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Study of Transient Natural Convection Flow Past an Accelerated Infinite Vertical Plate by using Finite Difference Method

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Abstract: This paper deals with a vertical hot plate moves with different wall temperature and with acceleration. The dimensionless governing equations of the problem have been solved numerically by the finite difference technique. The temperature and the velocity distributions versus several physical parameters like Grashof number, Prandtl Number and time are demonstrated graphically.
Keywords:** *Vertical* **Plate, temperature, velocity,** *Grashof number* **,** *Prandtl number.

I. INTRODUCTION

Study of flow with heat transfer plays an important role in engineering sciences. Cooling and heating of liquid metals liquid, industrial equipment, cooling of machine elements are few applications. Chaudhary et.al [1] have discussed the MHD flow past an infinite vertical oscillating plate through porous medium, taking account of the presence of free convection and mass transfer. Anjalidevi and Kandasamy [2] have studied the effect of a chemical reaction on the flow in the presence of heat transfer and magnetic field. Dash and Das [3] analyzed the effect of Hall current MHD free convection flow along an accelerated porous heated plate with mass transfer and internal heat generation. An exact solution of heat transfer of flow past an exponentially accelerated infinite vertical plate with variable temperature is analyzed by Muthucumaraswamy et al. [4]. Rao and Shivaiah [5] studied chemical reaction effects on unsteady MHD flow past semi- infinite vertical porous plate viscous dissipation. Sing [6] discussed that the heat and mass transfer in MHD boundry layer flow past an inclined plate with variable temperature and mass diffusion. Muthucumaraswamy [7] studied the interaction of thermal radiation on vertical oscillating plate with variable temperature and mass diffusion. Heat and mass transfer along a vertical plate with variable surface tension and concentration in the presence of the magnetic field was presented by Elbashbeshy[8]. Sattar [9] discussed free convection and mass transfer flow through a porous medium past an infinite vertical plate with time dependent temperature and concentration. Acharya et.al [10] studied the effect of chemical and thermal diffusion with Hall current on unsteady hydro magnetic flow near an infinite vertical porous plate.

Aim of the paper is to study of transient natural convection flow past an accelerated infinite vertical plate. that the greater part of introductory temperatures of quickened plate equivalent to the surrounding temperature. Now and again, the temperature is held constants and equivalents to the plate temperature for time more important than zero. The originally temperature of a vertical plate is greater than the surrounding temperature. As such, the plate is at first at high temperature or hot plate and after that suddenly it moves vertically with acceleration. So there is a heat exchange of a hot plate to the surrounding fluid and the plate temperature decreases with increasing time.

II. GOVERNING EQUATIONS

The flow of a viscous incompressible fluid past an infinite vertical plate with variable temperature is considered. The x'- axis is taken in the vertically upward direction along the plate and y' axis is taken normal to it. Since the motion is two dimensional and length of the plate is large, Let u' be the components of velocity in x' and y' directions, respectively, taken along and perpendicular to the plate. At time $t' \le 0$, the plate is at the temperature higher than T'_∞ and the fluid is at rest. At time $t' > 0$, the plate is linearly accelerated with increasing time in its own plane and the temperature decreases with temperature $T' = 1/(1 + At')$.
It is assumed that the effect of viscous dissipation is negligible and by usual Boussinesq's and boundary layer approximation. The unsteady flow is governed by the following equations:

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$$\frac{\partial u'}{\partial y'} = g\beta (T' - T'_{\infty}) + \nu \frac{\partial^2 u'}{\partial y'} \qquad \text{---} \quad (1)$$

$$\frac{\partial T'}{\partial y'} = \frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'} \qquad \text{--} \ (2)$$

With the appropriate initial and boundary conditions are given by

$$\left.\begin{array}{ll} t' \le 0: u' = 0, T' = T'_w \quad at \quad for\ all & y' = 0 \\ t' > 0: \ u' = U_0 a' t', T' = T'_{\infty} + \dfrac{(T'_w - T'_{\infty})}{1 + At'}, \quad at & y' = 0 \\ u' = 0, T' \to T'_{\infty} & at \quad y' \to \infty \end{array}\right\} \qquad \text{---} \ (3)$$

Introducing the following non dimensional quantities are

$$\left.\begin{array}{l} u = \dfrac{u'}{U_0}, t = \dfrac{U_0^2 t'}{\nu}, y = \dfrac{U_0 y'}{\nu}, Gr = \dfrac{g\beta\left(T'_w - T'_{\infty}\right)}{U_0^2}, \\ \theta = \dfrac{T' - T'_{\infty}}{T'_w - T'_{\infty}}, \Pr = \dfrac{\rho C_p}{k}, a = \dfrac{a'\nu}{U_0^2}, A = \dfrac{U_0^2}{\nu} \end{array}\right\} \qquad \text{---} \ (4)$$

In the view of above equation, the governing equations are as of the following form:

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr\theta \qquad \text{---} \ (5)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} \qquad \text{---} \ (6)$$

The initial and boundary conditions in non-dimensional quantities:

$$\left.\begin{array}{ll} t \le 0: u = 0, \theta = 1 \quad at \quad for\ all & y = 0 \\ t > 0: \ u = at, \theta = \dfrac{1}{1+t}, \quad at & y = 0 \\ u = 0, \theta \to 0 & at \quad y \to \infty \end{array}\right\} \qquad \text{---} \ (7)$$

III. METHOD OF SOLUTION

The dimensionless governing differential equations (5)-(6) subject to the initial and boundary conditions (7) are reduced to a system of difference equations using the following finite difference scheme, and then the system of difference equations is solved numerically by an iterative method. The scheme for a variable u is given by,

$$\frac{\partial u}{\partial t} = \left(\frac{u_i^{j+1} - u_i^j}{\Delta t}\right), \quad \frac{\partial u}{\partial y} = \left(\frac{u_{i+1}^j - u_i^j}{\Delta y}\right) \quad \frac{\partial u}{\partial t} = \left(\frac{u_{i+1}^j - 2u_i^j + u_{i-1}^j}{(\Delta y)^2}\right)$$

IV. RESULTS AND DISCUSSION

The effects of difference flow parameters on fluid velocity and temperature discussed numerically and presented graphically. Final results of velocity and temperature are calculated for different values of Grash of number and Prandtl number. In these computations, the parameter $a = 2$ is taken a constant throughout the calculation. In heating and cooling process Prandtl number(Pr) are chosen air ($Pr = 0.71$) and water ($Pr = 7$).The effect of velocity in air and water ($Pr = 0.71\ \&\ 7$) for different values of t and constant a is exhibited in figure 1 - 4. It is observed the increase in Prandtl number for constant Grashof number leads to decrease velocity fields figures 1 and 2, and also show that an increase the values of t leads to increase in velocity. The thermal Grashof number signifies the relative effect of the thermal buoyancy forces to the viscous hydrodynamic forces in the layer flow. This gives rise to an increase in induced flow. The velocity of the induced flow is much greater than the velocity of the plate as shown in figures 3 and 4. The temperature profiles are shown in figure 5 - 8 for different values of t and taking the values of air and water ($Pr = 0.71\ \&\ 7$) comparing figure 3 and 4, it observed that all profiles decay asymptotically to zero in the free flow. Prandtl number signifies that the thermal diffusivity of fluid decrease. So the temperature decreases due to the decrease of thermal boundary layer.

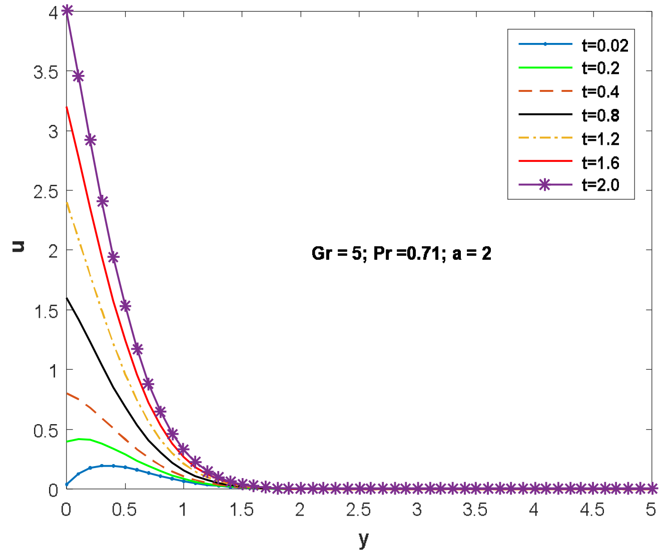

Fig. 1. Velocity profile for $Pr = 0.71$ and $Gr = 5$

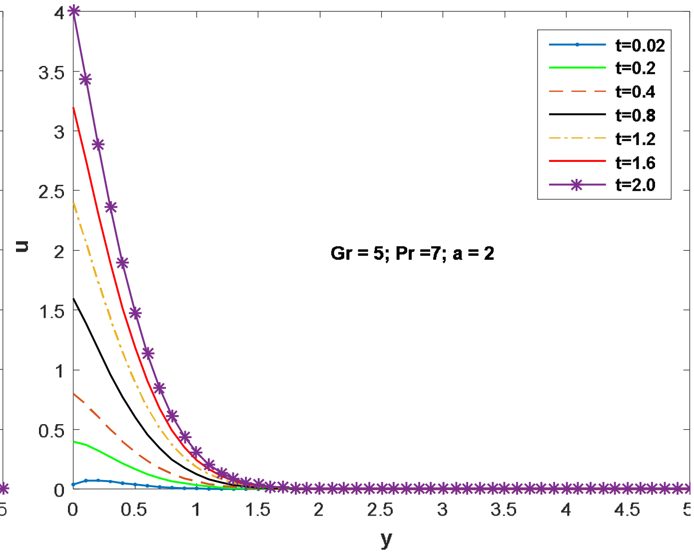

Fig. 2. Velocity profile for $Pr = 0.71$ and $Gr = 5$

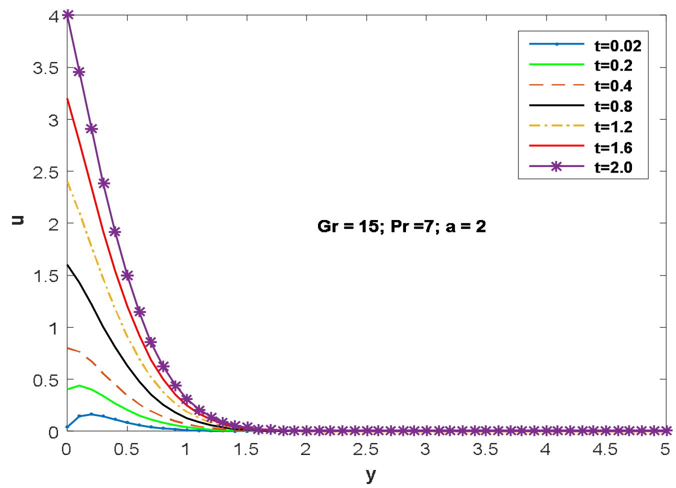

Fig.3.Velocity profile for $Pr = 7$ and $Gr = 15$

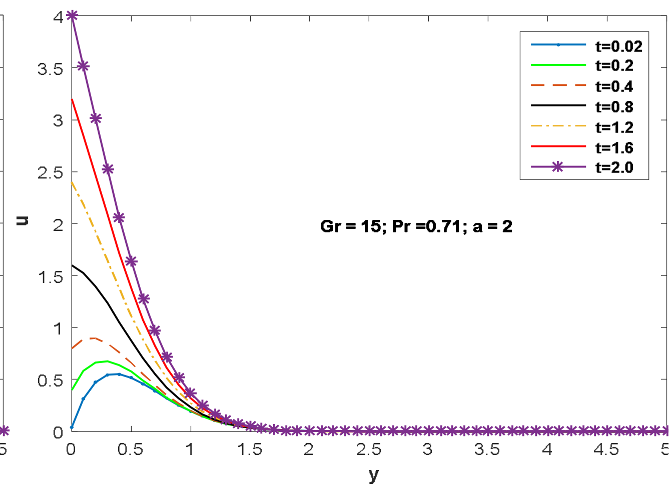

Fig.4. Velocity profile for $Pr = 7$ and $Gr = 15$

V. CONCLUSION

For larger values of Prandtl number, the heat transfer process occurs to the shorter length from the plate and vice versa. When we compare with the velocity of the plate, the fluid velocity adjacent the plate move with high velocity in the presence of the higher Grashof number.

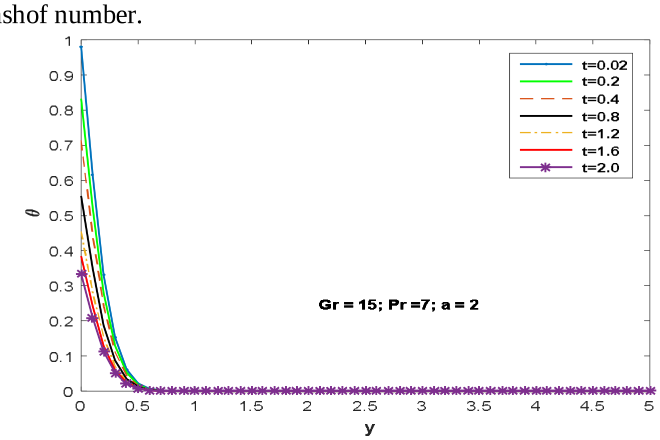

Fig. 5. Temperature profile for $Pr = 7$ and $Gr = 15$

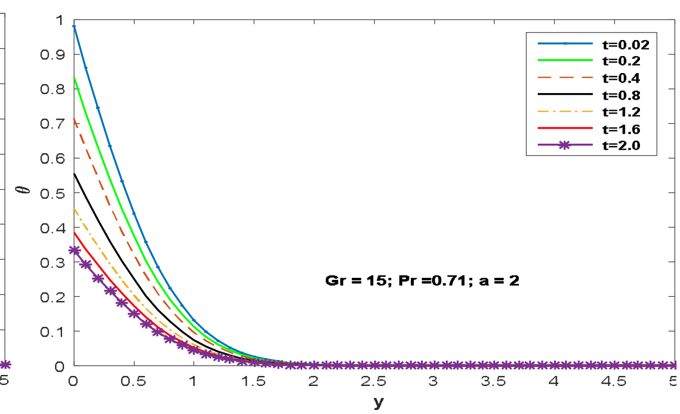

Fig. 6. Temperature profile for $Pr = 0.71$ and $Gr = 5$

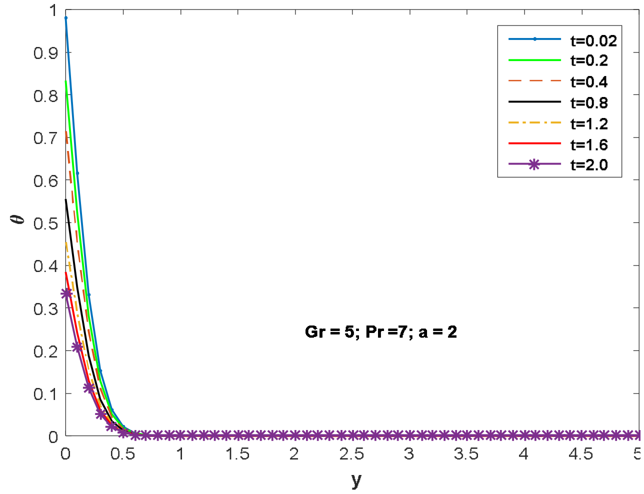

Fig.7. Temperature profile for $Pr = 7$ and $Gr = 15$.

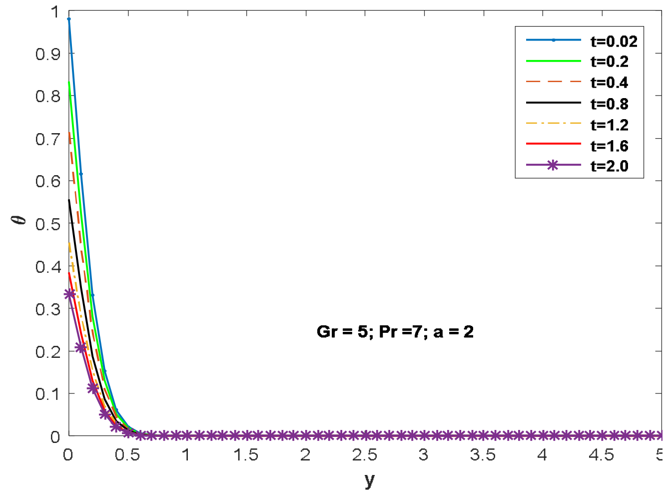

Fig .8. Temperature profile for $Pr = 7$ and $Gr = 15$.

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