SYNOPSIS

The subject of Magnetohydrodynamics, which is the study of flow of electrically conducting fluids, has currently received considerable attention. Apart from the mathematical interest born out of a curiosity to investigate the new subject representing a fusion of two classical disciplines namely, hydrodynamics and electromagnetism, it has evoked much interest among scientists and engineers because of its diverse application to practical problems. In the first instance, it is customary to investigate with simplified models so that the theoretical results thus obtained would point out the advantages and disadvantages and yield a rough estimate of the various quantities entering the problem. To this end we have discussed a few boundary value problems in Magnetohydrodynamics in the presence of cross magnetic fields. Free-convection flows under the influence of gravitational forces have been investigated most extensively because they are encountered frequently in nature as well as in engineering applications. We have also analysed some problems dealing with the free-convection flow of viscous fluids on simple and typical geometries: vertical and horizontal plates. In many of the problems we have made allowance for suction through the bodies with a view to

observe its influence on flow characteristics and to compare its qualitative behaviour with that of the magnetic field.

The thesis consists of seven chapters. Three of them deal with the flow of electrically conducting fluids between rotating discs and in channels, while three other consider the free-convection flow of viscous fluids about vertical and horizontal plates.

Chapter I is introductory. The development of Magnetohydrodynamics is traced citing its applications in Engineering and Technology. The basic equations exhibiting the characteristic interaction between the flow and magnetic fields are given along with the approximations made in Magnetohydrodynamics. The boundary conditions to be satisfied at the solid-fluid interface are listed. Finally a brief survey of the literature, mainly connected with the problems of the thesis, is made.

Chapter II is devoted to the study of the flow of an electrically conducting fluid between two unsteadily rotating discs and in the presence of an axial magnetic field. The analysis is restricted to small magnetic Reynolds number where the effects of the induced field are ignored. Analytical solutions are obtained for small Reynolds number. It is found that the magnetic field suppresses diviations of the flow velocities from the quasi-steady states. Also, it is observed that in the magnetic case, the results of torque computation related to quasi-steady states can be applied to unsteady states earlier than in the non-magnetic case.

Chapter III considers the unsteady Couette flow in Magnetohydrodynamics. It is divided into two parts. In the first part, the formation of Couette flow under a transverse magnetic field is studied when one of the bounding plates is impulsively started or uniformly accelerated, and a uniform suction or injection is imposed on the plates. Exact solutions are obtained using the method of Laplace transform under the condition that the magnetic Prandtl number $P_m = 1$. It is found that suction retards the flow and decreases the induced field. The magnetic field decelerates the flow near the moving plate but accelerates near the stationary one. The skin friction on the plate in motion increases with both suction and the magnetic field. In the second part, the above problem is reconsidered under the condition that the suction velocity oscillates in time over a constant mean. The response of the skin friction and the current density at the plates to variation in the frequency and the field is studied. Numerical results reveal that the amplitudes of the skin friction and the current density decrease while their phase lags increase as the frequency increases. With the increase in applied field, the amplitude of the skin friction on the moving plate decreases and that at the fixed plate increases, whereas the amplitude of the current densities at both the plates decrease. Their phase lags are decreased by the applied field.

In Chapter IV, the steady flow of a conducting fluid in an annular duct with porous walls is investigated. Two cases are considered when the external applied field is (i) circular, and (ii) radial. In each case the walls perpendicular to the field are subject to suction and injection whose magnitude at a point varies inversely as its distance from the coaxis. Exact solutions in the form of Fourier series are obtained. Depending on the magnetic and suction parameters M and R, it is found that the flow rate

(i) decreases as M increases in the case of solid walls,

(ii) decrease as R increases for a given small M and, for large M it increases for small R and then decreases as R increases, and

(iii) decreases for a given small R and increases for a large R, as M increases.

The study of free-convection flow over a non-isothermal, horizontal plate which executes small sinusoidal oscillations in its plane forms the subject matter of Chapter V. For small frequencies solutions are found using integral methods, and for large frequencies the solutions are developed in inverse powers of the frequency parameter ω about the Stoke's term. These two solutions are joined in terms of a critical frequency which is a function of the Prandtl number only. The response of the fluctuating components of the skin friction and the coefficient of heat transfer to imposed oscillations is analysed. At very high frequencies, the flow is of 'shear-wave' type. In this case, the unsteady skin friction coefficient leads the plate oscillation by 45° while the heat transfer result shows a phase lag of 45°.

Chapter VI deals with the unsteady free-convection flow along an infinite vertical plate subject to a periodic suction when the plate temperature oscillates in time over a constant mean. A Fourier expansion method is used and the basic equations are resolved into an infinite set of coupled equations for the velocity and temperature functions. These functions are expanded in powers of δ, the amplitude of the fluctuating component of the suction velocity. It is noticed that even though the basic equations are linear, the mean flow and temperature are found to be affected by all the higher harmonic terms. The mean skin friction increases with frequency to its asymptotic value of P_r^{-1}, where P_r is the Prandtl number, while the coefficient of heat transfer upto $O(\delta^2)$ remains unaffected by the frequency. Solutions are also obtained for the general case when the suction velocity varies slowly with respect to time and is continuously differentiable, but otherwise arbitrary. The method involves expanding the velocity and temperature functions about their quasi-steady states in terms of a set of non-dimensional parameters which are functions of time only.

The effect of mass transfer on the free-convection flow from a horizontal plate is studied in Chapter VII. By means of similarity transformations the governing boundary layer equations are reduced to a pair of ordinary differential equations. These non-linear equations are solved by an approximate method devised by Fettis. An analysis of the numerical results shows that the influence of suction is more on heat transfer than on skin friction for fluids of Prandtl number $Pr > 0.73$ and vice versa when $Pr < 0.73$. The asymptotic form of the heat transfer for large suction is also given. It is found that for fluids of higher Prandtl numbers, the asymptotic heat transfer value is reached for smaller suction velocities.