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HYDROMAGNETIC FREE CONVECTION FLOW FROM A VERTICAL INFINITE FLAT PLATE UNDER VARIABLE SUCTION

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Abstract

The influence of a constant horizontal magnetic field upon the free convection flow from a vertical infinite flat plate has been discussed when suction velocity is constant or time dependent. It is assumed that the fluid has small electrical conductivity so that the perturbation in the magnetic field due to the electric current flowing in the fluid may be neglected.

1. Introduction

Lighthill [1] has studied the problem in the absence of magnetic field and with a constant suction velocity. Pop [2] has analysed the influence of a constant horizontal magnetic field upon the free convectionflow from a vertical infinite flat plate with constant suction velocity when the plate temperature varies with time about a non-zero constant mean. For the purpose of simplifying the mathematical analysis, he assumed that the fluid has a very small electrical conductivity so that the perturbation in the magnetic field due to the electric current flowing in the fluid may be neglected.

In the present case two cases have been discussed when the suction velocity is constant and the suction velocity depends on some parameter A. Expressions for $u(y)$ the velocity component and T have been obtained. Graphical representation of temprature distribution with fluctuating frequency ω is shown. Expressions for the rate of heat transfer from the boundary to the fluid medium and skin-friction are obtained and discussed.

2. Basic Equations

Let the x-axis be along the plate, y-axis perpendicular to the plate. Let H_0 be the intensity of the magnetic field acting perpendicular to the plate.

Under this condition, the equations which describe hydromagnetic free convection flow of a viscous incompressible fluid past an infinite flat plate are

(1) $$\frac{\partial \bar{T}}{\partial \bar{t}} + \bar{v}_s \frac{\partial \bar{T}}{\partial \bar{y}} = k \frac{\partial^2 \bar{T}}{\partial \bar{y}^2}$$

(2) $$\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{v}_s \frac{\partial \bar{u}}{\partial \bar{y}} = g\beta (\bar{T} - \bar{T}\infty) - \frac{\sigma_1 \bar{B}_0^2}{\rho} \bar{u} + \nu \frac{\partial^2 \bar{u}}{\partial \bar{y}^2}$$

where $\bar{t}$ - time; $\bar{u}$ - the velocity component along the plate; $\bar{v}_s$ - a non-zero negative constant suction velocity; $\bar{T}$ - the temperature in the boundary layer; $\bar{B}_0 = \mu_c \bar{H}_0$ - the magnetic induction; ν - the kinematic viscosity; μ_c - the magnetic permeability of the fluid; β - the coefficient of volume expansion; g - the acceleration due to gravity; k - the thermal diffusivity.

To simplify the above equations, we introduce the following relations:

(3) $$\left[\begin{array}{l} u = \dfrac{\bar{u}}{|\bar{v}_s|} \quad y = \dfrac{\bar{y}\,|\bar{v}_s|}{\nu} \quad t = \dfrac{\bar{v}_s^2 \bar{t}}{\nu} \\[2ex] T = \dfrac{\bar{T} - \bar{T}_\infty}{\bar{T}_\omega - \bar{T}_\infty} \quad G = \dfrac{\beta g \nu (\bar{T}_\omega - \bar{T}_\infty)}{|\bar{v}_s^3|} \\[2ex] \sigma = \dfrac{\nu}{k} \quad M = \dfrac{\sigma_1 \bar{B}_0^2 \nu}{\rho \bar{v}_s^2} \end{array}\right.$$

where $\bar{T}_\omega$ - the mean wall temperature, G - the Grashof number, σ - the Prandtl number and M-the hydromagnetic parameter. Thus using equations (2.1), (2.2) and (2.3), we get

(4) $$\frac{\partial^2 T}{\partial y^2} + \frac{\partial T}{\partial y} - \tau \frac{\partial T}{\partial t} = 0$$

(5) $$\frac{\partial^2 u}{\partial y^2} + \frac{\partial u}{\partial y} - \frac{\partial u}{\partial t} = -GT + Mu$$

The above equations are to be solved with the use of following boundary conditions:

(6) $$\begin{cases} y = 0 : T = 1 + \varepsilon e^{i\omega t} + \cdots + \varepsilon^n e^{in\omega t}, \; u = 0 \\ y \to \infty : T \to 0, \; u \to 0. \end{cases}$$

3. Solution of equations

On the present general analysis, we consider two cases where in case (i), the suction velocity at the wall is constant and the velocity and temperature distribution in the boundary layer are expanded as series of n terms and case (ii), the suction velocity is variable and depends on certain parameter A such that $\varepsilon A \leqslant 1$. On putting $A=0$, we get the solution for case (i)

Case (i)

Here, $u(y, t)$, $T(y, t)$ are in the form

(7) $$u(y, t) = F_0(y) + F_1(y)\, \varepsilon e^{i\omega t} + \cdots + F_n(y)\, \varepsilon^n e^{in\omega t}$$

(8) $$T(y, t) = T_0(y) + T_1(y)\, \varepsilon e^{i\omega t} + \cdots + T_n(y)\, \varepsilon^n e^{in\omega t}$$

and to satisfy the boundary conditions (6), we have

(9) $$\left[\begin{array}{l} y=0 \ :\begin{cases} T_0 = T_1 = \cdots\cdots = T_n = 1 \\ F_0 = F_1 = \cdots\cdots = F_n = 0 \end{cases} \\ \\ y=\infty :\begin{cases} T_0 = T_1 = \cdots\cdots = T_n = 0 \\ F_0 = F_1 = \cdots\cdots = F_n = 0 \end{cases} \end{array}\right.$$

Case (ii)

In this case the suction velocity is assumed as timedependent and $\bar{v}_s$ in equation (1) is replaced by

(10) $$\bar{v}_s\,[1 + \varepsilon A e^{i\omega t} + \cdots + (\varepsilon A)^n e^{in\omega t}]$$

The series for $u(y, t)$ and $T(y, t)$ are given by

(11) $$u(y, t) = F_0(y)\, \varepsilon e^{t\omega t} + \cdots + F_n(y)\, \varepsilon^n e^{in\omega t}$$

(12) $$T(y, t) = T_0(y)\, T_1(y)\, \varepsilon e^{i\omega t} + \cdots + T_n(y)\, \varepsilon^n e^{in\omega t}$$

Solution for case (i)

Substituting equation (8) into (4) we have on equating the terms independent of $\varepsilon e^{i\omega t}$ to zero and equating the coefficients of harmonic terms as

(13) $$\left[\begin{array}{ll} T_n'' + \sigma T_0' & = 0 \\ T_1'' + \sigma T_1' - \sigma i\omega T_1 & = 0 \\ T_n'' + \sigma T_n' - \sigma in\omega T_n & = 0 \end{array}\right.$$

Whose solution with using the boundary conditions (9) is

(14) $$\left[\begin{array}{l} T_0(y) = \exp(-\sigma y) \\ T_1(y) = \exp(-h_1 \sigma y) \\ T_n(y) = \exp(-h_n \sigma y) \end{array}\right.$$

(15) $$\text{Where } h_n = \frac{1}{2}\left[1 + \left(1 + \frac{uin\omega}{\sigma}\right)^{1/2}\right] n = 1,\ 2,\ \ldots.$$

After the solutions for T_0, T_1.... are known, we may use these to find F_0, F_1, ... from the following relations.

$$\text{(16)} \quad \left[\begin{array}{l} F_0'' + F_0' - MF_0 = -GT_0 \\ F_1'' + F_1'' - i\omega F_1 - MF_1 = -GT_1 \\ F_n'' + F_n' - in\omega F_n - MF_n = -GT_n. \end{array}\right.$$

Solving equations of set (16) with the help from the equations of set (9) we have

$$\text{(17)} \quad F_0(y) = \frac{G}{\sigma(\sigma-1) - M}\left(\bar{e}^{\lambda y} - \bar{e}^{\sigma y}\right)$$

$$\text{(18)} \quad F_1(y) = \frac{G}{\sigma(\sigma-1)h_1^2 - M}\left(\bar{e}^{l_1 y} - \bar{e}^{h_1 \sigma y}\right)$$

$$\text{(19)} \quad \left[\begin{array}{l} \text{Where } \lambda = \frac{1}{2}[1 + (1 + 4M)^{1/2}] \\ l_1 = \frac{1}{2}[1 + (1 + 4i\omega + 4M)^{1/2}] \end{array}\right.$$

and

$$\text{(20)} \quad F_n(y) = \frac{G}{\sigma(\sigma-1)h_n^2 - M}\left(\bar{e}^{lny} - e^{hn\sigma y}\right)$$

$$\text{(21)} \quad \text{where } l_n = \frac{1}{2}[1 + (1 + 4ni\omega + 4M)^{1/2}]$$

Solution for case (ii)

In this case, we have from equations (4), (5) and (10)

$$\text{(22)} \quad \frac{\partial^2 T}{\partial y^2} + \sigma(1 + \varepsilon A e^{i\omega t} + \cdots + (\varepsilon A)^n e^{in\omega t})\frac{\partial T}{\partial y} - \sigma\frac{\partial T}{\partial y} = 0$$

$$\text{(23)} \quad \frac{\partial^2 u}{\partial y^2} - (1 + \varepsilon A e^{i\omega t} + \cdots + (\varepsilon A)^n e^{in\omega t})\frac{\partial u}{\partial y} - \frac{\partial u}{\partial y} = -GT + Mu$$

Thus using equation (12) into equation (22) and equating the terms independent of time and harmonic terms to zero, we have

$$\text{(24)} \quad T_0'' + \sigma T_0' = 0$$

$$\text{(25)} \quad T_1'' + \sigma(T_1' + AT_0') - \sigma T_1 i\omega = 0$$

$$\text{(26)} \quad T_2'' + \sigma(T_2' + AT_1' + A^2 T_0') - \sigma T_2(2i\omega) = 0$$

$$\text{(27)} \quad T_n'' + \sigma(T_n' + AT_{n-1}' + A^2 T_{n-2}' + \cdots + A^n T_0') - \sigma T_n(in\omega) = 0$$

where $n = 1, 2, 3, \ldots\ldots$

Solving above equations satisfying the boundary conditions of set (9) we have

(28) $$T_0(y) = \exp(-\sigma y)$$

(29) $$T_1(y) = \exp(-h_1 \sigma y) + \frac{i\sigma A}{\omega}(e^{-\sigma y} - e^{-h_1 \sigma y})$$

(30) $$T_2(y) = \exp(-h_2 \sigma y) + a(e^{-\sigma y} - e^{-h_2 \sigma y}) + b(e^{-h_1 \sigma y} - e^{-h_2 \sigma y})$$

Where

(31) $$\left[\begin{aligned} h_1 &= \frac{1}{2}\left[1 + \left(1 + \frac{ui\omega}{\sigma}\right)^{1/2}\right] \\ h_2 &= \frac{1}{2}\left[1 + \left(1 + \frac{\delta i\omega}{\sigma}\right)^{1/2}\right] \\ a &= \frac{i\sigma A^2}{2\omega} - \frac{\sigma^2 A^2}{2\omega^2} \\ b &= \frac{\sigma^2 A h_1 - i\sigma^3 A^2 h_1}{h_1^2 \sigma^2 - h_1 \sigma^2 - 2 i\omega\sigma} \end{aligned}\right.$$

Similarly for F_n, we have the following set of the equations

(32) $$F_0'' + F_0' - MF_0 = -GT_0$$

(33) $$F_1'' + F_1' - (i\omega + M) F_1 = -GT_1 - AF_0'$$

(34) $$F_2'' + F_2' - (2 i\omega + M) F_2 = -GT_2 - AF_1' - A^2 F_0'$$

(35) $$F_n'' + F_n' - (in\omega + M) F_n = -GT_n - AF_{n-1}' - A^2 F_{n-2}' \cdots A^n F_0'$$

Solving above equations with the boundary conditions from set (9) we have

(36) $$F_0(y) = \frac{G}{\sigma(\sigma - 1) - M}(e^{-\lambda y} - e^{-\sigma y})$$

(37) $$F_1(y) = c(e^{-h_1 \sigma y} - e^{-l_1 y}) + d(e^{-\sigma y} - e^{-l_1 y}) + e(e^{-\lambda y} - e^{-l_1 y}$$

(38) $$F_2(y) = a_1(e^{-h_2 \sigma y} - e^{-l_2 y}) + a_2(e^{-h_1 \sigma y} - e^{-l_2 y}) + a_3(e^{-\sigma y} - e^{-l_2 y}) + \\ + a_4(e^{-l_1 y} - e^{-l_2 y}) + a_5(e^{-\lambda y} - e^{-l_2 y}).$$

Where

$$\left[\begin{aligned} \lambda &= \frac{1}{2}[1 + (1 + 4M)^{1/2}] \\ c &- G\left(\frac{i\sigma A}{\omega} - 1\right)/[h_1^2 \sigma^2 - h_1 \sigma - (i\omega + M)] \\ d &= -G\sigma A\left(\frac{i}{\omega} + \frac{1}{\sigma(\sigma - 1) - M}\right)/[\sigma^2 - \sigma - (i\omega + M)] \\ e &= \frac{\lambda GA}{[\sigma(\sigma - 1) - M][\lambda^2 - \lambda - (i\omega + M)]} \end{aligned}\right.$$

$$(39)\quad \left| \begin{aligned} a_1 &= G(a-b-1)/[h_2^2\sigma^2 - h_2\sigma - (2i\omega + M)] \\ a_2 &= [Ach_1\sigma - Gb]/[h_1^2\sigma^2 - h_1\sigma - (2i\omega + M)] \\ a_3 &= \left[Ac\sigma - \frac{A^2\sigma G}{\sigma(\sigma-1)-M} - Ga \right] / [\sigma^2 - \sigma(2i\omega + M)] \\ a_4 &= Al_1(c+b+e)/[l_1^2 - l - (2i\omega + M)] \\ a_5 &= A\lambda\left[e + \frac{AG}{\sigma(\sigma-1)-M} \right] / [\lambda^2 - \lambda - (2i\omega + M)] \end{aligned} \right.$$

Similarly the expressions for $F_3(y)$, $F_4(y)$, ... $F_n(y)$ may be evaluated.

4. Discussions

For case (i), the non-dimensional form of the rate of heat transfer from the wall to the fluid

$$(40)\quad q = -G\left(\frac{\partial T}{\partial y}\right)_{y=0} = G\sigma[1 + \varepsilon h_1 e^{j\omega t} + \varepsilon^2 h_2 e^{2i\omega t} + \cdots + \varepsilon^n h_n e^{in\omega t}]$$

and the expression for skin-friction is given by

$$(41)\quad \tau_\omega = \left(\frac{\partial u}{\partial y}\right)_{y=0} = \frac{G}{\sigma}\left[\frac{\sigma - \lambda}{(\sigma-1) - \frac{M}{\sigma}} + \frac{h_1\sigma - l_1}{(\sigma-1)h_1^2 - \frac{M}{\sigma}}\varepsilon e^{i\omega t} + \cdots + \frac{h_n\sigma - l_n}{(\sigma-1)h_n^2 - \frac{M}{\sigma}}\varepsilon^n e^{in\omega t} \right]$$

When the magnetic field is fixed and ω is large, then we have

$$(42)\quad \left\{ \begin{aligned} & h_1 \sim \left(\frac{i\omega}{\sigma}\right)^{1/2}, \quad h_n \sim \left(\frac{in\omega}{\sigma}\right)^{1*_2} \\ & l_1 \sim (i\omega)^{1/2}, \quad l_n \sim (in\omega)^{1/2} \end{aligned} \right.$$

Thus

$$(43)\quad \left\{ \begin{aligned} & T_1 \sim \exp(-y\sqrt{i\omega\sigma}), \quad T_n \sim \exp(-y\sqrt{i\omega\sigma n}) \\ & F_1 \sim \frac{iG}{\omega(1-\sigma)}[\exp(-y\sqrt{i\omega} - \exp(-y\sqrt{i\omega\sigma})] \end{aligned} \right.$$

$$(44)\quad \left[\begin{aligned} & q \sim G\sigma\left[1 + \varepsilon e^{i\omega t}\sqrt{\frac{i\omega}{\sigma}} + \varepsilon^2 e^{2i\omega t}\sqrt{\frac{2i\omega}{\sigma}} + \cdots + \varepsilon^n e^{in\omega t}\sqrt{\frac{in\omega}{\sigma}} \right] \\ & \tau_\omega \sim \frac{G}{\sigma}\left[\frac{\sigma-\lambda}{\sigma - 1 - \frac{M}{\sigma}} + \varepsilon\frac{e^{i\omega t}\sigma}{(\sqrt{\sigma}+1)\sqrt{i\omega}} + \cdots + \frac{\varepsilon^n e^{in\omega t}}{(\sqrt{\sigma}+1)\sqrt{in\omega}} \right] \end{aligned} \right.$$

Thus neglecting the terms containing ε^2, ε^3, ... ε^n, we have equations (16) of Pop [2] In case (ii) the non-dimensional form of the rate of heat transfer from the boundary to the fluid medium is

$$(45)\qquad q=-G\left(\frac{\partial T}{\partial y}\right)_{y=0}=G\sigma\left[1+\varepsilon e^{i\omega t}\left\{h_1+\frac{i\sigma A}{\omega}(1-h_1)\right\}+\varepsilon^2 e^{2i\omega t}\{h_2+\right.$$
$$\left.+a(1-h_2)+b(h_1-h_2)\}+\cdots\right]$$

Which may be written as

$$(46)\qquad q=G\sigma\left[1+\varepsilon e^{i\omega t}h_1\left(1-\frac{i\sigma A}{\omega}+b\varepsilon e^{i\omega t}\right)+\frac{i\sigma A}{\omega}\varepsilon e^{i\omega t}+\right.$$
$$\left.+h_2\varepsilon^2 e^{2i\omega t}(1-a-b)+a\varepsilon^2 e^{2i\omega t}+\cdots\right]$$

The expression for the skin-friction

$$(47)\qquad \tau_\omega=\left(\frac{\partial u}{\partial y}\right)_{y=0}\frac{G}{\sigma(\sigma-1)M}(\sigma-\lambda)+\varepsilon e^{i\omega t}[l_1(c+d+e)-\sigma(ch_1+d)-c\lambda+$$
$$+\varepsilon^2 e^{2i\omega t}[l_2(a_1+a_2+a_3+a_4+a_5)-\sigma(a_1h_2-a_2h_1+a_3-(a_4l_1+a_5\lambda)]+\cdots$$

When the magnetic field is fixed and ω is large, then we have

$$(48)\qquad \left[\begin{array}{l} a\sim\dfrac{i\sigma A^2}{2\omega} \\[2ex] b\sim\left[\dfrac{-A\sqrt{i\omega\sigma}+iA^2\sigma\sqrt{\dfrac{i\omega}{\sigma}}}{\sqrt{i\omega\sigma}+i\omega}\right] \\[2ex] c\sim\dfrac{G}{\sqrt{i\omega\sigma}-i\omega(\sigma-1)} \end{array}\right.$$

Where d and e keep their original values if ω is not too high and thus

$$(49)\qquad T_1\sim\exp\left(-y\sqrt{i\omega\sigma}\right)+\frac{i\sigma A}{\omega}[\exp(-\sigma y)-\exp\left(-y\sqrt{i\omega\sigma}\right)]$$

$$(50)\qquad T_2\sim\exp\left(-y\sqrt{2i\omega\sigma}\right)+\frac{i\sigma A^2}{2\omega}\{\exp(-\sigma y)-\exp\left(-y\sqrt{2i\omega\sigma}\right)\}+$$
$$+\left\{\frac{iA^2\sigma\sqrt{\dfrac{i\sigma}{\omega}}-A\sqrt{i\omega\sigma}}{\sqrt{i\omega\sigma}-i\omega}\right\}\{\exp\left(-y\sqrt{i\omega\sigma}\right)-\exp\left(-y\sqrt{2i\omega\sigma}\right)\}$$

The skin friction at the wall equation (37) may be discussed for large ω.

When ω is small, some cases are discussed following Lal [3] where the calculations aie not much complicated. As an example we have from equations (15) and (21) that

(51) $$h_n = h_{nr} + ih_{ni} \simeq \left\{ 1 + \frac{\omega^2 n^2}{\sigma^2} + i\left(\frac{\omega n}{\sigma} - \frac{2n^3\omega^3}{\sigma^3} \right) \right\}$$

(52) $$l_n = l_{nr} + il_{ni} \simeq \left[\frac{1}{2}\left(1 + \sqrt{1+4M}\right) + \frac{n^2\omega^2}{(1+4M)^{3/2}} \right] + $$

$$+ i\left[\frac{n\omega}{1+4M} - \frac{2n^2\omega^3}{(1+4M)^{5/2}} \right.$$

Where h_{nr}, l_{nr} stand for real parts and h_{ni}, l_{ni} for the imaginary parts of h_n, l_n. We further have

(53) $$\sigma(\sigma-1)h_n^2 - M \simeq \frac{1}{(\sigma^2-\sigma-M)}\left[1 - \frac{2i(\sigma-1)}{\sigma^2-\sigma-M}D - \frac{4D^2(\sigma-1)^2}{(\sigma^2-\sigma-M)^2} \right]$$

(54) $$\text{Where } D = \left[n\omega + \frac{\sigma}{2i}\sqrt{1 + \frac{4in\omega}{\sigma}} \right]$$

Substituting above relations into (14) and (20), we have on separating into real and imaginary parts, expressions for T_n and F_n. Simplification for F_n is much more complicated and for T_n, we have

(55) $$T_n(y) = \exp\left[-\left(\sigma + \frac{\omega^2 n^2}{\sigma} \right) \right] - \exp\left[-iy\left(\omega n - \frac{2n^3\omega^3}{\sigma^2} \right) \right]$$

From which by considering real parts, for the temperature distribution, we have

(56) $$Re\,T(y,t) = T_0(y) = \sum_{n=1}^{n} \varepsilon^n \cos\left[n\omega t - \left(\omega n - \frac{2n^3\omega^3}{\sigma^2} \right) y \right]$$

As ω is small, the value of $\left(n\omega - \frac{2n^3\omega^3}{\sigma^2} \right) y$ is expected to be small for all values of $n-1, 2, \ldots\ldots$ for given σ. Hence the fluid temperature lags behind the wall temperature by an angle α.

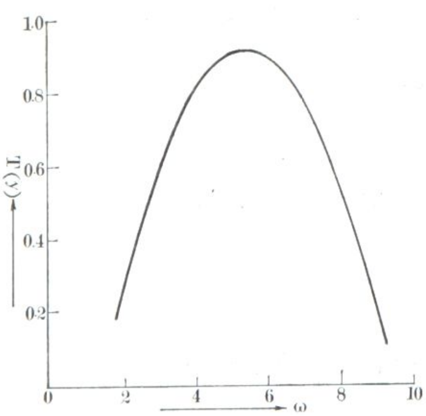

Fig. 1

Graph between temperature distribution and $\omega\,(\sigma = 1;\ y = 1)$. From. fig (1), we see that the value of $T_0(y)$ first increases for $\omega = 1, 2, \ldots 5$ and then it decreases for higher values of ω. Thus we conclude that by increasing the fluctuating frequency there is always rapid decrease in temperature.

For the temperature field, we need the expressions for h_1, h_2 and other terms. Thus we have

(57) $$h_1 \simeq \left(1 + \frac{\omega^2}{\sigma^2} - \frac{5\omega^4}{\sigma^4} \right) + 1\left(\frac{\omega}{\sigma} + \frac{2\omega^3}{\sigma^3} \right)$$

(58) $$h_2 \simeq \left(1 + \frac{4\omega^2}{\sigma^2} - \frac{80\omega^4}{\sigma^4} \right) + 1\left(\frac{2\omega}{\sigma} - \frac{16\omega^3}{\sigma^3} \right)$$

and

(59) $$T_1(y) \simeq e^{-\sigma y}\left[1-\left(\frac{\omega^2}{\sigma}-\frac{5\omega^4}{\sigma^3}\right)y\right]\exp\left[-iy\left(\omega-\frac{2\omega^3}{\sigma^2}\right)\right]+$$
$$+\frac{i\sigma A}{\omega}\left[e^{-\sigma y}\left\{\left(\frac{\omega^2}{\sigma}+\frac{5\omega^4}{\sigma^3}\right)y-\frac{\omega^4 y^2}{2\sigma^2}\right\}\right]$$

which may be simplified as

(60) $$T_1(y) \simeq e^{-\sigma y}\exp\left\{-iy\left(\omega-\frac{2\omega^3}{\sigma^3}\right)\right\}\left[\left\{\left(\frac{\omega^2}{\sigma}+\frac{5\omega^4}{\sigma^3}\right)y-\frac{\omega^4 y^2}{2\sigma^2}\right\}\left\{\frac{i\sigma A}{\omega}-1\right\}+1\right]$$
$$\simeq e^{-\sigma y}[P_r+iP_i]$$

(61) $$\text{Where } P_r=\left[-y\left(\frac{\omega^2}{\sigma_1}+\frac{5\omega^4}{\sigma^3}\right)+y^2\left\{\frac{\omega^4}{2\sigma^2}+A\left(\omega^2+\frac{5\omega^4}{\sigma^2}\right)\right]+\right.$$
$$\left.+y^3\left(\frac{\omega^4}{2\sigma}-\frac{\omega^4 A}{2\sigma}\right)+\frac{Ay^4\omega^4}{6}\right]$$

(62) $$P_i=\left\{\omega+\frac{5\omega^3}{\sigma^2}\right\}yA+y^2\left(\frac{\omega^3}{2\sigma}\right)-\frac{A\omega^3}{2}y^3.$$

Thus if we use the above relations into (12) we have the second term in $T(y, t)$ as

(63) $$T_1(y)\,\varepsilon\, e^{i\omega t} \simeq |P|\,\varepsilon\, e^{-\sigma y}\exp[i\omega t+i\beta]$$

where

(64) $$\begin{cases} |P| = \sqrt{P_r^2+P_i^2} \\ \beta = \tan^{-1} P_i/P_r \end{cases}$$

It is possible to show that the amplitude P increases uniformly as the value of the fluctuating frequency ω increases.

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CONVECTION NATURELLE MAGNÉTOHYDRODYNAMIQUE SUR UNE PLAQUE PLANE AVEC UNE ASPIRATION VARIABLE

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Résumé:

Le sujet de ce travail est une étude de l'influence d'un champ magnétique horizontal à la convection naturelle sur une plaque plane, verticale et infinie, si la vitesse d'aspiration est constante ou bien variable. En supposant que la conductivité électrique reste si petite que le champ magnétique induit dans l'écoulement peut être négligé, l'auteur donne les solutions analytiques des équations différentielles en question et, finalement, calcule le transfert de chaleur ainsi que la contrainte tangentielle sur la plaque plane.

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