CHAPTER 7
CONCLUSIONS AND FUTURE SCOPE

7.1 CONCLUSIONS
Thermal stability and thermosolutal stability of hydrodynamic and hydromagnetic systems of
various non-Newtonian fluids viz. Walters’, Rivlin-Ericksen, couple-stress, ferromagnetic and
micropolar fluids have been considered. In the present thesis, the linearized stability theory and
normal mode analysis have been used to study the effects of various important parameters like
suspended particles, compressibility, rotation, magnetic field, Hall currents, solute gradient,
variable gravity, porous medium, micropolar coefficient, coupling parameter, micropolar heat
conduction parameter etc. on various stability problems.

The principal conclusions from the study of the effect of magnetic field, rotation and suspended
particles on thermosolutal convection in Rivlin-Ericksen elastico-viscous fluid saturating a
porous medium are as follows:

(i) For stationary convection, the suspended particles have destabilizing effect on the system.
(ii) The medium permeability has a destabilizing effect in the absence of rotation whereas in
the presence of rotation it has a destabilizing effect when \( T_{A_1} < \frac{(1 + x + PQ_1)^2}{P^2(1 + x)} \) \( \varepsilon^2 \) and
has stabilizing effect when \( T_{A_1} > \frac{(1 + x + PQ_1)^2}{P^2(1 + x)} \) \( \varepsilon^2 \).
(iii) The magnetic field has a stabilizing effect in the absence of rotation whereas in the
presence of rotation it has a stabilizing effect when \( T_{A_1} < \frac{(1 + x + PQ_1)^2}{P^2(1 + x)} \) \( \varepsilon^2 \) and has
destabilizing effect when \( T_{A_1} > \frac{(1 + x + PQ_1)^2}{P^2(1 + x)} \) \( \varepsilon^2 \).
(iv) The rotation and stable solute gradient have stabilizing effect on thermosolutal convection
of the system.
(v) The critical Rayleigh numbers and critical wave numbers for the onset of instability are also determined numerically and the sensitiveness of the critical Rayleigh number $R_c$ with respect to changes in medium permeability, magnetic field, rotation, solute gradient and suspended particles parameter is depicted graphically which are in agreement with analytical results.

(vi) The principle of exchange of stabilities is satisfied in the absence of magnetic field, rotation and stable solute gradient. The presence of magnetic field, rotation and stable solute gradient introduces oscillatory modes (as $\sigma_i$ may not be zero).

The principal conclusions from the analysis of the effect of magnetic field, rotation, variable gravity field and suspended particles on thermosolutal convection in Rivlin-Ericksen elastic-viscous fluid saturating a porous medium are as follows:

(i) For stationary convection, the suspended particles have destabilizing effect for $\lambda > 0$ and stabilizing effect for $\lambda < 0$.

(ii) When gravity increases upwards (i.e. $\lambda > 0$), the medium permeability has a destabilizing effect in the absence of rotation whereas in the presence of rotation it has a destabilizing effect when $T_{A_i} < \frac{(1 + x + PQ_i)^2}{P^2(1 + x)} \varepsilon^2$ and has stabilizing effect when $T_{A_i} > \frac{(1 + x + PQ_i)^2}{P^2(1 + x)} \varepsilon^2$.

(iii) The magnetic field has a stabilizing effect in the absence of rotation when gravity increases upwards whereas in the presence of rotation it has a stabilizing effect when $T_{A_i} < \frac{(1 + x + PQ_i)^2}{P^2(1 + x)} \varepsilon^2$ and has destabilizing effect when $T_{A_i} > \frac{(1 + x + PQ_i)^2}{P^2(1 + x)} \varepsilon^2$.

(iv) For stationary convection, the stable solute gradient is found to have stabilizing effect whereas effect of rotation is stabilizing for $\lambda > 0$ and destabilizing for $\lambda < 0$.

(v) The principle of exchange of stabilities is satisfied in the absence of magnetic field, rotation and stable solute gradient. The presence of magnetic field, rotation and stable solute gradient introduces oscillatory modes (as $\sigma_i$ may not be zero).
The theoretical investigations have been made to analyze the effect of various parameters such as magnetic field, Hall currents and suspended particles on thermal stability of ferromagnetic fluids. The main results from the analysis are as follows:

(i) It is found that suspended particles and Hall currents have a destabilizing effect whereas magnetic field has a stabilizing effect on the system.

(ii) The critical Rayleigh numbers and the associated wave numbers are found for stationary convection for various parameters involved and it has been found that it increases with the increase in magnetic field parameter and decreases with the increase in suspended particle parameter and Hall currents parameter thereby confirming the stabilizing role of magnetic field and destabilizing role of suspended particles and Hall currents.

(iii) The principle of exchange of stabilities is not valid for the problem under consideration whereas in the absence of magnetic field it is valid under certain conditions.

The main results from the study of the effect of magnetic field, Hall currents, suspended particles and compressibility on thermal stability of ferromagnetic fluids are as follows:

(i) It is found that suspended particles and Hall currents have a destabilizing effect whereas magnetic field has a stabilizing effect on the system.

(ii) The effect of compressibility is to postpone the onset of instability.

(iii) The critical Rayleigh numbers and the associated wave numbers are found for stationary convection for various parameters involved and it has been found that it increases with the increase in magnetic field parameter and decreases with the increase in suspended particle parameter and Hall current parameter thereby confirming the stabilizing role of magnetic field and destabilizing role of suspended particles and Hall currents.

(iv) The principle of exchange of stabilities is not valid whereas in the absence of Hall currents (hence magnetic field), it is valid under certain conditions.

The combined effect of stable solute gradient, medium permeability, magnetic field and Hall currents has been considered on the thermal stability of a ferromagnetic fluid. The main results from the analysis are as follows:
(i) It is found that Hall currents have a destabilizing effect whereas magnetic field and stable solute gradient have a stabilizing effect on the system.

(ii) For small values of Hall currents parameter, the medium permeability always hastens the onset of convection for all wave numbers as the Rayleigh number decreases with an increase in medium permeability parameter whereas for higher values of Hall currents parameter, the medium permeability postpones the onset of convection for small wave numbers as the Rayleigh number increases with an increase in medium permeability parameter and hastens the onset of convection for higher wave numbers as the Rayleigh number decreases with an increase in medium permeability parameter.

(iii) The critical Rayleigh numbers and the associated wave numbers are found for stationary convection for various parameters involved and it has been found that it increases with the increase in magnetic field and solute gradient parameter and decreases with the increase in Hall currents parameter thereby confirming the stabilizing role of magnetic field and solute gradient and destabilizing role of Hall currents. Medium permeability parameter has conditional effect on the system.

(iv) The principle of exchange of stabilities is not valid for the problem under consideration whereas in the absence of magnetic field and stable solute gradient it is valid under certain conditions.

The principal conclusions from the theoretical investigations of the effect of medium permeability, horizontal magnetic field and Hall currents on the thermal stability of a ferromagnetic fluid are as follows:

(i) It is found that Hall currents have a destabilizing effect whereas magnetic field has a stabilizing effect on the system.

(ii) For small values of Hall currents parameter the medium permeability has destabilizing effect for all wave numbers whereas for higher values of Hall currents parameter, the medium permeability has destabilizing effect for small wave numbers as the Rayleigh number decreases with an increase in medium permeability parameter and stabilizing effect for higher wave numbers as the Rayleigh number increases with an increase in medium permeability parameter.
(iii) The critical Rayleigh numbers and the associated wave numbers are found for stationary convection for various parameters involved and it has been found that it increases with the increase in magnetic field parameter and decreases with the increase in Hall currents parameter thereby confirming the stabilizing role of magnetic field and destabilizing role of Hall currents. Medium permeability parameter has conditional effect on the system.

(iv) The principle of exchange of stabilities is not valid for the problem under consideration whereas in the absence of Hall currents (hence magnetic field), it is valid under certain conditions.

The thermal stability of a rotating couple-stress fluid in hydromagnetics has been considered. The main results from the analysis are as follows:

(i) It is found that rotation has stabilizing effect on the system.

(ii) The magnetic field and couple-stresses have a stabilizing effect in the absence of rotation whereas in the presence of rotation it has a stabilizing effect if

\[ T_A (1 + \chi) < \left[ 1 + F_1 (1 + \chi) \right] (1 + \chi)^2 + Q_i \] 

and destabilizing effect if

\[ T_A (1 + \chi) > \left[ 1 + F_1 (1 + \chi) \right] (1 + \chi)^2 + Q_i \] .

(iii) The principle of exchange of stabilities is satisfied in the absence of rotation and magnetic field.

Principal conclusions from the analysis of thermal stability of rotating couple-stress fluid permeated with suspended particles in hydromagnetics are as follows:

(i) It is found that rotation has stabilizing effect whereas suspended particles have destabilizing effect on the system.

(ii) The magnetic field and couple-stresses have stabilizing effect in the absence of rotation whereas in the presence of rotation it has a stabilizing effect if

\[ T_A (1 + \chi) < \left[ 1 + F_1 (1 + \chi) \right] (1 + \chi)^2 + Q_i \] 

and destabilizing effect if

\[ T_A (1 + \chi) > \left[ 1 + F_1 (1 + \chi) \right] (1 + \chi)^2 + Q_i \] .
(iii) The principle of exchange of stabilities is satisfied in the absence of rotation and magnetic field.

The effect of various parameters such as permeability, Hall currents, magnetic field and micropolar parameters on thermal stability of micropolar fluid has been investigated analytically as well as numerically. The principal conclusions from the analysis are as follows:

(i) The medium permeability has a destabilizing effect if $\bar{\delta} < \varepsilon / A$ and stabilizing effect if $\bar{\delta} > \varepsilon / A$. In the absence of micropolar heat conduction parameter ($\bar{\delta} = 0$), the medium permeability has always destabilizing effect on the system.

(ii) The micropolar coefficient $A$ has a stabilizing effect when condition $\bar{\delta} > P_i$ holds.

(iii) The coupling parameter $K$ has a stabilizing effect if $\frac{2}{P_i} > \frac{b}{\varepsilon}$ and $\bar{\delta} < \frac{\varepsilon}{A}$ holds.

(iv) The micropolar heat conduction parameter $\bar{\delta}$ has a stabilizing effect if $\frac{1}{P_i} > \frac{A}{\varepsilon}$ holds.

(v) The magnetic field and Hall currents have a stabilizing effect if $\bar{\delta} < \frac{\varepsilon}{A}$ and $\left(\frac{b}{P_i^2}\right)^2 > M\pi^2 b$.

(vi) The principle of exchange of stabilities is satisfied for micropolar fluids heated from below saturating a porous medium in the absence of hall currents, magnetic field and coupling between spin and heat flux ($\bar{\delta} = 0$).

7.2 FUTURE SCOPE

Nanofluids are mixtures of a regular fluid, with a very small amount of suspended metallic or metallic oxide nanoparticles or nanotubes, which is first utilized by Choi [231]. Nanoparticles materials may be taken as oxide ceramics (Al$_2$O$_3$, CuO), metal carbides (SiC), nitrides (AlN, SiN) or metals (Al, Cu) etc. Base fluids are water, ethylene or tri-ethylene glycols and other coolants, oil and other lubricants, bio-fluids, polymer solutions, other common fluids. Typical dimension of the nanoparticles is in the range of a few to about 100nm.

Heating or cooling of fluids is important for many industrial sectors, including energy supply and production, transportation and electronics. The thermal conductivities of these fluids play a vital role in the development of energy coefficient heat transfer equipment. However, heat
conventional heat transfer fluids have poor thermal transfer properties compared to most solids. In order to improve the thermal conductivity of these fluids numerous theoretical and experimental studies of the effective thermal conductivity of liquids containing suspended solid particles have been conducted. Nanofluid used as heat transfer nanofluid, chemical nanofluids, bio nanofluids, medical nanofluids (drug delivery and functional tissue cell interaction) etc. in many industrial applications.

Many researchers have considered the effect of some parameters on the thermal stability of nanofluids [232-241]. In recent years, considerable interest has been evinced in the study of nanofluid and it has become an innovative idea for thermal engineering because it has various applications in automotive industries, energy saving, nuclear reactors etc. Further suspensions of nanoparticles are being developed medical applications including cancer therapy. The thermal stability of nanofluid in a porous medium has been a topic of interest due to its applications in fields of food and chemical process, petroleum industry, bio-mechanics and geo-physical problems. Rotation plays important role in the thermal instability of fluid layer and has applications in rotating machineries such as nuclear reactors, petroleum industry, bio-mechanics etc. Owing to their enhanced properties as thermal transfer fluids for instance, nanofluids can be used in a plethora of engineering applications ranging from use in the automotive industry to the medical arena to use in power plant cooling systems as well as computers.