Numerical Solution of Unsteady MHD Free Convective Fluid Flow Past a Vertical Porous Plate with Magnetic Dissipation

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Abstract- *Numerical solution of an unsteady MHD free convective fluid flow of a viscous incompressible and electrically conducting fluid past a vertical porous plate in the presence magnetic dissipation is considered. The non – linear partial differential equations have been solved numerically. The effect of magnetic dissipation, on the velocity and temperature distributions and also on the mass transfer, is discussed in this paper. The effects of the various parameters on the velocity, temperature and concentration profiles are presented graphically for various values of physical parameters are discussed.*

Keywords- Soret number, MHD free convective flow, Vertical porous plate, Finite difference method.

I. INTRODUCTION

The problem streamline flow through a porous medium has become important in recent years significantly within the fields of agricultural engineering to review the underground water resources, ooze of water in watercourse beds, in chemical engineering for filtration and purification process; in crude oil technology to review the movement of gas, oil and water through the oil reservoirs. Oscillating flows play a crucial role in technological field. the consequences of free-stream oscillations on the flow past a semi-infinite plate were initial mentioned by Lin[1] for finite amplitude and by Lighthill[2] for little amplitude oscillations. Lighthill studied this drawback by using momentum integral technique. These results were confirmed by experimentation by Hill and Stenning[3]. In several industrial, aeronautic engineering, atomic propulsion and area science, the oscillating flow past associate infinite vertical porous plate plays a crucial role. Free convection effects on the oscillating flow past associate infinite vertical porous plate with constant suction was initiated by Soundalgekar[4-5]. In each the papers, suction was assumed to be constant. However, in several engineering applications variable suction exists and also the result of variable suction on the flow past associate infinite vertical porous plate was thought of by Soundalgekar[6]. altogether these studies, the plate temperature was assumed to be constant and therefore equal. But in several industrial applications, the flow is steady and within the upward direction and also the plate temperature is periodical. Such a study of the flow past associate infinite vertical porous plate, below periodical plate temperature and with constant or variable suction was bestowed by Soundalgekar et.al.[7]. The unsteady free convection flow past associate infinite plate with constant suction and warmth sources has been studied by Pop et.al.[8]. Raptis[9] obtained the free convective flow through a porous medium delimited by associate infinite vertical plate with periodical plate temperature and constant suction. Raptis et.al.[10] any analyzed the free convective flow through a extremely porous medium delimited by associate infinite vertical porous plate with constant suction once the free stream speed oscillates a few mean constant price. Hooper et.al.[11] have bestowed the matter of mixed convection on associate equal vertical plate in porous medium with injection and suction. Panda et. al.[12] thought of the unsteady free convection flow and mass transfer past a vertical porous plate. Soundalgekar et. al.[13] measured the free convection effects on hydrodynamics flow past associate infinite vertical periodical plate with constant heat flux. Chandran et. al.[14] analyzed the transient hydromagnetic natural convection on a vertical flat plate subject to heat flux. Sahoo et. al.[15] bestowed the magnetohydrodynamic unsteady free convection flow past associate infinite vertical plate with constant suction and warmth sink. Heat and mass transfer in hydrodynamics flow of a viscous fluid past a vertical plate below oscillating suction speed has been studied by Singh et. al.[16]. Helmy[17] studied the hydrodynamics unsteady free convection flow past a vertical porous plate. Acharya et. al.[18] created a scientific analysis of flux effectson the free-convective and mass transfer flow through porous medium with constant suction and constant heat flux. Ahmed et. al.[19] extended Acharya's[18] works to unsteady case by considering a standardized motion of the plate. Jaiswal et. al.[20] any extended his drawback. Unsteady free and made convection hydrodynamics flow past associate infinite vertical porous plate with variable suction and periodical plate temperature. Sharma et. al.[21-22] thought of the hydromagnetic unsteady mixed convection and mass transfer flow past a vertical porous plate immersed during a porous medium. Recently, Effects of unsteady surface temperature associated concentration on unsteady convection flow past an infinite vertical plate with constant suction mentioned by Sharma et. al[23]. within the on top of declared studies the flows with the oscillating suction speed and with the influence of uniform flux don't seem to be thought of whereas such flows ar encountered in geology issues, astronomy issues, soil sciences so on. Therefore, the current investigation is to review the consequences of permeableness and flux because the flow past a vertical plate embedded on a porous medium and subjected to periodical suction and temperature field. it's found that the permeableness and flux have important effects on the flow and warmth transfer. Sharma et.al.[24] studied associate approximate associatealysis of unsteady mixed convection flow of associate electrically conducting fluid past an infinite vertical porous plate embedded in porous medium below constant transversally applied flux. The periodic transversal suction speed is applied to the surface thanks to that the flow becomes unsteady. The surface is unbroken at periodical wall temperature. Analytical expressions for the transient speed, temperature, amplitude and part of the skin-friction and also the rate of warmth transfer are obtained and mentioned very well with the assistance of graphs, for different parameter values.

In this paper numerical resolution of unsteady mhd free convective fluid flow past a vertical porous plate with magnetic dissipation is taken into account. The non-linear partial differential equations governing the flow are solved numerically. The result of magnetic dissipation, on the velocity, temperature and concentration distributions and additionally on the mass transfer, is mentioned in this paper. The consequences of the varied parameters on the velocity, temperature and concentration profiles are presented through graphs.

II. FORMULATION OF THE PROBLEM

The flow of an electrically conducting viscous incompressible fluid through a porous medium bounded by an infinite vertically porous flat plate is considered. The x*-axis is taken along the plate, being the vertically upward direction of the flow and y*-axis is taken perpendicular to the plate directed into the fluid. The fluid flows with uniform free stream velocity U. A uniform magnetic field is imposed along the y*-axis. The induced magnetic field is negligible which is possible on a laboratory scale. Since the plate is considered infinite in the x*-direction, all the fluid properties are independent of x*. Let u*, v* be the fluid velocities along x*, y*-axes respectively and the plate temperature T* is oscillating about a non-zero plate temperature T_w^*. The variation of the suction velocity distribution is of the form $v^*\left(t^*\right) = -V\left(1 + \varepsilon\, e^{\omega^* t^*}\right)$ where V > 0 is the constant mean velocity and < 1.

The negative sign in the variation of the suction velocity indicates that the suction is towards the plate. Then under usual Boussineq's approximation, the governing equations and the initial and boundary conditions become in the non – dimensional form are given by

$$\frac{\partial u}{\partial t} - \left(1 + \varepsilon\, e^{\omega t}\right)\frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr\,\theta + Gm\,\phi + \left(M + \frac{1}{K}\right)(1 - u) \tag{2.1}$$

$$\frac{\partial \theta}{\partial t} - \left(1 + \varepsilon\, e^{\omega t}\right)\frac{\partial \theta}{\partial y} = \frac{1}{\mathrm{Pr}}\frac{\partial^2 \theta}{\partial y^2} + Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{2.2}$$

$$\frac{\partial \phi}{\partial t} - \left(1 + \varepsilon\, e^{\omega t}\right)\frac{\partial \phi}{\partial y} = \frac{1}{\mathrm{Sc}}\frac{\partial^2 \phi}{\partial y^2} + Sr\,\frac{\partial^2 \theta}{\partial y^2} \tag{2.3}$$

The initial and boundary conditions are

$$\begin{aligned} &When\ t = 0 \quad u = 0,\ \theta = 0,\ \phi = 0 \quad as\ y = 0 \\ &\qquad u = 0,\ \theta = 1 + \varepsilon\, e^{\omega t},\ \phi = 1 + \varepsilon\, e^{\omega t} \quad at\ y = 0 \\ &When\ t > 0 \\ &\qquad u = 1,\ \theta = 0,\ \phi = 0 \quad as\ y \to \infty \end{aligned} \tag{2.4}$$

III. FINITE DIFFERENCE METHOD

The governing equations (2.1) to (2.3) are coupled non – linear partial differential equations and have to be solved using the initial and boundary conditions (2.4). Since exact or approximate solutions are not possible for this set of equations, an explicit finite difference method is used. The finite difference scheme of governing equations (2.1) – (2.3) and the conditions (2.4) are given by

$$\frac{\partial u}{\partial t} = \frac{u(i,\ j+1) - u(i,\ j)}{\Delta t}$$

$$\frac{\partial \theta}{\partial t} = \frac{\theta(i,\ j+1) - \theta(i,\ j)}{\Delta t}$$

$$\frac{\partial \phi}{\partial t} = \frac{C(i,\ j+1) - C(i,\ j)}{\Delta t}$$

$$\frac{\partial u}{\partial y} = \frac{u(i+1,\ j) - u(i,\ j)}{\Delta y}$$

$$\frac{\partial \theta}{\partial y} = \frac{\theta(i+1,\ j) - \theta(i,\ j)}{\Delta y}$$

$$\frac{\partial \phi}{\partial y} = \frac{C(i+1,\ j) - C(i,\ j)}{\Delta y}$$

$$\frac{\partial^2 u}{\partial y^2} = \frac{u(i+1,\ j) - 2u(i,\ j) + u(i-1,\ j)}{\Delta y^2}$$

$$\frac{\partial^2 \theta}{\partial y^2} = \frac{\theta(i+1,\ j) - 2\theta(i,\ j) + \theta(i-1,\ j)}{\Delta y^2}$$

$$\frac{\partial^2 \phi}{\partial y^2} = \frac{C(i+1,\ j) - 2C(i,\ j) + C(i-1,\ j)}{\Delta y^2}$$

Here the suffix i corresponds to y and j corresponds to t and $\Delta t = t(j+1) - t(j)$ and $\Delta y = y(i+1) - y(i)$. The computations were carried out for different values the various physical parameters.

IV. RESULTS AND DISCUSSION

In order to get a physical insight, the effects of various governing parameters on the velocity, temperature and mass transfer are computed using numerical procedure.The velocity profiles are discussed through graphs for various parameters such as Hartmann number (M), Eckert number (Ec), thermal Grashoff number (Gr), Soret number (Sr), the Solutal Grashoff number (Gm), Prandtl number (Pr), and Schmidt number (Sc) etc.

The comparative study of the effect of the Hartmann number (*M*) is shown in the figure 1. The presence of a magnetic field in an electrically conducting fluid introduces the Lorentz force, which acts against the flow, the velocity decreases with the increasing of Hartmann number (M). From the figure, the decrease of velocity is observed with the increase of the magnetic field.The variation of velocity distribution to the thermal Grashoff number is discussed in the figure 2. The thermal Grashoff number is the relative effect of the thermal buoyancy force to the viscous hydrodynamic force in the boundary layer.The positive values of Grashoff number indicates the cooling of the plate. The rise in the velocity is observed due to the enhancement of the thermal buoyancy force. As thermal buoyancy increases, the velocity increases rapidly near the plate and gradually decreases to free stream velocity. Also it is coincide with the results of Sharma et al.[24].The effect of Solutal Grashoff number in a comparative manner is given in the figure 3. Similar to the thermal Grashoff number, the Solutal Grashoff number effect is also to increaseinthe velocity. The rise in the velocity distribution isobserved in the figure 3.The decrease of velocity distribution in theboundary layer for the permeability parameter (K) is observed from the figure 4. This effect can be reduced with the holes of the porous medium is decreased. With the increase of the Eckert number, it is seen from the figure 5 that the velocity increases. The figure 6 shows the decrease of velocity in the boundary layer with the increase of Prandtl number (Pr). An increase in the Prandtl number results a decrease of the thermal boundary layer thickness within the boundary layer.In the figure 7 the effects of Soret number is discussed. The velocity distribution increases with the increase in the Soret and number.

The substantial change in the temperature of the flow with variation of parameters like Prandtl number and Eckert number are discussed through figures 8and 9.The decrease of temperature in the boundary layer is observed from the figure 8 for an increase in the Prandtl number. A study is discussed through the figure 9. Here the decrease of temperature is observed for different values of Eckert number.

The substantial change in the concentration distribution with variation of parameters like Schmidt number and Prandtl number are discussed through figures 10to 12.The concentration distribution is vastly affected by the presence of foreign species such as Hydrogen (Sc = 0.22), Oxygen (Sc = 0.66),Sc = 2.0 and2.66, which is discussed in the figure 10.Here it is observed that the concentration decreases with the increase of the Schmidt number.The decrease of concentration is also observed for large Schmidt number such as Sc = 5.0 and Sc = 7.0 from the figure 11.The concentration is decreased with the increase of the Schmidt number i.e. with the presence of heavy foreign species.The decreased effect of Prandtl number is discussed in the figure 12.

V. CONCLUSIONS

An unsteady MHD free convective fluid flow of a viscous incompressible and electrically conducting fluid past a vertical porous plate in the presence of suction or injection is considered. The non-linear partial differential equations governing the flow have been solved numerically using finite difference method. The observed conclusions are

- With increase of Hartmann number (M), Thermal Grashoff number, and Solutal Grashoff number (Gm), velocity increases and also from the comparative study, the results are agreement with the results of Sharma et al. [24].
- With increase of Permeability parameter (K) and the Prandtl number (Pr), velocity decreases.
- Velocity increases with the increase of Soret and Eckert numbers.
- The temperature distribution decreases with the increase of Prandtl and Eckert numbers.
- The concentration is decreased with the increase of the Schmidt number i.e. with the presence of heavy foreign species.

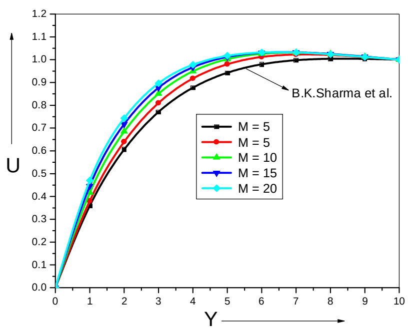

Fig.1 Transient velocity profiles for different M

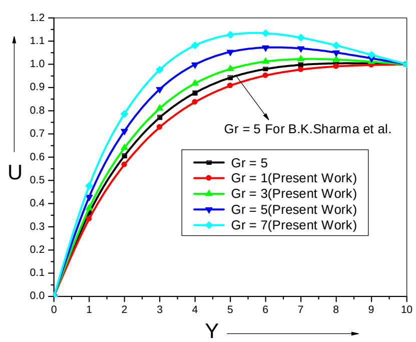

Fig.2 Transient velocity profiles for different Gr

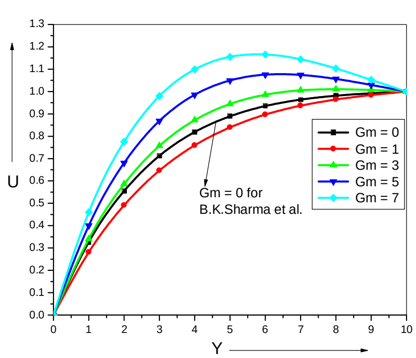

Fig.3 Velocity profiles for Gm variation

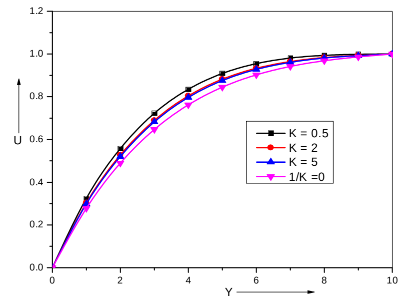

Fig.4 Velocity profiles for K variation

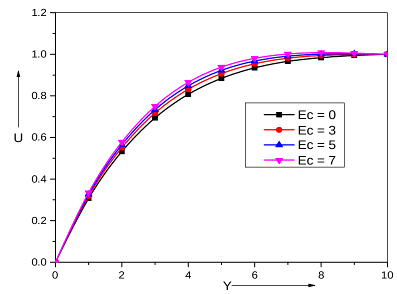

Fig. 5 Velocity profiles for Ec variation

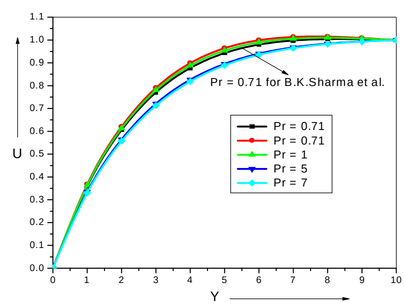

Fig.6 Transient velocity profiles for different Pr

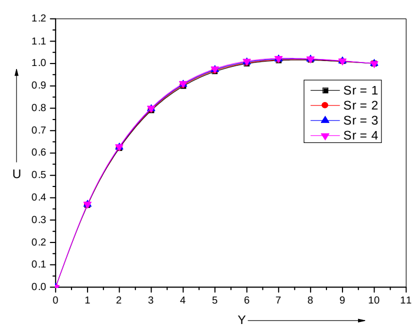

Fig.7 Velocity profiles for Sr variation

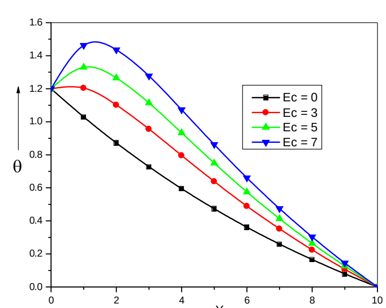

Fig. 8 Temperature profiles for Ec variation

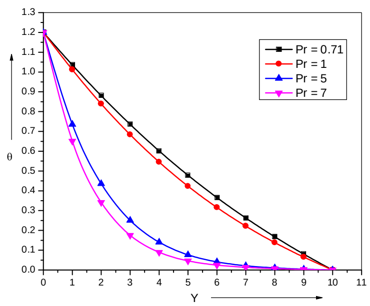

Fig.9 Temperature profiles for Pr variation

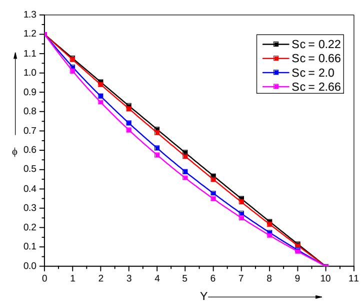

Fig.10 consontration profiles for Sc varition

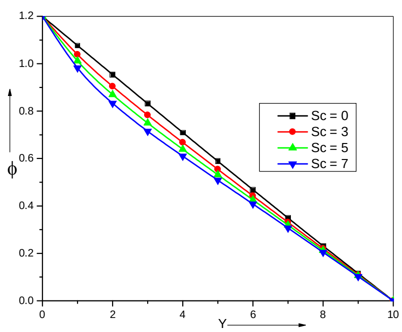

Fig. 11 Concentration profiles for Sc variation

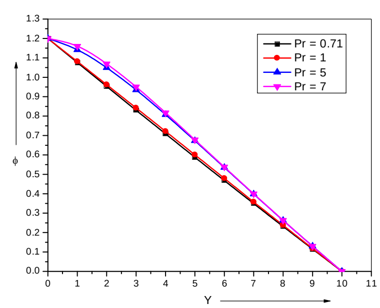

Fig.12 Consontration profiles for Pr variation

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