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RESEARCH ARTICLE

EFFECT OF RADIATION ABSORPTION ON THE ONSET OF INSTABILITY OF A ROTATING FLUID IN A POROUS MEDIUM

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ABSTRACT

The effect of radiation absorption on the onset of instability of a rotating fluid layer driven by convection is investigated when the fluid is heated from below in a porous medium taking into consideration viscous effect. The Boussinesq approximation is used for the radiative absorption in the energy equation. Using the linearised stability theory and normal mode analysis, the criteria for the onset of instability via stationary convection is obtained for the case of two free boundaries. Analytical expressions have been found for the onset of stationary and oscillatory instabilities and for the oscillatory frequency, which depend on the rate of radiation absorption. The critical wave number and the oscillatory frequency also depend strongly on this quantity. Graphs have been drawn and the results discussed with their help. The oscillatory thermal Rayleigh number for various values of of T,k_c, ω and B are shown in Table 1.

INTRODUCTION

Many investigators have studied two-dimensional laminar boundary layer flow and convective heat transfer. Not much attention has been given, however, to cases where thermal radiation becomes an additional factor on the instability of rotating fluids. Recent developments in hypersonic flight, missile re-entry, rocket combustion chambers, power plants for interplanetary flight and gas cooled nuclear reactors, have focused attention on thermal radiation as a mode of energy transfer, and emphasized the need for an improved understanding of heat transfer. Researchers have investigated the various aspects of the instability of a fluid layer heated from below. Chandrasekhar (1961) found the critical Rayleigh Number as a function of the Taylor Number for an infinite layer of fluid, and his results have become the standards for comparison. Since then, the problem has been solved in other geometries using either ‘slip’ or ‘rigid’ boundary conditions or a combination of the two. Jeffrey *et. al.* (1982) considered a rectangular domain infinitely long in one direction, with free conducting horizontal surfaces and rigid insulating vertical surfaces. They found that for certain width-to-depth ratios large enough Taylor Numbers, the critical Rayleigh for steady convection is less than that for the infinite case even though the system is more constrained. They also found that over stability sets in before stationary convection (for Prandtl Numbers corresponding to air, water and mercury) when the Taylor Number is greater than about 200.This in marked contrast to the infinite case, where stationary convection always sets in first for ≥ 0.677

Lapwood (1948) has studied the convection flow in a porous medium using linearised stability theory. The Rayleigh instability of a thermal boundary layer flow through a porous medium has been considered by wooding (1960) whereas Scanlon and Segel (1793) have considered the effect of suspended particles on the onset of Bernard convection and found that critical Rayleigh Number was reduced solely because the heat capacity of the pure gas was supplemented by the particles. The suspended particles were thus found to destabilise the fluid’s layer. El Mekki (2003) studied the thermal instability of a non-uniformly rotating fluid layer heated from below with emphasis on stationary convection and over_ Stability. In his result, it was established that in both types of instability the effect of the variation of the rate of rotation is to introduce a new branch to the marginal instability curves of uniform rotation which departs from them towards a zero of the Rayleigh Number as the horizontal wave Number approaches zero. Govender (2003) used linear stability theory to investigate analytically the effect of gravity on centrifugally driven convection in a rotating porous layer offset from the axis of rotation. He demonstrated in his work that the stationary mode is the critical mode of convection thereby resulting in the convection rolls being aligned parallel to the axis of rotation. Israel-Cookey *et.al.* (2007) studied the effects of Radiation on the linear stability of a horizontal layer in a fluid saturated media heated from below. In the works cited above, none considered the effect of radiation on the onset of instability of a rotating fluid in a porous medium. The aim of this present paper is

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to study the onset of instability of a rotating fluid bounded by two horizontal parallel plates with radiation absorption when viscous effects are taken into consideration in a porous medium. To demonstrate this we apply the classical linear stability theory of Chandrasekhar (1961) and adopt the Rosseland differential approximation for the radiation absorption Sparrow and Cess (1978).

Mathematical Formulations

We consider a rotating fluid layer of height, $d \succ 0$ bounded between two horizontal parallel layers located at $Z= +-$ and $z= Z= --$ in a porous medium taking into consideration viscous effects. The physical model and Cartesian coordinate system (x, y, z) with Ω being the angular velocity of the rotating fluid are shown in Figure 2.1.

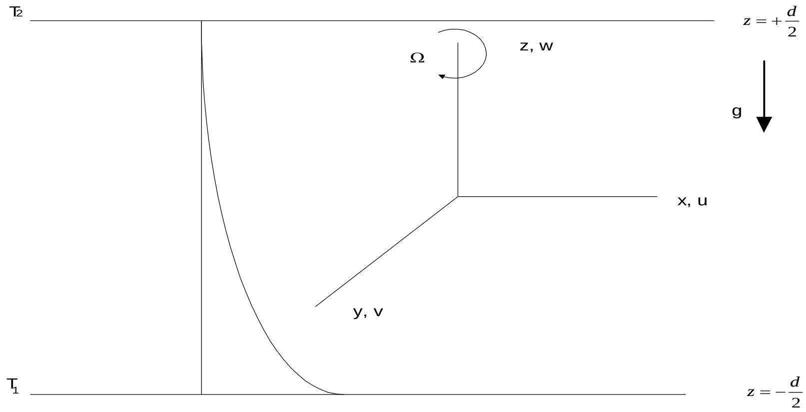

Figure 2.1: Physical model and coordinate system

Where u, v, and w are the velocity component along x-, y- and z-axes. The temperatures T_1 and T_2 are imposed at the bottom and top layers respectively. The equation of flow, momentum and energy taken into consideration the effect of radiation absorption are, Chandrasekhar (1961);

$$\vec{\nabla}' \cdot \vec{V}' = 0 \tag{2.1}$$

$$\rho_0\left(\frac{D\vec{V}'}{Dt'} + \vec{\Omega}' \times \vec{V}' \right) = -\vec{\nabla}' P' + \mu \vec{\nabla}'^2 \vec{V}' - \frac{\mu}{k}\vec{V}' + \rho g \vec{k} \quad (2.2$$

$$\rho C_p \frac{DT'}{Dt'} = \kappa \vec{\nabla}'^2 T' - \vec{\nabla}' \cdot \vec{q}_r' \tag{2.3}$$

Further, by assuming density linear dependence on T' we adopt the Boussinesq approximation

$$\rho = \rho_0 (1 - \beta_T (T' - T'_0)) \tag{2.4}$$

where, ρ_0 is the density of the rotating fluid at the lower boundary, and at $T = T_0, T_0$ is the initial temperature of the fluid layer, β_T is the thermal expansion coefficient and $\frac{D()}{Dt'} = \frac{\partial()}{\partial t'} + (\vec{V}' \cdot \vec{\nabla}')()$ is the convective derivative

We take a horizontal coordinate x' and a vertical component z' which increases vertically upwards. Then, under the Boussinesq approximation, equation (2.4), the momentum and energy equations become

$$\frac{\partial \vec{V}'}{\partial t'} + (\vec{V}' \cdot \vec{\nabla}')\vec{V}' + \vec{\Omega}' \times \vec{V}' = -\frac{1}{\rho_0}\vec{\nabla}' P' + \nu \vec{\nabla}'^2 \vec{V}' - \frac{\nu}{k}\vec{V}' - g\beta_T (T - T_0) k \tag{2.5}$$

$$\frac{\partial T'}{\partial t'} + (\vec{V}' \cdot \vec{\nabla}')T' = \frac{\kappa}{\rho_0 C_P}\vec{\nabla}'^2 T' - \frac{1}{\rho_0 C_P}\vec{\nabla}' \cdot \vec{q}_r' \tag{2.6}$$

where $\vec{V}$ is the velocity vector, $\vec{k}$ k is the unit vector in the upward direction, P the fluid's pressure, $\nu = \frac{\mu}{\rho_0}$ is the kinematic viscosity, κ the thermal diffusivity, and C_P is the specific heat capacity of the fluid;

The boundary conditions we propose in this problem are;

$$V^{'} = 0, T^{'} = T_1 \; at \; z^{'} = -\frac{d}{2} \quad (2.7)$$

$$V^{'} = 0, T^{'} = T_2 \; at, z^{'} = +\frac{d}{2}$$

Now since the fluid is considered to be grey, absorbing/emitting and radiating in a non-scattering medium, the optically thick approximation is imperative. Hence the radiative heat flux q_r could be approximated by the Rosseland differential form as used in Israel-Cookey *et.al* (2007)

$$\vec{q}_r^{'} = -\frac{4\sigma^{'}\vec{\nabla}^{'}T^{'^4}}{3\delta} \quad (2.8)$$

where δ is the mean absorption coefficient and σ the steffan- Boltzmann constant. Further, we assume that the temperature differences within the fluid and the porous medium is sufficiently small for which $T^{'4}$ can be expressed as a linear function of $T^{'}$.By employing Taylor's series expansion about the reference temperature, T_0 and neglecting higher order terms yield;

$$T^{'4} \cong 4T_0^{'3}T^{'} - 3T^{'4} \quad (2.9)$$

So that

$$q_r^{'} = -\frac{16\sigma^{'}T_0^{'^3}\nabla^{'}T^{'}}{3\delta} \quad (2.10)$$

The energy equation, upon using (2.10) become

$$\frac{\partial T^{'}}{\partial t^{'}} + (\vec{V}^{'} \cdot \vec{\nabla}^{'})\vec{V}^{'} = \frac{\kappa}{\rho_0 C_P}\vec{\nabla}^{'2}T^{'} + \frac{16\sigma^{'}T_0^{'^3}\vec{\nabla}^{'}T^{'}}{3\rho_0 C_P \delta} \quad (2.11)$$

On introducing the following non-dimensional parameters and variables:

$$t = \frac{t^{'}\nu}{d^2}, \vec{V} = \frac{d\vec{v}}{\nu}, (x, \quad y, \quad z) = \frac{1}{d}(x^{'}, y^{'}, z^{'}) \quad \theta = \frac{T^{'} - T^{'}_0}{T_1 - T_2}, \quad P_r = \frac{\nu}{a}, \quad B^2 = \frac{16\sigma^{'}T_0^{'3}d^2}{3\kappa\delta}, \chi = \frac{d^2}{k}, \; P = \frac{d^2 p^{'}}{\rho_0 \nu^2}$$

$$R_T = \frac{g\beta_T d^2 (T - T_0)}{a\nu}, a = \frac{\kappa}{\rho_0 C_P}, T = \frac{d^4\Omega^2}{\nu^2} \quad (2.12)$$

where R_T is the thermal Rayleigh number, P_r the Prandtl number, χ the porosity parameter, B^2 and T are the non-dimensional radiation absorption and Taylor's number respectively. Using Equations (2.10) and (2.12), the model is transformed into the following non-dimensional form of equations:

$$\nabla \cdot V = 0 \quad (2.13)$$

$$\frac{\partial \vec{V}}{\partial t} + \left(\vec{V} \cdot \vec{\nabla}\right)\vec{V} + T^{\frac{1}{2}}\left(\vec{k} \times \vec{V}\right) = -\vec{\nabla}P + \vec{\nabla}^2\vec{V} - \chi^2\vec{V} - \frac{R_T}{P_r}\theta k \quad (2.14)$$

$$P_r\left(\frac{\partial\theta}{\partial t}+\left(\vec{V}\cdot\vec{\nabla}\right)\theta\right)=\left(1+B^2\right)\vec{\nabla}^2\theta \tag{2.15}$$

With boundary conditions:

$$\text{w=0}, \theta=\pm\frac{1}{2} \text{ at } Z=\mp\frac{1}{2} \tag{2.16}$$

Linear Stability Analysis

Basic flow and linearization

The basic state of the system is given by the basic static solution V=0 of the system of equations (2.13)-(2.15), in which corresponds the static temperature T_S and static pressure P_S given respectively by

$$\frac{dP_S}{dz}=-\frac{1}{P_r}R_T T_S \qquad (3.1)`$$

$$\frac{d^2T_S}{dz^2}=0 \tag{3.2}$$

Subject to the conditions

$$T_S=\pm\frac{1}{2} \text{ at } Z=\mp\frac{1}{2} \tag{3.3}$$

The solutions of equations (3.1) and (3.2) subject to (3.3) yield the basic state of the system:

$$P_S=-\int\frac{R_T}{P_r}T_S dz \ , \ T_S=-Z \tag{3.4}$$

Consequently, we have

$$P_S=\int\frac{R_T}{P_r}zdz \tag{3.5}$$

Now to access the stability of the steady solutions, we assume small perturbations around the basic solution, (Chandrasekhar (1961); Drazin and Reid (2004));

$$\vec{V}=0+\vec{u}\,,\theta=T_S+\overline{\theta}\,,P=P_S+\overline{P} \tag{3.6}$$

Following the classical procedure of linear mode analysis (Chandrasekhar (1961); Israel-Cookey *et.al.* (2007)), we substitute equation (3.6) into systems

(2.13), (2.14) and (2.15) and the boundary condition (2.16) to obtain the linearised equation of motion as

$$\nabla\cdot u=0 \tag{3.7}$$

$$\left(\frac{\partial}{dt}-\vec{\nabla}^2+\chi^2\right)\vec{u}=-\nabla p+\frac{1}{p_r}R_T(\overrightarrow{\theta k})+T^{\frac{1}{2}}(\vec{u}\times\vec{k}) \tag{3.8}$$

$$‘\ P_r\left[\frac{\partial\overline{\theta}}{\partial t}+w\frac{\partial}{\partial z}\right]T_s=\left(1+B^2\right)\vec{\nabla}^2\overline{\theta} \tag{3.9}$$

Since T_S=-Z, equation (3.9) becomes

$$[P_r \frac{\partial}{\partial t} - (1+B^2)]\overline{\theta} = P_r w \qquad (3.10)$$

Equation (3.8) and (3.10) are to be solved subject to the boundary conditions

$$w = 0,\ \overline{\theta} = \pm\frac{1}{2}, \text{ at } Z = \mp\frac{1}{2} \qquad (3.11)$$

Next we reduce the momentum equation (3.8) to a scalar by taking the curl and double curl of it, using the equation of continuity (3.7) and keeping the only vertical component of the velocity w, yields

$$\left(\frac{\partial}{\partial t} - \nabla^2 + \chi^2\right)\xi = T^{\frac{1}{2}}\frac{\partial w}{\partial z} \qquad (3.12)$$

$$\left(\frac{\partial}{\partial t} - \nabla^2 + \chi^2\right)\nabla^2 w = T^{\frac{1}{2}}\frac{\partial \xi}{\partial z} + \frac{1}{P_r}R_T\nabla^2{}_h\overline{\theta} \qquad (3.13)$$

where $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = \xi$ is the z-component of the vorticity and

$\nabla^2{}_h = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ is the Laplacian operator in the horizontal plate

Effect of Perturbation and Normal Mode Analysis

Following the classical approach of Chandrasekhar (1961), we analyse an arbitrary disturbance into a complete set of normal modes and examine the stability of each of these modes individually. For the problem in focus, the analysis can be made in terms of two-dimensional periodic waves of assigned wave numbers. Thus we ascribe to all quantities describing the perturbations of dependence on x, y and t of the form;

exp [i ($k_x x + k_y y$) + ht]

where $k^2 = k^2{}_x + k^2{}_y$ is the wave number of the disturbance and h is a constant (which can be complex).We employs the normal representation of the form;

w=$W(Z)$ exp [i ($k_x x + k_y y$) + ht]

$\overline{\theta}$ =$\Theta(Z)$ exp [i ($k_x x + k_y y$) + ht] (3.14)

$\xi = \psi(Z)$ exp [i ($k_x x + k_y y$) + ht]

where $h = h_r + ih_I$

Further, for functions with this dependence on x, y and t, we have;

$$\frac{\partial}{\partial t} = h$$

$$\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} = -k^2 \qquad (3.15)$$

$$\nabla^2 = \frac{d^2}{dZ^2} - k^2$$

Substituting equation (3.14) into equations (3.10), (3.12) and (3.13) taking (3.15) into consideration, we have the following set of equations

$$\left[\left(1+B^2\right)\left(D - k^2\right) - P_r h\right]\Theta = P_r W \quad (3.16)$$

$$\left[\left(D^2 - k^2\right) - \chi^2 - h\right]\psi = -T^{\frac{1}{2}} W \quad (3.17)$$

$$\left[\left(D^2 - k^2\right)\left(D^2 - k^2 - \chi^2 - h\right)\right]W = -T^{\frac{1}{2}}\psi - \frac{1}{P_r} R_T k^2 \Theta \quad (3.18)$$

The elimination of ψ and Θ from equations (3.16) and (3.17) and using the results in equation (3.18) give the following equation satisfied by w:

$$\left[\left(D^2 - k^2\right)\left(D^2 - k^2 - \chi^2 - h\right)^2\left(D^2 - k^2 - P_r h\right)\right]W - T\left(D^2 - k^2 - P_r h\right)W$$

$$-\frac{R_T k^2}{\Gamma}\left(D^2 - k^2 - \chi^2 - h\right)W = 0 \quad (3.19)$$

Here, we assume that the temperature at the boundaries is kept fixed, the fluid layer is confined between two free boundaries and adjoining medium is electrically non conducting. The boundary conditions appropriate to the problem are Chandrasekhar (1961), Veronis (1965)

$$W = D^2 W = D^4 W = 0 \text{ at } Z = \pm\frac{1}{2} \quad (3.20)$$

W must vanish for z=± − and hence the appropriate solution of W characterising the lowest mode is

$$W = a \sin \pi z \quad (3.21)$$

a is a constant.

Substituting equation (3.21) into (3.19) and simplifying, we have

$$\left(\pi^2 + k^2\right)\left(\pi^2 + k^2 + \chi^2 + h\right)^2\left(\pi^2 + k^2 + P_r h\right) + T\left(\pi^2 + k^2 + P_r h\right) = \frac{R_T k^2}{\Gamma}\left(\pi^2 + k^2 + \chi^2 + h\right) \quad (3.22)$$

or

$$R_T = \frac{\Gamma}{k^2\left(\pi^2 + k^2 + \chi^2 + h\right)}\left[\left(\pi^2 + k^2\right)\left(\pi^2 + k^2 + \chi^2 + h\right)^2\left(\pi^2 + k^2 + \Pr h\right) + T\left(\pi^2 + k^2 + \Pr h\right)\right] \quad (3.23)$$

where

$$\Gamma = 1 + B^2$$

Haven established the expression for the thermal Rayleigh number; we are now in a position to study the stationary and oscillatory convections.

CASE I: STATIONARY CONVECTION

To study the case of marginal instability which corresponds to stationary convection, we set $h = 0$ and $R_T = R_{ks}$ in equation (3.23) and obtain

$$R_{ks} = \frac{\Gamma}{k^2\left(\pi^2 + k^2 + \chi^2\right)}\left[\left(\pi^2 + k^2\right)^2\left(\pi^2 + k^2 + \chi^2\right)^2 + T\left(\pi^2 + k^2\right)\right] \quad (3.24)$$

The critical wave number can be obtained by setting $k = k_c$ and finding the minimum of $R_{ks}(k_c)$ as follows

$$\frac{\partial}{\partial k_c^2}\left(R_{ks}(k_c)\right) = 0 \qquad (3.25)$$

This results in a tenth order polynomial in k_c given by

$$4k_c^{10} + k_5 k_c^8 + k_4 k_c^6 + k_3 k_c^4 - k_2 k_c^2 - k_1 = 0 \qquad (3.26)$$

where

$$k_1 = 2\pi^8\chi^2 + 4\pi^4\chi^4 + 4\pi^6\chi^2 + 2\pi^4\chi^6 + 2\pi^6\chi^4 + 2\pi^{10} + \left(2\pi^4 - 2\pi^2\chi^2\right)T$$

$$k_2 = 8\pi^4\chi^4 + 4\pi^2\chi^6 + 8\pi^6\chi^2 + 4\pi^2 T - 4\pi^4\chi^2 - 4\pi^2\chi^4$$

$$k_3 = 12\pi^4\chi^2 + 6\pi^2\chi^4 + 4\pi^6 + 4\pi^2\chi^2 - 2T + 2\chi^6$$

$$K_4 = 16\pi^4 + 24\pi^2\chi^2 + 12\chi^2 - 4\chi^4$$

$$k_5 = 14\pi^2 + 10\chi^2$$

CASE II: OSCILLATORY CONVECTION (INSTABILITY)

Here, we consider the possibility of oscillatory instability setting into the rotating fluid layer. The oscillatory frequency is given by Govender (2003);

$$h = h_r + ih_I \qquad (3.53)$$

And for marginal stability, $h_r = 0$ so that the oscillatory frequency contains only the imaginary part, $h = i\omega$ where $h_I = \omega$ .Substituting $h = i\omega$ in equation (3.45), we have the oscillatory thermal Raleigh number;

$$R_{TOS} = \frac{\Gamma}{k^2\left(\pi^2 + k^2 + \chi^2 + i\omega\right)}\left[\left(\pi^2 + k^2\right)\left(\pi^2 + k^2 + \chi^2 + i\omega\right)^2\left(\pi^2 + k^2 + P_r i\omega\right) + T\left(\pi^2 + k^2 + P_r i\omega\right)\right] \qquad (3.54)$$

By letting $s = \pi^2 + k^2$ and $\lambda = \pi^2 + k^2 + \chi^2$ in equation (3.54), we have

$$R_{TOS} = \frac{\Gamma}{k^2(\lambda + i\omega)}\left[s(\lambda + i\omega)^2(s + P_r i\omega) + T(s + P_r i\omega)\right] \qquad (3.55)$$

Simplifying equation (3.55) and separating the real and imaginary parts, we have

$$\mathrm{Re}\{R_{TOS}\} = \frac{\Gamma}{k^2\left(\lambda^2 + \omega^2\right)}\left[-P_r\omega^4 + \left(P_r T - P_r\lambda + s\lambda\right)\omega^2 + s\lambda\left(\lambda^2 + T\right)\right] \qquad (3.56)$$

$$\mathrm{Im}\{R_{TOS}\} = \frac{\Gamma}{k^2\left(\lambda^2 + \omega^2\right)}\left[\left(P_r\lambda + s\right)\omega^3 + \left(s\lambda^2 + P_r\lambda^3 + P_r\lambda T - Ts\right)\omega\right] \qquad (3.57)$$

Since the Rayleigh number is real, it is sufficient to consider ω as purely imaginary for some real s .Thus, equating equation (3.57) to zero we find

$$\left(P_r\lambda + s\right)\omega^2 + s\lambda^2 + P_r\lambda^3 + P_r\lambda T - Ts = 0 \qquad (3.58)$$

The solution of equation (3.58) for various values of k_c, T and P_r are summarised in table 1

RESULTS AND DISCUSSION

For the analysis of the effect of radiation absorption on the onset of instability of rotating fluid layer in a porous medium, we have equation (3.24) to be;

$$R_{ks} = \frac{\Gamma}{k^2\left(\pi^2 + k^2 + \chi^2\right)}\left[\left(\pi^2 + k^2\right)^2\left(\pi^2 + k^2 + \chi^2\right)^2 + T\left(\pi^2 + k^2\right)\ \right] \qquad (4.1)$$

Further, Equation (3.26) is a tenth degree polynomial in the critical wave Number,k_c and its roots cannot be solved analytically and so we resort to numerical methods. For the numerical solution we use the software 'Mathematica' (Wolform (1991)).Using the parameters ℵ = 0.18 and T=0,the roots of Equation (3.26) gives ten roots in k_c in which only one of the roots is real i.e. k_c =2.22130 $\approx \sqrt{\ }$ and the remaining nine are complex conjugates. This value of k_c agrees well with the classical Rayleigh-Bernard problem of Chandrasekhar (1961). In fig 1, thermal Rayleigh number R_T is plotted against the critical wave number k_c for χ =0.2 B=0.0, 0.5, 1.0 and T=10.From the graph it is evident that B is a stabilising factor. Increase in B from 0.0 to 0.5 shows a decrease in Rayleigh number while appreciable increase corresponds to increase in Rayleigh number. Thus, for stationary convection, the variation of B for fixed χ and T delays the onset of instability in the system. Figs (2&3) shows the dependence of thermal Rayleigh number R_T on the wave number k_c. In fig 2 thermal Rayleigh number is plotted against k_c for χ =0.0, 0.5, 1.0,B=0.3,T=10.It is evident that increase in χ with both B and T fixed have the effect of decreasing the thermal Rayleigh number. However further increase in both χ and B leads to increase in thermal Rayleigh number R_T. In figure 3 it is clear that simultaneous increase in both B and χ enhances the onset of instability of the rotating fluid with greater destabilisation occurring at higher values of the thermal Rayleigh number.

In Table 1, the oscillatory critical Rayleigh number, $R_{TOS}^{(c)}$ increases as the radiation parameter, B increases from 0.0 to 1.0 for $\omega_1 = 14.8571i$, $\omega_2 = -14.8571i$ and $k_c = 2.221$ .This shows that in the absence of rotation, the onset of instability is delayed. But from row two of the same table with T=10 and $k_c = 2.22565$, the oscillatory Rayleigh number increases as B increase from 0.0 to 1.0. However, for $\omega_1 = 14.7779i$, oscillatory Rayleigh decreases for every increase in radiation parameter, B. The situation is similar in rows 3 and 4. This revealed to us that stability is enhanced as the rotation increases.

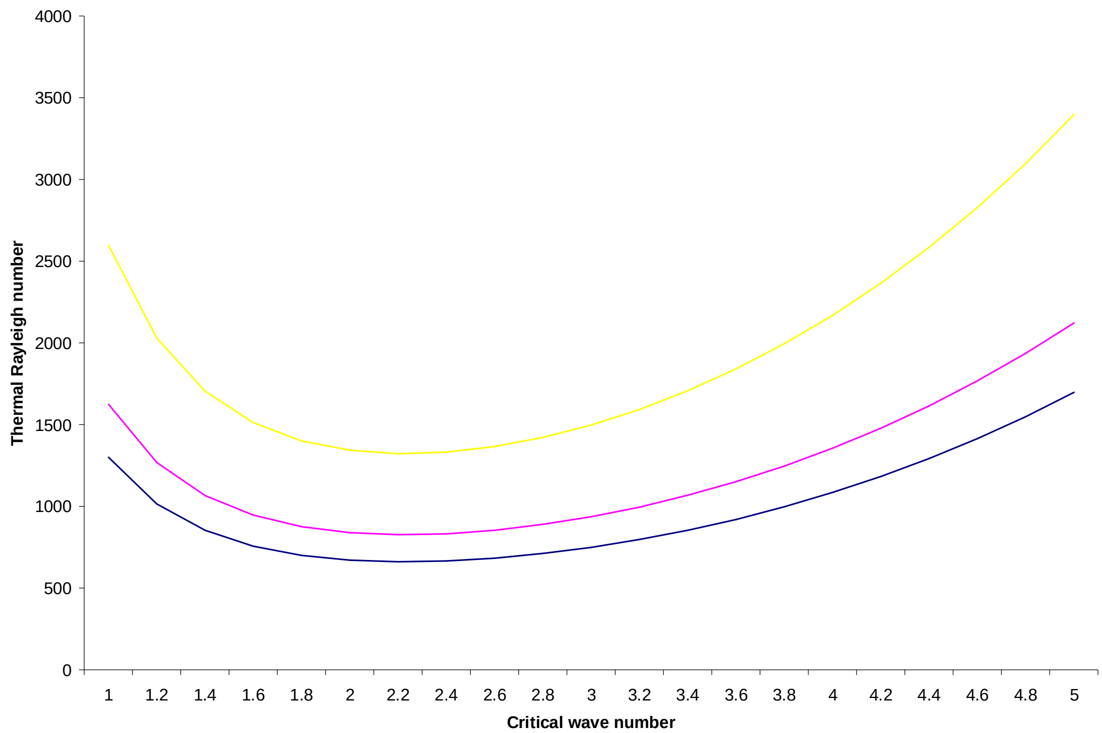

Figure 1: Variation of thermal Rayleigh number, R_T with critical wave number for fixed porosity, χ =0.2, Taylor number T =10 and varying radiation B=0.0,0.5,1.0

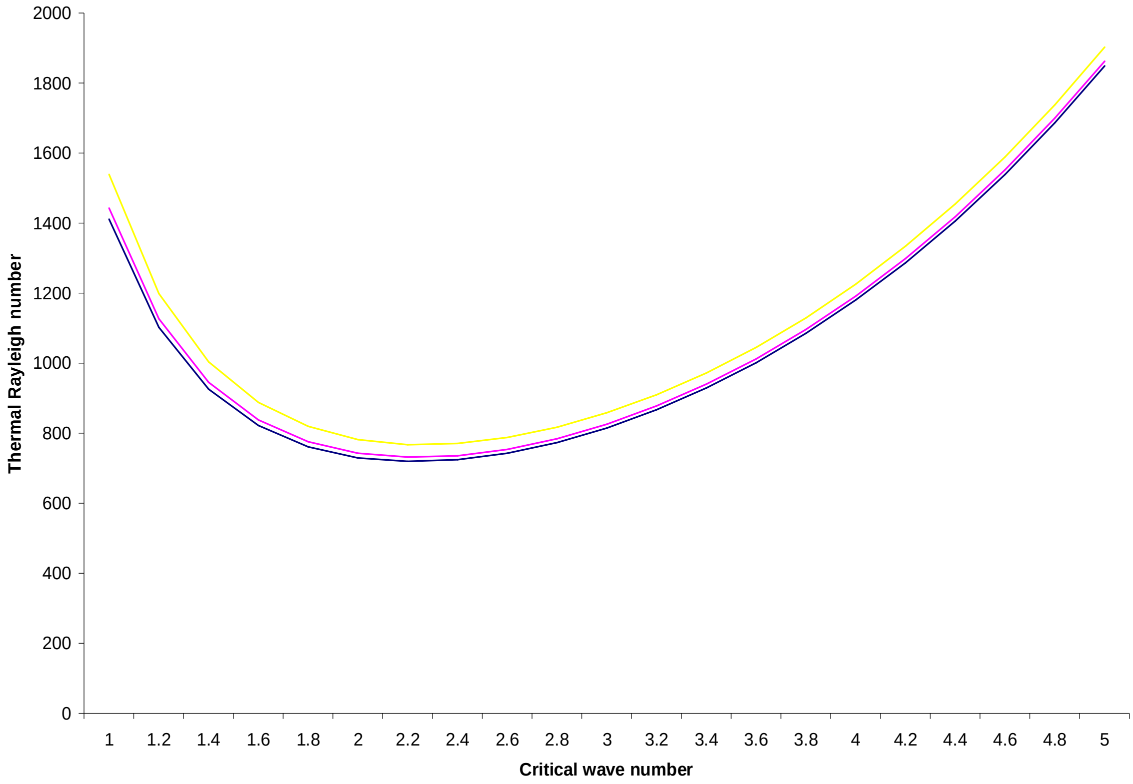

Figure 2: Variation thermal Rayleigh number with critical wave number for fixed radiation parameter, B=0.3 Taylor number T =10 ℵ=0.0,0.5,1.0

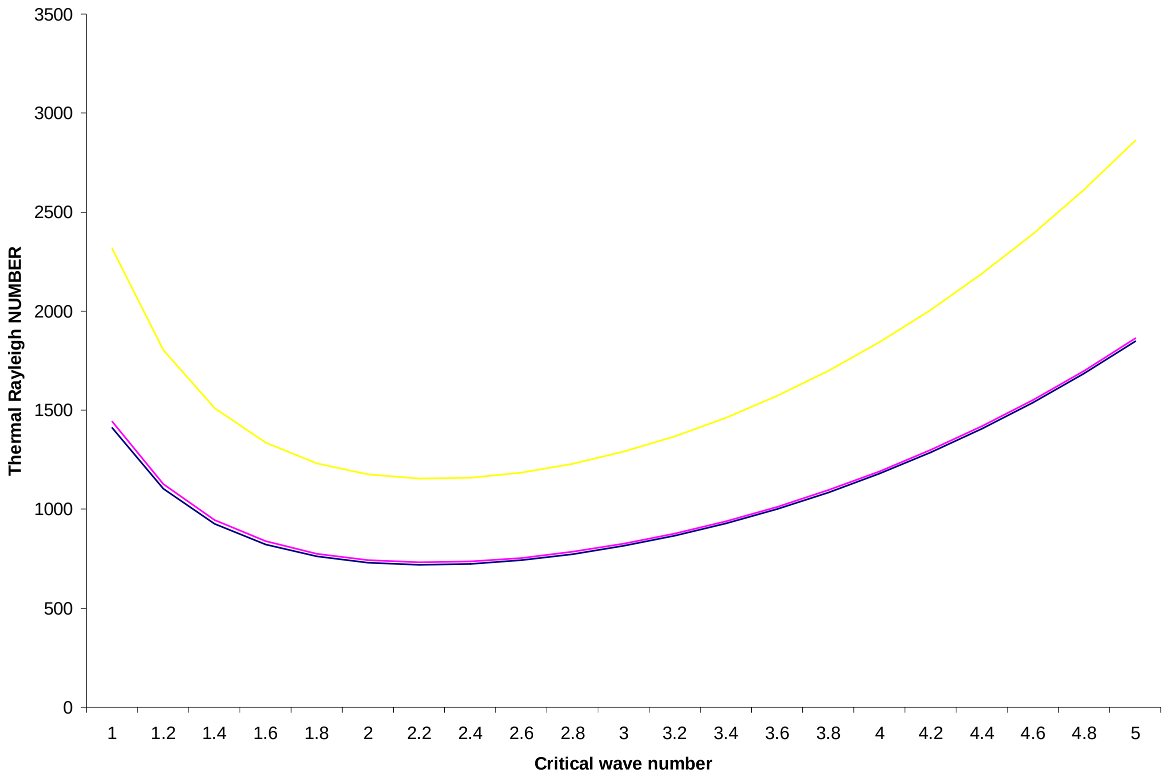

Figure 3: Variation of thermal Rayleigh number, R_T with critical wave number, k_c for simultaneous increase in porosity, χ =0.0,0.5,1.0 radiation parameter B=0.3,0.3,0.8 and fixed Taylor number T =10

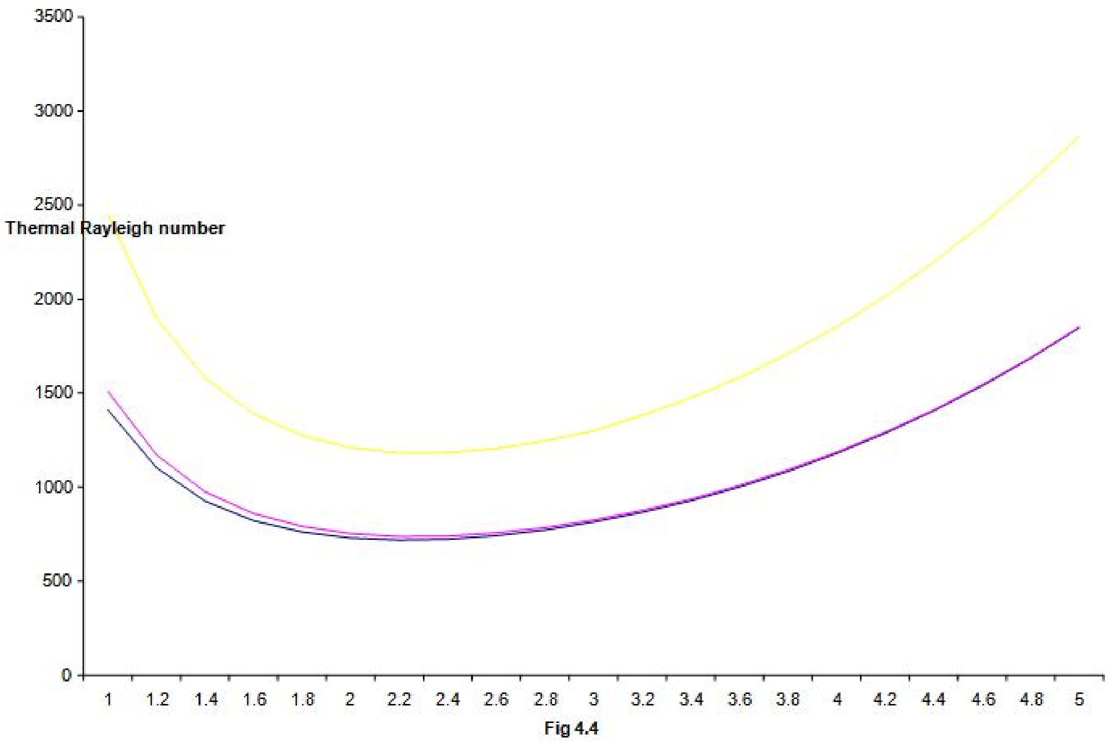

Figure 4. Variation of thermal Rayleigh number, R_T with critical wave number for simultaneous increase in porosity, χ =0.0,0.0,1.0 radiation B=0.3,0.3,0.8 and Taylor number T =10,100,100

Table 1. Variation of Oscillatory critical thermal Rayleigh number with critical wave number for various values of B and T

Taylor Number	wave number	Growth Rate	Oscillatory critical thermal Rayleigh number					
T			B=0.0	B=0.2	B=0.4	B=0.6	B=0.8	B=1.0
0	2.221	-14.8571i	153.0863	159.2098	117.2030	208.1971	252.0617	306.1725
0	2.221	14.8571i	0.9120	0.0948	0.1058	0.1240	0.1496	0.1824
10	2.2256	-14.7779i	226.9809	236.0600	263.2974	308.6931	372.2482	453.9606
10	2.2256	14.7779i	-272.7524	-283.6624	-316.3924	-370.9423	-447.3136	-545.5035
100	2.2629	-14.2770i	150.5177	156.5383	174.6009	204.7039	246.8490	301.0361
100	2.2629	14.2770i	-264.6713	-275.2580	-307.0195	-359.9529	-434.0611	-529.3440
1000	2.5621	-7.5595i	113.8219	118.3746	132.0334	154.7975	186.6676	227.6439
1000	2.5621	7.5595i	-76.7758	-79.8467	-89.0599	-104.4148	-125.9121	-153.5516

Conclusions

Thermal instability of a rotating fluid in a porous medium has been investigated. Expressions for thermal Rayleigh number, critical thermal Rayleigh number and oscillatory thermal Rayleigh number have been derived. From the analysis of the results, the principal conclusions are as follows;

(1) Increase in the radiation parameter delayed the onset of instability in the system for fixed porosity, χ
(2) Higher values of radiation parameter ,B are associated with greater stabilization of the system
(3) The presence of rotation and medium permeability introduces oscillatory modes.

The effects of various parameters, χ , B, T on the thermal instability have also been shown graphically in figures1-4 and Table 1

REFERENCES

Chandrasekhar, S.: Hydrodynamics and Hydromagnetics Stability. Oxford University Press, Oxford. (1961) 1-5, 21-91.
Drazin, P.G and Reid, W.H: Hydromagnetic Stability, Cambridge University Press, 2nd Edition, Cambridge, England, (2004), 69-123.
Govender, S.: Oscillatory Convection induced by gravity and Centrifugal forces in a rotating porous layer distant from the axis of rotation. (2003), International Journal of Engineering Science 41,539-545.
Israel-Cookey, C. David, I, Omubo-Pepple, V.B, Alaminiokuma, G.I:Effect of Radiation absorption on the onset of thermosolutal convection in a horizontal fluid layer with first order chemical reaction in a porous medium.(2007) Journal of Mathematical Science,vol. 18,75-86.
Israel-Cookey, C and Omubo-Pepple, V.B: The effects of Radiation on the linear stability of a Horizontal layer in a fluid saturated media heated from below. (2007) J. Appl. Sci. Environ. Manage. Vol.11 (3)59-62.
Jeffrey Buel and Ivan Catton: Effect of rotation on the stability of a bounded cylindrical layer of fluid heated from below (1982). Phys fluid 26(4).
El Mekki, O.M: On thermal instability of a non-uniformly rotating fluid layer heated from below (2001). Solar Physics 202, 1-9.
Lapwood, E.R: Proc. Camb. Phil. (1948), 44,508-519.
Scanlon, J.W and Segel, L.A: Physics Fluids (1973), 16, 1573-78.
Wooding, R.A: J.Fluid Mech. (1960), 9, 183-192.

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