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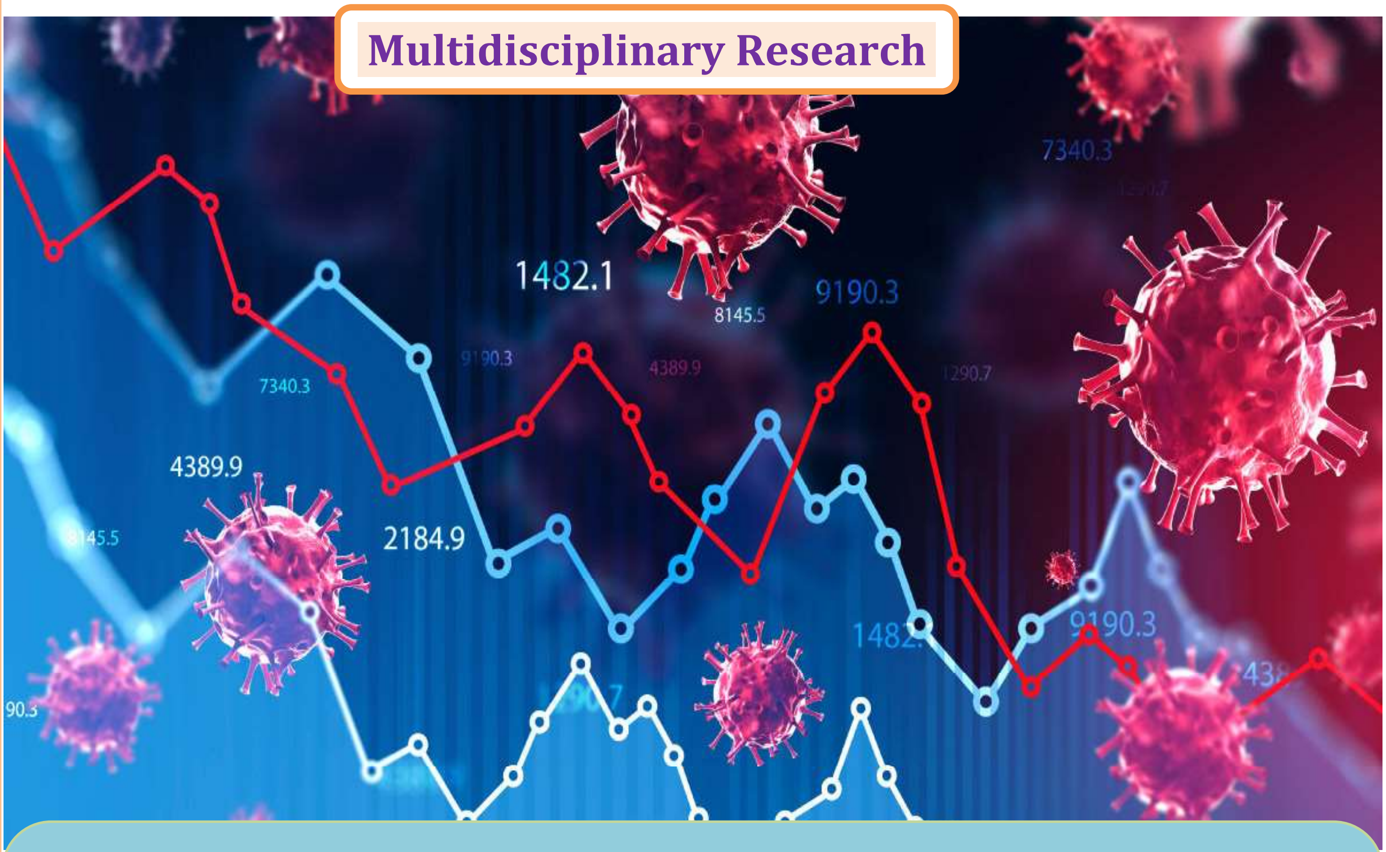

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INDEX

Rotating Fluid of Magneto Hydrodynamics Flow Past An Impulsively Started Infinite Vertical Plate

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Abstract :

This paper present an exact solution to the a rotating fluid of magneto hydrodynamics flow past an impulsively stated infinite vertical plate. Dimensionless governing equation are solved by Laplace-transform technique. Expressions of axial and transfer component of velocity, skin friction are derived. It is demonstrated that both axial and transverse components of velocity decrease due to increasing t. The axial component of skin-friction increases with increasing M but the transverse component of skin friction decrease with increasing M.

Keywords : MHD flow, Laplace transform, Rotating fluid.

Nomenclature:

Cp: Specific heat at constant pressure. EK: Ekman number
Gr : Grashof number

g: Acceleration due to gravity K: Thermal conductivity
Pr: Prandtl number

T': Temperature of the fluid near the plate T'W: Temperature of the plate
T'∞: Temperature of the fluid far away from the plate
t′: Time

Uo: Reference velocity (Eq 2.5)

G′: Angular speed

(uu, vu):Velocity components along x, and y, axis respectively

z′: Coordinate normal to x',y', plane

Greek Symbols :

v : Kinematic viscosity
β : Coefficient of volume expansion þ∗ : Coefficient of species expansion ρ : Density
μ: Viscosity

Introduction:

If the plate is given motion in a rotation fluid, how the motion takes place? This has been discussed by Batchelor (1967). Many papers were published on this topic by different authors. The fluid assumed was stationary. Flow of a viscous incompressible fluid past an impulsively started infinite vertical plate, on taking into account the presence of free convection currents was studied by Soundalgekar (1977) and presented an exact solution to coupled linear partial differential equation by the Laplace transform technique. The effects of transversely applied

Magnetic field on the flow of an incompressible viscous conducting fluid were also studied by Soundalgekar, Gupta and Aranke (1978)The flow of a viscous incompressible fluid past an impulsively started infinite vertical plate in a rotating fluid was recently studied by Lahurikar, Jahagirdar & Soundalgekar 2009 and here we study the effects of transversely applied magnetic field on the flow of a viscous incompressible electrically conducting fluid of the flow past an impulsively started infinite vertical plate in a rotating fluid. In section2 the mathematical analysis is presented and In sec.3 the conclusions are set out.

Mathematical Analysis :

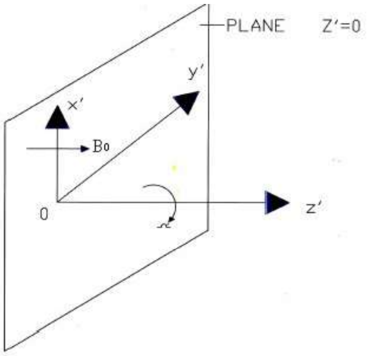

FIG.1: SCHEMATIC DIAGRAM

As shown in Fig1 we assume that an infinite vertical plate is surrounded by an infinite mass of stationary viscous incompressible fluid. we take x’_axis along the vertical plate in the upward direction and y’- axis is assumed to be normal to the plate. Then the z’- axis is taken normal to the x’ y’ -plane. Initially at time t’<0, the temperature of the plate and the fluid is maintained the same. At time t’ >0 ,the plate starts moving upward with a velocity U0,the fluid starts rotating about the z’-axis with an angular speed G’and the plate temperature is raised to T’w such that T’w –T′∞ > 0, causing the presence of free convection currents and uniform transverse magnetic B0,is assumed to the applied parallel to z’-axis. In the present case we can show that the physical variables are functions of z’ and t’ only then under usual Boussinesq’s approximation,

Introduce the following non-dimensional quantities :

$$u = \frac{u'}{U_0} \qquad v = \frac{v'}{U_0}, \qquad t = \frac{t' Gr {U_0}^2}{v}, \qquad z = \frac{z'\sqrt{Gr}\, U_0}{v} \quad , \quad Pr = \frac{\mu Cp}{k}$$

$$Gr = \frac{v g \beta (T'w - T'\infty)}{U_0}, \theta = \frac{T' - T'\infty}{T'w - T'\infty,'} \quad E_K = \frac{\Omega' v}{Gr U_0}, M = \frac{v \sigma {B_0}^2}{Gr {U_0}^2} \qquad (1)$$

the fluid flow is governed by the following equations

$$\frac{\partial u'}{\partial t'} - 2\Omega' v' = g\beta(T' - T'\infty) + v\frac{\partial^2 u'}{\partial z'^2} - \frac{\sigma {B_0}^2}{\rho} u' \qquad (2)$$

$$\frac{\partial v'}{\partial t'} + 2\Omega' u' = \nu \frac{\partial^2 v'}{\partial z'^2} - \frac{\sigma {B_0}^2}{\rho} v' \tag{3}$$

$$\rho C_P \frac{\partial T'}{\partial t'} = k \frac{\partial^2 T'}{\partial z'^2} \tag{4}$$

All the physical variables are defined in the notation. The initial and boundary conditions are

$$\begin{array}{llll} u' = 0, & v' = 0\,, & T' = T'_\infty & for\ all\ z', t' \le 0 \\ u' = U_0, & v' = 0\,, & T' = T'_w & at\ z = 0, t' > 0 \\ u' = 0, & v' = 0\,, & T' = T'_\infty & as\ z' \to \infty, t' > 0 \end{array} \tag{5}$$

In equations (1) -(5) and we have

$$\frac{\partial q}{\partial t} + 2iE_K q = \theta + \frac{\partial^2 q}{\partial z^2} - Mq \tag{6}$$

$$Pr \frac{\partial \theta}{\partial t} = \frac{\partial^2 q}{\partial z^2} \tag{7}$$

where $q = u + iv$

with the following initial and boundary conditions :

$$\begin{array}{lll} q = 0, & \theta = 0, & for\ all \quad z, t \le 0 \\ q = 1, & \theta = 1 & at\ z = 0\,, t > 0 \\ q = 0, & \theta = 0 & as\ z \to \infty, t > 0 \end{array} \tag{8}$$

The solutions to these coupled linear systems can be derived by the usual Laplace- transform technique and it is as follows:

$$q = \frac{1}{2}\left(1 - \frac{1}{b}\right)\left\{e^{-2\eta\sqrt{bt}} erfc\left(\eta - \sqrt{bt}\right) + e^{2\eta\sqrt{bt}} erfc\left(\eta + \sqrt{bt}\right)\right\} + \frac{e^{at}}{2b}\{e^{-2\eta\sqrt{(a+b)t}} erfc(\eta$$
$$- \sqrt{(a+b)t}) + e^{2\eta\sqrt{(a+b)t}}.erfc\ \left(\eta\sqrt{(a+b)t}\,\right)\Big\} + \frac{1}{b} erfc\ \left(\eta\sqrt{Pr}\right)$$
$$- \frac{e^{at}}{2b}\left\{2^{-2\eta\sqrt{aPrt}}.erfc\left(\eta\sqrt{Pr} - \sqrt{at}\right) + e^{2\eta\sqrt{aPrt}}.erfc\left(\eta\sqrt{Pr} + \sqrt{at}\right)\right\}$$

Where $a = \frac{b}{Pr-1}$, $\qquad b = 2iE_K + M \qquad$ (9)

And $\eta = \frac{z}{2.\sqrt{t}}$

we have carried out numerical computation for u. v and 8. In order to gain physical insight into this problem However, for Pr=0.71, the argument of erfc function becomes complex and hence we have to separate these into real and imaginary parts.

Let

$$f_n(X,Y) = 2X - 2XCos(2XY)Cosh(nY) + nSinh(nY)sin(2XY)$$

$$g_n(X,Y) = 2XCosh(nY)Sin(2XY) + nSinh(nY)cos(2XY)$$

$$|\in(X,Y)| = 10^{-16}|\,\mathrm{erf}(X+iY).$$

We use of the following formula for separating real and imaginary parts:

$$Er.f(X+iY)$$
$$= \mathrm{erf}(X) + \frac{\exp(-X^2)}{2\pi X}[(1 - Cos(2XY) + iSin(2XY))]$$
$$+ [\frac{2\exp(-X)^2}{\pi}]\sum_{n=1}\frac{\exp(-\frac{n^2}{4})}{n^2+4X^2}[f_n(X,Y) + ig_n(X,Y)] +$$
$$\in(X,Y) \qquad (10)$$

Thus the computed values of the axial and transverse velocity profiles are shown on Figs 2. We conclude that an increase in M leads to a decrease in the axial velocity and increase in the transverse velocity.

From Fig.3 and 4 we observe that both u and v decrease due to more rotating of the fluid or owing to increasing time. Knowing the velocity field, we now study the skin-friction which is given by

$$\tau' = -\mu\frac{\partial u}{\partial y}\ \Big|y' = 0\ |y' = 0 \qquad (11)$$

And in view of (1), equation (11) reduce to

$$\tau = \frac{\tau'}{\rho U_0} = -\frac{1}{2\sqrt{t}}\frac{dq}{dn}|n = 0 \qquad (12)$$

From (9) and (12) ,we have

$$\tau = 2\left(\frac{1}{b} - 1\right)\left\{\frac{e^{-bt}}{\sqrt{x}} + \sqrt{bt}\,\mathrm{erf}(\sqrt{bt})\right\} - \frac{2e^{at}}{b}\left\{\frac{e^{-(a+b)t}}{\sqrt{\pi}} + \sqrt{(a+b)t}.\,\mathrm{erf}\,(\sqrt{(a+b)t})\right\}$$
$$+ \frac{2\sqrt{Pr}e^{at}}{b}\left\{\frac{e^{-at}}{\sqrt{\pi}} + \sqrt{at}.\,\mathrm{erf}\,(\sqrt{at})\right\}$$
$$- \frac{2\sqrt{Pr}}{\sqrt{\pi b}} \qquad (13)$$

Where

$$a = \frac{b}{Pr - 1}, \qquad b = 2iE_k + M$$

Table I(**Value of**v)

In table I we listed the numerical values of [– v] are computed by using (10) .

we observe an increase in the magnetic field parameter M leads to an increase in the axial skin friction and a decrease in the transverse skin friction. But both axial as well as transverse skin friction increase owing to more rotating of the fluid.

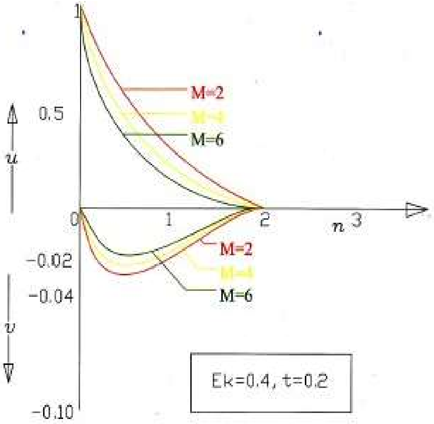

FIG.2: AXIAL AND TRANSVERSE VELOCITY PROFILES,Pr=0.71

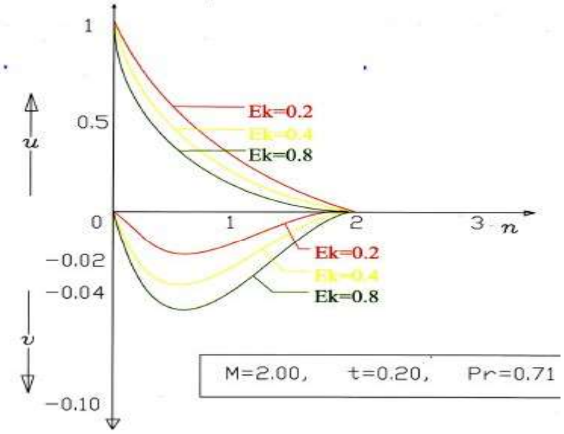

FIG.3: AXIAL AND TRANSVERSE VELOCITY PROFILES

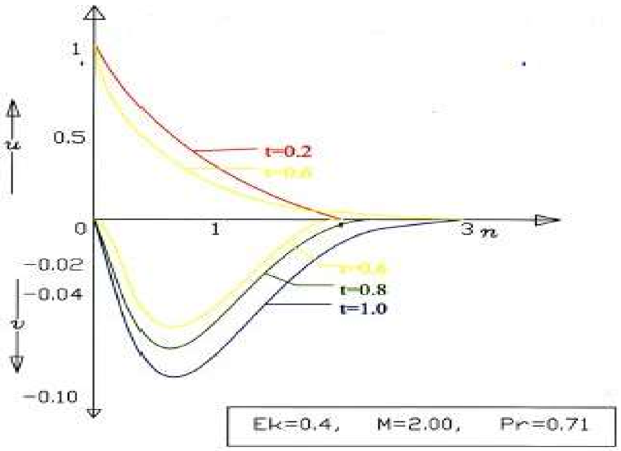

FIG.4: AXIAL AND TRANSVERSE VELOCITY PROFILES,EFFECT OF TIME

Conclusions.

(i) By increasing the Ekman number , the axial as well as transverse components of velocity decrease.

(ii) By increasing time t, the axial as well as transverse components of velocity decrease.

(iii) Due to increasing M, the axial component of velocity decreases But the transverse component of velocity increases.

(iv) Due to increase in time t. the axial as well as transverse components of skin friction increases

(iv) The Axial component of skin friction increases with increasing M or Ek

(v) The transverse component of skin friction decrease with increasing M and increase owing to an increase in the Ek.

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