection flow of a micropolar fluids past a vertical porous plate embedded in a porous medium was investigated by Kim [10]. Chamkha *et.al*. [11] analyzed the fully developed free convection flow of a micropolar fluid in a vertical channel. Transient mixed radiative convection flow of a micropolar fluid past a moving, semi–infinite vertical porous plate was studied by Kim and Fedorov [12]. Kim [13] investigated the heat and mass transfer in MHD micrpoloar flow over a vertical moving porous plate in a porous medium. The problem of electromagnetic free convection flow of a micropolar fluid with relaxation time through a porous medium was discussed by Zakaria [14]. Saeid [15] presented an analysis of mixed convection in a vertical porous layer using non–equilibrium model. Periodic free convection from a vertical plate in a saturated porous medium, non–equilibrium model was given by Saeid and Abdulmajeed [16]. Badruddin *et.al*. [17] investigated the free convection and radiation for a vertical wall with varying temperature embedded in a porous medium. Magnetohydrodynamics and radiative effects on free convection flow of fluid with variable viscosity from a vertical plate through a porous medium was studied by Abdou *et. al.* [18]. Dash *et. al.* [19] considered the effects of heat and mass transfer of an electrically conducting and heat generating/absorbing fluid on a uniformly moving vertical permeable surface in the presence of a magnetic field considering the first order homogeneous chemical reaction and energy loss due to the viscous joule heat dissipations. Sharma *et. al.* [20] investigated the radiation effects on unsteady MHD free convective flow with Hall current and mass transfer through viscous incompressible fluid past a vertical porous plate embedded in porous medium with heat source/sink. Heat and mass transfer in MHD unsteady free convective flow of a micropolar fluid over a vertical moving porous plate embedded in porous medium in the presence of thermal radiation was studied by Kumar *et. al.* [21]. Kumar and Gupta [22] investigated the fully–developed MHD free–convective flow of micropolar and viscous fluids through porous medium in a vertical channel.

The aim of the present paper is to investigate the effects of thermal radiation, free convection and mass transfer on an unsteady flow of a viscous incompressible micropolar fluid over a vertical moving porous plate immersed in a porous medium with time varying suction velocity. It is also considered that the free stream consists of a mean velocity over which is superimposed an exponentially varying time.

II. FORMULATION OF THE PROBLEM

Consider the two–dimensional free convective unsteady flow of a viscous incompressible micropolar fluid past a semi–infinite vertical moving porous plate embedded in a porous medium in the presence of thermal radiation.

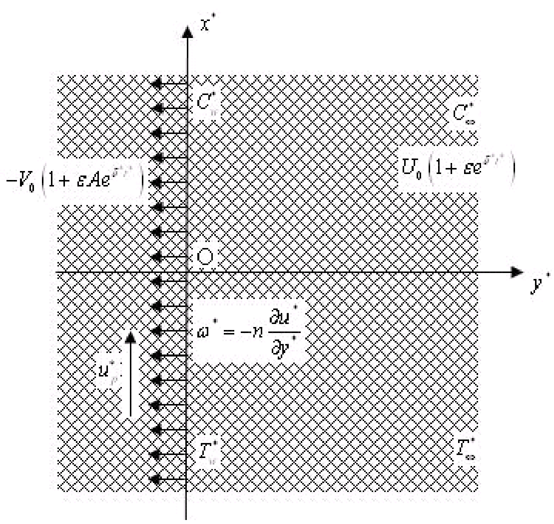

Fig. 1. Geometrical configuration.

The x^*–axis is taken along the porous plate in the upward direction and y^*–axis normal to it. The fluid velocity far away from the plate along y^*–axis follows as exponential small perturbation law. It is assumed that the hole size of the porous plate is significantly larger than a characteristic microscopic length scale of the porous medium. Due to semi–infinite plane surface assumption, the flow variables are functions of y^* and t^* only. The model of porous medium is based on Darcy's law so the porous material is simply define by one parameter; the intrinsic permeability.

The free–convective flow through porous medium is governed by Navier–Stokes equation for viscous incompressible fluid along with Buoyancy force term and Darcy's law. The mass buoyancy effect is also taken into account which can be given by Navier–stokes equations along with diffusion equation. The temperature flowing in the fluid is governed by energy conservation equation involving the heat generated by the radiation in the fluid.

Under these conditions, the governing equations of flow can be written in a Cartesian frame of reference, as:

Equation of Continuity

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

Equation of Linear Momentum

$$\frac{\partial u^*}{\partial t^*} + v^*\frac{\partial u^*}{\partial y^*} = -\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} + (\nu+\nu_r)\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_f (T^* - T^*_\infty)$$

$$+ g\beta_c (C^* - C^*_\infty) - \nu\frac{u^*}{K^*} + 2\nu_r\frac{\partial \omega^*}{\partial y^*}, \qquad \ldots (2)$$

Equation of Angular Momentum

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

Equation of Energy

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \alpha\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*}, \qquad \ldots (4)$$

Equation of Mass Transfer

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

The third term on the RHS of the momentum Equation (2) denotes buoyancy effects; fourth term due mass buoyancy effects and the fifth term is the bulk matrix linear resistance *i.e.* Darcy term. The heat due to viscous dissipation is neglected for small velocities in Equation (4) and the second term on the RHS of the energy Equation (4) denotes the radiation effects. Also, Darcy dissipation term is neglected because it is the same order–of– magnitude as the plate velocity.

The vertical plate is moving with velocity u^*_p along its own plane. Suppose plate is kept at constant temperature T^*_w. Under these assumptions, the appropriate boundary conditions for the velocity and temperature fields are

$$u^* = u^*_p,\ T^* = T^*_w,\ \omega^* = -n\frac{\partial u^*}{\partial y^*}$$

$$C^* = C^*_w \text{ at } y^* = 0,$$

$$u^* \to U^*_\infty = U_0(1 + \varepsilon e^{\delta^* t^*}),\ T^* \to T^*_\infty,$$

$$\omega^* \to 0,\ C^* \to C^*_\infty \text{ as } y^* \to \infty, \qquad \ldots (6)$$

where ε and δ* are the small quantities less than unity, U^*_∞ is the free stream velocity follows an exponentially small perturbation law and U_0 is a scale of free stream velocity.

The boundary condition for micro–rotation variable ω* describes its relationship with the surface stress. The parameter n is a number between 0 and 1. The value $n = 0$ corresponds to the case where the particle density is sufficiently large so that microelements close to the wall are unable to rotate. The value $n = 0.5$ is indicative of weak concentrations, and when $n = 1$ flows are believed to represent turbulent boundary layers (Rees and Bassom, [23]).

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

$$v^* = -V_0(1 + \varepsilon A e^{\delta^* t^*}) \qquad \ldots(7)$$

where A is a real positive constant and *A* small less than unity and $\delta^* t^* << 1$. Outside the boundary layer, Equation (2) gives.

$$-\frac{1}{\rho}\frac{\partial p^*}{\partial x^*} = \frac{dU^*_\infty}{dt^*} + \frac{\nu}{K^*}U^*_\infty \qquad \ldots(8)$$

The local radiant for the case of an optically thin gray gas is expressed by

$$\frac{\partial q_r}{\partial y^*} = -4a\sigma(T^{*4}_\infty - T^{*4}) \ , \qquad \ldots(9)$$

Expending T^{*4} in a Taylor's Series about T^*_∞ and neglecting the higher order terms, we have

$$T^{*4} \cong 4T^{*3}_\infty T^* - 3T^{*4}_\infty, \qquad \ldots(10)$$

So equation (4) gives

$$\frac{\partial T^*}{\partial t^*} + v^*\frac{\partial T^*}{\partial y^*} = \alpha\frac{\partial^2 T^*}{\partial y^{*2}} + \frac{16a\sigma}{\rho C_p}(T^*_\infty - T^*)T^{*3}_\infty \qquad \ldots(11)$$

Furthermore, the spin–gradient viscosity γ which gives some relationship between the coefficients of micro–inertia, is defined as

$$\gamma = \left(\mu + \frac{1}{2}\wedge\right)j^* = \mu j^*\left(1 + \frac{1}{2}\beta\right), \beta = \frac{\wedge}{\mu}, \qquad \ldots(12)$$

Introducing the following non–dimensional quantities:

$$u = \frac{u^*}{U_0}, v = \frac{v^*}{V_0}, y = \frac{V_0 y^*}{\nu}, U_\infty = \frac{U^*_\infty}{U_0},$$

$$U_p = \frac{u^*_p}{U_0}, \omega = \frac{\nu}{U_0 V_0}\omega^*, t = \frac{t^* V_0^2}{\nu}, \delta = \frac{\delta^*\nu}{V_0^2},$$

$$\theta = \frac{T^* - T^*_\infty}{T^*_w - T^*_\infty}, C = \frac{C^* - C^*_\infty}{C^*_w - C^*_\infty}, K = \frac{K^* V_0^2}{\nu^2}$$

$$j = \frac{V_0^2}{\nu^2}j^*, Gc = \frac{\nu\beta_c g(C^*_w - C^*_\infty)}{U_0 V_0^2}, Sc = \frac{\nu}{D^*},$$

$$Pr = \frac{\nu\rho C_P}{\kappa} = \frac{\nu}{\alpha}, N = \frac{16a\sigma\nu^2 T^3_\infty}{\kappa V_0^2} \qquad \ldots(13)$$

into the equations (2) to (5) and using the equations (8) to (12), we have

$$\frac{\partial u}{\partial t} - (1 + \varepsilon A e^{\delta t})\frac{\partial u}{\partial y} = \frac{dU_\infty}{dt} + (1+\beta)\frac{\partial^2 u}{\partial y^2} + Gr\theta + GcC +$$

$$\frac{1}{K}(U_\infty - u) + 2\beta\frac{\partial\omega}{\partial y} \qquad \ldots(14)$$

$$\frac{\partial\omega}{\partial t} - (1 + \varepsilon A e^{\delta t})\frac{\partial\omega}{\partial y} = \frac{1}{\eta}\frac{\partial^2\omega}{\partial y^2} \qquad \ldots(15)$$

$$\frac{\partial\theta}{\partial t} - (1 + \varepsilon A e^{\delta t})\frac{\partial\theta}{\partial y} = \frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2} - \frac{N}{\Pr}\theta \qquad \ldots(16)$$

$$\frac{\partial C}{\partial t} - (1 + \varepsilon A e^{\delta t})\frac{\partial C}{\partial y} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} \qquad \ldots(17)$$

where $\eta = \frac{\mu j^*}{\gamma} = \frac{2}{2+\beta}$ and the corresponding boundary conditions are

$$u = U_p,\ \theta = 1,\ \omega = -n\frac{\partial u}{\partial y},\ C = 1 \text{ at } y = 0;$$

$$u \to U_\infty = (1 + \varepsilon^{\delta t}),\ \theta \to 0,\ \omega \to 0,\ C \to 0 \text{ as } y \to \infty \qquad \ldots(18)$$

III. METHOD OF SOLUTION

In order to reduce the above nonlinear partial differential equations into ordinary differential equations, we may represent the translational velocity, micro–rotation, temperature and concentration as:

$$u(y,t) = u_0(y) + \varepsilon e^{\delta t}u_1(y) + O(\varepsilon^2),$$
$$\omega(y,t) = \omega_0(y) + \varepsilon e^{\delta t}\omega_1(y) + O(\varepsilon^2),$$
$$\theta(y,t) = \theta_0(y) + \varepsilon e^{\delta t}\theta_1(y) + O(\varepsilon^2),$$
$$C(y,t) = C_0(y) + \varepsilon e^{\delta t}C_1(y) + O(\varepsilon^2) \qquad \ldots(19)$$

Substituting (19) into Equations (14) to (17), equating the coefficients of like powers of ε, and neglecting the coefficient of $O(\varepsilon^2)$, we obtain the following sets of differential equations

Zeroth order equations

$$(1+\beta)\frac{d^2u_0}{dy^2} + \frac{du_0}{dy} - \frac{1}{K}u_0 = -\frac{1}{K} - GrT_0 -$$

$$GcC_0 - 2\beta\frac{d\omega_0}{dy} \qquad \ldots(20)$$

$$\frac{d^2\omega_0}{dy^2} + \eta\frac{d\omega_0}{dy} = 0 \qquad \ldots(21)$$

$$\frac{d^2\theta_0}{dy^2} + Pr\frac{d\theta_0}{dy} - N\theta_0 = 0 \quad ...(22)$$

$$\frac{d^2C_0}{dy^2} + Sc\frac{dC_0}{dy} = 0 \quad ...(23)$$

First order equations

$$(1+\beta)\frac{d^2u_1}{dy^2} + \frac{du_1}{dy} - \left(\frac{1}{K}+\delta\right)u_1 = -\left(\frac{1}{K}+\delta\right) - GrT_1 -$$

$$GcC_1 - 2\beta\frac{d\omega_1}{dy} - A\frac{du_0}{dy} \quad ...(24)$$

$$\frac{d^2\omega_1}{dy^2} + \eta\frac{d\omega_1}{dy} - \eta\delta\omega_1 = -\eta A\frac{d\omega_0}{dy} \quad ...(25)$$

$$\frac{d^2\theta_1}{dy^2} + Pr\frac{d\theta_1}{dy} - (N+\delta \Pr)\theta_1 = -Pr\ A\frac{d\theta_0}{dy} \quad ...(26)$$

$$\frac{d^2C_1}{dy^2} + Sc\frac{dC_1}{dy} - Sc\delta C_1 = -ScA\frac{dC_0}{dy} \quad ...(27)$$

and the corresponding boundary conditions are

$u_0 = U_p$, $u_1 = 0$, $\omega_0 = -n\frac{du_0}{dy} = -nh_1$, $\omega_1 = -n\frac{du_1}{dy}$
$= -nh_2$, $\theta_0 = 1$, $\theta_1 = 0$, $C_0 = 1$, $C_1 = 0$ at $y = 0$,
$u_0 \to 1$, $u_1 \to 1$, $\omega_0 \to 0$, $\omega \to 0$, $\theta_0 \to 0$, $\theta_1 \to 0$,
$C_0 \to 0$, $C_1 \to 0$ as $y \to \infty$. … (28)

Now, the equations from (20) to (27) are ordinary linear differential equations with constant coefficients. Through straight forward algebra their solutions are known under boundary conditions (28), and given by

$$u_0 = 1 + b_1e^{R_{10}y} + L_2e^{R_4y} + L_3e^{-Scy} + L_4h_1e^{-\eta y} \quad ...(29)$$

$$u_1 = 1 + b_2e^{R_{12}y} + L_5e^{R_6y} + L_7e^{R_{10}y} + L_8\left(h_2 + \frac{\eta h_1A}{\delta}\right)e^{R_8y}$$

$$+L_9e^{R_4y} + L_{10}e^{-Scy} + L_{11}e^{-\eta y} \quad ...(30)$$

$$\omega_0 = -nh_1e^{-\eta y} \quad ...(31)$$

$$\omega_1 = -\left(nh_2 + \frac{n\eta Ah_1}{\delta}\right)e^{R_8y} + \frac{n\eta Ah_1}{\delta}e^{-\eta y} \quad ...(32)$$

$$\theta_1 = L_1(e^{R_6y} - e^{R_4y}) \quad ...(33)$$

$$\theta_0 = e^{R_4y} \quad ...(34)$$

$$C_0 = e^{-Scy}, \quad ...(35)$$

$$C_1 = \frac{ASc}{\delta}\left(e^{R_2y} - e^{-Scy}\right), \quad ...(36)$$

where b_1, b_2, h_1, h_2, R_4, R_6, R_8, R_{10}, R_{12} and L_1 to L_{11} are constants, not included here for the sake of brevity.

IV. COEFFICIENT OF SKIN–FRICTION

The coefficient of skin–friction at the vertical porous plate is given by

$$C_f = \frac{2\tau_w^*}{\rho U_0V_0} = 2[1+(1-n)\beta]\left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$$= 2[1+(1-n)\beta]\left[\left(\frac{du_0}{dy}\right)_{y=0} + \varepsilon e^{\delta t}\left(\frac{du_1}{dy}\right)_{y=0}\right] \quad ...(37)$$

V. NUSSELT NUMBER

The rate of heat transfer in terms of Nusselt number at the porous plate is given by

$$\mathrm{Nu} = x\frac{\left(\frac{\partial T^*}{\partial y^*}\right)_{y^*=0}}{T_w^* - T_\infty^*} = -\mathrm{Re}\left(\frac{\partial\theta}{\partial y}\right)_{y=0}$$

$$= -\mathrm{Re}\left[\left(\frac{d\theta_0}{dy}\right)_{y=0} + \varepsilon e^{\delta t}\left(\frac{d\theta_1}{dy}\right)_{y=0}\right] \quad ...(38)$$

where $\mathrm{Re} = \frac{V_0x}{\upsilon}$.

VI. SHERWOOD NUMBER

The ratio of convective to diffusive mass transport at the plate in terms of Sherwood number is given by

$$Sh = -x\frac{\left(\frac{\partial C^*}{\partial y^*}\right)_{y^*=0}}{\left(C_w^* - C_\infty^*\right)} = -Re\left(\frac{\partial C}{\partial y}\right)_{y=0}$$

$$= -Re\left(\frac{dC_0}{dy} + \varepsilon e^{\delta t}\frac{dC_1}{dy}\right)_{y=0} \quad ...(39)$$

VII. RESULTS AND DISCUSSIONS

In order to show the effects of various flow parameters on the fluid flow characteristic, the following discussion is set out. The values of *Pr* (Prandtl number) are taken as 0.71 and 7.0 that represent air and water at 20°C temperature and one atmosphere pressure respectively.

It is observed from figure 2 that the magnitude of fluid velocity in case of unsteady flow is less than that of mean flow. In case of unsteady flow, the fluid velocity amplifies with an increment of permeability parameter, mass or thermal buoyancy effect (modified Grashof number or Grashof number); while it diminishes due to increase in Radiative heat or the ratio of momentum of diffusivity (viscosity) over mass diffusivity (Schmidt number). In addition to it, fluid velocity for air is more than that of water. Physically it is possible because fluids with high Prandtl number have high viscosity and hence move slowly.

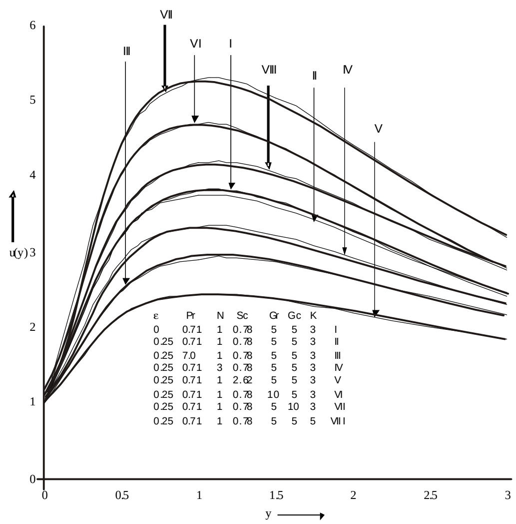

Fig. 2. Velocity distribution versus *y*, when *A* = 1, *Up* = 1, = δ = 0.5, β = 0.5, *n* = 0.5 and *t* = 1.

Fig. 3. depicts that the magnitude of angular velocity of fluid of unsteady flow is greater than that of mean flow; while repeal effect is observed near the plate. Further, in case of unsteady flow, the fluid angular velocity increases with an increase of Radiative heat or the ratio of momentum of diffusivity over mass diffusivity; while it reduces due to increase in permeability parameter, mass or thermal buoyancy effects. Moreover, the angular velocity for water is greater than that of air.

It is noticed from Fig. 4. that the magnitude of fluid temperature in case of unsteady flow is more than that of mean flow. Further, in case of unsteady flow, the fluid temperature decreases due to increase in Radiative heat. In addition, the fluid temperature for air is more than that of water; this is due to the fact that the thermal conductivity of the fluid decreases with increasing of Prandtl number.

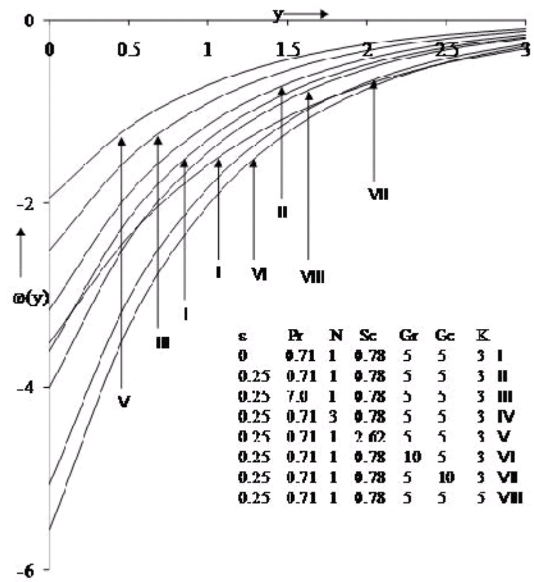

Fig. 3. Angular Velocity distribution versus *y*, when A = 1, *Up* = 1, δ = 0.5, β = 0.5, *n* = 0.5 and *t* = 1.

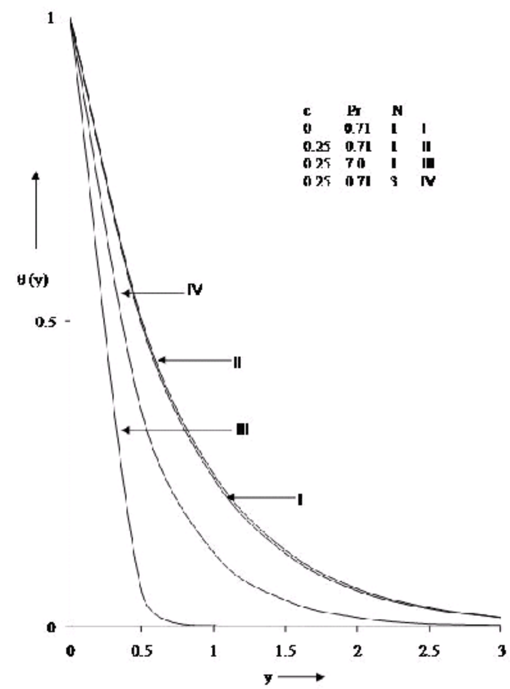

Fig. 4. Temperature distribution versus *y*, when *A* = 1, δ = 0.5 and *t* = 1.

Figu. 5. shows that the magnitude of fluid concentration in case of unsteady flow is less than that of mean flow. In unsteady flow, fluid concentration decreases with an increase of the ratio of momentum of diffusivity over mass diffusivity.

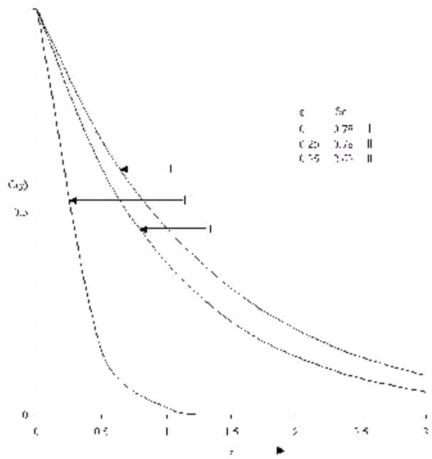

Fig. 5. Concentration distribution versus y, when A = 1, t = 1 and δ = 0.5.

An increase of shearing stress (parameter n) supports the magnitude of fluid velocity, as noticed from figure 6.

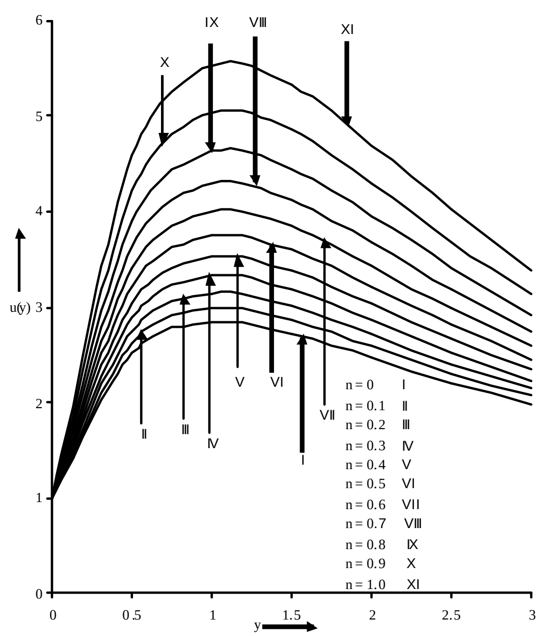

Fig. 6. Velocity distribution versus y, when A = 1, Up = 1, δ = 0.5, β = 0.5, Pr = 0.71, Sc = 0.78, N = 3, Gr = 5, Gc = 5 and K = 3.

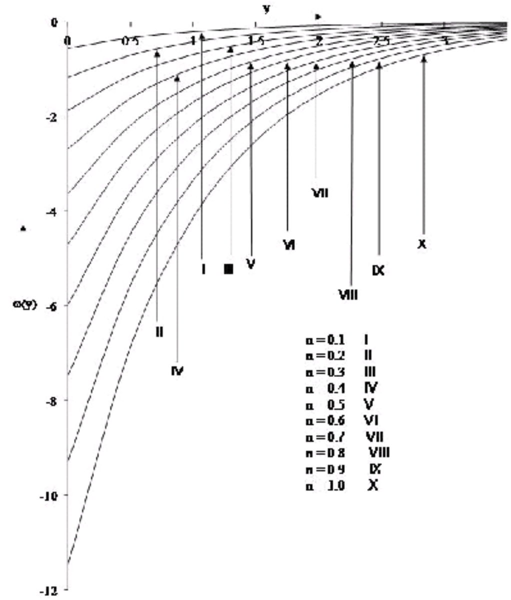

Fig. 7. Angular Velocity distribution versus y, when A = 1, δ = 0.5, β = 0.5, Pr = 0.71, Sc = 0.78, N = 3, Gr = 5, Gc = 5 and K = 3.

Fig. 7. depicts that the angular fluid velocity decreases with an increase of shearing stress.

Table 1 shows that coefficient of skin–friction at the vertical surface in case of unsteady flow is less than that of steady flow. Further in case of unsteady flow, the coefficient of skin–friction at the vertical surface increases with the increase of the shearing stress, the permeability parameter, thermal or mass buoyancy effects; while it decreases due to the increase of the Prandtl number, ratio of momentum of diffusivity over mass diffusivity or Radiative heat.

Also the Nusselt number at the vertical plate in case of unsteady flow is less than that of mean flow. In case of unsteady flow, Nusselt number at the vertical plate increases due to increase of the Radiative heat or Prandtl number.

It is also observed from the table that Sherwood number at the vertical plate for unsteady flow is larger than that of mean flow. Further in the case of unsteady flow, Sherwood number increases with an increase of the ratio of momentum of diffusivity over mass diffusivity.

Table1: Values of the coefficient of skin–friction, Nusselt number and Sherwood number at the plate for various values of physical parameters, where *Up* =1, β = 0.5, δ = 0.5, *t* = 1 and *Re* = 1.

ε	Pr	N	Sc	Gr	Gc	K	n	Cf	Nu	Sh
0	0.71	1	0.78	5	5	3	0.25	16.59226	1.416143	0.78
0.25	0.71	1	0.78	5	5	3	0.25	16.55099	1.384811	1.002655
0.25	7.0	1	0.78	5	5	3	0.25	11.48811	5.130505	1.002655
0.25	0.71	3	0.78	5	5	3	0.25	14.43839	2.110327	1.002655
0.25	0.71	1	2.62	5	5	3	0.25	8.594504	1.384811	3.547794
0.25	0.71	1	0.78	10	5	3	0.25	23.35845	1.384811	1.002655
0.25	0.71	1	0.78	5	10	3	0.25	25.112	1.384811	1.002655
0.25	0.71	1	0.78	5	5	5	0.25	17.99331	1.384811	1.002655
0.25	0.71	1	0.78	5	5	3	0.5	18.10389	1.384811	1.002655

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