Chapter 8

Conclusion and suggestion for future work

This chapter summarizes the thesis, mentioning the technique of solution, pointing out the key findings of the model problems considered and outlines some direction for future research scope in this field. A strategic framework has been elaborated in **first chapter** by stating key terms, basic equations, boundary conditions and presenting a brief review related to the problems discussed in this thesis. Brief analysis of physical interpretations, limitations and influences of the relevant parameters has been submitted in **Chapter 2-7**. Some flow models are designed in rotating environment. Some problems are studied in presence of convective heat exchange under Arrhenius reaction rate/kinetics. Several frame of geometry have been modeled by taking radiation, porous channel and slip condition into consideration. Problems are solved analytically and/or numerically.

In **second chapter**, the impact of radiative heat transfer and magnetic field on a fully developed mixed convective flow with asymmetric heating of the walls have been discussed. The governing equations of the motion under relevant boundary conditions are solved analytically in usual manner. The squared-Hartmann number slows down the fluid motion near the hot wall and enhances near the cold wall. As radiation parameter increases, the induced magnetic field decreases near the cold wall while it increases near the hot wall of the channel. Buoyancy force enhances the induced magnetic field. With increasing radiation parameter, the fluid temperature is lowering within the channel. The shear stress at the cold wall increases while that at the hot wall decreases with an increase in radiation parameter. In the absence of the buoyancy force, there is no flow reversal in the channel. Radiation causes to increase the critical Grashof number near the cold wall while it causes to decrease near the hot wall of the channel.

Oscillatory MHD Couette flow between two infinite horizontal parallel plates in a rotating environment has been considered in **third chapter**. The governing equations are solved assuming the plate velocity in the form of Fourier series. Asymptotic expansion ensures that either for large frequency parameter or for large rotation parameter, there exists a double-deck boundary layers whereas for large Hartmann number there exists a single-deck boundary layer. The steady primary velocity increases while the steady secondary velocity decreases with an increase in squared-Hartmann number. Phase angle causes to decrease the unsteady primary velocity while it causes to increase the unsteady secondary velocity. The shear stress corresponding to the steady primary velocity increases with an increase in either rotation parameter or squared-Hartmann number. The shear stress corresponding to the steady secondary velocity increases for rotation parameter while decreases for squared-Hartmann number. Rotation parameter leads to increase the amplitudes. Magnitudes of the tangent of phase angles decrease with an increase in squared-Hartmann number.

An investigation on hydromagnetic oscillatory flow of a viscous incompressible electrically conducting reactive fluid through a porous channel with asymmetrical convective boundary conditions in a rotating frame of reference has been done in **fourth chapter**. The heat transfer characteristic has also been studied by taking viscous and Joule dissipations into account. The velocity components, wall shear stresses are obtained in closed form and the non-linear energy equation is tackled numerically using pdepe MATLAB's subroutine. Both the primary and secondary velocity components have retarding influence with an increase in either magnetic field or phase angle. The primary velocity decreases while the secondary velocity increases until it reaches maximum and then decreases as rotation parameter increases. Biot number and Eckert number increase the fluid temperature across the channel. A decrease in fluid temperature with increased Prandtl number while increasing reaction parameter causes an increase in temperature within the channel. An increase in reaction parameter reduce the rate of heat transfer at upper plate of the channel. Increasing magnetic field intensity reduces wall shear stresses while increasing suction Reynolds number enhances the wall shear stresses.

In **fifth chapter**, a numerical study for slip flow and heat transfer of an electrically conducting Boussenesq couple-stress fluid over an exponentially stretching sheet embedded in a porous medium subject to the variable magnetic field and thermal radiation with viscous and Joule heating has been presented. By means of similarity transformation, the governing partial differential equations of the modeled problem are converted into non-linear ordinary differential equations which are solved by making the use of shooting iteration technique along with the fourth order Runge-Kutta integration. The velocity profile is found to decrease with strengthening of magnetic field. The velocity profile boosts with a rise in Darcy number. The velocity is observed to reduce when slip parameter is increased. The temperature profile is observed to increase with an increase in either magnetic parameter or Eckert number, while it decreases with an increase in either radiation parameter or Darcy number. The thermal radiation is observed to influence the growth of thermal boundary layer thickness. Stream lines distort in the presence of porous materials. Both the shear stress and rate of heat transfer at sheet surface are reduced by increasing the slip parameter. The shear stress at the surface of the stretching sheet enhances considerably with elevation of magnetic filed. The combination of couple stress parameter and Eckert number greatly affect the flow characteristics due to the stretching sheet. Increasing the Prandtl number results in reduction of thermal boundary layer thickness. Consequently, the rate of heat transfer increases with increasing Prandtl number.

The impact of Hall currents on unsteady MHD convective flow and heat transfer of a viscous incompressible electrically conducting fluid in a moving vertical channel adopting Cogley-Vincent-Gilles heat flux model have been investigated in **sixth chapter**. Employing the Laplace transform technique, the governing equations are solved. The velocity components are declined due to increasing values of the magnetic field or radiation parameter. Increasing Hall parameter strongly accelerates the velocity components. The buoyancy force significantly enhances the fluid velocity components throughout the channel. An enhancement in thermal radiation parameter leads to cooling of fluid. The wall shear stresses are significantly increased by increasing Hall parameter. The wall shear stresses are reduced by increasing radiation parameter. As time progresses there is enhancement in the rate of heat transfer at the moving channel walls. Inclusion of Hall currents exerts a profound influence on the flow characteristics.

In **seventh chapter**, We have examined the influences of Hall currents on an unsteady hydromagnetic flow of a reactive, viscous, incompressible, electrically conducting fluid between two infinitely long horizontal parallel porous plates in the presence of a uniform transverse magnetic field when one of the plate is set into impulsive/uniformly accelerated motion under the Arrhenius reaction rate. Using the Laplace transform technique, the velocity field and shear stresses are derived in a closed form while the energy equation is solved numerically using MATLAB software package. The velocity of a reactive viscous fluid in the channel is significantly modified by the combined effects of magnetic field and Hall currents. The primary velocity is enhanced while the secondary velocity decreases due to uniform suction. The velocity of a reactive viscous fluid increases with time. The temperature of the reactive viscous fluid in the channel is reduced with increase in the Hall parameter or the variable thermal conductivity parameter, while it increases with the magnetic field or suction/injection parameter. The shear stresses at the channel plates increase with increasing values of the magnetic parameter or Hall currents while they are reduced at increasing values of the suction parameter. The rate of heat transfer at the channel plates is reduced due to increase in either variable thermal conductivity parameter or suction parameter.

Future Research Scope

In this section, we first like to remind the geometry of problems considered. Chapter 3, 4, 6 and 7 are based on time dependent unsteady problems. Radiation parameter is imposed in Chapter 2, 5 and 6. Chapter 3 and 4 are designed in rotating frame of reference. Arrhenius reaction rate has been implemented in Chapter 4 and 7. Hall currents are encountered in Chapter 6 and 7. Depending on the flow geometry, modeled for this research work, we will seek for improvement to the geometry which may lead to noble ideas and some interesting results. Many new areas can yet be explored and some points from this work can be further clarified. Moreover, we can construct problems by changing only the boundary conditions for future continuation of this work. Based on the current work completed in this area, the influence of Hall currents, radiation, porous medium, nanofluid and rotating environment can be considered.

Extension of scopes exists in the third and fourth chapters taking Hall currents into account. The present configuration of radiation effect on MHD fully developed mixed convection in a vertical channel with asymmetric heating can be well developed by considering a porous medium in between the channel and/or adding viscous and Joule dissipation terms in the energy equation. Couette flow under uniform transverse magnetic field in a rotating system can be further improved by assuming porous channel and/or taking radiation into account. The present configuration of Hydromagnetic oscillatory reactive flow through a porous channel in rotating frame subject to convective heat exchange under Arrhenius kinetics can be changed on taking Hall currents into consideration. Layout of Boussinesq couple-stress fluid flow over an exponentially stretching sheet with slip in porous space subject to variable magnetic field can be rearranged by taking nanofluid instead of porous material. More precise influence of Hall currents on unsteady magneto-convection in a moving channel with Cogley heat flux model can be obtained considering porous medium and/or Arrhenius reaction rate and/or viscous, Joule dissipation. Hall effects on unsteady MHD reactive flow through a porous channel with convective heating under Arrhenius reaction rate can be redesigned in rotating environment and/or taking nanofluid into account.

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