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VISCOUS DISSIPATION EFFECTS ON UNSTEADY FREE CONVECTIVE FLOW PAST AN INFINITE, VERTICAL POROUS PLATE WITH CONSTANT SUCTION

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Abstract—An analysis of viscous dissipative heat on the two-dimensional unsteady free convective flow past an infinite, vertical, porous plate is carried out when the plate temperature oscillates in time and there is constant suction at the plate. Approximate solutions of the coupled non-linear equations are obtained for the fluctuating parts of the velocity profile, the transient velocity and temperature profiles, the amplitude and phase of the skin-friction and the rate of transfer. During the course of discussion, the effects of G (Grashof number), E (Eckert number), P (Prandtl number) and the ω (frequency) have been presented.

NOMENCLATURE

$|B|$, amplitude of the skin-friction;
c_p, specific heat at constant pressure;
E, Eckert number;
f_x, gravitational force;
G, Grashof number;
k, thermal conductivity;
M_r, M_i, fluctuating parts of the unsteady velocity;
P, Prandtl number;
q, rate of heat transfer;
T', temperature in the boundary Layer;
T'_∞, free stream temperature;
T'_w, plate temperature;
T_r, T_i, fluctuating parts of the unsteady temperature;
t', time;
u', v', velocity components in the x', y'-directions;
v_0, suction velocity;
x', y', co-ordinate axes along and perpendicular to the plate;
β, coefficient of volume expansion;
ρ', density;
μ, viscosity;
ν, kinematic viscosity;
ω', frequency;
ε, amplitude of the unsteady part;
τ', skin-friction;
α, phase of the skin-friction;
α_1, phase of the rate of heat transfer.

1. INTRODUCTION

FREE convection flow past vertical plates has been studied extensively in the literature. Under usual assumptions, the viscous dissipation term is usually neglected in the energy equation. However, Ostrach [1–5] has discussed the effects of viscous dissipative heat on the steady free convection and also on combined free and forced convection flows between parallel plates. Recently, Gebhart and Mollendorf [6] have also studied the effects of viscous dissipative heat on the natural convection flows past a semi-infinite plate. It has been observed by Gebhart [7] that in natural convection flow fields of extreme size, or extremely low temperatures, or in high gravity, the heat due to viscous dissipation does play an important role.

Now all these studies mentioned above are steady free convective flows. The unsteady free convective flows have also received attention of many research workers. But in all these papers, viscous dissipative heat is always neglected. Notable papers in this field are by Nanda and Sharma [8] and Pop [9]. In [8], the effects of suction velocity proportional to $t^{-\frac{1}{2}}$ have been considered and in [9], the effects of variable suction velocity have been studied. The hydromagnetic case corresponding to [9] has been presented in different ways by Pop [10] and Soundalgekar [11]. In [8–11], it was assumed that the plate temperature undergoes a time-dependent variation in temperature. Now as in steady case, viscous dissipative heat also plays an important role in unsteady free convective flows past porous plates. Such a study has not been presented as yet in the literature on heat transfer.

Hence it is proposed to present an analytical analysis, in the present paper, of unsteady free convective flow past an infinite, vertical porous plate with constant suction on taking into consideration, the heat due to viscous dissipation. The approximate solutions of the governing coupled, nonlinear equations are derived for velocity and temperature field in Sec. 2. The fluctuating parts of the velocity, the transient velocity profiles, the transient temperature profiles are shown on graphs whereas, the numerical values of the amplitude and phase of the skin-friction and the rate of heat transfer are entered in tables. This is followed by a detailed discussion.

2. MATHEMATICAL ANALYSIS

An unsteady two-dimensional flow of an incompressible, viscous fluid past an infinite, vertical porous plate is considered. The x'-axis is taken along the plate in the vertical direction and the y'-axis is taken normal to the plate. All the fluid properties are assumed to be constant except that the influence of the density variations with temperature is considered only in the body force term. We also assume that the variations in density in the body force term does not affect other terms of the momentum and energy equations. Also it is assumed that the variations of expansion coefficient with temperature are very small and hence neglected. Then under these assumptions, the physical variables are functions of y' and t' only. Hence the flow is now governed by the following equations:

$$\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'} = f_x\,\beta(T' - T'_\infty) + v\frac{\partial^2 u'}{\partial y'^2} \quad (1)$$

$$\frac{\partial v'}{\partial t'} = -\frac{1}{\rho'}\frac{\partial p'}{\partial y'} \quad (2)$$

$$\frac{\partial v'}{\partial y'} = 0 \quad (3)$$

$$\rho' C_p\left(\frac{\partial T'}{\partial t'} + v\frac{\partial T'}{\partial y'}\right) = k\frac{\partial^2 T'}{\partial y'^2} + \mu\left(\frac{\partial u'}{\partial y'}\right)^2. \quad (4)$$

In equation (4), the last term represents the heat due to viscous dissipation. As the pressure term and the influence of the pressure on the density are omitted, the analysis presented in this paper is applicable to liquids and not to gases. Also all the physical variables are defined in the notation.

As the suction velocity at the plate is assumed to be constant, equation (3) now integrates to

$$v' = -v_0 \quad (5)$$

where v_0 is the suction velocity and the negative sign in (5) indicates that the suction velocity is directed towards the plate.

We now define the following non-dimensional quantities:

$$y = v_0 y'/v,\ t = v_0^2 t'/4v,\ \omega = 4v\omega'/v_0^2,$$

$$u = u'/v_0,\ T = \frac{T' - T'_\infty}{T'_w - T'_\infty},$$

$$G = \frac{v f_x \beta(T'_w - T'_\infty)}{v_0^3} \quad (6)$$

$$P = \frac{\mu C_p}{k},\ E = v_0^2/C_p(T'_w - T'_\infty).$$

Then, in view of (5) and (6), equations (1) and (4) now reduce to the following non-dimensional form:

$$\frac{1}{4}\frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = GT + \frac{\partial^2 u}{\partial y^2} \tag{7}$$

$$\frac{P}{4}\frac{\partial T}{\partial t} - P\frac{\partial T}{\partial y} = \frac{\partial^2 T}{\partial y^2} + PE(\partial u/\partial y)^2. \tag{8}$$

The boundary conditions are

$$\left.\begin{aligned} &u = 0,\ T = T_w(t) = 1 + \varepsilon\, e^{i\omega t} && \text{at } y = 0 \\ &u \to 0,\ T \to 0 && \text{as } y \to \infty \end{aligned}\right\} \tag{9}$$

To solve these coupled non-linear equations (7) and (8), following Lighthill [12], we assume that the unsteady flow is superimposed on the mean flow. Then, in the neighbourhood of the plate, we represent the velocity and the temperature field as follows:

$$\left.\begin{aligned} u(y,t) &= u_0(y) + \varepsilon\, e^{i\omega t} u_1(y) \\ T(y,t) &= T_0(y) + \varepsilon\, e^{i\omega t} T_1(y). \end{aligned}\right\} \tag{10}$$

Here, ε is a small constant quantity. Then, substituting (10) in (7) and (8) and equating harmonic terms neglecting coefficients of ε^2, we get

$$u_0'' + u_0' = -G\,T_0 \tag{11}$$

$$u_1'' + u_1' - \frac{i\omega}{4} u_1' = -G\,T_1 \tag{12}$$

$$T_0'' + P\,T_0' = -PE\,u_0'^2 \tag{13}$$

$$T_1'' + P\,T_1' - \frac{i\omega P}{4} T_1 = -2PE\,u_0' u_1'. \tag{14}$$

In equations (11)–(14), the primes indicate the differentiation with respect to y.

The corresponding boundary conditions are:

$$\left.\begin{aligned} &u_0 = 0,\ u_1 = 0,\ T_0 = 1,\ T_1 = 1 && \text{at } y = 0 \\ &u_0 = 0,\ u_1 \to 0,\ T_0 \to 0,\ T_1 \to 0 && \text{as } y \to \infty \end{aligned}\right\} \tag{15}$$

Equations (11)–(14) are still coupled non-linear equations. To solve them, we follow the series solution method. As the fluid is incompressible and the suction velocity is also small, the parameter E, the Eckert number, is also small ($\ll 1$). Hence, we expand u_0, u_1, T_0, T_1 in powers of E and neglect terms of $0(E^2)$. Hence, we have

$$u_0(y) = u_0(y) + E\,u_{02}(y) \tag{16}$$

$$u_1(y) = u_{11}(y) + E\,u_{12}(y) \tag{17}$$

$$T_0(y) = T_{01}(y) + E\,T_{02}(y) \tag{18}$$

$$T_1(y) = T_{11}(y) + E\,T_{12}(y). \tag{19}$$

Substituting (16–19) in (11)–(14), equating the coefficients of E and neglecting terms in E^2 and higher order, we obtain

$$u_{01}'' + u_{01}' = -G\,T_{01} \tag{20}$$

$$u_{02}'' + u_{02}' = -G\,T_{02} \tag{21}$$

$$T_{01}'' + P\,T_{01}' = 0 \tag{22}$$

$$T_{02}'' + P\,T_{02}' = -Pu_{01}'^2 \tag{23}$$

$$u_{11}'' + u_{11}' - \frac{i\omega}{4} u_{11} = -G\,T_{11} \tag{24}$$

$$u_{12}'' + u_{12}' - \frac{i\omega}{4} u_{12} = -G\,T_{12} \tag{25}$$

$$T_{11}'' + P\,T_{11}' - \frac{i\omega P}{4} T_{11} = 0 \tag{26}$$

$$T_{12}'' + P\,T_{12}' - \frac{i\omega P}{4} T_{12} = -2Pu_{01}'u_{11}'. \tag{27}$$

The corresponding boundary conditions are:

$$\left.\begin{aligned} &u_{01} = 0,\ u_{02} = 0,\ T_{01} = 0,\ T_{02} = 0 \\ &\qquad\qquad \text{at } y = 0 \\ &u_{01} = 0,\ u_{02} = 0,\ T_{01} = 0,\ T_{02} = 0 \\ &\qquad\qquad \text{as } y \to \infty \\ &u_{11} = 0,\ u_{12} = 0,\ T_{11} = 1,\ T_{12} = 0 \\ &\qquad\qquad \text{at } y = 0 \\ &u_{11} = 0,\ u_{12} = 0,\ T_{11} = 0,\ T_{12} = 0 \\ &\qquad\qquad \text{as } y \to \infty. \end{aligned}\right\} \tag{28}$$

Solving (20)–(27) under the boundary conditions (28) and substituting in (16)–(19), we have

$$u_0(y) = \frac{G}{P^2 - P}(e^{-y} - e^{-2Py}) + \frac{EG^3}{(P-1)^2}$$
$$\left[\left(\frac{P-3}{2(P-2)} - \frac{2P}{P+1}\right)\frac{e^{-y} - e^{-Py}}{P^2 - P}\right.$$

$$- \frac{e^{-y} - e^{-2Py}}{4P(P-1)} - \frac{e^{-y} - e^{-2y}}{4(P-2)} + \left. \frac{2(e^{-y} - e^{-(P+1)y})}{(P+1)^2} \right] \tag{29}$$

$$u_1(y) = \frac{G}{m^2 - m - (i\omega/4)}(e^{-ny} - e^{-my}) + \frac{EG^2}{(P-1)(m^2 - m - (i\omega/4)} \times \left[\frac{2n}{P+2n-1}(e^{-ny} - e^{-(P+n)y}) - \frac{1}{(P+m)^2 - (P+m) - (i\omega/4)} \times (e^{-ny} - e^{-(P+m)y}) - (e^{-ny} - e^{-(n+1)y}) + \frac{2m}{m^2 - m - (i\omega/4)}(e^{-ny} - e^{-(m+1)y}) - \frac{2n(P-1) + 2m - 1}{m^2 - m - (i\omega/4)}(e^{-ny} - e^{-my}) \right] \tag{30}$$

$$T_0(y) = e^{-Py} + \frac{EG^2}{(P-1)^2}\left[\frac{e^{-Py} - e^{-2Py}}{2} - \frac{e^{-Py} - e^{-2y}}{2(P-2)} - \frac{2P(e^{-Py} - e^{-(P+1)y})}{P+1} \right] \tag{31}$$

$$T_1(y) = e^{-my} + \frac{EG^2}{(P-1)(m^2 - m - (i\omega/4)} [2Pn(e^{-(P+n)y} - e^{-my}) - (e^{-(P+m)y} - e^{-my}) - 2n(e^{-(n+1)y} - e^{-my}) + 2m(e^{-(m+1)y} - e^{-my})] \tag{32}$$

where

$$n = \tfrac{1}{2}(1 + (1 + i\omega)^{\frac{1}{2}})$$

$$m = \frac{P}{2}\left(1 + \left(1 + \frac{i\omega}{P}\right)^{\frac{1}{2}}\right).$$

Substituting (29)–(32) in (10), we get the expression for the velocity and temperature profiles. We can now express the expressions for the velocity and the temperature profiles in terms of the fluctuating parts of the unsteady part as

$$u(y, t) = u_0(y) + \varepsilon(M_r \cos \omega t - M_i \sin \omega t) \tag{33}$$

and

$$T(y, t) = T_0(y) + \varepsilon(T_r \cos \omega t - T_i \sin \omega t) \tag{34}$$

where

$$M_r + iM_i = \frac{G}{m^2 - m - (i\omega/4)}(e^{-ny} - e^{-my}) + \frac{EG^2}{(P-1)[m^2 - m - (i\omega/4)]} \times \left[\frac{2n}{P+2n-1}(e^{-ny} - e^{-(P+n)y}) - \frac{1}{(P+m)^2 - (P+m) - (i\omega/4)} \times (e^{-ny} - e^{-(P+m)y}) - (e^{-ny} - e^{-(n+1)y}) + \frac{2m}{m^2 - m - (i\omega/4)}(e^{-ny} - e^{-(m+1)y}) - \frac{2n(P-1) + 2m - 1}{m^2 - m(i\omega/4)}(e^{-ny} - e^{-my}) \right] \tag{35}$$

$$T_r + iT_i = e^{-my} + \frac{EG^2}{(P-1)[m^2 - m - (i\omega/4)} \times [2Pn(e^{(P+n)y} - e^{-my}) - (e^{-(P+m)y} - e^{-my}) - 2n(e^{-(n+1)y} - e^{-my}) + 2m(e^{-(m+1)y} - e^{-my})]. \tag{36}$$

Hence, we can now obtain the expressions for the transient velocity and temperature profiles from (33) and (34) respectively, for $\omega t = \pi/2$, as

$$u(y, \pi/2\omega) = u_0(y) - \varepsilon M_i \tag{37}$$

and

$$T(y, \pi/2\omega) = T_0(y) - \varepsilon T_i \tag{38}$$

M_r, M_i, $u(y, \pi/2\omega)$ and $T(y, \pi/2\omega)$ are shown on Figs. 1–4.

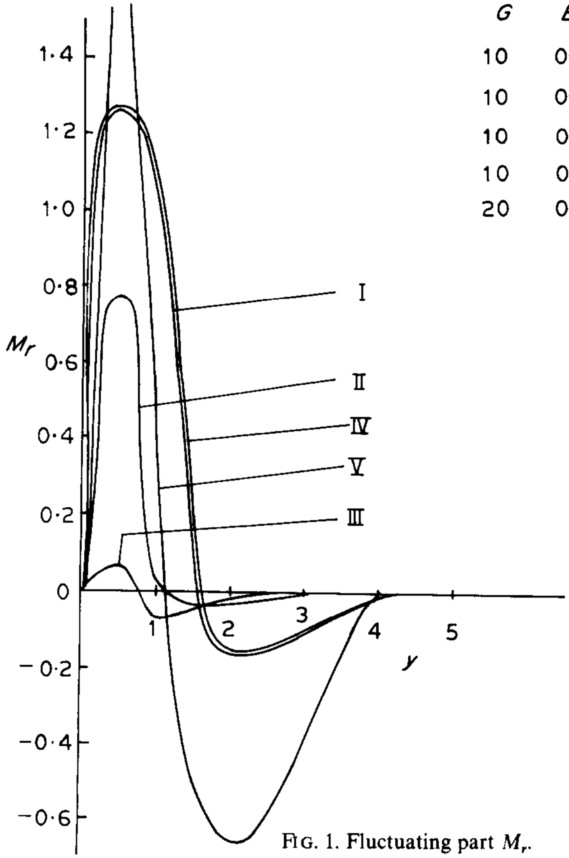
Knowing the velocity profiles, we can now derive the expression for the skin-friction as

$$\tau' = \mu(\partial u'/\partial y')_{y'=0} \tag{39}$$

which, in view of (6), reduces to the following non-dimensional form:

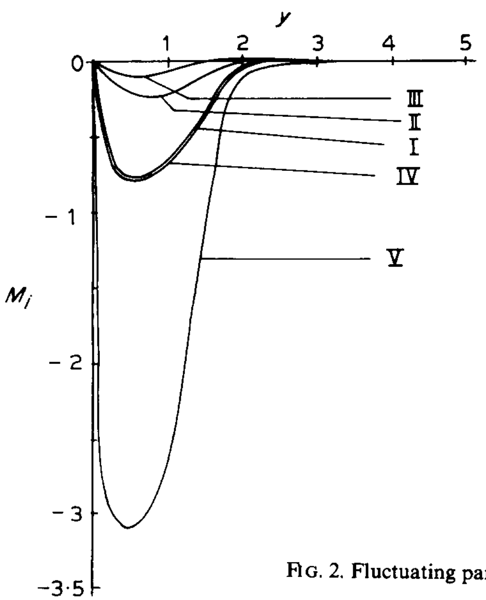
$$\tau = \tau'/\rho v_0^2 = \left.\frac{\partial u}{\partial y}\right|_{y=0} \tag{40}$$

$$\tau = (u_0' + \varepsilon e^{i\omega t} u_1')_{y=0}. \tag{41}$$



G	E	P	ω	
10	0·1	3	5	I
10	0·1	3	10	II
10	0·1	5	5	III
10	0·3	3	5	IV
20	0·1	3	5	V

FIG. 1. Fluctuating part M_r.



G	E	P	ω	
10	0·1	3	5	I
10	0·1	3	10	II
10	0·1	5	5	III
10	0·3	3	5	IV
20	0·1	3	5	V

FIG. 2. Fluctuating part M_i.

G	E	P	ω	
20	0·1	3	5	I
20	0·1	3	10	II
20	0·1	5	5	III
20	0·3	5	5	IV
10	0·1	3	5	V

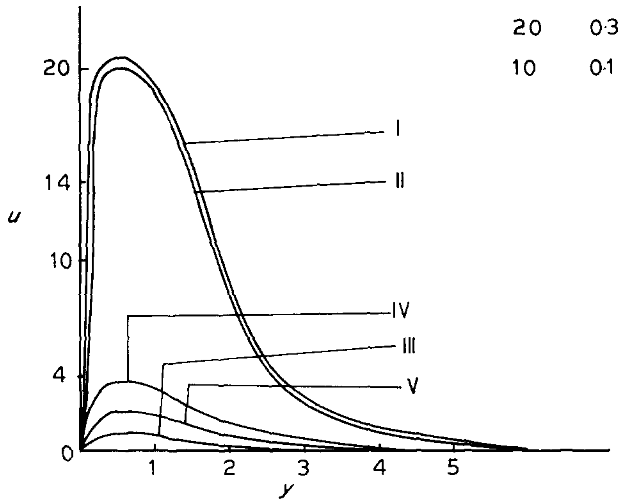
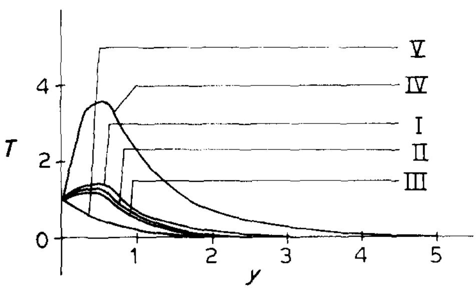


FIG. 3. Transient velocity profile $\varepsilon = 0{\cdot}2$, $\omega t = \pi/2$.



G	E	P	ω	
20	0·1	3	10	I
20	0·1	5	10	II
20	0·1	5	15	III
20	0·3	3	10	IV
10	0·1	3	10	V

FIG. 4. Transient temperature profile $\varepsilon = 0{\cdot}2$, $\omega t = \pi/2$.

Here primes denote differentiation with respect to y. Substituting for u_0 and u_1 from (29) and (30) in (41), we obtain,

$$\tau = \frac{G}{P} + \frac{EG^3}{2P(P+1)^2} + \varepsilon e^{i\omega t} \times \left[\frac{G(m-n)}{m^2 - m - (i\omega/4)} + \frac{EG^2}{(P-1)[m^2 - m - (i\omega/4)]}\left\{\frac{2nP}{P+2n-1} - \frac{P+m-n}{(P+m)^2 - (P+m) - (i\omega/4)} - 1 + \frac{2m(m+1-n)}{m^2 - m - (i\omega/4)} - \frac{(2n(P-1)+2m-1)(m-n)}{m^2 - m - (i\omega/4)}\right\}\right]. \quad (42)$$

The expression for the skin-friction, (42), can also be written in terms of the amplitude and phase of the skin friction as

$$\tau = u_0'|_{y=0} + \varepsilon |B| \cos(\omega t + \alpha) \quad (43)$$

where

$$B = B_r + iB_i = \frac{G(m-n)}{m^2 - m - (i\omega/4)} + \frac{EG^2}{(P-1)[m^2 - m - (i\omega/4)]}\left\{\frac{2nP}{P+2n-1} - \frac{P+m-n}{(P+m)^2 - (P+m) - (i\omega/4)} - 1 + \frac{2m(m+1-n)}{m^2 - m - (i\omega/4)} - \frac{(2n(P-1)+2m-1)(m-n)}{m^2 - m - (i\omega/4)}\right\} \quad (44)$$

and

$$\tan\alpha = B_i/B_r. \quad (45)$$

The numerical values of $|B|$ and $\tan\alpha$ are entered in Table 1.

We can also obtain the expression for the rate of heat transfer from

$$q' = -k\left.\frac{\partial T'}{\partial y'}\right|_{y'=0} \quad (46)$$

which, in view of (6), reduces to the following non-dimensional form:

Table 1.

G	E	P/ω	1	5	10	15
				Values of $\lvert B\rvert$		
20	0·1	3	8·7710	5·0000	3·2370	2·3984
		5	4·4261	4·1976	2·5243	1·7224
	0·3	3	17·003	15·9114	11·1388	8·4595
		5	5·1953	3·7096	2·8273	2·2779
10	0·1	3	3·5170	1·6060	1·0170	0·7869
				Values of $\lvert Q\rvert$		
20	0·1	3	407	388	348	329
		5	123	151·60	151·63	153
	0·3	3	384	388	348	329
		5	123	151·60	151·63	153
10	0·1	3	101	97	87	82
		5	30	37·900	37·908	38
				Values of $\tan\alpha$		
20	0·1	3	1·5330	−0·5234	−0·0305	0·1174
		5	0·3918	5·9405	−3·3957	−1·9598
	0·3	3	5·2004	−0·0231	0·4822	0·7447
10	0·1	3	0·9316	−1·7978	−0·8679	−0·7129
		5	0·3155	2·2417	28·59	−7·1001
				Values of $\tan\alpha_1$		
20	0·1	3	0·6144	1·5164	1·5199	1·3678
		5	0·4538	0·9298	0·8778	0·7661
	0·3	3	0·9144	1·5164	1·5199	1·3678

$$q = -\frac{q'v}{kv_0(T'_w - T'_\infty)} = \frac{\partial T}{\partial y}\bigg|_{y=0} = (T'_0 + \varepsilon\, e^{i\omega t}\, T'_1)_{y=0}. \quad (47)$$

Here primes denote differentiation with respect to y. Substituting for T_0 and T_1 from (31) and (32) respectively and carrying out the differentiation and putting $y = 0$, we obtain

$$q = -P + \frac{EG^2}{(P-1)^2}\left(\frac{2P}{P+1} + \frac{P+1}{2}\right) + \varepsilon\, e^{i\omega t}\left[-m + \frac{E\,G^2}{(P-1)\,[m^2 - m - (i\omega/4)]} \times \{2Pn(m - P - n) + P - 2m(m - n - 1) - 2m\}\right]. \quad (48)$$

The rate of heat transfer, q, can also be expressed in terms of the amplitude and the phase-angle as

$$q = -P + \frac{EG^2}{(P-1)^2}\left(\frac{2P}{P+1} + \frac{P+1}{2}\right) + \varepsilon|Q|\cos(\omega t + \alpha_1) \quad (49)$$

where

$$Q = Q_r + iQ_i = -m + \frac{EG^2}{(P-1)\,[m^2 - m - (i\omega/4)]} \times \left\{2Pn(m - P - n) + P - 2n(m - n - 1) - 2m\right\} \quad (50)$$

and

$$\tan\alpha_1 = Q_i/Q_r. \quad (51)$$

The numerical values of $|Q|$ and $\tan\alpha_2$ are entered in Table 1.

DISCUSSIONS

In order to understand the physical meaning of the problem, we study them from the figures and Table 1.

In Fig. 1, M_r is plotted. We observe from it that an increase in ω leads to a decrease in M_r(I,II). Also, as the Prandtl number P increases, M_r decreases (I,III) when G, E, ω are constant. An increase in E or G leads to an increase in M_r (I, IV) and (IV).

From Fig. 2, we observe that an increase in ω, P leads to an increase in M_i(I, II), (I, III). But an increase in E or G leads to a decrease in M_i(I, IV) (I, V).

In Fig. 3, the transient velocity profiles are shown. We observe that an increase in ω, P, or G leads to a decrease in u(I, II), (I, III), (I, V). An increase in E leads to an increase in u(III, IV).

From Fig. 4, it can be seen that as ω, P or G increases, T decreases (II, III), (I, II), (I, V). But with increasing E, there is an increase in T (I, IV).

From Table 1, we observe that an increase in ω, or P leads to a decrease in $|B|$. But as E or G increases, $|B|$ also increases.

The amplitude of the rate of heat transfer $|Q|$ decreases with increasing ω for small values of P, but for large values of P, $|Q|$ increases. An increase in P leads to a decrease in $|Q|$ only at small values of ω, say $\omega = 1$ but for large ω, an increase in E has no effect on $|Q|$. As G increases, $|Q|$ also increases.

In case of the skin-friction, there is a phase-lead at $\omega = 1$ whereas there is a phase-lag, for large values of ω, when G is small, say $G = 10$ or $G = 20$, $P = 5$. But for large G and E, for small and large ω, there is a phase-lead for $P = 3$. With the increase in G, the phase also increases.

The phase of the rate of heat transfer is always positive. Hence there is always phase-lead. It increases with increase of ω. Only at small values of ω (say $= 1$), it is affected by the heat due to viscous dissipation i.e. it increases with increasing E. It is not affected by the viscous dissipative heat for large ω.

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EFFETS DE LA DISSIPATION VISQUEUSE SUR UN ÉCOULEMENT INSTATIONNAIRE DE CONVECTION NATURELLE CONTRE UNE PLAQUE POREUSE INFINIE VERTICALE AVEC SUCCION CONSTANTE

Résumé— On étudie la chaleur dissipée par viscosité dans l'écoulement instationnaire bi-dimensionnel à convection naturelle le long d'une plaque poreuse, infinie et verticale, quand la température du plan oscille en fonction du temps, et quand il y a une succion superficielle constante. Des solutions approchées des équations non linéaires couplées sont obtenues pour la part fluctuante du profil de vitesse, les profils de vitesse transitoire et de température, l'amplitude et la phase du frottement superficiel et le flux. Au cours de la discussion on a présenté les effets de G (nombre de Grashof), E (nombre d'Eckert), P (nombre de Prandtl) et de la fréquence ω.

VISKOSE, DISSIPATIVE EFFEKTE IN EINER INSTABILEN FREIEN KONVEKTIONSSTRÖMUNG AN EINER UNENDLICHEN- VERTIKALEN, PORÖSEN PLATTE MIT KONSTANTER SAUGWIRKUNG.

Zusammenfassung—Eine Analyse der viskosen dissipativen Wärme in einer zweidimensionalen, instabilen freien Konvektionsströmung an einer unendlichen, vertikalen, porösen Platte wurde für den Fall durchgeführt, dass die Plattentemperatur zeitlich schwankt und die Saugwirkung an der Platte konstant ist. Für die veränderlichen Teile des Geschwindigkeitsprofils, die instationären Geschwindigkeits- und Temperaturprofile, die Amplitude und Phase der Oberflächenreibung und die Übertragungsrate wurden Näherungslösungen der gekoppelten nichtlinearen Gleichungen gewonnen. Während des Verlaufs der Untersuchung lagen die Einflüsse von G (Grashof-Zahl), E (Eckert-Zahl), Pr (Prandtl-Zahl) und (Kreisfrequenz) vor.

ВЛИЯНИЕ ВЯЗКОЙ ДИССИПАЦИИ НА НЕСТАЦИОНАРНОЕ СВОБОДНОКОНВЕКТИВНОЕ ОБТЕКАНИЕ БЕСКОНЕЧНОЙ ВЕРТИКАЛЬНОЙ ПОРИСТОЙ ПЛАСТИНЫ С ПОСТОЯННЫМ ОТСОСОМ ЖИДКОСТИ

Аннотация—Исследуется влияние вязкой диссипации тепла на двумерное нестационарное свободноконвективное обтекание бесконечной вертикальной пористой пластины при колебании во времени температуры пластины и при постоянном отсосе. Получены приближенные решения связанных нелинейных уравнений для флуктуирующих частей профиля скорости, нестационарных профилей скорости и температуры, амплитуды и фазы напряжения поверхностного трения и тепловых потоков. Обсуждается влияние чисел G (Грасгофа), E (Эккерта), P (Прандтля) и ω (частоты).