SYNOPSIS

The present thesis deals with some flow and heat-transfer problems in magnetohydrodynamics. It is divided into six chapters.

In the Chapter I, a brief review of the previous results, directly related to the present work, is given.

The Chapter II is devoted to the study of free convective boundary layer flows for high and low Prandtl numbers past a semi infinite vertical flat plate in the presence of a magnetic field, applied perpendicularly to the plate. The problem is analysed by an integral method. Thermal and viscous boundary layers are separately treated with different polynomials, representing the velocity and the temperature profiles in different regions of the boundary layers. It is seen that the effect of the magnetic field on the flow and heat transfer will be more pronounced in the low Prandtl number case. The same thing can be expressed by saying that a magnetic field of comparatively greater intensity is required to affect the flow and heat transfer noticeably in the high Prandtl number case. It is observed that for fluids with low Prandtl numbers, both the temperature and the velocity at a point within the boundary layer decrease, as the strength of the applied magnetic field increases; while for high Prandtl numbers, the velocity decreases; but the temperature increases.

Copyright IIT Kharagpur

It is also observed that both the skin-friction and the Nusselt number at the plate decrease with increase in the magnetic field.

The fully developed hydromagnetic flow in a straight rotating channel, subjected to a constant transverse magnetic field, is analysed in the Chapter III. An exact solution of the governing equations is obtained; and a few particular cases of interest are discussed. The solution in the dimensionless form contains two parameters: the Hartmann number M^2 , and K^2 which is the reciprocal of the Ekman number. The effects of these parameters on the velocity and the magnetic field distributions are studied. For large K^2 , the oscillatory character of the flow is observed. The shear stress at the plates decrease, as both M^2 and K^2 increase. For large values of K^2 , the effect of the magnetic field is almost negligible; but at lower speeds of rotation, the magnetic field has an appreciable effect in lowering the skin-friction. At higher values of K^2, mass flow decreases due to the formation of thin boundary layers at the plates.

The Chapter IV is devoted to a study of the magnetohydrodynamic flow between two disks, rotating with the same angular velocity Ω about two different axes, distant a apart. The imposed axial magnetic field is assumed to be uniform. An exact solution of the equations

Copyright IIT Kharagpur

of motion is obtained in a simple closed form. It is found that the effect of the magnetic field is to increase the torque, experienced by the disks. For large values of K^2, and M^2, boundary layers are formed at the disks. The thicknesses of these layers will be

$$O\left(\frac{1}{K}\right), \text{ if } K \gg M, \text{ and } O\left(\frac{1}{M}\right), \text{ if } M \gg K.$$

In the Chapter V, the flow due to torsional oscillations of an axisymmetric body in the presence of a uniform magnetic field, acting along a normal to the body surface, is analysed by the method of successive approximations. An orthogonal system $(\bar{x}, \theta, \bar{z})$ of coordinates is chosen, such that the $\bar{x}$ -axis is measured from the body corner along the generating curve; the θ -axis along a latitude; and the $\bar{Z}$ -axis along a perpendicular to the surface, passing through the point of intersection of the $\bar{x}$ and θ axes. The axis of symmetry lies in the plane $\theta = 0$. The primary flow is confined to a thin layer whose thickness decreases with increase in the magnetic field. Due to rotational oscillations of the body, a secondary circulatory flow is developed in the meridian plane (The plane, perpendicular to the θ -axis). This flow consists of a steady part, and an unsteady part which executes oscillations with twice the frequency of the body oscillations.

Copyright IIT Kharagpur

The steady secondary flow is confined only to the meridian plane; while the flow in the circumferential direction is purely oscillatory. The steady and the unsteady parts of the secondary flow along the generating curve are confined to two boundary layers whose thicknesses decrease with increase in the magnetic field; while the flow along the $\overline{z}$-axis persists at large distances from the body. The skin-friction along the x-direction consists of a steady part, and an oscillatory part which oscillates with twice the frequency of the body oscillations; and has a phase lag over it. The component of the skin-friction along the θ-direction is purely oscillatory, oscillating with the same frequency as the exciting body oscillations; and has a phase lead over it. The magnitude of this component increases with the magnetic field.

As a particular case, the flow due to the torsional oscillations of a sphere is studied. The stream lines are plotted for a few representative values of the Hartmann number. It is seen that the fluid approaches the sphere at the poles; and recedes from it at the equator (The equatorial plane is a diametral plane, perpendicular to the axis of rotation). The effect of the magnetic field is to shift the stream lines away from the sphere.

The Chapter VI deals with the effect of the Hall currents on two specific flow problems.

Copyright IIT Kharagpur

In the first part of this chapter is discussed the hydromagnetic Rayleigh problem. Laplace transform technique is applied to get an exact solution. Limiting cases for small and large times are discussed. It is found that the initial impulsive start of the plate develops a Rayleigh layer, unaffected by the magnetic field, and the Hall currents. When terms of order t (time variable) become important, a transverse flow is induced, and simultaneously the Rayleigh layer is modified due to the interplay of the viscous diffusion, and the electromagnetic forces with Hall effect. As $t \to \infty$, the "Hartmann layer" as modified by the Hall currents is established. The thickness of this layer increases due to the Hall effect. The final steady state is approached through oscillations which damp out effectively in a dimensionless time of the order of $\frac{1+N^2}{M^2}$, where N is the Hall parameter.

In the second part, we consider the effect of Hall currents on the flow due to a disk, performing torsional oscillations about a state of rotation with constant angular velocity Ω in a fluid which is also rotating with the same angular velocity. The flow is characterised by two opposite circularly polarised waves, travelling with different phase velocities. Both the radial and the circumferential components of the flow decay exponentially with distance from the disk; thereby exhibiting the boundary layer character of the flow. The boundary layer

Copyright IIT Kharagpur

character is governed by two different layer thicknesses, δ_1, and δ_2. It is observed that both δ_1, and δ_2 at first increase rapidly with increase in N ; but for higher values of N , both of them remain almost unaffected. The effects of both the magnetic field, and the frequency of oscillations are to increase δ_1 for all values of N ; while δ_2 shows a complicated behaviour. Both the radial and the transverse components of the shear stress at the disk have the same amplitude, but complementary phase angles. The effect of the Hall currents is to increase the amplitude of the shear stress at the disk. The influence of the Hall effect on the shear stress amplitude is more pronounced for small values of N .

Copyright IIT Kharagpur