Effect of Constant Suction on Transient Free Convective Gelatinous Incompressible Flow past a Perpendicular Plate with Cyclic Temperature Variation in Slip Flow Regime

Monika Kalra, Dinesh Verma

Abstract- ***The wavering free convective gelatinous incompressible flow past a perpendicular permeable flat plate with cyclic temperature in slip flow system has been discussed. Presumptuous constant suction velocity at the porous plate, methodical expressions for flow characteristic are obtained. The possessions of various parameters on the transient velocity, transient temperature, the skin friction and rate of heat transfer are discussed with the help of graphs.***

Keywords-

I. INTRODUCTION

The incident of free convection arises in the fluid when temperature changes reason density variation principal to buoyancy forces stand-in on the fluid elements. This can be seen in our day after day life in the atmospheric flow, this is determined by temperature Differences.

Effect of variable suction on transient free convective viscous incompressible flow past a vertical plate with periodic temperature variations in slip flow regime has been studied by P.K.Sharma and R.C.Chaudhary [1] Free convective flow past vertical plate has been studied extensively by Ostrich [2-3] and many others. Siegel [4] studied the transient free convection from a vertical flat plate. The free convective heat transfer on a vertical semi-infinite plate has been investigated byBerezovsky et al. [5]. Martynenko et al. [6] investigated the laminar free convection from a vertical plate. In all these papers, the plate was assumed to be maintained at a constant temperature, which is also the temperature of the surrounding stationary fluid.

In many engineering applications, transient free convection flow occurs as such a flow acts as a cooling device. [7] studied the unsteady free convection flow past an infinite vertical plate with constant suction and mass transfer. It was assumed that the plate temperature oscillates in such a way that its amplitude is small. [8] studied MHD unsteady free convection flow past a vertical porous plate.

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The transient free convection flow past an infinite vertical plate with periodic temperature variation was studied analytically by Das et al. [9].Recently; Hossain et al. [10] investigated the effect of a fluctuating surface temperature and concentration on natural convection flow from a vertical flat plate.

The aim of this paper is to study the effects of constant suction on transient free convection flow past an infinite vertical plate in slip-flow regime, when the temperature of the plate oscillates in time about a constant mean.

II. MATHEMATICAL FORMULATION

A wavering free convective flow of a gummy incompressible fluid past a vast vertical porous flat serving dish in slip flow regime, with constant suction is considered. As well it is assumed that the temperature of the serving dish oscillates in time concerning a non zero constant mean. We bring in a co-ordinate system with wall two-faced vertically in $x^* - y^*$ plane. The x^*-axis is taken in perpendicularly upward way along the vertical porous plate and y^* - axis is in use normal to the plate. Since the plate is measured infinite in the x^*- direction, hence all physical quantities will be in- dependent of x^*. Under these assumptions, the corporeal variables are function of y^* and t^* only. Then neglecting viscous dissipation and presumptuous variation of density in the body force term the problem can be governed by the following set of equations:

$$\frac{\partial u^*}{\partial t^*} - V_0^* \frac{\partial u^*}{\partial y^*} = g\beta\left(T^* - T_\infty^*\right) + \nu \frac{\partial^2 u^*}{\partial y^{*2}} \qquad (1)$$

$$\rho C_p \left(\frac{\partial T^*}{\partial t^*} - V_0^* \frac{\partial T^*}{\partial y^*}\right) = \kappa\left(\frac{\partial^2 T^*}{\partial y^{*2}}\right) \qquad (2)$$

The boundary conditions of the problem are:

$$\left.\begin{aligned} & u^* = L^*\left(\frac{\partial u^*}{\partial y^*}\right), T^* = T_w^* + \varepsilon(T_w^* - T_\infty^*)e^{i\omega^* t^*} \quad at \ y^* = 0 \\ & u^* \to 0, \ T^* \to T_\infty^*, \qquad as \ y^* = \infty \end{aligned}\right\} \qquad (3)$$

We now introduce the following non- dimensional quantities (1) to (3),

$$y = \frac{y^* V_0^*}{\nu}, t = \frac{t^* V_0^{*^2}}{4\nu}, \omega = \frac{4\nu\omega^*}{V_0^{*^2}}, u = \frac{u^*}{V_0^*}, T = \frac{\left(T^* - T_\infty^*\right)}{\left(T_w^* - T_\infty^*\right)}$$ Equation

(1) and (2) in the non dimensional form:

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$$\frac{1}{4}\frac{\partial u}{\partial t}-\frac{\partial u}{\partial y}=G_rT+\frac{\partial^2 u}{\partial y^2} \quad (4)$$

$$\frac{1}{4}\frac{\partial T}{\partial t}-\frac{\partial T}{\partial y}=\frac{1}{P_r}\frac{\partial^2 T}{\partial y^2} \quad (5)$$

The boundary conditions to the problem in the dimensionless form are

$$\left.\begin{array}{ll} u=h(\frac{\partial u}{\partial y}) \ , T=1+\varepsilon e^{i\omega t}, & at \ y=0 \\ u\to 0 \ , T\to 0 \ , & as \ y=\infty \end{array}\right\} \quad (6)$$

III. SOLUTION OF THE PROBLEM

Assuming the small amplitude oscillations ($\varepsilon \ll 1$), we can represent the velocity u and temperature T, near the plate as:

$$\left.\begin{array}{l} u(y,t)=u_0(y)+\varepsilon e^{i\omega t}u_1(y) \\ T(y,t)=T_0(y)+\varepsilon e^{i\omega t}T_1(y) \end{array}\right\} \quad (7)$$

Substituting (7) in (4) and (5) and comparing the co-efficient of identical powers of ε neglecting those of ε^2, ε^3 etc. we get:

$$\left.\begin{array}{l} u_0^{''}+u_0^{'}=-G_rT_0 \\ u_1^{''}+u_1^{'}-\left(\frac{i\omega}{4}\right)u_1=-G_rT_1 \\ T_0^{''}+P_rT_0^{'}=0 \\ T_1^{''}+P_rT_1^{'}-\frac{i\omega}{4}P_rT_1=0 \end{array}\right\} \quad (8)$$

The corresponding boundary conditions reduce to

$$\left.\begin{array}{ll} u_0=h(\frac{\partial u_0}{\partial y}), u_1=h(\frac{\partial u_1}{\partial y}), T_0=1, T_1=1 & at \ y=0 \\ u_0=0, u_1=0, T_0=0, T_1=0 & as \ y=\infty \end{array}\right\} \quad (9)$$

Where primes denote differentiation with respect to 'y'. Solving the set of equations (8) under the boundary conditions (9) we get

$$T_0=e^{-P_ry} \quad (10)$$

$$T_1=e^{-m_2y} \quad (11)$$

$$u_0=B_1e^{-y}-B_2e^{-P_ry} \quad (12)$$

$$u_1=B_3e^{-m_4y}-B_4e^{-m_2y} \quad (13)$$

Where,

$$m_1=\frac{-P_r+\sqrt{P_r^2+i\omega P_r}}{2}, m_2=\frac{(P_r+\sqrt{P_r^2+i\omega P_r})}{2},$$

$$m_3=\frac{-1+\sqrt{1+i\omega}}{2}, m_4=\frac{1+\sqrt{1+i\omega}}{2}$$

$$B_1=\frac{G_r(hP_r+1)}{(P_r^2-P_r)(1+h)} \ , \ B_2=\frac{G_r}{(P_r^2-P_r)}$$

$$B_3=\frac{G_r(hm_2+1)}{(m_2^2-m_2-\frac{i\omega}{4})(1+hm_4)} \ , \ B_4=\frac{G_r}{(m_2^2-m_2-\frac{i\omega}{4})}$$

Substituting equations (10) to (13) in equations (7), we get the expression of velocity and temperature profiles

$$u(y,t)=(B_1e^{-y}-B_2e^{-P_ry})+\varepsilon e^{i\omega t}(B_3e^{-m_4y}-B_4e^{-m_2y})$$

$$T(y,t)=e^{-P_ry}+\varepsilon e^{i\omega t}e^{-m_2y}$$

IV. SKIN FRICTION

The dimensionless shearing pressure on the surface of a body, suitable to a fluid activity, is identified as skin friction and is defined by the Newton's law of viscosity

$$\tau_x^{\ *}=\mu(\frac{\partial u^*}{\partial y^*})$$

Substituting equation (12) and (13) into equation (7) we can calculate the shearing stress component in dimensionless form

as $\tau_x=\frac{\tau_x^{\ *}}{\rho V_0^{\ *2}}=(\frac{\partial u}{\partial y})_{y=0}=\tau_m+\varepsilon|B|\cos(\omega t+\alpha)$ (14) Where,

$$\tau_m=-B_1+P_rB_2, |B|=\sqrt{B_r^{\ 2}+B_i^{\ 2}} \ , \ \tan\alpha=\frac{B_i}{B_r}$$

$$B=B_r+iB_i=(-m_4B_3+m_2B_4)$$

V. HEAT TRANSFER

In the dynamics of glutinous fluid one is not greatly involved to identify every one the particulars of the velocity and temperature fields although would surely like to know quantity of heat substitute among the body of the fluid. While at the border line the heat exchanged between the fluid and the body is only suitable to condition, according to Fourier's law, we have

$$q_w^{\ *}=-\kappa(\frac{\partial T^*}{\partial y^*})_{y^*=0}$$

Where y^* is the direction of the normal to the surface of the body. Substituting equations (10) and (11) into (7), we can compute the dimensionless coefficient of heat transfer which is generally known as nusselt number (Nu) as follows

$$Nu=\frac{q_w^{\ *}}{\rho V_0^{'}C_p(T_W^{\ *}-T_\infty^{\ *})}=-\frac{1}{P_r}(\frac{\partial T}{\partial y})_{y=0}=1+\varepsilon|H|\cos(\omega t+\delta)$$

Where, $|H|=\sqrt{H_r^{\ 2}+H_i^{\ 2}}, \tan\delta=\frac{H_i}{H_r}, H=H_r+iH_i=\frac{m_2}{P_r}$

VI. RESULT AND DISCUSSION

It is observed from Fig: I that transient velocity decreases with increasing the Rarefraction parameter h, while increases with increasing frequency ω. The transient temperature profiles are given in Fig: II. it may be observe from this figure that transient temperature decreases with increasing ω. The transient temperature decreases rapidly for p=7(water) than p=.71(air) in the vicinity of the plate.

The mean skin- friction increases with the increasing h (Rarefaction parameter) for air (P=.71), while the reverse effect is observed in the case of water (P=7). Therefore skin-friction decreases with increasing Pr. It is observed that the amplitude and phase of skin friction decrease with increasing h in both the situations (P=.71 and P=7).

It is observed that the amplitude and phase of heat transfer increase with increasing frequency ω .The value of amplitude and phase of heat transfer are greater in air than water.

VII.NOMENCLATURE

$$G_r(Grashof\ number) = \frac{\nu\beta g(T_w^* - T_\infty^*)}{V_0^{*^3}}$$

$$P_r(\Pr andtl\ number) = \frac{\nu}{\kappa / \rho C_p}$$

$$H(Rarefaction\ parameter) = \frac{V_0^* L^*}{\nu}$$

υ = kinematics viscosity

ω = frequency

ρ = density of fluid

g = acceleration due to gravity

β = coefficient of thermal expansion

T^* = Temperature

C_p = specific heat at constant pressure

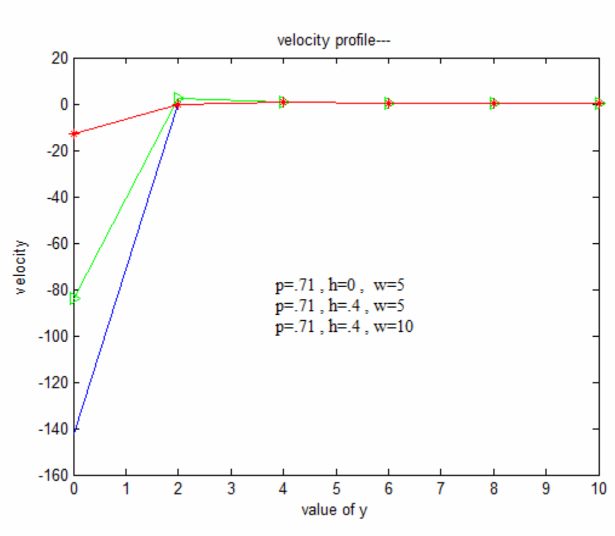

Fig-1

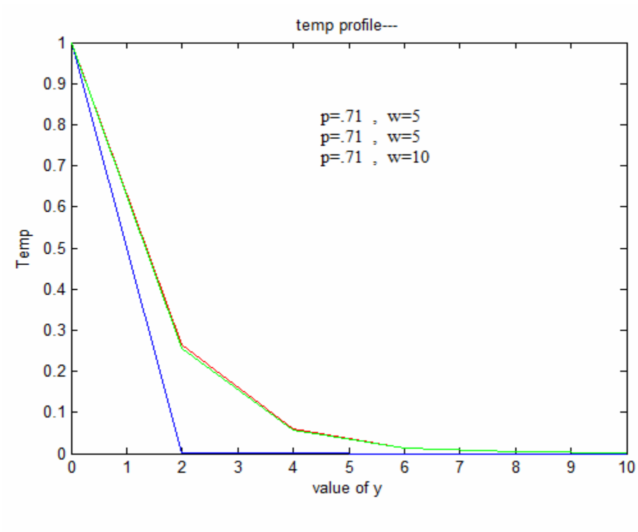

Fig-2

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