Quest Journals
Journal of Research in Applied Mathematics
Volume 7 ~ Issue 11 (2021) pp: 07-14
ISSN(Online) : 2394-0743 ISSN (Print): 2394-0735
www.questjournals.org

Research Paper

Magnetic Field Effect on the Onset of Thermosolutal Convection of an Elastico-Viscous Nanofluid in Porous Medium

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Abstract- *In this paper, the magnetic field effect on the onset of thermosolutal convection of an elastic-viscous nanofluid in porous medium described analytically. For this, Walters`(model B`) is used to explain the rheological performance of the nanofluid in porous medium and perturbation method, normal mode technique, and dispersion relation want to analyze this problem. For stationary convection, the onset criterion derived analytically and experiential that elastic-viscous nanofluid behaves as an regular Newtonian nanofluid. The Oscillatory convection does not exist. The effect of thermo-nanofluid Lewis number, thermosolutal Lewis number, solutal Rayleigh number and magnetic field analyze analytically and graphically.*
Keywords- *Nanofluid; thermosolutal instability; Walters`(model B`); porous medium; magnetic field.*

Received 01 November, 2021; Revised: 12 November, 2021; Accepted 14 November, 2021 © The author(s) 2021. Published with open access at www.questjournals.org

I. Introduction

The thermosolutal instability is a very imperative observable fact that has a lot of applications to many fields such as soil science, oceanography, geography, engineering etc. The nanofluid term was firstly used by Choi [3] in regular fluid with nanometer sized particles for the colloidal suspension. The nanoparticles size is less than 100 nm in a base fluid, in nanofluids, for instance water, engine oils, ethanol are commonly used as base fluids. In a fluid, the nanoparticles are very small particle loading drawn the world concentration by the enrichment of the abnormal thermal conductivity. The materials of nanoparticles may be in use as nitrides (AIN, SiN), metal carbides (SiC), oxide ceramics (Al_2O_3, Cuo) or metals (Cu, Al). The thermal instability for Newtonian fluid with hydrodynamic and hydromagnetic assumptions was discussed by Chandrasekhar [2]. Masuda et al. [10] studied that due to the existence of nanoparticles the thermal conductivity of nanofluid was enhanced and after some time Eastman et al.[4] reveled that the thermal conductivity of ethylene glycol whould raise 40% if in ethylene glycol were added 0.3% of copper nanoparticles. Firstly Tzou [14] examine the instability problem in nanofluids by using the Buongiorno`s model [1]. For the nanofluid layer, thermal instability problem on the boundaries, the nanofluids stability depends on the giving out of the nanoparticles investigated by Kuznetsov and Nield [8]. Mahajan and Sharma [9] numerically investigated the onset of instability in a thin magnetic nanofluid layer saturating in porous medium with varies gravitational field. The stability varies with magnetic field parameter in the onset of convection under vertical magnetic field in a horizontal nanofluids layer investigated by Gupta et al. [7]. The mixture of pyridine and polymethyl methacrylate at 25^0C counting 30.5g of polymer per liter with density 0.98g per liter acts like the Walters`(model B`) elastico-viscous fluid reported by Walters` [15]. The thermosolutal and thermal instability problems for Walters`(model B`) with elastico-viscous fluid in a porous medium studied by Rana and Sharma [12], Rana et al. [13], Gupta and Aggarwal [5]. Mehta et al. [11] studied thermosolutal convection in compressible Walters` B elastico-viscous fluid in the presence magnetic field and rotation in porous medium and saw that for stationary convection Walters elastic-viscous fluid behaves like an ordinary Newtonian fluid and the oscillatory mode are not allowed. Gupta et al. [6] establish the thermal stability of the nanofluidic layer increase with the magnetic field when the system is the bottom heavy nanofluid. Yadav et al. [16] numerically studied to the magnetic field effect on the onset of nanofluid convection and establish that the magnetic field has stabilizing effect while the modified diffusivity, the volumetric fraction, Lewis number and density ratio have a destabilizing effect on the system. In this paper our main aspire is to study the on the onset of thermosolutal convection of an elastico-viscous nanofluid in porous medium in presence of magnetic field.

II. Mathematical Model

Here we regard as an immeasurable horizontal layer with thickness d of Walters`(model B`) elastico-viscous nanofluid situated between the plates $z = 0$ and $z = d$ in the presence of uniform magnetic field $\boldsymbol{H} = (0,0,H_0)$. The fluid layer is heated from lower layer and working upwards direction with a gravity force $\boldsymbol{g} = (0,0,-g)$. Temperature T_D, concentration C_D and volumetric fraction φ_D of nanoparticle, at the upper boundary and lower boundary are taken to be T_1 and T_0, C_1 and C_0, φ_1 and φ_0 respectively, with $T_0 > T_1$, $C_0 > C_1$ and $\varphi_0 > \varphi_1$. The governing equation for Walters'(model B') for magnetic field and elastico-viscous nanofluid in porous medium as given by Rana et al. [13] and Kuznetsov and Nield [8] are:

$$\nabla \boldsymbol{q}_D = 0 \quad (1)$$

$$\frac{\rho}{\varepsilon}\left[\frac{\partial \boldsymbol{q}_D}{\partial t} + \frac{1}{\varepsilon}(\boldsymbol{q}_D.\nabla)\boldsymbol{q}_D\right] = -\nabla p + \rho \boldsymbol{g} - \frac{1}{k_1}\left(\mu - \mu' \frac{\partial}{\partial t}\right)\boldsymbol{q}_D + \frac{\mu_e}{4\pi}(\boldsymbol{H}.\nabla)\boldsymbol{H} \quad (2)$$

where $\boldsymbol{q}_D, p, \mu, \mu', \boldsymbol{g}, k_1, \mu_e, \boldsymbol{H}, \rho,$ and ε denoted by the Darcy velocity, hydrostatic pressure, viscosity, viscoelasticity, acceleration attainable to gravity, medium permeability, magnetic permeability of fluid, magnetic field, density and porosity respectively.

$$\rho \boldsymbol{g} = \varphi_D \rho_p + (1 - \varphi_D)\rho_f \quad (3)$$

where the density of base fluid is ρ_f, ρ_p is the density of nanoparticles and φ_D is the volume fraction of nanoparticles,

$$\rho \boldsymbol{g} = \left(\varphi_D \rho_p + (1 - \varphi_D)\{\rho(1 - \alpha_T(T_D - T_0) - \beta_C(C_D - C_0))\}\right)\boldsymbol{g} \quad (4)$$

where β_C is comparable to solute concentration and α_T is the coefficient of thermal expansion.

$$0 = -\nabla p + \rho\left(\varphi_D \rho_p + (1 - \varphi_D)\{\rho(1 - \alpha_T(T_D - T_0) - \beta_C(C_D - C_0))\}\right)\boldsymbol{g} - \frac{1}{k_1}\left(\mu - \mu' \frac{\partial}{\partial t}\right)\boldsymbol{q}_D + \frac{\mu_e}{4\pi}(\boldsymbol{H}.\nabla)\boldsymbol{H} \quad (5)$$

For the nanoparticles, the continuity equation given by Biongiorno[1] as:

$$\frac{\partial \varphi_D}{\partial t} + \boldsymbol{q}_D.\nabla \varphi_D = D_B \nabla^2 \varphi_D + \frac{D_T}{T_1}\nabla^2 T_D \quad (6)$$

where D_B and D_T are the Brownian diffusion coefficient and the thermoporetic diffusion coefficient, respectively.

For the nanofluid, the equation of thermal energy is given as:

$$(\rho_c)_m \frac{\partial T}{\partial t} + (\rho_c)_f \boldsymbol{q}_D.\nabla T_D = k_m \nabla^2 T_D + \varepsilon(\rho_c)_p\left[D_B \nabla \varphi_D.\nabla T_D + \frac{D_T}{T_1}\nabla T_D.\nabla T_D\right] + (\rho_c)_f D_{TC}\nabla^2 C_D \quad (7)$$

where D_{TC} is a Dufour diffusivity, k_m is thermal conductivity, $(\rho_c)_p$ is the heat capacity of nanoparticles and $(\rho_c)_m$ is heat capacity of the fluid in porous medium.

The equation of conservation of solute concentration is given as:

$$\frac{\partial C_D}{\partial t} + \frac{1}{\varepsilon}\boldsymbol{q}_D.\nabla C = D_{SM}\nabla^2 C + D_{CT}\nabla^2 T_D \quad (8)$$

where D_{CT} and D_{SM} are Soret type diffusivity and the solute diffusivity of porous medium.

The Maxwell equation is given as:

$$\frac{\partial H}{\partial t} + (\boldsymbol{q}_D \nabla)\boldsymbol{H} = (\mathbf{H}\nabla)\boldsymbol{q}_D + \eta \nabla^2 \boldsymbol{H} \quad (9)$$

$$\nabla \boldsymbol{H} = 0 \quad (10)$$

where η is the fluid electrical resistivity.

The boundary conditions are given as:

$$w = 0, \quad T_D = T_0, \quad \varphi_D = \varphi_0, \quad C_D = C_0 \text{ at } z = 0 \quad (11)$$

$$w = 0, \quad T_D = T_1, \quad \varphi_D = \varphi_1, \quad C_D = C_1 \text{ at } z = 1 \quad (12)$$

We establish nondimensional variables as:

$$(x^*, y^*, z^*) = \frac{(x,y,z)}{d}, \qquad \boldsymbol{q}^* = \boldsymbol{q}_D \frac{d}{\kappa_m}, \qquad t^* = \frac{t\kappa_m}{\sigma d^2}, \qquad p^* = \frac{pk_1}{\mu \kappa_m},$$

$$\phi^* = \frac{\varphi_D - \varphi_0}{\varphi_1 - \varphi_0}, \qquad T^* = \frac{T_D - T_1}{T_0 - T_1}, \qquad C^* = \frac{C_D - C_1}{C_0 - C_1}, \quad \boldsymbol{H}^* = \frac{\boldsymbol{H}}{H_0}$$

where $\kappa_m = \frac{k_m}{(\rho_c)_f}$, $\sigma = \frac{(\rho_c)_m}{(\rho_c)_f}$.

Dropping the star(*) for simplication. Equations (1) and equation (5) to (10) reduce in nondimensional form:

$$\nabla \boldsymbol{q} = 0 \quad (13)$$

$$0 = -\nabla p - \left(1 - F\frac{\partial}{\partial t}\right) - R_m \hat{k} - R_n \varphi \hat{k} + R_a T \hat{k} + \frac{Rs}{Le} C\hat{k} + Q\frac{Pr_1}{Pr_2}(\boldsymbol{H}.\nabla)\boldsymbol{H} \quad (14)$$

$$\frac{1}{\sigma}\frac{\partial \varphi}{\partial t} + \boldsymbol{q}.\nabla \varphi = \frac{1}{Ln}\nabla^2 \varphi + \frac{N_A}{Ln}\nabla^2 T \quad (15)$$

$\frac{\partial T}{\partial t}+\boldsymbol{q}.\nabla T=\nabla^2 T+\varepsilon\frac{N_B}{Ln}\nabla\varphi.\nabla T+\varepsilon\frac{N_A N_B}{Ln}\nabla T.\nabla T+N_{CT}\nabla^2 C$ (16)

$\frac{1}{\sigma}\frac{\partial C}{\partial t}+\frac{1}{\varepsilon}\boldsymbol{q}.\nabla C=\frac{1}{Le}\nabla^2 C+N_{TC}\nabla^2 T$ (17)

$\frac{\partial \boldsymbol{h}}{\partial t}+\sigma(\boldsymbol{q}\nabla)\boldsymbol{H}=\sigma(\boldsymbol{H}\nabla)\boldsymbol{q}+\sigma\frac{Pr_1}{Pr_2}\nabla^2\boldsymbol{H}$ (18)

$\nabla\boldsymbol{H}=0$ (20)

where the dimensionless parameters are:

Thermosolutal Lewis number $Le=\frac{\kappa_m}{D_{SM}}$, Thermonanofluid Lewis number $Ln=\frac{\kappa_m}{D_B}$, Kinematic viscoelastic parameter $F=\frac{\mu'\kappa_m}{\mu\sigma d^2}$, Density Rayleigh number $R_m=\frac{\rho_p\varphi_0+\rho(1-\varphi_0)gk_1 d}{\mu\kappa_m}$, Nanoparticle Rayleigh number $R_n=\frac{(\rho_p-\rho)(\varphi_1-\varphi_0)gk_1 d}{\mu\kappa_m}$, Thermal Rayleigh Darcy numer $R_a=\frac{\rho\alpha_T(T_0-T_1)gk_1 d}{\mu\kappa_m}$, Solutal Rayleigh number $R_s=\frac{\rho\beta_C(C_0-C_1)gk_1 d}{\mu D_{SM}}$, Prandtl number $Pr_1=\frac{\mu}{\rho\kappa_m}$, Magnetic Prandtl number $Pr_2=\frac{\mu}{\rho\eta}$, Chandrasekhar number $Q=\frac{\mu_e H_0^2 k_1}{4\pi\eta\mu}$, Modified diffusivity ratio $N_A=\frac{D_T(T_0-T_1)}{D_B T_1(\varphi_1-\varphi_0)}$, Modified particle density increment $N_B=\frac{(\rho_c)_p(\varphi_1-\varphi_{0_1})}{(\rho_c)_f}$, Soret parameter $N_{CT}=\frac{D_{TC}(C_0-C_1)}{\kappa_m(T_0-T_1)}$, Dufour parameter $N_{TC}=\frac{D_{TC}(T_0-T_1)}{\kappa_m(C_0-C_1)}$.

The dimensionless boundary conditions are:

$w=0,\quad T=1,\quad \varphi=1,\quad C=0$ at $z=0$ (21)

$w=0,\quad T=0,\quad \varphi=0,\quad C=1$ at $z=1$ (22)

2.1 Basic states and its solutions

The basic state of nanofluid is assumed and does not depend on time and describes as:

$$\boldsymbol{q}^*(u,v,w)=0,\ \ p^*=p_i(z),\ \ T^*=T_i(z),\ \ \varphi^*=\varphi_i(z),\ \ \boldsymbol{H}=(0,0,1)$$

The basic variable represented by subscript i.

The equations (13) to (16) with boundary conditions (21) and (22) gives the solution:

$T_i=1-z,\quad C_i=1-z$ and $\varphi_i=z.$ (23)

2.2 Perturbation solutions

We introduced small perturbations on the basic state for the investigate the stability of the system and write

$\boldsymbol{q}^*=0+\boldsymbol{q}'(u,v,w),\qquad T^*=(1-z)+T',\qquad C^*=(1-z)+C',\qquad \varphi^*=z+\varphi',$

$p^*=p_i+p',\ \ \boldsymbol{H}=(0,0,1)+\boldsymbol{H}'$ (24)

Using equation (24) in equations (13) to (20) and linearise by disuse the multiplication of the prime quantities, and after dipping the dash ($'$), we get the subsequent equations:

$\nabla\boldsymbol{q}=0$ (25)

$0=-\nabla p-\left(1-F\frac{\partial}{\partial t}\right)-R_n\varphi\hat{k}+R_a T\hat{k}+\frac{Rs}{Le}C\hat{k}+Q\frac{Pr_1}{Pr_2}\frac{\partial h}{\partial z}\hat{k}$ (26)

$\frac{1}{\sigma}\frac{\partial\varphi}{\partial t}+\boldsymbol{w}=\frac{1}{Ln}\nabla^2\varphi+\frac{N_A}{Ln}\nabla^2 T$ (27)

$\frac{\partial T}{\partial t}-w=\nabla^2 T+\varepsilon\frac{N_B}{Ln}\left(\frac{\partial \mathrm{T}}{\partial z}-\frac{\partial\varphi}{\partial z}\right)-2\varepsilon\frac{N_A N_B}{Ln}\frac{\partial \mathrm{T}}{\partial z}+N_{CT}\nabla^2 C$ (28)

$\frac{1}{\sigma}\frac{\partial C}{\partial t}-\frac{1}{\varepsilon}\boldsymbol{w}=\frac{1}{Le}\nabla^2 C+N_{TC}\nabla^2 T$ (29)

$\frac{\partial\boldsymbol{h}}{\partial t}=\sigma\frac{\partial w}{\partial z}\hat{k}+\frac{Pr_1}{Pr_2}\nabla^2\boldsymbol{H}$ (30)

$\nabla\boldsymbol{H}=0$ (31)

and boundary conditions are:

$w=0,\quad T=0,\quad \varphi=0,\quad C=0\quad$ at $z=0$ and $z=1.$ (32)

R_m is not involved in these because R_m is presently a estimate of basic static pressure gradient. So by operating equation (26) with $\hat{k}.curl.curl$, we get:

$\left(1-F\frac{\partial}{\partial t}\right)\nabla^2 w=R_a\nabla_H^2 T-R_n\nabla_H^2\varphi+\frac{Rs}{Le}\nabla_H^2 C+Q\frac{\partial^2 w}{\partial z^2}$ (33)

where $\nabla_H^2=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}$

III. Normal Mode Analysis

The disturbances analyzing by normal mode analysis as follow:

$[w,T,C,\varphi]=[W(z),\Theta(z),\Gamma(z),\phi(z)]exp\left(ik_x x+ik_y y+nt\right)$ (34)

where n is the growth rate and k_x and k_y are the wave number along x and y directions, respectively.

Using equation (34) in equations(27) to (29) and equation (33), we get;

$$(1-nF)(D^2-a^2)W+QD^2W+R_a a^2\Theta+\frac{Rs}{Le}a^2\Gamma-a^2R_n\phi=0 \quad (35)$$
$$W-\frac{N_A}{Ln}(D^2-a^2)\Theta+\left[\frac{n}{\sigma}-\frac{D^2-a^2}{Ln}\right]\phi=0 \quad (36)$$
$$W+\left[(D^2-a^2)-n+\varepsilon\frac{N_B}{Ln}D-2\varepsilon\frac{N_AN_B}{Ln}D\right]\Theta+N_{TC}(D^2-a^2)\Gamma-\varepsilon\frac{N_B}{Ln}D\phi=0 \quad (37)$$
$$\frac{W}{\varepsilon}+N_{CT}(D^2-a^2)\,\Theta+\left(\frac{D^2-a^2}{Le}-\frac{n}{\sigma}\right)\,\Gamma=0 \quad (38)$$

where $D=\frac{d}{dz}$ and $a^2=k_x^2+k_y^2$ is the dimensionless ensuing wave number and the boundary conditions in view of normal mode are:

$$W=D^2W=\Gamma=\Theta=\phi=0 \text{ at } z=0 \text{ and } z=1 \quad (39)$$

1. Linear stability analysis

The eigen functions $f_i(z)$ corresponding to the eigen values problem (35) to (38) are $f_j=\sin(\pi z)$. the corresponding solutions are:

$$W=W_0\sin(\pi z),\quad \Theta=\Theta_0\sin(\pi z),\quad \Gamma=\Gamma_0\sin(\pi z),\ \phi=\phi_0\sin(\pi z) \quad (40)$$

The linear system has a solutions if and only if

$$R_a=\frac{1}{J^2\sigma\varepsilon+n\varepsilon Le-N_{CT}J^2Le\sigma}\left[\frac{\left((1-nF)J^2+\pi^2Q\right)\varepsilon}{a^2}\left((J^2+n)(J^2\sigma+nLe)-N_{CT}N_{TC}J^4Le\sigma\right)+R_s\sigma\left(\varepsilon N_{TC}J^2-\right.\right.$$
$$J2+n-RnLe\sigma LnJ2\sigma+nLeJ2+nLn+J2NAJ2\sigma+nLe\varepsilon+NCTJ4Le\sigma LnNTC\varepsilon+NA \quad (41)$$

where $J^2=\pi^2+a^2$.

2. The stationary convection

The stationary convection will be characterized by $n=0$ in equation (42), and reduce it to

$$R_a=\frac{1}{(\varepsilon-N_{CT}Le)}\left[\frac{J^2(J^2+\pi^2Q)\varepsilon}{a^2}(1-N_{CT}N_{TC}Le)+R_s(\varepsilon N_{TC}-1)-\frac{R_nLe}{Ln}\left((Ln+N_A)\varepsilon+N_{CT}Le(LnN_{TC}\varepsilon+N_A)\right)\right] \quad (42)$$

the thermal Darcy Rayleigh number reveal by equation (42) which is a function of $a, N_{CT}, N_{TC}, Le, N_A, R_s, R_n, Ln$. Since elastico-viscous parameter F vanish with n, so the Walters`(model B`) elastico-viscous nanofluid react similar to usual Newtonian nanofluid, In the nonappearance of the Dufour and Soret parameters equation (42) reduces to

$$R_a=\left[\frac{(\pi^2+a^2)(\pi^2+a^2+\pi^2Q)}{a^2}-R_s-\frac{R_nLe}{Ln}(Ln+N_A)\right] \quad (43)$$

Here, $x=\frac{a^2}{\pi^2}$, in equation (43), then we get

$$R_a=\pi^2\left[\frac{(1+x)^2}{x}+\frac{Q(1+x)}{x}\right]-R_s-\frac{R_nLe}{Ln}(Ln+N_A) \quad (44)$$

The thermal Rayleigh number R_a takes its minimum value when $x^2=(1+Q)\pi$. So the critical wave number x reveal a sizeable grow with the Chandrasekhar number.

3. The oscillatory convection

For oscillatory convection, we put $n=i\omega$ in (41) and let us take Lewis number approach to infinity with Dufour and Soret parameters are negligible with unity heat capacity, the real and imagenary parts compare, we get $\omega^2=-J^2(R_aa^2(J^2+\pi Q)^{-1}+1)$. So oscillatory mode is not possible.

IV. Results and Discussion

The equation (44) express for stationary thermal Rayleigh number are compute as a function of solute Rayleigh number, nanoparticle Rayleigh number, modified diffusivity ratio, thermo-solutal Lewis number, thermo-nanofluid Lewis number and magnetic field.

We observe the nature of $\frac{\partial R_a}{\partial Le},\frac{\partial R_a}{\partial N_A},\frac{\partial R_a}{\partial R_n},\frac{\partial R_a}{\partial R_s},\frac{\partial R_a}{\partial Q}$ and $\frac{\partial R_a}{\partial Ln}$ analytically. Equation (44) gives

$\frac{\partial R_a}{\partial Le}<0$, $\frac{\partial R_a}{\partial N_A}<0$, ,$\frac{\partial R_a}{\partial R_n}<0$, $\frac{\partial R_a}{\partial R_s}<0$ and $\frac{\partial R_a}{\partial Q}>0$, $\frac{\partial R_a}{\partial Ln}>0$.

This implies that for stationary convection, thermo-nanofluid Lewis number and magnetic field has stabilizing effect whenever Lewise number, modified diffusivity ration, nanoparticle Rayleigh number and Solute Rayleigh number have destabiliging effect on the system.

Figure 1 represents the Rayleigh number increase when magnetic field increase for different values of nanoparticle Rayleigh number $R_n=1,5,10$ with the constant values of $N_A=5$, $Le=10$, $R_s=50$, $Ln=1000$. The Rayleigh number R_a increase with the magnetic field Q, which implise that on the stationary convection magnetic field has stabilizing effect.

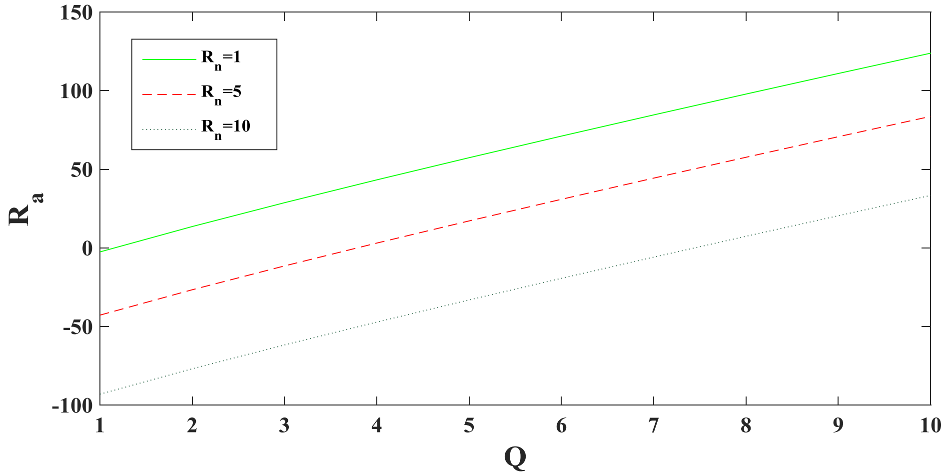

fig. 1: Variation of stationary Rayleigh number with magnetic field

Figure 2 represents the Rayleigh number decrease when nanoparticle Rayleigh number increase for different values of magnetic field $Q = 10,5,1$ with the constant values of $N_A = 5$, $Le = 10$, $R_s = 100, Ln = 500$. The Rayleigh number R_a decrease with the nanoparticle Rayleigh number, which implies that on the stationary convection nanoparticle Rayleigh number has destabilizing effect.

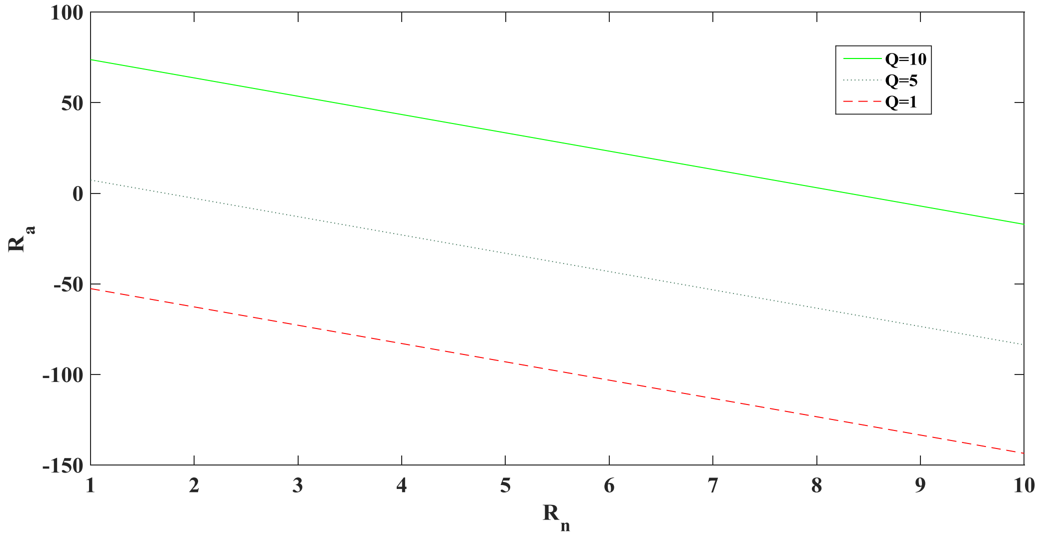

fig. 2: Variation of stationary Rayleigh number with nanoparticle Rayleigh number

Figure 3 represents the Rayleigh number decrease when solute Rayleigh number increase for different values of nanoparticle Rayleigh number $R_n = 1,5,10$ with the constant values of $N_A = 5$, $Le = 10, Q = 10, Ln = 500$. The Rayleigh number R_a decrease with the solute Rayleigh number, which implise that on the stationary convection solute Rayleigh number has destabilizing effect.

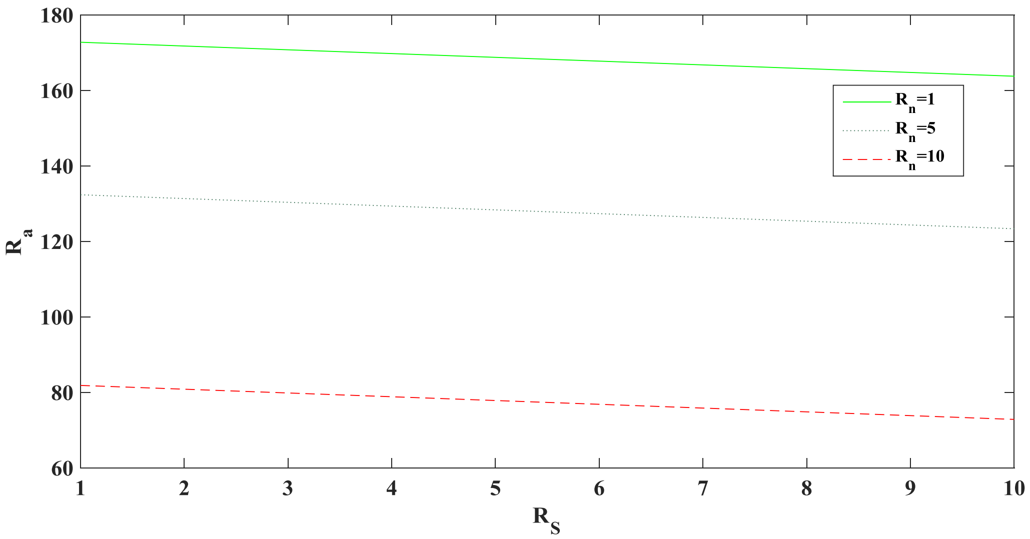

fig. 3: Variation of stationary Rayleigh number with solutal Rayleigh number

Figure 4 represents the Rayleigh number decrease when thermo-solutal Lewis number increase for different values of nanoparticle Rayleigh number $R_n = 1,5,10$ with the constant values of $N_A = 5$, $R_s = 50, Q = 10, Ln = 500$. The Rayleigh number R_a decrease with the solute Rayleigh number, which implise that on the stationary convection thermo-solutal Lewis number has destabilizing effect.

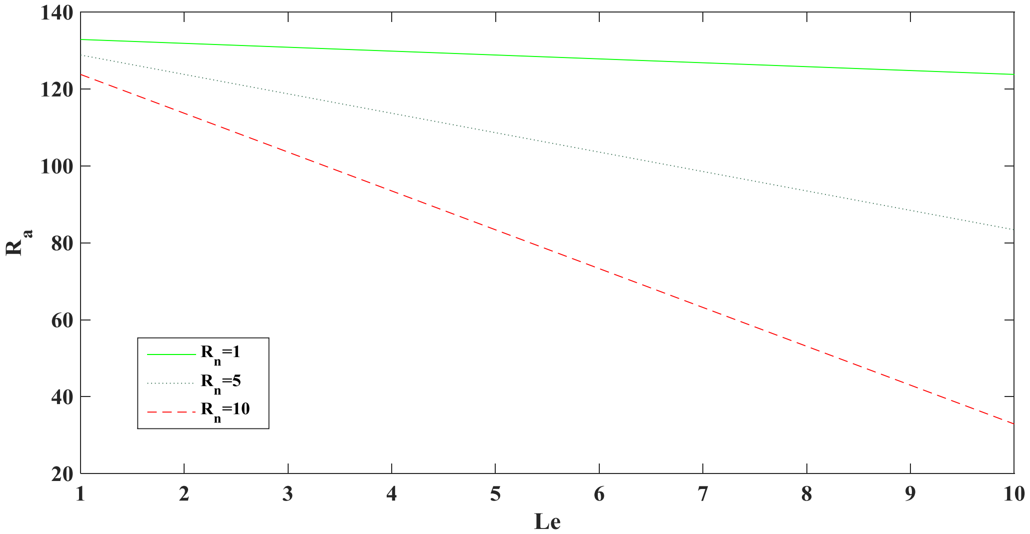

fig. 4: Variation of stationary Rayleigh number with thermosolutal Lewis number

Figure 5 represents the Rayleigh number decrease when modified diffusivity ration increase for different values of thermo-solutal Lewis number $Le = 10,20,30$ with the constant values of $R_n = 10$, $R_s = 50, Q = 10, Ln = 500$. The Rayleigh number R_a decrease with the modified diffusivity ration, which implise that on the stationary convection modified diffusivity ration has destabilizing effect.

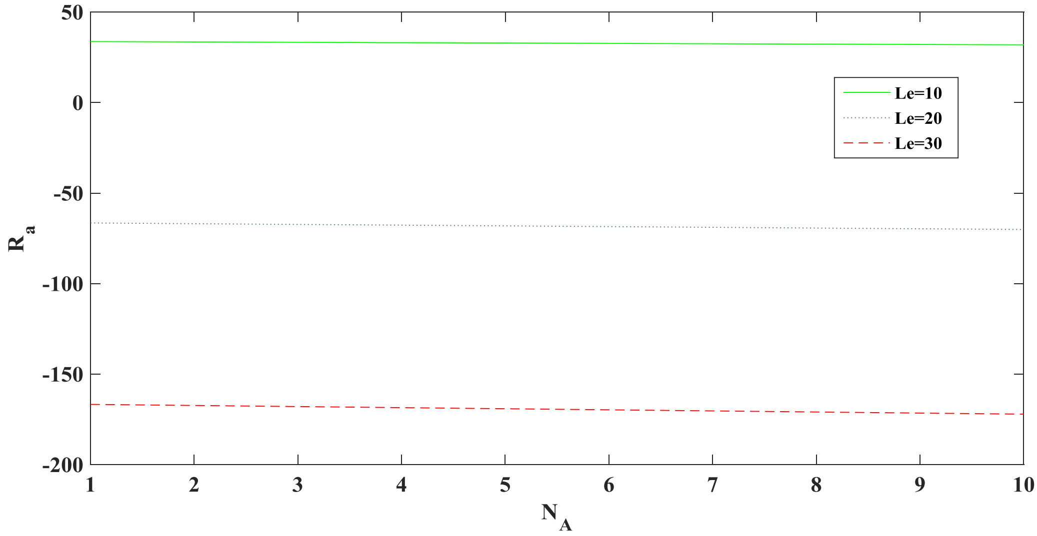

fig. 5: Variation of stationary Rayleigh number with modify diffusivity ratio

Figure 6 represents the Rayleigh number increase when thermo-nanofluid Lewis number increase for different values of nanoparticle Rayleigh number $R_n = 1,5,10$ with the constant values of $N_A = 5$, $Le = 10$, $R_s = 50, Q = 10$. The Rayleigh number R_a increase with the thermo-nanofluid Lewis number, which implise that on the stationary convection thermo-nanofluid Lewis number has stabilizing effect.

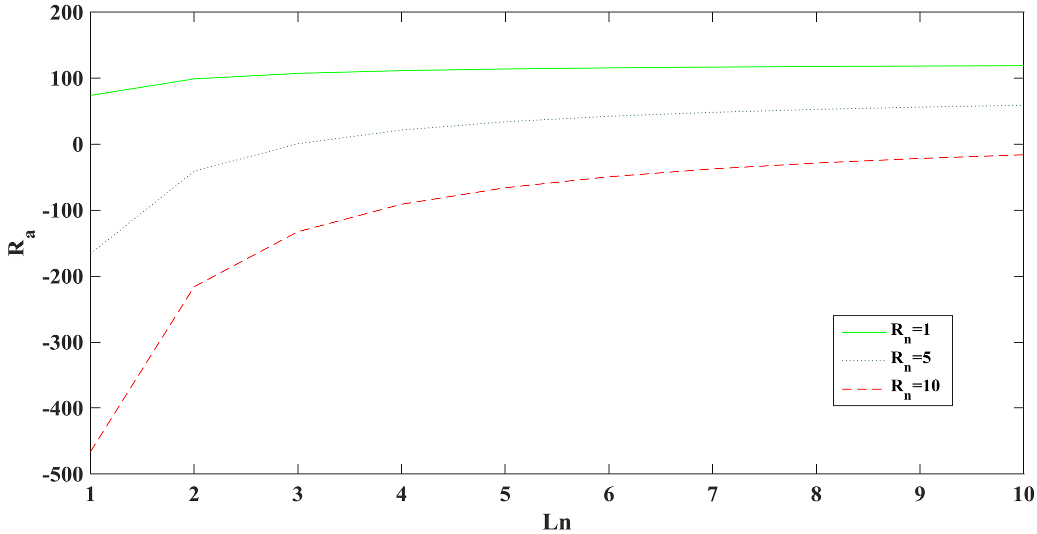

fig. 6: Variation of stationary Rayleigh number with thermo-nanofluid Lewis number

V. Conclusion

The thermosolutal convection of an elastico-viscous nanofluid in porous medium in presence of magnetic field is investigated by using linear stability analysis. We drawn the main conclusion are following as:

(i) The magnetic field and thermo-nanofluid Lewis number have stabilizing effect for stationary convection.

(ii) The modified diffusivity ration, Lewis number, nanoparticle Rayleigh number and Solute Rayleigh number have destabilizing effect for stationary convection.

(iii) The Walters`(model B`) elastico-viscous nanofluid react similar to regular Newtonian nanofluid for stationary convection.

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