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TRANSIENT FREE CONVECTION MHD FLOW BETWEEN TWO LONG VERTICAL PARALLEL PLATES WITH VARIABLE TEMPERATURE AND UNIFORM MASS DIFFUSION IN A POROUS MEDIUM

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ABSTRACT

The unsteady MHD transient free convection flow of an incompressible viscous electrically conducting fluid between two infinite vertical parallel plates with variable temperature and uniform mass diffusion in a porous medium has been considered, under the assumption that the induced magnetic field is negligible. Applied magnetic field is fixed relative to the fluid and plates. The Laplace transform method has been used to find the solutions for the velocity, temperature and concentration profiles. The velocity, temperature and concentration profiles have been studied for different parameters like Prandtl number, Schmidt number, magnetic parameter, buoyancy ratio parameter, permeability parameter and time. The value of the skin-friction for different parameters has been tabulated.

Keywords: transient free convection, heat transfer, mass diffusion, MHD, variable temperature, porous medium, vertical parallel plates.

1. INTRODUCTION

The Study of flows through porous medium has become of great interest in many scientific and engineering applications, such as, in chemical engineering for filtration and purification process; in agriculture engineering to study the underground water resources; in petroleum technology to study the movement of natural gas, water and oil through the oil reservoirs. Singh *et al.*, [1] have studied the transient free convection flow of a viscous incompressible fluid in a vertical parallel plate channel, when the walls are heated asymmetrically. Jha BK. [2] has studied the combined effect of natural convection and uniform transverse magnetic field on the unsteady couette flow. Narahari *et al.*, [3] have studied the transient free convection flow between two infinite vertical parallel plates with constant heat flux at one boundary. Jha *et al.*, [4] have presented the transient free convection flow in a vertical channel as a result of symmetric heating of the channel walls. Transient free convection flow of a viscous and incompressible fluid between two vertical walls as a result of asymmetric heating or cooling of the walls is studied by Singh and Paul [5]. Narahari Marneni [6] has studied the transient free convection flow of a viscous incompressible fluid between two infinite vertical parallel plates in the presence of constant temperature and mass diffusion.

2. MATHEMATICAL ANALYSIS

In the present problem, we assume that the magnetic Reynolds number is so small that the induced magnetic field can be neglected in comparison to the applied one. A magnetic field (fixed relative to the fluid and plates) of uniform strength B_0 is assumed to be applied transversely to the plates. The x' - axis is considered along one of the vertical plates and y' - axis is taken normal to the plates. Initially, at time $t' \leq 0$ the temperature of the fluid and the plates are same as T'_d and the concentration of the fluid is C'_d. At $t' > 0$, the plate temperature is raised linearly with time t and the concentration of the fluid at $y' = 0$ is raised to C'_w causing the flow of free convection currents. The governing equations under the usual Boussinesq's approximation are as follows:

$$\frac{\partial u'}{\partial t'} = g\beta(T'-T'_d) + g\beta^*(C'-C'_d) + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\sigma B_0^2}{\rho}u' - \frac{\nu}{K^*}u', \tag{1}$$

$$\rho C_p \frac{\partial T'}{\partial t'} = k\frac{\partial^2 T'}{\partial y'^2}, \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2}. \tag{3}$$

The initial and boundary condition are as follows:

$$t' \leq 0: \quad u' = 0, \qquad T' = T'_d, \qquad C' = C'_d \quad \text{for} \quad 0 \leq y' \leq d,$$

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$$t'>0: \quad u'=0, \qquad T'=T'_d+(T'_w-T'_d)\frac{t'\nu}{d^2}, \qquad C'=C'_w \quad \text{at} \quad y'=0,$$

$$u'=0, \qquad T'=T'_d, \qquad C'=C'_d \quad \text{at} \quad y'=d. \tag{4}$$

Where,

u' = velocity of the fluid
g = acceleration due to gravity
β = volumetric coefficient of thermal expansion
t' = time
d = distance between two vertical plates
T' = temperature of the fluid
T'_d = temperature of the plate at $y'=d$
β^* = volumetric coefficient of concentration expansion
C' = species concentration in the fluid
C'_d = species concentration at the plate $y'=d$
ν = kinematic viscosity
y' = coordinate axis normal to the plates
ρ = density
C_p = specific heat at constant pressure
k = thermal conductivity of the fluid
D = mass diffusion coefficient
T'_w = temperature of the plate at $y'=0$
C'_w = species concentration at the plate $y'=0$.
B_0 = uniform magnetic field
σ = electrical conductivity
K^* = permeability of the porous medium.

Introducing the following non-dimensional quantities:

$$y=\frac{y'}{d},\ t=\frac{t'\nu}{d^2},\ u=\frac{u'\nu}{d^2 g\beta(T'_w-T'_d)}=\frac{u'd}{\nu\ Gr},$$

$$Gr=\frac{g\beta(T'_w-T'_d)d^3}{\nu^2},\quad \theta=\frac{T'-T'_d}{T'_w-T'_d},\quad \Pr=\frac{\mu C_p}{k},$$

$$C=\frac{C'-C'_d}{C'_w-C'_d},\quad Gm=\frac{g\beta^*(C'_w-C'_d)d^3}{\nu^2},\quad Sc=\frac{\nu}{D},$$

$$N=\frac{Gm}{Gr},\ M=\frac{\sigma B_0^2 d^2}{\mu},\ \mu=\rho\nu,\ K=\frac{K^*}{d^2} \tag{5}$$

Where,

u = dimensionless velocity
y = dimensionless coordinate axis normal to the plates
t = dimensionless time
θ = dimensionless temperature
C = dimensionless concentration
Gr = thermal Grashof number
Gm = mass Grashof number
μ = coefficient of viscosity
Pr = Prandtl number
Sc = Schmidt number
N = buoyancy ratio parameter
M = magnetic parameter
K = permeability parameter.

The model is then transformed into the following non-dimensional form of equations:

$$\frac{\partial u}{\partial t}=\theta+NC+\frac{\partial^2 u}{\partial y^2}-Mu-\frac{1}{K}u, \tag{6}$$

$$\Pr\frac{\partial\theta}{\partial t}=\frac{\partial^2\theta}{\partial y^2}, \tag{7}$$

$$\text{Sc}\frac{\partial C}{\partial t}=\frac{\partial^2 C}{\partial y^2}. \tag{8}$$

The initial and boundary conditions become:

$$t\le 0: \quad u=0, \quad \theta=0, \quad C=0 \quad \text{for} \quad 0\le y\le 1,$$

$$t>0: \quad u=0, \quad \theta=t, \quad C=1 \quad \text{at} \quad y=0,$$

$$u=0, \quad \theta=0, \quad C=0 \quad \text{at} \quad y=1, \tag{9}$$

The final solution of equations (6), (7) and (8) with boundary condition (9) is as under:

Case I: Pr ≠ 1, Sc ≠ 1

$$u(y,t)=\frac{1}{2HR}\exp(Rt)\sum_{n=0}^{\infty}\{F_1(a,1,c_1,t)-F_1(b,1,c_1,t)\}+\left(\frac{1}{2HR}+\frac{N}{2H}\right)\sum_{n=0}^{\infty}\{F_1(b,1,H,t)-F_1(a,1,H,t)\}$$

$$+\frac{1}{H}\sum_{n=0}^{\infty}\{F_2(b,1,H,t)-F_2(a,1,H,t)\}+\frac{N}{2H}\exp(Qt)\sum_{n=0}^{\infty}\{F_1(a,1,c_2,t)-F_1(b,1,c_2,t)\}$$

$$+\frac{1}{2HR}\exp(Rt)\sum_{n=0}^{\infty}\{F_1(b,\Pr,R,t)-F_1(a,\Pr,R,t)\}+\frac{1}{2HR}\sum_{0}^{\infty}\{F_1(a,\Pr,0,t)-F_1(b,\Pr,0,t)\}$$

$$+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_3\left(a,\Pr,t\right)-F_3\left(b,\Pr,t\right)\right\}+\frac{N}{2H}\exp\left(Qt\right)\sum_{n=0}^{\infty}\left\{F_1\left(b,Sc,Q,t\right)-F_1\left(a,Sc,Q,t\right)\right\}$$

$$+\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_1\left(a,Sc,0,t\right)-F_1\left(b,Sc,0,t\right)\right\}, \quad (10)$$

$$\theta(y,t)=\sum_{n=0}^{\infty}\left[\left\{F_3\left(a,\Pr,t\right)-F_3\left(b,\Pr,t\right)\right\}\right], \quad (11)$$

$$C(y,t)=\sum_{n=0}^{\infty}\left[\frac{1}{2}\left\{F_1\left(a,Sc,0,t\right)-F_1\left(b,Sc,0,t\right)\right\}\right]. \quad (12)$$

Case II: Pr = 1, Sc ≠ 1

$$u(y,t)=\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_1\left(b,1,H,t\right)-F_1\left(a,1,H,t\right)\right\}+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_2\left(b,1,H,t\right)-F_2\left(a,1,H,t\right)\right\}$$

$$+\frac{N}{2H}\exp\left(Qt\right)\sum_{n=0}^{\infty}\left\{F_1\left(a,1,c_2,t\right)-F_1\left(b,1,c_2,t\right)\right\}+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_3\left(a,1,t\right)-F_3\left(b,1,t\right)\right\}$$

$$+\frac{N}{2H}\exp\left(Qt\right)\sum_{n=0}^{\infty}\left\{F_1\left(b,Sc,Q,t\right)-F_1\left(a,Sc,Q,t\right)\right\}+\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_1\left(a,Sc,0,t\right)-F_1\left(b,Sc,0,t\right)\right\}, \quad (13)$$

$$\theta(y,t)=\sum_{n=0}^{\infty}\left[\left\{F_3\left(a,1,t\right)-F_3\left(b,1,t\right)\right\}\right], \quad (14)$$

$$C(y,t)=\sum_{n=0}^{\infty}\left[\frac{1}{2}\left\{F_1\left(a,Sc,0,t\right)-F_1\left(b,Sc,0,t\right)\right\}\right]. \quad (15)$$

Case III: Pr ≠ 1, Sc = 1

$$u(y,t)=\frac{1}{2HR}\exp\left(Rt\right)\sum_{n=0}^{\infty}\left\{F_1\left(a,1,c_1,t\right)-F_1\left(b,1,c_1,t\right)\right\}+\left(\frac{1}{2HR}+\frac{N}{2H}\right)\sum_{n=0}^{\infty}\left\{F_1\left(b,1,H,t\right)-F_1\left(a,1,H,t\right)\right\}$$

$$+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_2\left(b,1,H,t\right)-F_2\left(a,1,H,t\right)\right\}+\frac{1}{2HR}\exp\left(Rt\right)\sum_{n=0}^{\infty}\left\{F_1\left(b,\Pr,R,t\right)-F_1\left(a,\Pr,R,t\right)\right\}$$

$$\frac{1}{2HR}\sum_{0}^{\infty}\left\{F_1\left(a,\Pr,0,t\right)-F_1\left(b,\Pr,0,t\right)\right\}+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_3\left(a,\Pr,t\right)-F_3\left(b,\Pr,t\right)\right\}$$

$$+\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_1\left(a,1,0,t\right)-F_1\left(b,1,0,t\right)\right\}, \quad (16)$$

$$\theta(y,t)=\sum_{n=0}^{\infty}\left[\left\{F_3\left(a,\Pr,t\right)-F_3\left(b,\Pr,t\right)\right\}\right], \quad (17)$$

$$C(y,t)=\sum_{n=0}^{\infty}\left[\frac{1}{2}\left\{F_1\left(a,1,0,t\right)-F_1\left(b,1,0,t\right)\right\}\right]. \quad (18)$$

Case IV: Pr = 1, Sc = 1

$$u(y,t)=\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_1\left(b,1,H,t\right)-F_1\left(a,1,H,t\right)\right\}+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_2\left(b,1,H,t\right)-F_2\left(a,1,H,t\right)\right\}$$

$$+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_3\left(a,1,t\right)-F_3\left(b,1,t\right)\right\}+\frac{N}{2H}\sum_{n=0}^{\infty}\{F_1\left(a,1,0,t\right)-F_1\left(b,1,0,t\right)\}, \tag{19}$$

$$\theta(y,t)=\sum_{n=0}^{\infty}[\{F_3\left(a,1,t\right)-F_3\left(b,1,t\right)\}], \tag{20}$$

$$C(y,t)=\sum_{n=0}^{\infty}\left[\frac{1}{2}\{F_1\left(a,1,0,t\right)-F_1\left(b,1,0,t\right)\}\right]. \tag{21}$$

where $a=2n+y,\ b=2-y+2n,\ H=M+\dfrac{1}{K},\ R=\dfrac{H}{\Pr-1},\ Q=\dfrac{H}{Sc-1},\ c_1=H+R,\quad c_2=H+Q$

and $F_1(D_1,D_2,D_3,D_4), F_2(D_1,D_2,D_3,D_4)$ and $F_3(D_1,D_2,D_3)$ are defined in appendix as:

$$F_1(D_1,D_2,D_3,D_4)=\exp\left(-D_1\sqrt{D_2.D_3}\right)erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}-\sqrt{D_3.D_4}\right)+\exp\left(D_1\sqrt{D_2.D_3}\right)erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}+\sqrt{D_3.D_4}\right),$$

$$F_2(D_1,D_2,D_3,D_4)=\exp\left(-D_1\sqrt{D_2.D_3}\right)erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}-\sqrt{D_3.D_4}\right)\left(\frac{D_4}{2}-\frac{D_1}{4\sqrt{D_3}}\right)$$

$$\left(D_1\sqrt{D_2.D_3}\right)erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}+\sqrt{D_3.D_4}\right)\left(\frac{D_4}{2}+\frac{D_1}{4\sqrt{D_3}}\right) \text{ and}$$

$$F_3(D_1,D_2,D_3)=\left(D_3+\frac{D_1^2D_2}{2}\right)erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_3}}\right)-\left(D_1\sqrt{\frac{D_2D_3}{\pi}}\right)\exp\left(-\frac{D_1^2D_2}{4D_3}\right).$$

3. RESULTS AND DISCUSSIONS

The numerical values of the velocity, concentration, temperature and skin-friction are computed for different parameters like Prandtl number Pr, Schmidt number Sc, magnetic parameter M, buoyancy ratio parameter N, permeability parameter K and time t. When N = 0, there is no mass transfer and the buoyancy force is due to the thermal diffusion only. N > 0 means that mass buoyancy force acts in the same direction of thermal buoyancy force, while N < 0 means that mass buoyancy force acts in the opposite direction. The values of the main parameters considered are: the magnetic parameter M = 1.0, 2.0, 3.0; time t = 0.2, 0.4, 0.6; buoyancy ratio parameter N = 0.2, 0.4, -0.2, -0.4; permeability parameter K = 0.5, 1.0; Prandtl number Pr = 3 (for the saturated liquid Freon at 273.3^0K), 7 (for water) and 10 (for Gasoline at 1 atm. Pressure at 20 ^{0}C) and Schmidt number Sc = 0.22 (for Hydrogen), 0.60 (for Oxygen) and 0.78 (for Ammonia). Graphs have been plotted for the temperature, concentration and velocity profiles to show the effects of different parameters.

Figures 1 and 2 show the effect of Prandtl number Pr on the temperature of fluid at t = 0.2 and t = 0.4, respectively. It is observed that temperature decreases with increase of Prandtl number at t = 0.2 and t = 0.4. From Figures 1 and 2, it is also clear that the temperature of fluid increases with increase of time t.

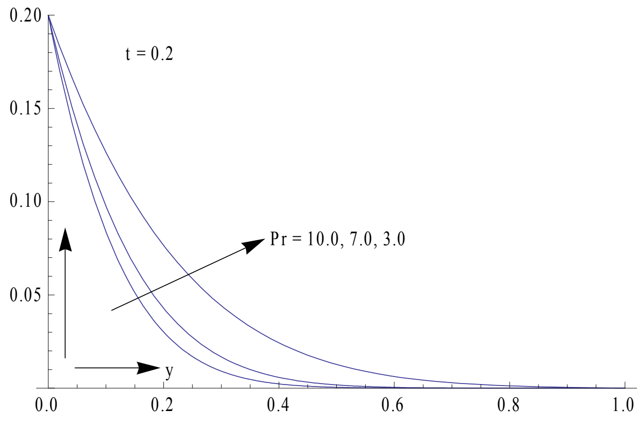

Figure-1. Temperature profiles.

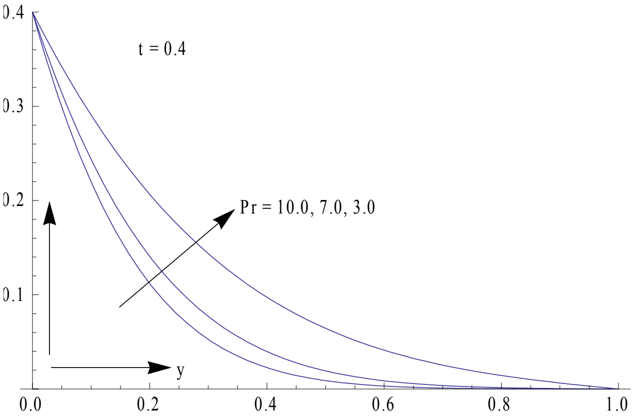

Figure-2. Temperature profiles.

Figures 3 and 4 show the effect of Schmidt number Sc and time t on the concentration of fluid, respectively. It is observed that the concentration decreases with increase of Schmidt number, but it increases with increase of time t.

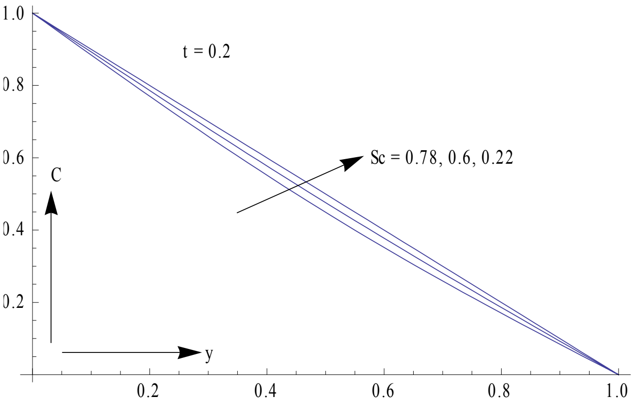

Figure-3. Concentration profiles.

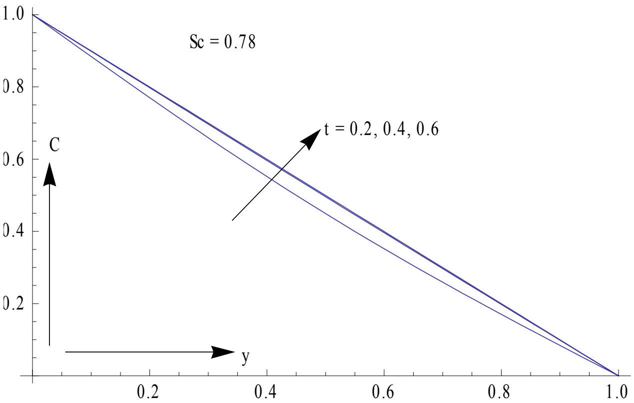

Figure-4. Concentration profiles.

Figures 5 and 6 illustrate the effect of magnetic parameter M and buoyancy ratio parameter N on the velocity of fluid, respectively. It is observed that the velocity decreases with increase of magnetic parameter. Fruther, the velocity increases in the presence of aiding flows (N >0), but it decreases in the presence of opposing flows (N < 0).

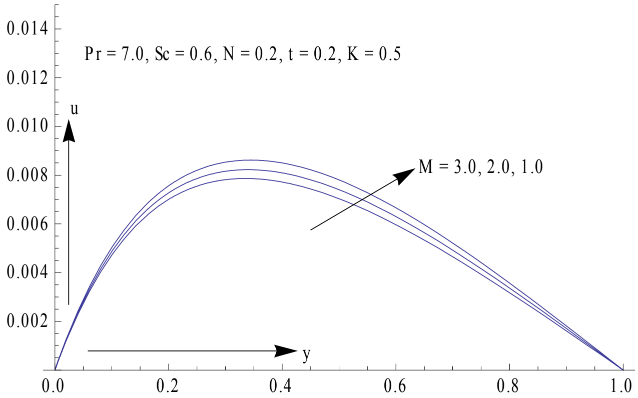

Figure-5. Velocity profiles.

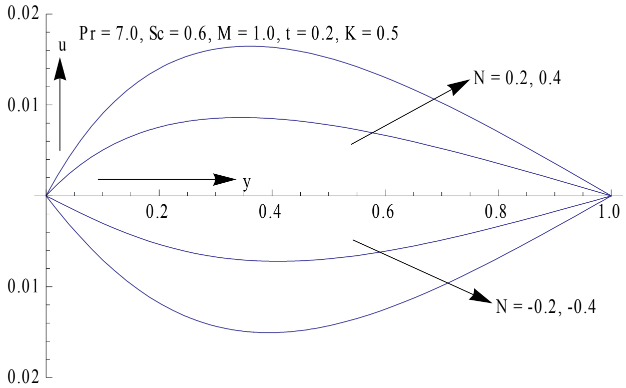

Figure-6. Velocity profiles.

Figures 7 and 8 show the effect of time t and permeability parameter K on the velocity of fluid respectively. It is observed that the velocity increases with increase of time and permeability parameter.

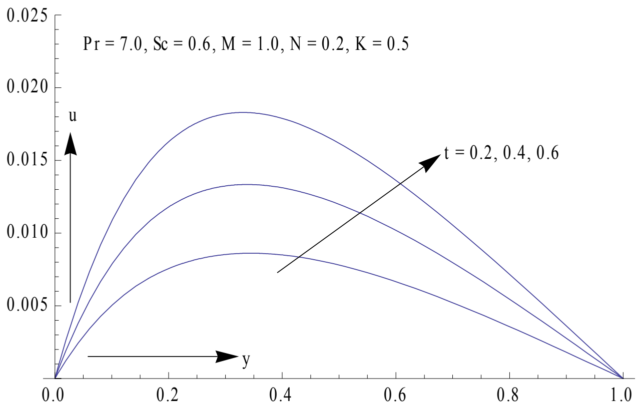

Figure-7. Velocity profiles.

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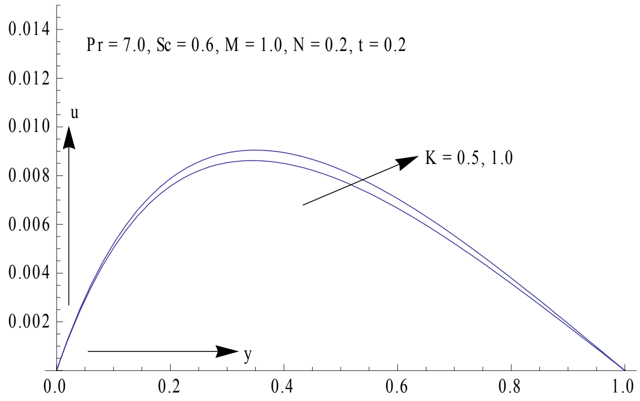

Figure-8. Velocity profiles.

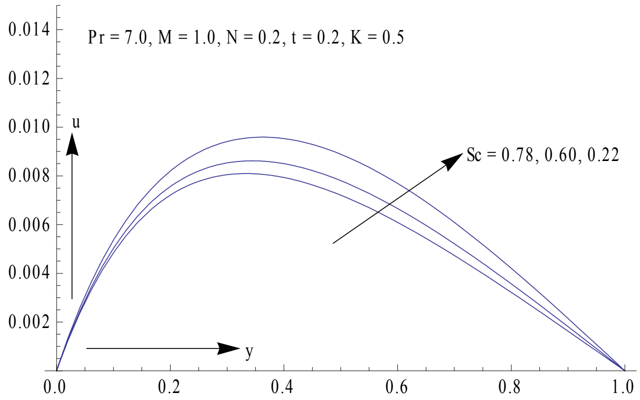

Figure-9. Velocity profiles.

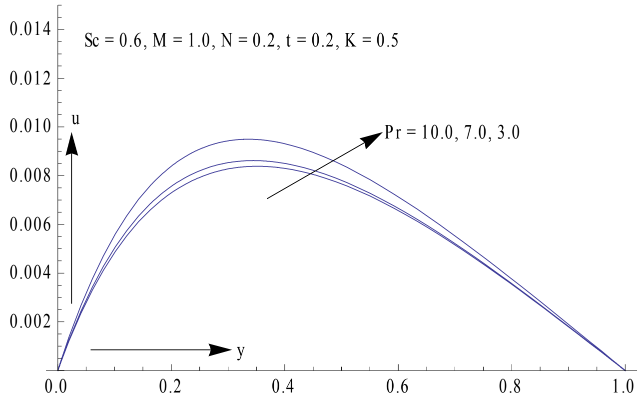

Figure-10. Velocity profiles.

Figures 9 and 10 show the effect of Schmidt number Sc and Prandtl number Pr on the velocity of fluid respectively. It is observed that the velocity decreases with increase of Schmidt number and Prandtl number.

The skin-friction has been studied for $Sc \neq 1$, $Pr \neq 1$. Therefore using the expressions (10) the skin-friction (τ_0, τ_1) in non-dimensional form are given by:

$$\tau_0 = \frac{\tau_0' \nu}{dg\beta(T_w' - T_d')} = \left.\frac{du}{dy}\right|_{y=0}$$
$$= -\frac{1}{2HR}\exp(Rt)\sum_{n=0}^{\infty}\left\{F_4(2n,1,c_1,t) + F_4(2+2n,1,c_1,t)\right\} + \frac{1}{2}\left(\frac{1}{HR}+\frac{N}{H}\right)\sum_{n=0}^{\infty}\left\{F_4(2n,1,H,t) + F_4(2+2n,1,H,t)\right\}$$
$$+\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_5(2n,1,H,t) + F_5(2+2n,1,H,t)\right\} - \frac{N}{2H}\exp(Qt)\sum_{n=0}^{\infty}\left\{F_4(2n,1,c_2,t) + F_4(2+2n,1,c_2,t)\right\}$$
$$+\frac{1}{2HR}\exp(Rt)\sum_{n=0}^{\infty}\left\{F_4(2n,\Pr,R,t) + F_4(2+2n,\Pr,R,t)\right\} - \frac{1}{2HR}\sum_{n=0}^{\infty}\left\{F_4(2n,\Pr,0,t) + F_4(2+2n,\Pr,0,t)\right\}$$
$$-\frac{1}{H}\sum_{n=0}^{\infty}\left\{F_6(2n,\Pr,t) + F_6(2+2n,\Pr,t)\right\} + \frac{N}{2H}\exp(Qt)\sum_{n=0}^{\infty}\left\{F_4(2n,Sc,Q,t) + F_4(2+2n,Sc,Q,t)\right\}$$
$$-\frac{N}{2H}\sum_{n=0}^{\infty}\left\{F_4(2n,Sc,0,t) + F_4(2+2n,Sc,0,t)\right\}, \quad (22)$$

$$\tau_1 = -\left.\frac{du}{dy}\right|_{y=1} = \sum_{n=0}^{\infty}\left\{\frac{1}{HR}\exp(Rt)F_4(1+2n,1,c_1,t) - \left(\frac{N}{H}+\frac{1}{HR}\right)F_4(1+2n,1,H,t) - \frac{2}{H}F_5(1+2n,1,H,t)\right\}$$
$$+\sum_{n=0}^{\infty}\left\{\frac{N}{H}\exp(Qt)F_4(1+2n,1,c_2,t) - \frac{1}{HR}\exp(Rt)F_4(1+2n,\Pr,R,t) + \frac{1}{HR}F_4(1+2n,\Pr,0,t)\right\}$$
$$+\sum_{n=0}^{\infty}\left\{\frac{1}{H}F_6(1+2n,\Pr,t) - \frac{N}{H}\exp(Qt)F_4(1+2n,Sc,Q,t) + \frac{N}{H}F_4(1+2n,Sc,0,t)\right\}, \quad (23)$$

where $F_4(D_1,D_2,D_3,D_4), F_5(D_1,D_2,D_3,D_4)$ and $F_6(D_1,D_2,D_3)$ are defined in appendix as:

$$F_4(D_1,D_2,D_3,D_4)=\frac{1}{\sqrt{\pi D_4}}e^{-D_1\sqrt{D_2.D_3}-\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}-\sqrt{D_3.D_4}\right)^2}\sqrt{D_2}+\frac{1}{\sqrt{\pi D_4}}e^{D_1\sqrt{D_2.D_3}-\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}+\sqrt{D_3.D_4}\right)^2}\sqrt{D_2}$$

$$+e^{-D_1\sqrt{D_2.D_3}}\sqrt{D_2.D_3}\ erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}-\sqrt{D_3.D_4}\right)-e^{D_1\sqrt{D_2.D_3}}\sqrt{D_2.D_3}\ erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}+\sqrt{D_3.D_4}\right),$$

$$F_5(D_1,D_2,D_3,D_4)=\frac{1}{\sqrt{\pi D_4}}e^{-D_1\sqrt{D_2.D_3}-(a_1)^2}b_1+\frac{1}{\sqrt{\pi D_4}}e^{D_1\sqrt{D_2.D_3}-(a_2)^2}b_2+\frac{1}{4\sqrt{D_3}}e^{-D_1\sqrt{D_2.D_3}}Erfc(a_1)$$

$$+e^{-D_1\sqrt{D_2.D_3}}\sqrt{D_2.D_3}\ b_1Erfc(a_1)-\frac{1}{4\sqrt{D_3}}e^{D_1\sqrt{D_2.D_3}}Erfc(a_2)-e^{D_1\sqrt{D_2.D_3}}\sqrt{D_2.D_3}\ b_2Erfc(a_2)$$

and $$F_6(D_1,D_2,D_3)=\frac{2}{\sqrt{\pi}}e^{-\frac{D_1^2D_2}{4D_3}}\sqrt{D_2D_3}-D_1D_2Erfc\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_3}}\right).$$

Here $a_1=\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}-\sqrt{D_3D_4}\right)$, $a_2=\left(\frac{D_1\sqrt{D_2}}{2\sqrt{D_4}}+\sqrt{D_3D_4}\right)$, $b_1=\left(\frac{D_4}{2}-\frac{D_1}{4\sqrt{D_3}}\right)$ and $b_2=\left(\frac{D_4}{2}+\frac{D_1}{4\sqrt{D_3}}\right)$

The numerical values of skin-friction τ_0 and τ_1 are presented in Table-1. From Table, it is observed that the skin-friction decreases with of increase of magnetic parameter M, Prandtl number Pr and Schmidt number Sc. It is also observed that the skin-friction increases with increase of time t, permeability parameter K and in the presence of aiding flows (N >0), but it decreases in the presence of opposing flows (N > 0).

Table-1. Skin-friction and volume flux for Sc ≠ 1, Pr ≠1.

Pr	Sc	M	N	K	t	τ_0	τ_1
7.0	0.6	1.0	0.2	0.5	0.2	0.0674194	0.0182031
7.0	0.6	2.0	0.2	0.5	0.2	0.0657353	0.0171354
7.0	0.6	3.0	0.2	0.5	0.2	0.0641674	0.0161599
7.0	0.6	1.0	0.4	0.5	0.2	0.1169550	0.0359719
7.0	0.6	1.0	-0.2	0.5	0.2	-0.0316515	-0.0173345
7.0	0.6	1.0	-0.4	0.5	0.2	-0.0811869	-0.0351033
7.0	0.6	1.0	0.2	1.0	0.2	0.0692319	0.0193740
7.0	0.6	1.0	0.2	0.5	0.4	0.1046440	0.0278678
7.0	0.6	1.0	0.2	0.5	0.6	0.1435360	0.0363477
10.0	0.6	1.0	0.2	0.5	0.2	0.0652610	0.0180565
3.0	0.6	1.0	0.2	0.5	0.2	0.0731511	0.0190625
7.0	0.78	1.0	0.2	0.5	0.2	0.0655374	0.0163304
7.0	0.22	1.0	0.2	0.5	0.2	0.0708260	0.0210604

4. CONCLUSIONS

In the present paper, the general analytical solutions for the unsteady MHD transient free convection flow of an electrically conducting fluid between two infinite vertical parallel plates with Variable temperature and uniform mass diffusion in a porous medium has been determined. The solutions for the model have been determined by using Laplace transform method. Some conclusions of the study are as below:

- The temperature increases with increasing time t but decreases with increasing the value of the Prandtl number Pr.
- The concentration increases with increasing time t but decreases with increasing the value of the Schmidt number Sc.
- The velocity and skin-friction of the fluid increase in case of aiding flows ($N > 0$) and decrease with opposing flows ($N < 0$).
- The velocity and skin-friction of the fluid increase with increasing the value of time t and permeability parameter K but decrease with increasing the value of the Prandtl number Pr, Schmidt number Sc, magnetic parameter M.

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