SYNOPSIS

One of the most successful fascinating and useful application of mathematics is study of motion of fluids. Fluid mechanics is that branch of science that deals with the behavior of the fluids (liquids or gases) at rest as well as in motion. Fluid dynamics or Hydrodynamics is that branch of science which is concerned with the study of the motion of fluids or that of bodies in contact with fluids. Fluid mechanics is one of the major areas of the applied mathematics and has obvious practical applications in many important disciplines like aeronautics, meteorology, geophysical fluid mechanics and bio-fluid mechanics etc. Magneto hydro dynamics (MHD) (magneto fluid dynamics or hydro magnetics) is a special academic discipline of the fluid dynamics, which studies the dynamics of electrically conducting fluid such as plasmas, liquid metals and salt water. The field of MHD (Magneto-magnetic field, Hydro-liquid and Dynamics-movement) was first discovered by Farady. Further Swedish scientist Hannes Alfven realized that new waves unknown to fluid mechanics and electromagnetism can be propagated through a conducting fluid in a magnetic field. The basic idea of MHD is that magnetic fields can induce currents in a moving conductive fluid, which create forces on the fluid and also change the magnetic field itself.

Magneto hydro dynamic convection plays a significant role in various industrial applications. Examples include magnetic control of molten iron flow in the steel industry, liquid metal cooling in nuclear reactors and magnetic suppression of molten semi-conducting materials. It is of importance in connection with many engineering areas, such as sustained plasma confinement for controlled thermonuclear fusion and electromagnetic casting of metals, MHD pumps and MHD bearings etc. In a broader sense, MHD has applications in three different subject areas, such as astrophysical, geophysical and engineering problems. The study of magneto hydro dynamic viscous flows is important to industrial technological and geothermal applications such as high temperature plasmas, cooling of nuclear reactors, liquid metal fluids, MHD accelerators and power generation systems. The study of MHD flows has stimulated considerable interest due to its important applications in cosmic fluid dynamics, meteorology, and solar physics and in the motion of Earth's core.

The application of electromagnetic fields in controlling the heat transfer as in aerodynamic heating leads to the study of MHD heat transfer. This MHD heat transfer has gained significance owing to recent advancement of space technology. The MHD heat transfer can be divided into two sections. One contains problem in which the heating is an incidental by-product of the electromagnetic fields as in MHD generators, pumps etc., and the second consists of problems in which the primary use of electromagnetic fields is to control heat transfer. Liquid in the geothermal region is an electrically conducting liquid because of high temperature. Hence the study of the interaction of the geomagnetic field with the fluid in the geothermal region is of great interest, thus leading to the study of MHD convection flow through a porous medium.

In general heat transfer plays a vital role in MHD flows. When a fluid is at a different temperature from that of its surroundings, the thermal energy transfer from high temperature region to low temperature region until the fluid and the surroundings attain thermal equilibrium. This is called heat transfer or heat exchange. Heat transfer and fluid flow due to free convection in the presence of magnetic field and internal heat generation along porous plate find useful applications in different branches of Science and Technology such as nuclear science, fire engineering, combustion modeling, geophysical etc.

The phenomenon of free convection arises in the fluid when temperature fluctuations cause density variation leading to buoyancy forces acting on the fluid elements. When all the time derivatives of a flow field vanish, the flow is considered to be steady flow. Otherwise it is called unsteady. All fluids are compressible to some extent that is changes in pressure or temperature will result in changes in density. However, in many situations, the changes in pressure and temperature are sufficiently small that the changes in density are negligible. Such flows are called incompressible fluids. Boussinesq's approximations are used in the field of buoyancy driven flow (also known as natural convection). It states that density differences are sufficiently small to be neglected, except where they appear in terms multiplied by 'g' (the acceleration due to gravity). Free convection flows are of great interest in a number of industrial applications such as fiber and granular insulation, geothermal systems etc. Buoyancy is also of importance in the environment where difference between land and air temperature can give rise to complicated flow patterns. Bestman and Adjepong [8] studied unsteady hydro-magnetic free convection flow with radiative heat transfer in a rotating fluid. Soundalgekar [29, 30 and 31] investigated a two dimensional steady free – convection flow of an incompressible, viscous, electrically conducting fluid past an infinite vertical porous plate with constant suction and plate temperature when the difference between the plate temperature and free stream is moderately large to cause free–convection currents.

Flow through porous media is very prevalent in nature and therefore the study of flow through porous medium has become of principal interest in many scientific and engineering applications. In the theory of flow through a porous medium, the role of momentum equation or free balance is occupied by the numerous experimental observations summarized mathematically as the Darcy's law. It is observed that the Darcy's law is applicable as long as the Reynolds number based on average grain (pore) diameter does not exceed a value between 1 and 10.

The requirements of modern technology have stimulated interest in fluid flow studies which involve the interaction of several phenomena. One such study is related to the effects of free convection flow through a porous medium, which play an important role in agriculture, engineering, petroleum industries, and heat transfer. The convection problem in a porous medium also has several applications in geothermal reservoirs and geothermal energy extractions. Porous media are widely used for a heated body to maintain its temperature for a long time. To make the heat insulation of the surface more effective, it is necessary to steady the free convection effects on the flow through a porous medium and estimate its influence on the heat transfer. Convective heat transfer through porous medium has been a subject of great interest for the last three decades. The flow of a viscous, incompressible fluid past an infinite isothermal vertical plate, oscillating in its own plane was solved by Soundalgekar [27].

The study of heat generation or absorption effects in moving fluids is important in view of several physical problems such as fluids undergoing exothermic or endothermic chemical reactions. Vajravelu [34] studied the exact solution for a hydrodynamic uniform suction and internal heat generation/absorption. Chamkha and Khaled [10] investigated the problem of coupled heat and mass transfer by MHD free convection from an inclined plate in the presence of internal heat generation or absorption. Alam et al. [6] studied the problem of free convection heat and mass transfer flow past an inclined semi-infinite heated surface of an electrically conducting and steady viscous incompressible fluid in the presence of magnetic field and heat generation. Chamkha [11] investigated unsteady MHD convective heat and mass transfer past a semi-infinite porous moving plate with heat absorption.

The process involving the convection of internal energy of the solution in to radiation energy is known as radiation heat transfer. Raptis [23] analyzed the thermal radiation and free convection flow through a porous medium by using perturbation technique. Ogulu et al. [21] have discussed MHD Free-Convection and mass transfer flow with radiative heat transfer. Abd-El-Naby et al. [1] presented a finite difference solution of radiation effects on MHD unsteady free convection flow over a vertical porous plate. Dulal Pal et al. [13] have discussed Heat and Mass transfer in MHD non-Darcian flow of a micropolar fluid over a stretching sheet embedded in a porous media with non-uniform heat source and thermal radiation. Chamkha [9] studied thermal radiation and buoyancy effects on hydro-magnetic flow over an accelerating permeable surface with heat source or sink.

All the above mentioned studies are based on the hypothesis that the effect of dissipation is neglected. This is possible in case of ordinary fluid flow like air and water under gravitational force. But this effect is expected to be relevant for fluids with high values of the dynamic viscosity flows. Moreover Gebhart [14], Gebhart and Mollendorf [15] have shown that viscous dissipation heat in the natural convective flow is important, when the fluid is of extreme size or is at extremely low temperature or in high gravitational field. The effect of viscous dissipation changes the temperature distributions by playing a role as an energy source, which affects the heat transfer rates. The merit of the effect of viscous dissipation depends on whether the plate is being cooled or heated.

Soundalgekar [28] analyzed viscous dissipative heat on the two dimensional unsteady free convective flow past an infinite vertical porous plate when the temperature oscillates in time and there is constant suction at the plate. Chen [12] examined the effect of combined heat and mass transfer on MHD free convection from a vertical surface with the Ohmic heating and viscous dissipation. Gireesha et al. [16] analyzed the effect of viscous dissipation and heat source on flow and heat transfer of dusty fluid over unsteady stretching sheet. Ahmed [2] presented the effects of viscous dissipation and chemical reaction on transient free convective MHD flow over a vertical porous plate. Aiyesimi et al. [3] studied viscous dissipation effect on the boundary layer radiative MHD flow over a vertical plate in a porous medium with internal heat generation and convective boundary condition. Kishore et al. [20] discussed the effect of thermal radiation and viscous dissipation on MHD heat and mass diffusion flow past an oscillating vertical plate embedded in a porous medium with variable surface conditions.

The effect of chemical reaction on MHD flows also plays an important role. This effect depends on whether the reaction is homogeneous or heterogeneous, in turn depends on whether they occur at interface or as a single phase volume reaction. In well-mixed systems, the reaction is heterogeneous, if it takes place at an interface and homogeneous, if it takes place in a solution. In most cases of chemical reactions, the reaction rate depends on the concentration of the species itself. The present trend in the field of chemical reaction analysis is to give a mathematical model for the system to predict the reactor performance. Kandaswamy et al. [18] have discussed the effects of chemical reaction, heat and mass transfer on boundary layer flow over a porous wedge with heat radiation in the presence of suction or injection. Effects of chemical reaction and radiation absorption on free convective flow through porous medium with variable suction in the presence of uniform magnetic field were studied by sudheer babu and satyanarayana [32]. Recently Rao and Sivaiah [22] analyzed the effects of chemical reaction on unsteady MHD flow past semi infinite vertical porous plate with viscous dissipation. Kesavaiah et al. [19] studied effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction.

The applications of the effect of Hall current on the fluid flow with variable concentration have been seen in MHD power generators, astrophysical and meteorological studies as well as in plasma physics. The Hall Effect is due merely to the sideways magnetic force on the drifting free charges. The electric field has to have a component transverse to the direction of the current density to balance this force. In many works on plasma physics, the Hall Effect is disregarded. But if the strength of magnetic field is high and the number density of electrons is small, the Hall Effect cannot be ignored as it has a significant effect on the flow pattern of an ionized gas. Hall Effect results in a development of an additional potential difference between opposite surfaces of a conductor for which a current is induced perpendicular to both the electric and magnetic field. This current is termed as Hall current. Model studies on the effect of Hall current on MHD convection flows have been carried out by many authors due to application of such studies in the problems of MHD generators and Hall accelerators. Ajay Kumar Singh [4] made an attempt to study the steady MHD free convection and mass transfer flow with Hall current, viscous dissipation and joule heating, taking in to account the thermal diffusion effect. Alam et al. [5] have studied unsteady free convective heat and mass transfer flow in a rotating system with Hall currents, viscous dissipation and Joul heating. Anand Rao and Srinivasa Raju [7] studied the effect of hall current on an unsteady magnetohydrodynamic flow past along a porous flat plate with heat and mass transfer in presence of viscous dissipation. Satyanarayana and Venkataramana [24] studied Hall current effect on magnetohydrodynamic free convection flow past a semi-infinite vertical porous plate with mass transfer. Singh and Kumar [25] studied the combined effects of Hall current and rotation on free convection MHD flow in a porous channel. Singh and Reena pathak [26]examined the Effect of rotation and Hall current on mixed convection MHD flow through a porous medium filled in a vertical channel in presence of thermal radiation,

In all above studies the thermal-diffusion effect (Soret effect) has been neglected. This assumption is true when the concentration level is very low. There are, however, exemptions. The Soret effect for instance, has been utilized for isotope separation and in mixtures between gases with very low molecular weight (H_2, He) and the medium molecular weight (N_2, air) the Soret effect was found to be of a magnitude so it cannot be neglected. In view of the importance of this Soret effect, recently Jha and Singh [17] studied the free convection and mass transfer flow in an infinite vertical plate moving impulsively in its own plane, taking into the account of Soret effect. Vempati et al. [35] studied the Soret and Dufour effects on unstedy MHD flow past an infinite vertical porous plate with thermal radiation. Uwanta et al. [33] obtained the analytical solution for MHD fluid flow over a vertical plate with Dufour and Soret effects.

In the present thesis we made an attempt to analyze the effect of Thermal radiation, Heat absorption, rotation, Chemical reaction, Hall current and thermal diffusion on an unsteady MHD free (or natural or mixed) flow through a porous medium in the presence of viscous dissipation under varying initial and boundary conditions. The governing equations of the flow field are coupled and non-linear. As such exact solutions are not possible for such problems by opting a Finite Element technique wherever required are used for getting the approximate solutions of the equations. In order to get a physical insight into the problems, the behavior of the Velocity, Temperature, Concentration, Skin-friction, Nusselt number and Sherwood number are discussed computationally for variations in the governing parameters. The present thesis comprises of five chapters.

***Chapter – I:* Unsteady MHD free convection flow past an infinite vertical plate with viscous dissipation and heat absorption**

In this chapter, we investigate the effects of viscous dissipation and heat absorption on unsteady MHD free convection flow of a viscous, incompressible, electrically-conducting fluid past an infinite vertical porous plate. The dimensionless governing equations are solved by Finite element technique. Numerical evaluation of the analytical results is performed. Graphical results for velocity, temperature and concentration profiles and tabulated results for skin friction coefficient, Nusselt number and Sherwood number are presented and discussed.

***Chapter – II:* Chemical reaction and Radiation effects on unsteady MHD natural convection flow of a rotating fluid past a vertical porous flat plate in the presence of viscous dissipation**

The aim of this chapter is to examine the effects of chemical reaction and radiation on unsteady MHD natural convection flow of a rotating fluid past a vertical porous flat plate in the presence of viscous dissipation. The chemical reaction has been assumed to be of first-order. The dimensionless governing equations are solved numerically by using finite element method. The effects of the various physical parameters on the complex velocity, temperature and concentration fields across the boundary layer are investigated. It has been observed that the concentration decrease with the increase in the chemical reaction parameter and there is an increase in temperature with an increase in the value of radiation parameter.

***Chapter – III:* Thermal radiation and Rotation effect on an unsteady MHD mixed convection flow through a porous medium with Hall current and Heat absorption**

The effect of thermal radiation and rotation on an unsteady magneto hydrodynamic mixed convection flow through a porous medium with hall current in the presence of viscous dissipation and heat absorption has been studied in this chapter. The non-linear partial differential equations, governing the flow field under consideration, have been transformed by a similarity transformation and then solved numerically by finite element method. A uniform magnetic field is applied in the direction normal to the planes of the plates. The entire system rotates about an axis normal to the planes of the plates with uniform angular velocity Ω. The temperature of one of the plates varies periodically and the temperature difference of the plates is high enough to induce radiative heat transfer. The effects of various parameters on the velocity profiles, temperature field, the skin friction, rate of heat transfer in terms of their amplitude and phase angles are shown graphically.

***Chapter – IV:* Effects of Heat source and Radiation on an unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium in the presence of Thermal Diffusion**

In this chapter, we have explored the influence of heat source and radiation on unsteady magneto hydrodynamic free convection flow past an infinite heated vertical plate in a porous medium, by taking into account the thermal-diffusion (Soret) effects. The governing boundary layer equations are written into a dimensionless form by similarity transformations. The transformed nonlinear differential equations are solved numerically with finite element methods. Numerical calculations are carried out for different values of dimensionless parameters. The results are presented graphically for velocity, temperature and concentration profiles, and show that the flow field and other quantities of physical interest are significantly influenced by these parameters.

***Chapter – V:* The effect of Hall current on an unsteady MHD flow along a porous flat plate with Viscous Dissipation and Heat absorption**

An analysis is presented to investigate the effect of Hall current and heat absorption on MHD flow of an electrically conducting incompressible fluid along an infinite vertical porous plate with viscous dissipation. The governing partial differential equations are non-dimensionalized and transformed into a system of nonlinear ordinary differential similarity equations. The resulting nonlinear equations are solved under appropriate transformed boundary conditions by using Galerkin finite element method. Computations are performed for a wide range of the governing flow parameters viz. Grashof Number, Modified Grashof Number, Transpiration cooling parameter, Prandtl Number, Schmidt Number, Eckert number, Hartmann number, Heat absorption parameter and Hall parameter on the flow field. Numerical results for the dimensionless velocity, temperature and concentration profiles are obtained and displayed graphically for the above parameters.

The contents of chapters I, II and III are communicated for publication.

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