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Heat and Mass Transport on MHD Free Convective Flow through a Porous Medium Past an Infinite Vertical Plate

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Abstract

In this chapter, we have considered the unsteady free convective flow of a viscous incompressible electrically conducting fluid over an infinite vertical porous plate under the influence of uniform transverse magnate field with time dependent permeability and oscillatory suction. The governing equations of the flow field are solved by a regular perturbation method for small amplitude of the permeability. The solutions for the velocity, temperature and concentration have been derived analytically and also its behavior is computationally discussed with reference to different flow parameters with the help of profiles. The skin fiction on the boundary, the heat flux in terms of the Nusselt number and rate of mass transfer in terms of Sherwood number are also obtained and their behavior computationally discussed.

Keywords: Heat and mass transfer, MHD, Porous medium, vertical plates, unsteady flows.

1. INTRODUCTION

Magnetohydrodynamics (MHD) is of that conductive fluids whether liquids or gaseous, which can support magnetic fields. In earlier years MHD was applied to astrophysical and geophysical problems, where it is still very important. In engineering MHD is employed to study mostly the magnetic behavior of plasmas in fusion reactors, liquid- metal cooling of nuclear reactors and electromagnetic casting. Many people have extensively studied in this field with its applications. Das et al. [17] have studied the unsteady MHD flow and heat transfer of incompressible electrically conducting viscous fluid past an infinite heated porous plate. The unsteady MHD natural convection flow and mass transfer along an accelerated porous plate in a porous medium have been studied by Sattar and Maleque [7], and Sattar et al. [8]. Natural convection or free convection is a mechanism of heat transport in which the motion of the fluid is not generated by any external source like a pump, suction device etc. but only by density differences in the fluid which occurs due to temperature gradients. Anwar [6] has worked on MHD unsteady free convective flow past a vertical porous plate. Goshdastidar [14] has done a comparative study on various fields of free convection flows and also its application. Nield and Bejan [4] have also worked in the same field. Vedhanayagam et al. [11], Martynenko et al. [12], Kolar et al. [2], Ramanaiah et al. [5] and Camargo et al. [15] have extensively studied free convection effect on flow past a vertical surface with different boundary conditions. Also Revankar [18], Sahoo et al. [13] have worked on hydromagnetic natural convection flow past a vertical surface. Thermal radiation is the transfer of energy by the emission of electromagnetic waves which carry energy away from the emitting object. The effects of thermal radiation on natural convective flow are significant in problems involving absorbing and emitting fluids. Many authors have studied experimentally and theoretically fluid flow through a porous channel because of its wide applications in many fields such as diffusion technology, transpiration cooling etc. Samad and Rahman [9] have analyzed thermal radiation interaction with unsteady MHD flow past a vertical porous plate immersed in porous medium. Ibrahim et al. [10] have investigated thermal radiation effect on a porous media under optically thick approximation using Newton Scheme method from Taylor series. The flow of an incompressible viscous fluid near a porous oscillating infinite plate with suction or blowing condition was studied by Biihler and Zierep [3]. Das et al. [16] have made an analytical investigation to study the radiation effect on natural convective flow past a vertical plate in the presence of porous medium. Veera Krishna and Chamkha [20] investigated The diffusion-thermo, radiation-absorption and Hall and ion slip effects on MHD free convective rotating flow of nano-fluids past a semi-infinite permeable moving plate with constant heat source. Veera Krishna et al.[21] discussed the Soret and Joule effects of MHD mixed convective flow of an incompressible and electrically conducting viscous fluid past an infinite vertical porous plate taking Hall effects into account. Veera Krishna and Chamkha [22] discussed the MHD squeezing flow of a water-based nanofluid through a saturated porous medium between two parallel disks, taking the Hall current into account. The effects of radiation and Hall current on an unsteady MHD free convective flow in a vertical channel filled with a porous medium have been studied by Veera Krishna et al. [23]. The heat generation/absorption and thermo-diffusion on an unsteady free convective MHD flow of radiating and chemically reactive second grade fluid near an infinite vertical plate through a porous medium and taking the Hall current into account have been studied by Veera Krishna and Chamkha [24]. Veera Krishna et al. [25] discussed the heat and mass transfer on unsteady, MHD oscillatory flow of second-grade fluid through a porous medium between two vertical plates under the influence of fluctuating heat source/sink, and chemical reaction. Veera

Krishna et al. [26] investigated the heat and mass transfer on MHD free convective flow over an infinite non-conducting vertical flat porous plate. Veera Krishna and Jyothi [27] discussed the effect of heat and mass transfer on free convective rotating flow of a visco-elastic incompressible electrically conducting fluid past a vertical porous plate with time dependent oscillatory permeability and suction in presence of a uniform transverse magnetic field and heat source. Veera Krishna and Subba Reddy [28] investigated the transient MHD flow of a reactive second grade fluid through a porous medium between two infinitely long horizontal parallel plates. Veera Krishna et al. [29] discussed heat and mass-transfer effects on an unsteady flow of a chemically reacting micropolar fluid over an infinite vertical porous plate in the presence of an inclined magnetic field, Hall current effect, and thermal radiation taken into account. Veera Krishna et al. [30] discussed Hall effects on MHD peristaltic flow of Jeffrey fluid through porous medium in a vertical stratum. The effects of heat and mass transfer on free convective flow of micropolar fluid were studied over an infinite vertical porous plate in the presence of an inclined magnetic field with a constant suction velocity and taking Hall current into account have been discussed by Veera Krishna et al.[31]. Veera Krishna and Chamkha [32] have discussed the systematic solution of time-dependent mean velocity on MHD peristaltic rotating flow of an electrically conducting couple stress fluid in a uniform elastic porous channel.

Keeping the above mentioned facts, in this paper, MHD we have considered the unsteady free convective flow of a viscous incompressible electrically conducting fluid over an infinite vertical porous plate under the influence of uniform transverse magnate field with time dependent permeability and oscillatory suction.

2. FORMULATION AND SOLUTION OF THE PROBLEM:

We considered the unsteady MHD free convection flow of an incompressible viscous electrically conducting fluid with simultaneous heat and mass transfer over an infinite vertical plate through porous medium with time dependent permeability and oscillatory suction. The *y*-axis is taken along the plate and *x*-axis perpendicular to it and *u* is the velocity along the *x*-direction.

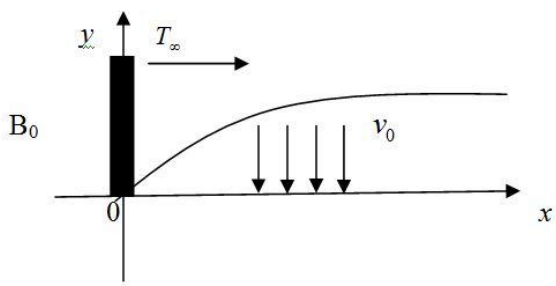

Fig. 4.1 Physical configuration of the problem

The basic assumptions are

1. All fluid proportions are constant.
2. The plate and the fluid are to be at the same temperature and the species concentration is raised or lowered.
3. The magnetic Reynolds number is so small that the induced magnetic field are neglected in comparison to the applied magnetic field.
4. The permeability of the porous medium is

$$K(t)=k(1+\varepsilon e^{i\omega t}) \tag{1}$$

5. The suction velocity is

$$v(t)=-v_0(1+\varepsilon e^{i\omega t}) \tag{2}$$

Where, v_0 represents the suction / injection velocity at the plate.

6. If the plate is extended to infinite length, then all the physical variables are functions of *y* and *t* alone.

The governing equations are given by

$$\frac{\partial u}{\partial y}=0 \tag{3}$$

$$\frac{\partial u}{\partial t}-v\frac{\partial u}{\partial y}=\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma\mu_e{}^2H_0^2}{\rho}u-\frac{\nu}{K(t)}u+g\beta(T-T_\infty)+g\beta^*(C-C_\infty) \tag{4}$$

$$\frac{\partial T}{\partial t}-v\frac{\partial T}{\partial y}=\alpha\frac{\partial^2 T}{\partial y^2}-S_1(T-T_\infty) \tag{5}$$

$$\frac{\partial C}{\partial t}-v\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}-K_1(C-C_\infty) \tag{6}$$

The boundary conditions are

$$\begin{aligned} u(y,t)=T(y,t)=C(y,t)&=f(t) \quad \text{at} \quad y=0 \\ &=0 \quad \text{at} \quad y\to\infty \end{aligned} \tag{7}$$

Where, $f(t)=1+\varepsilon e^{i\omega t}$.The Boussinesq's approximation is taken into account. We are following non-dimensional variables.

$$u^*=\frac{u}{v_0},y=\frac{v_0 y^*}{\nu},t^*=\frac{v_0^2 t}{\nu},$$

$$\omega^*=\frac{\nu\omega}{v_0{}^2},\ \theta=\frac{T-T_\infty}{T_w-T_\infty},\ \phi=\frac{C-C_\infty}{C_w-C_\infty}$$

Making use of non-dimensional variables, the governing equations reduces to (Dropping asterisks)

$$\frac{\partial u}{\partial t} - v_o(1+\varepsilon e^{i\omega t})\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} - \left(M^2 + \frac{1}{K(1+\varepsilon e^{i\omega t})}\right)u + \mathrm{Gr}\,\theta + \mathrm{Gm}\,C \quad (8)$$

$$\Pr\frac{\partial \theta}{\partial t} - v_0(1+\varepsilon e^{i\omega t})\Pr\frac{\partial \theta}{\partial y} = \frac{\partial^2 \theta}{\partial y^2} - \Pr S\,\theta \quad (9)$$

$$\mathrm{Sc}\frac{\partial \phi}{\partial t} - v_0(1+\varepsilon e^{i\omega t})\mathrm{Sc}\frac{\partial \phi}{\partial y} = \frac{\partial^2 \phi}{\partial y^2} - \mathrm{KcSc}\phi, \quad (10)$$

Corresponding boundary conditions are

$$u(y,t) = \theta(y,t) = \phi(y,t) = 1+\varepsilon e^{i\omega t} \quad \text{at} \quad y=0$$
$$= 0 \quad \text{at} \quad y\to\infty \quad (11)$$

Where $M^2 = \frac{\sigma B_0^2 \nu}{\rho v_0^2}$, is the Hartmann number (Magnetic field parameter), $K = \frac{\nu^2}{k v_0^2}$ is the permeability parameter (Porosity or Darcy parameter), $\Pr = \frac{\nu}{\alpha}$ is the Prandtl number, $\mathrm{Sc} = \frac{\nu}{D}$ is the Schmidt number, $\mathrm{Kc} = \frac{K_1 \nu}{v_0^2}$ is the chemical reaction parameter, $S = \frac{S_1 \nu}{v_0^2}$ is the Heat Source parameter,

$\mathrm{Gr} = \frac{g\beta\nu(T_w - T_\infty)}{v_0^3}$ is the thermal Grashof number and

$\mathrm{Gm} = \frac{g\beta^* \nu(C_w - C_\infty)}{v_0^3}$ is the mass Grashof number.

To solve the equations, (8) – (10) using boundary conditions (11), we assume the solutions of the following form, because the amplitude $\varepsilon(<<1)$ of permeability is very small.

$$u(y,t) = u_0(y) + \varepsilon\, u_1(y) e^{i\omega t} \quad (12)$$

$$\theta(y,t) = \theta_0(y) + \varepsilon\, \theta_1(y) e^{i\omega t} \quad (13)$$

$$\phi(y,t) = \phi_0(y) + \varepsilon\, \phi_1(y) e^{i\omega t} \quad (14)$$

Substituting the Eqs. (12) – (14) into the Eqs. (8) – (10) respectively and equate the harmonic and non-hormonic terms to obtain the zeroth and first orders ordinary differential equations for momentum, temperature and concentration distributions.

Zeroth order:

$$\frac{\partial^2 \phi_0}{\partial y^2} + \mathrm{Sc}v_0\frac{\partial \phi_0}{\partial y} - \mathrm{KcSc}\phi_0 = 0 \quad (15)$$

$$\frac{\partial^2 \theta_0}{\partial y^2} + \Pr v_0\frac{\partial \theta_0}{\partial y} - \Pr S\theta_0 = 0 \quad (16)$$

$$\frac{\partial^2 u_0}{\partial y^2} + v_0\frac{\partial u_0}{\partial y} - \left(M^2 + \frac{1}{K}\right)u_0 = -\mathrm{Gr}\theta_0 - \mathrm{Gm}\phi_0 \quad (17)$$

Corresponding boundary conditions are

$$\phi_0 = 1, \theta_0 = 1, u_0 = 1 \quad \text{at} \quad y=0 \quad (18)$$

$$\phi_0 = 0, \theta_0 = 0, u_0 = 0 \quad \text{at} \quad y\to\infty \quad (19)$$

Solving the equations (15) – (17) with relevant boundary conditions (18) and (19), we obtained the zeroth order concentration, temperature and velocity.

First order:

$$\frac{\partial^2 \phi_1}{\partial y^2} + \mathrm{Sc}v_0\frac{\partial \phi_1}{\partial y} - \mathrm{Sc}(\mathrm{Kc}+i\omega)\phi_1 = -\mathrm{Sc}v_0\frac{\partial \phi_0}{\partial y} \quad (20)$$

$$\frac{\partial^2 \theta_1}{\partial y^2} + \Pr v_0\frac{\partial \theta_1}{\partial y} - \Pr(S+i\omega)\theta_1 = -\Pr v_0\frac{\partial \theta_0}{\partial y} \quad (21)$$

$$\frac{\partial^2 u_1}{\partial y^2} + v_0\frac{\partial u_1}{\partial y} - \left(M^2 + \frac{1}{K} + i\omega\right)u_1 = -v_0\frac{\partial u_0}{\partial y} - \mathrm{Gr}\,\theta_1 - \mathrm{Gm}\,\phi_1 \quad (22)$$

Corresponding boundary conditions are

$$\phi_1 = 1, \theta_1 = 1, u_1 = 1 \quad \text{at} \quad y=0 \quad (23)$$

$$\phi_1 = 0, \theta_1 = 0, u_1 = 0 \quad \text{at} \quad y\to\infty \quad (24)$$

Solving the equations (20) – (22) with relevant boundary conditions (23) and (24), we obtained the first order concentration, temperature and velocity.

$$\phi_0 = e^{-m_1 y} \quad (25)$$

$$\theta_0 = e^{-m_3 y} \quad (26)$$

$$u_0 = A_1 e^{-m_5 y} - \frac{\mathrm{Gr}}{A_2}e^{-m_3 y} - \frac{\mathrm{Gm}}{A_3}e^{-m_1 y} \quad (27)$$

$$\phi_1 = \left(1 - \frac{\mathrm{Sc}\,v_0\,m_1}{m_1^2 + \mathrm{Sc}\,v_0\,m_1 - \mathrm{Sc}(\mathrm{Kc}+i\omega)}\right)e^{-m_2 y} + \frac{\mathrm{Sc}\,v_0\,m_1\,e^{-m_1 y}}{m_1^2 + \mathrm{Sc}\,v_0\,m_1 - \mathrm{Sc}(\mathrm{Kc}+i\omega)} \quad (28)$$

$$\theta_1 = \left(1 - \frac{\Pr v_0\, m_3}{m_3^2 + \Pr v_0\, m_3 - \Pr(S + i\omega)}\right) e^{-m_4 y} + \frac{\Pr v_0\, m_3\, e^{-m_3 y}}{m_3^2 + \Pr v_0\, m_3 - \Pr(S + i\omega)} \quad (29)$$

$$u_1 = (1 - B_1 + \text{Gr}B_2 + \text{Gm}B_3)e^{-m_6 y} + \frac{A_8}{A_{11}} e^{-m_5 y} + \frac{A_9}{A_{12}} e^{-m_3 y} + \frac{A_{10}}{A_{13}} e^{-m_1 y}$$
$$-\text{Gr}\left(\frac{A_4}{A_{14}} e^{-m_4 y} + \frac{A_5}{A_{12}} e^{-m_3 y}\right) - \text{Gm}\left(\frac{A_6}{A_{15}} e^{-m_2 y} + \frac{A_7}{A_{13}} e^{-m_1 y}\right) \quad (30)$$

The skin friction at the plate in terms of amplitude and phase is given by

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = \left(\frac{\partial u_0}{\partial y}\right)_{y=0} + \varepsilon \left(\frac{\partial u_1}{\partial y}\right)_{y=0} = F_1 + \varepsilon |F_2| \cos(\omega t + \psi) \quad (31)$$

Where, $F_1 = \left(\frac{\partial u_0}{\partial y}\right)_{y=0}$; $F_2 = \left(\frac{\partial u_1}{\partial y}\right)_{y=0}$ and $\tan(\psi) = \frac{\text{Re}[F_2]}{\text{Im}[F_2]}$.

The Nusselt number at the plate in terms of amplitude and phase is given by

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = \left(\frac{\partial \theta_0}{\partial y}\right)_{y=0} + \varepsilon \left(\frac{\partial \theta_1}{\partial y}\right)_{y=0} = F_3 + \varepsilon |F_4| \cos(\omega t + \gamma) \quad (32)$$

Where, $F_3 = \left(\frac{\partial \theta_0}{\partial y}\right)_{y=0}$; $F_4 = \left(\frac{\partial \theta_1}{\partial y}\right)_{y=0}$ and $\tan(\gamma) = \frac{\text{Re}[F_4]}{\text{Im}[F_4]}$.

The Sherwood number at the plate in terms of amplitude and phase is given by

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} = \left(\frac{\partial \phi_0}{\partial y}\right)_{y=0} + \varepsilon \left(\frac{\partial \phi_1}{\partial y}\right)_{y=0} = F_5 + \varepsilon |F_6| \cos(\omega t + \zeta) \quad (33)$$

Where, $F_5 = \left(\frac{\partial \phi_0}{\partial y}\right)_{y=0}$; $F_6 = \left(\frac{\partial \phi_1}{\partial y}\right)_{y=0}$ and $\tan(\zeta) = \frac{\text{Re}[F_6]}{\text{Im}[F_6]}$.

3. RESULTS AND DISCUSSION:

We have considered the unsteady free convective flow of a viscous incompressible electrically conducting fluid over an infinite vertical porous plate under the influence of uniform transverse magnate field with time dependent permeability and oscillatory suction. Figures (2-3) represent velocity, Figures (4) and Figures (5) represent the temperature and concentration distributions respectively. The stresses, Nusselt number and Sherwood number at the plate are evaluated numerically and discussed with governing parameters and are tabulated in the tables (1-3). Fixing the parameters M=2, K=1, Pr=0.71, S=1, Sc=0.22, Kc=1, Gr=5, Gm=10, v_0=0.2 and $\omega = \pi / 6$, we draw the profiles varying for each parameter while the other parameters being fixed.

From the Figures 2(a-f), we noticed that the magnitude of the velocity component *u* reduces with increasing the intensity of the magnetic field M. Due to the Lorentz force the velocity retards continuously throughout the fluid region. Similar behaviour is observed with increasing Prandtl number Pr and heat source parameter *S*. Whereas the velocity component *u* enhance with increasing permeability parameter K, thermal Grashof number Gr or mass Grashof number Gm throughout the fluid region. Lower the permeability of the porous medium lesser the fluid speed in the entire region. The Figures (3) depict the velocity component *u* experiences retardation in the flow field with increasing chemical reaction parameter Kc, Schmidt number Sc, suction parameter v_0 or frequency of oscillation ω in the entire the fluid region. Figures 4(a-d) showed the effect of heat source parameter *S*, the Prandtl number Pr, suction parameter v_0 or frequency of oscillation ω on the temperature of the flow field. We noted that the temperature of the flow field diminishes as the Pr increases. This is consistent with the fact that the thermal boundary layer thickness decreases with increasing Pr. With increasing heat S reduces the temperature of the flow field. This may happen due the elastic property of the fluid. It is observed that temperature of the flow field diminishes as the suction parameter or ω increases. Figures 4(a-d) depict the effect of the Sc and ω on concentration distribution. The concentration distribution decreases at all points of the flow field with the increase in the Schmidt number or chemical reaction parameter Kc. This shows that the heavier diffusing species have a greater retarding effect on the concentration distribution of the flow field. Also, it is observed that presence of ω or increasing the v_0 reduces the concentration distribution.

The frictional force is significant phenomenon which characterizes the frictional drag force at the solid surface. From Table 1, it is observed that the 'τ'increases with the increase in *K*, Gr, Gm and v_0, but it is interesting to note that the 'τ'decreases with the increase in *M*, Pr, Sc, Kc, *S* and ω.. Similarly the amplitude augments with increase *K*, Sc, Kc, Gr, Gm and v_0 retards with increase *M*, Pr, *S* and ω. The magnitude of the phase angle increase with Pr, S and Gm and reduces with *K* Sc, Kc, Gr and ω. From Table 2, it is to note that all the entries are positive. It is seen that *S*, Pr and v_0 increase amplitude and Nu at the surface of the plate. Reduce the phase angle and increase the amplitude and Nu with increase ω. From Table 3, it is to note that all the entries are positive. It is observed that Sc, Kc and v_0 increase amplitude and 'Sh' at the surface of the plate. Increase the ω , enhance the amplitude, 'Sh' decrease the phase angle. Table 4 represents the comparison of the results. These results are very good agreement with the results of Ashraf [19] when Sc=0.

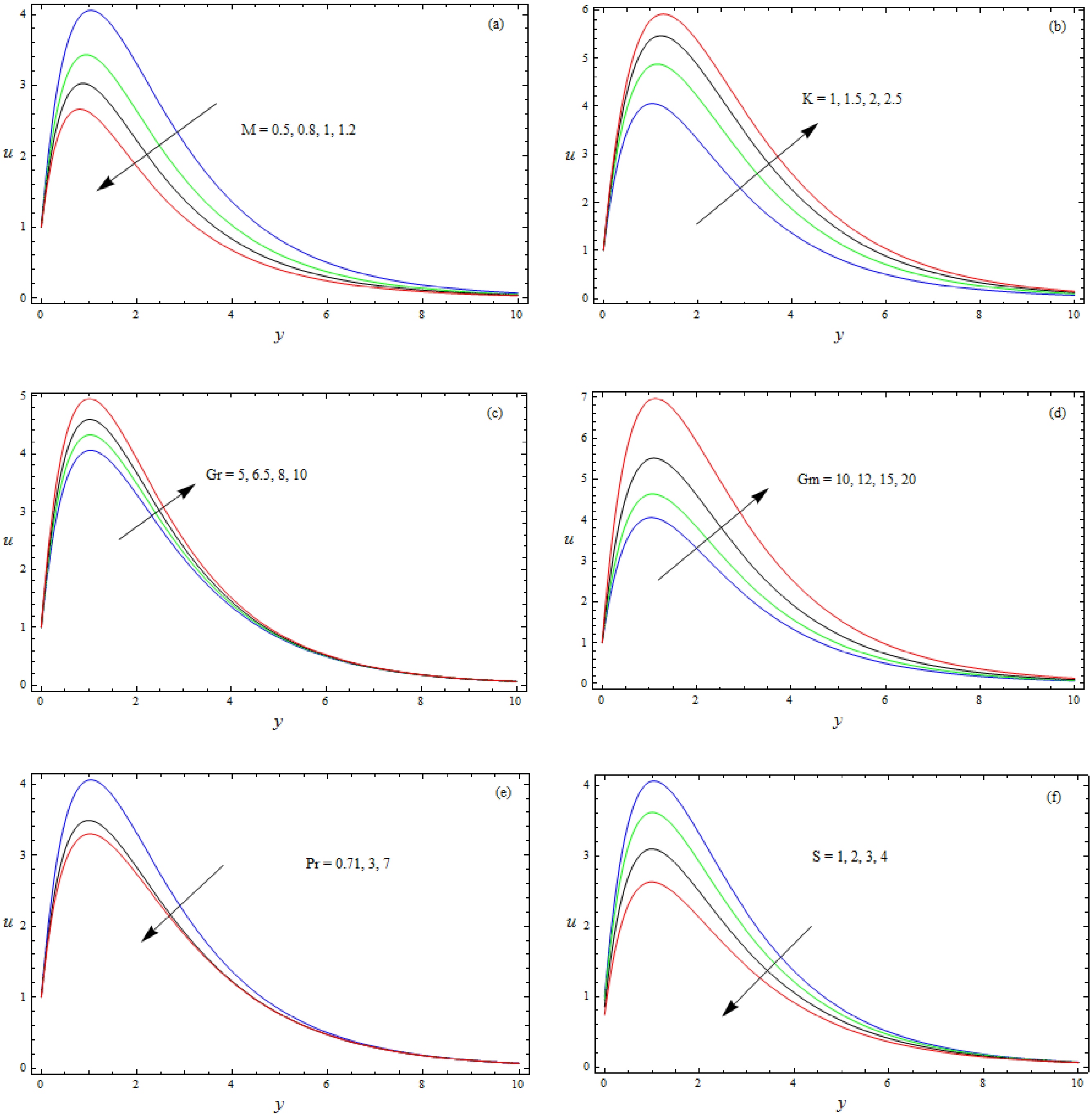

Fig 4(a-f): The velocity Profiles against *M*, *K*, Gr, Gm, Pr and *S* with $\varepsilon = 0.001, t = 1$

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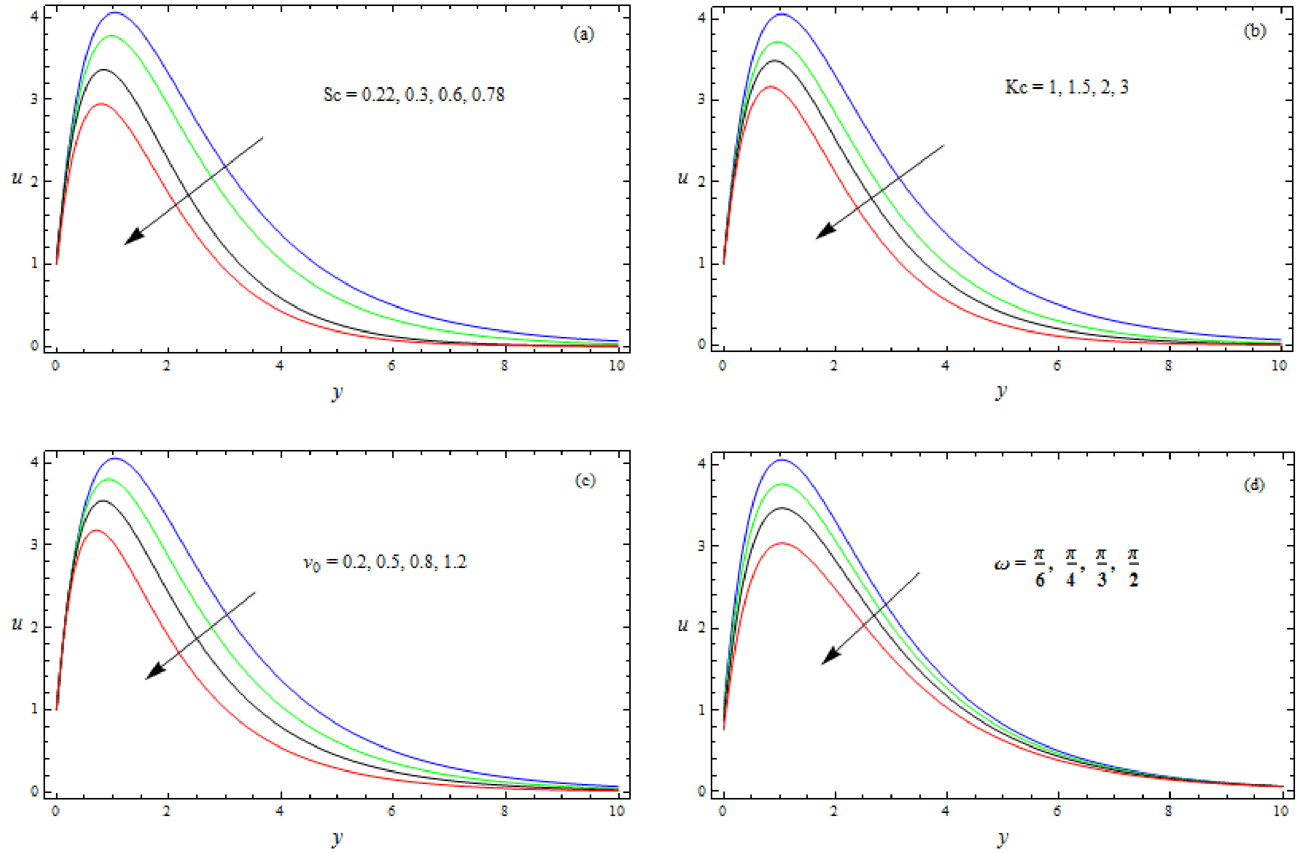

Fig 3(a-d): The velocity Profiles against Sc, Kc, v_0 and ω with $\varepsilon = 0.001, t = 1$

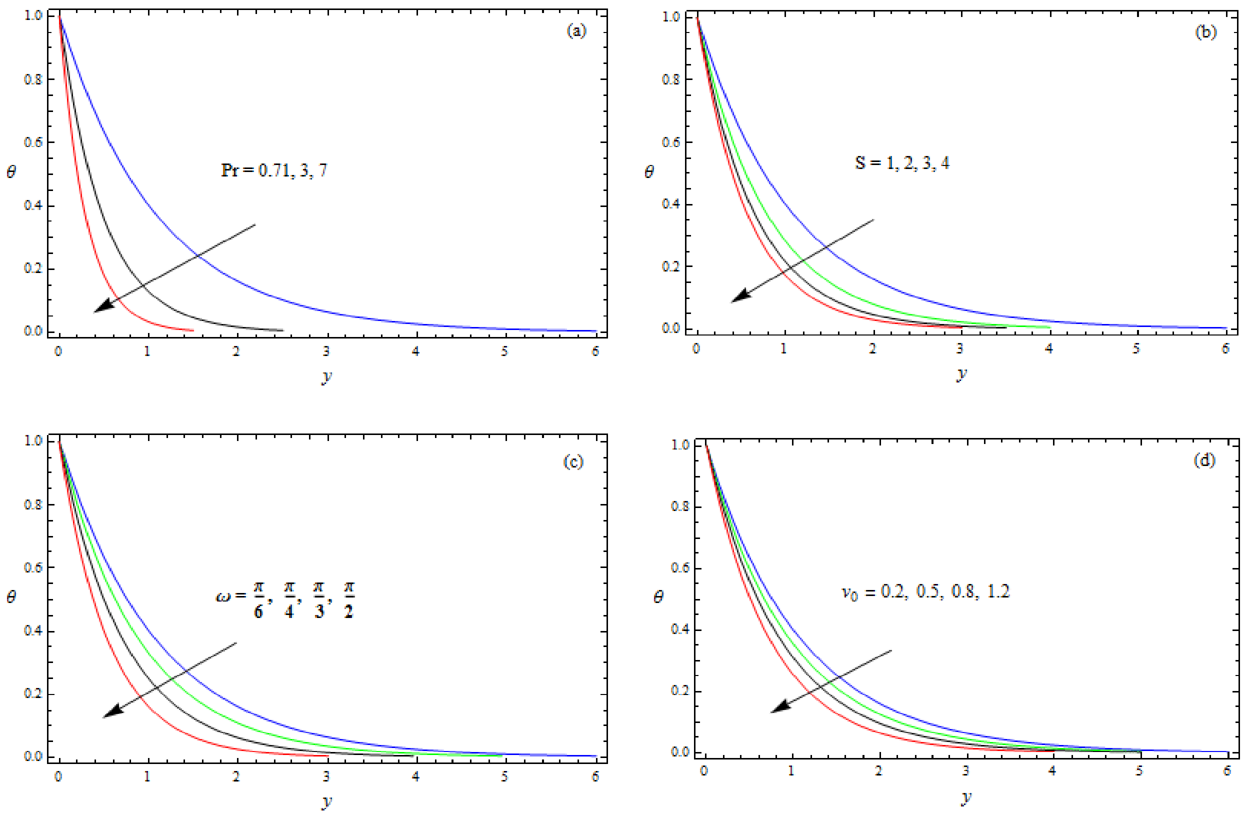

Fig 4(a-d): The temperature profiles against Pr, S, ω and v_0 with $\varepsilon = 0.001, t = 0.2$

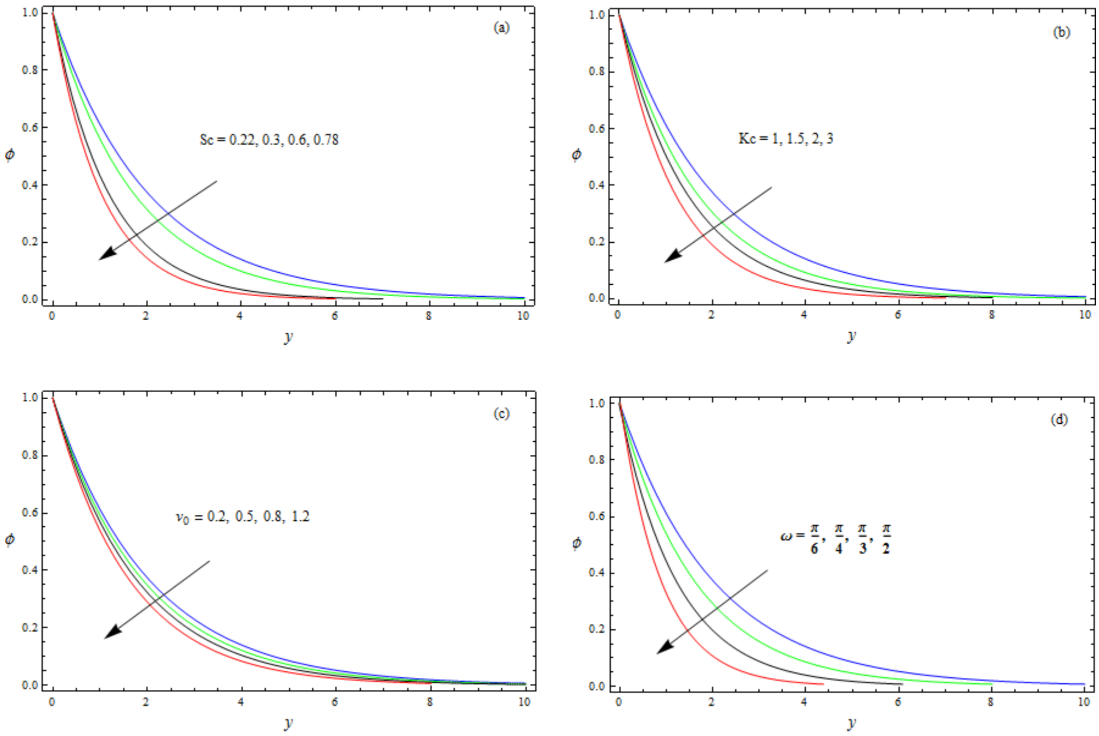

Fig 5(a-d): The Concentration profiles against Sc, Kc, v_0 and ω with $\varepsilon = 0.001, t = 0.2$

Table 1. Shear stresses with $\varepsilon = 0.001, t = 0.2$

M	*K*	Pr	Sc	Kc	*S*	Gr	Gm	v_0	ω	Amplitude $\lvert F_2 \rvert$	Phase Angle (ψ)	τ
0.5	**2**	**0.71**	**0.22**	**1**	**1**	**5**	**10**	**0.2**	$\pi/6$	11.6485	-1.08662	9.91165
2										4.27658	-1.55299	3.45314
3										1.29628	-1.41396	0.97579
	3									12.9525	-1.00391	10.8957
	4									13.1681	-0.92668	11.5053
		3								10.9926	-1.28004	8.71502
		7								10.8139	-1.30829	8.13573
			0.3							13.2281	-1.01306	9.40431
			0.6							13.5472	-0.09769	8.21942
				1.5						13.0636	-0.99636	9.30427
				2						14.0976	-0.85477	8.86116
					2					11.6012	-1.13883	9.61323
					3					11.3064	-1.18272	9.40427
						8				12.8687	-0.98211	11.6903
						10				13.7484	-0.92315	12.8765
							15			16.7650	-1.17909	13.8706
							20			21.9576	-1.22812	17.8302
								0.5		23.0389	-0.60875	10.3117
								0.8		33.0972	-0.02048	10.5091
									$\pi/4$	8.03813	-0.88627	9.91118
									$\pi/3$	6.43892	-0.63184	9.91105

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Table 2. Nusselt number (Nu) with $\varepsilon = 0.001, t = 0.2$

Pr	S	v_0	ω	Amplitude $\lvert F_4 \rvert$	Phase Angle γ	Nu
0.71	**1**	**0.2**	$\pi / 6$	1.00365	1.39869	0.91666
3				2.20629	1.44928	2.05788
7				3.60564	1.47239	3.43676
	2			1.31588	1.48355	1.26473
	3			1.56988	1.51423	1.53210
		0.5		1.10256	1.46078	1.03861
		0.8		1.21656	1.48335	1.17317
			$\pi / 4$	1.06122	1.31218	0.91670
			$\pi / 3$	1.12272	1.24229	0.91673

Table 3. Sherwood number (Sh) with $\varepsilon = 0.001, t = 0.2$

Sc	Kc	v_0	ω	Amplitude $\lvert F_6 \rvert$	Phase Angle (ζ)	Sh
0.22	**1**	**0.2**	$\pi / 6$	0.536249	1.365880	0.491611
0.3				0.632410	1.373015	0.578602
0.6				0.916662	1.393062	0.836984
	1.5			0.629483	1.429490	0.596922
	2			0.712364	1.464392	0.685691
		0.5		0.574058	1.422405	0.527289
		0.8		0.603609	1.454160	0.565233
			$\pi / 4$	0.566008	1.276890	0.491634
			$\pi / 3$	0.599008	1.206869	0.491650

Table 4. Comparison of Results

Sc	v_0	ω	Sh	
			Ashraf et al.[19]	Present work [Kc=0]
0.22	**0.2**	$\pi / 6$	0.045262	0.044020
0.3			0.061854	0.060238
0.6			0.120552	0.120325
	0.5		0.115245	0.110179
	0.8		0.176334	0.176133
		$\pi / 4$	0.046625	0.044236
		$\pi / 3$	0.046246	0.044253

4. CONCLUSIONS

We have considered the unsteady free convective flow of a viscous incompressible electrically conducting fluid over an infinite vertical porous plate under the influence of uniform transverse magnate field with time dependent permeability and oscillatory suction. The conclusions are made as the following.

1. The velocity reduces with increasing the intensity of M or Pr or *S*.
2. The velocity enhance with increasing thermal Gr or Gm.
3. The resultant velocity enhances with increasing the K throughout the fluid region. Lower the permeability of the porous medium lesser the fluid speed in the entire region.
4. The reversal behaviour is observed with increasing Sc, Kc, v_0 or ω.
5. The magnitude of the temperature of the flow field diminishes as the Pr, S or v_0 or ω
6. The concentration reduces at all points of the flow field with the increase in the Sc, Kc, v_0 and presence of the ω.
7. The skin friction increases with the increase in *K* Gr, Gm and v_0 and decreases with the increase in *M*, Pr, Sc, Kc, *S* and ω.
8. Nu at the surface of the plate and amplitude increase with increase *S*, Pr and v_0. Also enhance the amplitude, Nu decrease the phase angle with increase the ω.
9. Sc, Kc, ω and v_0 increase the amplitude, the phase angle and the rate of mass transfer at the surface of the plate.
10. Increase the frequency of oscillation enhance the amplitude, Sherwood number decrease with the phase angle.

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