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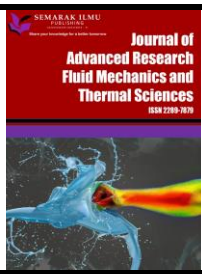

Effect of Temperature Gradients and DC Electric Field on Electrothermal Convection in a Rotating Layer of Walter's-B Fluid Saturated Porous Media

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ABSTRACT

Thermal convection in fluid-saturated porous media has diverse applications across geothermal energy utilisation, thermal insulation engineering, grain storage and understanding geodynamic processes. The thermal convection's physics is crucial for optimising the thermofluid system, improving energy efficiency, and enhancing our understanding of natural phenomena. The study examines how the initiation of electrothermal convection in a rotating viscoelastic fluid layer (Walter's B) is influenced by basic temperature gradients and a uniform vertical DC electric field, considering three different types of velocity boundary conditions: free-free, rigid-rigid, and lower rigid and upper free. By applying an electric field to a fluid, studying electrothermal convection helps engineers design effective cooling systems for electronics. The eigenvalue problem is solved by using the Galerkin technique. The Galerkin method is a widely used numerical technique for solving eigenvalue problems. The DC electric field effect exhibits a more stabilising effect for free-free boundaries than rigid and rigid-rigid boundaries. Moreover, the linear temperature profile exhibits a more stabilising effect than the parabolic temperature profile. The control of electrothermal convection on the system with the impact of other physical parameters is also discussed.

1. Introduction

Thermal convection in fluid-saturated porous media is a fascinating phenomenon with numerous practical applications. Its understanding and utilisation contribute to advancements in energy production, engineering design, agricultural practices, and our knowledge of Earth's geophysical processes. A large volume of work in this area is documented in the literature, such as the work of Bear [1], Ingham and Pop [2], Vafai and Hadim [3], and Nield and Bejan [4]. Lin [5] has presented the applications of electrothermal convection.

In dielectric fluids, an applied temperature gradient produces the dielectric permittivity and/or non-uniformities in the electrical conductivity. Realising the importance of the relationship between

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an electric field and fluid mechanics, Turnbull [6] studied electroconductive instability with a stabilising temperature gradient. They focused on investigating fluid flow behaviour in the presence of electric fields and temperature gradients. Roberts [7] investigated Electrohydrodynamic convection. Takashima and Aldridge [8] studied the stability of the horizontal layer of dielectric fluid under the simultaneous action of a vertical D.C electric field and vertical temperature gradient. Martin and Richardson [9] investigated conductivity models in electrothermal convection in dielectric liquids, aiming to understand the interplay between electric fields, temperature gradients, and fluid flow. Extensive research has been conducted by Toru *et al.,* [10] on natural convection in a dielectric fluid layer influenced by AC and DC electric fields. Pontiga and Castellanos [11] investigated the physical mechanism of instability in a liquid layer. The instability study of EHD (Electrohydrodynamic) in a horizontal fluid layer, which involves an electrical conductivity gradient and is subjected to a weak shear flow, was presented by Chang *et al.,* [12]. The effect of rotation on electrothermal convection was examined by Takashima [13]. Douiebe *et al.,* [14] investigated the impacts of an alternating current electric field and rotation on the flow of Benard-Marangoni convection. The electrothermal convection instability of a rotating layer of viscoelastic fluid heated from below was examined by Othman [15]. Ruo *et al.,* [16] analysed the electrothermal convection of a horizontally rotating fluid layer featuring a vertical electrical conductivity gradient. Shivakumara *et al.,* [17] have reported the combined effect of a volumetric heat source and DC electric field on the onset of convection in a dielectric fluid layer. Shivakumara *et al.,* [18] have studied the effect of temperature boundary conditions and velocity on electrothermal convection in a rotating dielectric fluid layer.

Exploring thermal convective instability within viscoelastic fluids is gaining popularity due to its increasing relevance in modern technology and industries. Notably, the viscoelastic behaviour is an important rheological phenomenon. Several authors have recently focused on investigating thermal convective instability in viscoelastic fluid-saturated porous layers. The thermal instability caused by buoyancy forces in a horizontal porous layer saturated with a viscoelastic fluid has been addressed by Kim *et al.,* [19]. Following Akhatov and Chembarisova's [20] approach, Yoon *et al.,* [21] investigated the beginning of thermal convection in an isothermally heated porous layer saturated with viscoelastic fluid analytically. The impact of local thermal non-equilibrium on the initiation of convection within a porous medium saturated with an Oldroyd-B viscoelastic fluid has been examined by Shivakumara *et al.,* [22] and Malashetty *et al.,* [23,24]. All these previous investigators have considered the effect of basic temperature gradient and AC electric field on the onset of convection in a viscoelastic rotating fluid layer. Nevertheless, the literature has yet to extensively explore the impact of basic temperature gradients and DC electric fields on electrohydrodynamics (EHD) instability, a prevalent challenge in various scientific and technological domains.

This study aims to investigate how different temperature profiles, including linear and parabolic profiles, impact the initiation of electrothermal convection in a rotating viscoelastic fluid layer under different velocity boundary conditions. These conditions include free and rigid boundaries; the lower boundary is rigid, while the upper boundary is free. The numerical solution of the corresponding eigenvalue problem is carried out using the Galerkin approach, and the results will be presented graphically.

2. Mathematical Formulation

The study focuses on a horizontal layer of Walter's B viscoelastic fluid-saturated porous medium with a thickness of d. The temperature distribution on the lower and upper surfaces of the porous layer is determined by external forces, as shown in Figure 1.

T=T_0 +$^{\Delta T}/_2$ at z = 0 (1)

T=T_0–$^{\Delta T}/_2$ at z = d (2)

In this setup, the reference temperature is denoted by T_0. The lower and upper surfaces are maintained at constant temperatures T_0 +$\Delta T/2$ and T_0 − $\Delta T/2$ respectively. Furthermore, a vertical DC electric field is applied across the layer, with the lower and upper surfaces maintained at alternating potentials of V_0 +$\Delta T/2$ and V_0 − $\Delta T/2$, respectively. A Cartesian framework of (x, y, z) is adopted as its coordinate system, where the origin is located at the bottom of the porous layer, while the z-axis points vertically upwards.

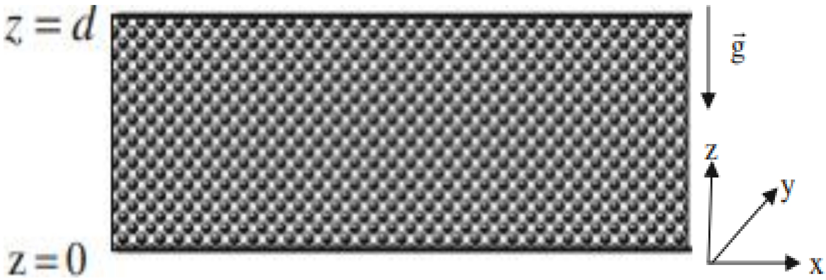

Fig. 1. Physical configuration

The governing equations are:

$$\Delta.\vec{q}=0 \tag{3}$$

$$\rho_0\left[\frac{1}{\varepsilon}\frac{\partial \vec{q}}{\partial t}-\frac{2}{\varepsilon}\left(\vec{q}\times\vec{\Omega}\right)\right]=-\nabla p+\rho\vec{g}-\frac{1}{k}\left(\eta-\eta_v\frac{\partial}{\partial t}\right)\vec{q}+f_e \tag{4}$$

$$\frac{\partial T}{\partial t}+(\vec{q}.\nabla)T=K\nabla^2T \tag{5}$$

$$f_e=\rho_e\vec{E}-\frac{1}{2}\vec{E}.\vec{E}\nabla\varepsilon+\frac{1}{2}\nabla\left(\rho\frac{\partial\varepsilon}{\partial\rho}\vec{E}.\vec{E}\right) \tag{6}$$

$$\rho=\rho_0\{1-\alpha(T-T_0)\} \tag{7}$$

where:
ρ_0 = reference thickness
k = effective thermal diffusivity
$\vec{q}$ = velocity
K = permeability of the porous medium
p = pressure
$\vec{g}$ = gravitational acceleration
T = temperature
ε = the porosity of the medium
α = coefficient of volumetric extension
µ = consistency
μ_v = viscoelastic consistent of Walters B fluid
$\vec{E}$ = electric field

ρ_e = density of free charges,
Ω = (0, 0, Ω) = the angular velocity.

Each of these quantities has a particular meaning.

In Eq. (6), the first term pertains to the Coulomb force, which indicates the presence of free charge. The last two terms, on the other hand, address the non-uniformities in the dielectric constant. It should be noted that these terms do not affect an incompressible fluid, as the last term can be incorporated into the pressure.

The relevant Maxwell's equations are,

$$\nabla \times \vec{E} = 0 \tag{8}$$

Considering (7), $\vec{E}$ can be written as: $\vec{E}= -\nabla V$ (9)

Where $\rho_e = \nabla.(\varepsilon, \vec{E})$ denotes the charge density, V represents the electric potential, and the dielectric constant is ε. It is assumed to be a linear function of temperature, i.e.:

$$\sigma = \sigma_0(1 - \beta(T - T_0) \tag{10}$$

The thermal expansion coefficient of electrical conductivity is $(\beta = {\sigma_o}^{-1}(\partial\sigma/\partial T)$ and it is assumed to be small.

$$\partial\rho_e/\partial t + \nabla.J = 0 \tag{11}$$

$$J = \sigma\vec{E} + \rho_e\vec{q} \tag{12}$$

2.1 Basic State

A quiescent state is represented by,

$$\vec{q} = \vec{q}_b = 0, T = T_b(z),\ p = p_b(z),\ \vec{E}=E_b(z)\quad \vec{\rho} = \rho_b(z)\ \ \varepsilon = \varepsilon_b(z)\ \ v = v_b(z) \tag{13}$$

where the subscript, *b*, indicates the fundamental state.

$$\rho_{\ b}\vec{g} - \nabla p_b + f_e \ = \ 0 \tag{14}$$

$$\frac{dT_b}{dz} = \ -\ \frac{\Delta T}{d} f(z) \tag{15}$$

The expression for $p_b$and ρ_b are not required in the subsequent analysis.

$$\rho_b = \rho_0\{1 + \alpha\beta z\} \tag{16}$$

$$\nabla \times \vec{E}_b = 0, \quad \nabla.\left(\varepsilon\, \vec{E}_b\right) = 0 \tag{17}$$

$$\nabla.\sigma_b \nabla v_b = 0 \tag{18}$$

$$\rho_{eb} = \in \left(\nabla.\overrightarrow{E_b}\right) \tag{19}$$

where $f(z)$ is the basic temperature gradient, which satisfies the condition,

$$\int_0^d f(z)dz = -\Delta T/d \tag{20}$$

$$V_b = V_O - \Delta v\left[{}^1\!/_2 - {}^z\!/_d\right] \tag{21}$$

2.2 Perturbed State

We introduce a small disturbance of the fundamental state in the form of Eq. (22) to investigate the stability of the fundamental state.

$$\vec{q} = \overrightarrow{q'}\;\; p = p_b + p', \quad \vec{E} = \vec{E}_b + \overrightarrow{E'}\;\; T = T_b + T', \rho = \rho_B + \rho', \varepsilon = \varepsilon_b + \varepsilon' \tag{22}$$

where q', p', E', T', ρ' and ε' represents the perturbs. Substituting Eq. (20) into Eq. (3) to Eq. (10) will produce:

$$\left\{\frac{1}{\varepsilon}\frac{\partial}{\partial t} - \frac{\eta}{k\rho_0}\left(1 - \frac{\eta_v}{\eta}\frac{\partial}{\partial t}\right)\right\}\nabla^2 w = -\alpha g \nabla^2{}_b T - \frac{2\Omega}{\varepsilon}\frac{\partial \xi}{\partial z} - \frac{\Delta v \Delta^2(\Delta^2 v_b)}{d} \tag{23}$$

$$\left\{\frac{1}{\emptyset_p}\frac{\partial}{\partial t} + \frac{\eta}{k\rho_0}\left(1 - \frac{\eta_v}{\eta}\frac{\partial}{\partial t}\right)\right\}\xi = \frac{2\Omega}{\varepsilon}\frac{\partial w}{\partial z} \tag{24}$$

$$\left(\frac{\partial}{\partial t} - k\nabla^2\right)T = -f(z)w \tag{25}$$

$$\epsilon\frac{\partial}{\partial t}\nabla^2 v' = -\sigma_0\Delta^2 v' - \sigma_0\beta T'\frac{\Delta v}{d}\frac{dT'}{dz} \tag{26}$$

Non-dimensionalisation of the equations is done by considering the parameters as follows:

$$\xi' = \frac{k}{d^2}, T^* = \frac{T}{\Delta T},\;(x^*, y^*, z^*) = \left(\frac{x}{d}, \frac{y}{d}\frac{z}{d}\right), \quad t^* = \frac{t}{d^2\varepsilon/k}, \quad \vec{q}' = \frac{k}{d}, w^* = \frac{w}{k/d}, \quad V' = \gamma E_0 \Delta T d$$

By substituting Eq. (25) into the respective equations as in Eq. (21) to Eq. (24), we obtain:

$$\left\{\frac{1}{pr}\frac{\partial}{\partial t} + Da^{-1}\left(1 - \frac{\Gamma\mathrm{p}}{pr}\frac{\partial}{\partial t}\right)\right\}\nabla^2 w + R_t\nabla^2{}_b T + Ta^{1/2}\frac{\partial \xi}{\partial z} + R_{ed}\nabla^2(\nabla^2 v_b) = 0 \tag{27}$$

$$\left\{\frac{1}{pr}\frac{\partial}{\partial t} + Da^{-1}\left(1 - \frac{\Gamma p}{pr}\frac{\partial}{\partial t}\right)\right\}\xi - Ta^{1/2}\frac{\partial w}{\partial z} = 0 \tag{28}$$

$$\left(\frac{\partial}{\partial t} - \nabla^2\right)T = -f(z)w \tag{29}$$

$$\left[\rho_e\frac{\partial}{\partial t} + 1\right]\nabla^2 V = -\frac{\partial T}{\partial z} \tag{30}$$

where:
$R_t = \alpha g \Delta T d^3/vk$ = thermal Rayleigh number
$R_{ed} = \gamma^2\varepsilon_0 E^2{}_0(\Delta T)^2 d^2/kv$ = DC electric Rayleigh number

$Ta = {4\Omega^2 d^4}/{v^2}$ = Taylor number
$Pr = v/k\varepsilon^2$ = modified Prandtl number
$\Gamma\mathrm{p} = \mu_v \varepsilon/\rho_0 d^2$ = elastic parameter
$\rho_{e={\varepsilon k}/{d^2\sigma_0}}$ = electric Prandtl number
$Da = k/d^2$ = Darcy number
$\xi = \partial v/\partial x - \partial u/\partial y$ = vorticity of the z-component

The boundaries of the porous layer are assumed to be either free or rigid, with fixed temperatures and electric potentials. Consequently, the stress-free boundary conditions can be described as follows:

$$w = \frac{\partial^2 w}{\partial z^2} = T = \frac{\partial \xi}{\partial z} = \frac{\partial v}{\partial z} = 0 = DT \tag{31}$$

The boundary condition at the rigid margin is:

$$w = \frac{\partial w}{\partial z} = T = \xi = V = 0 \tag{32}$$

2.3 Normal Mode Analysis

We express the disturbances into normal modes of the form.

$$(w, T, V, \xi) = (W, \theta, \phi, Z)(Z)\mathrm{e}^{(ilx+imy+\omega t)} \tag{33}$$

where 'l' and 'm' are the horizontal wave numbers in the x and y directions, respectively and $\omega = \omega_r + i\omega_i$ is the growth rate. Substituting Eq. (33) into Eq. (27) to Eq. (30), we obtain:

$$[\rho_e w + 1]\left\{\frac{w}{pr} + Da^{-1}\left(1 - \frac{\Gamma\mathrm{p}}{pr}w\right)\right\}(D^2 - a^2)W + [\rho_e w + 1]R_t a^2\theta + [\rho_e w + 1]Ta^{1/2}DZ + R_{ed}a^2 D\theta = 0 \tag{34}$$

$$\left\{\frac{w}{pr} + Da^{-1}\left(1 - \frac{\Gamma p}{pr}w\right)\right\}Z - Ta^{1/2}DW = 0 \tag{35}$$

$$\left(w - (D^2 - a^2)\right)\theta + f(z)w = 0 \tag{36}$$

where $D = d/dz$ and $a = \sqrt{l^2 + m^2}$ is the dimensionless horizontal wave number.

The abovementioned equations are to be solved while considering appropriate boundary conditions.

At the rigid- rigid,

$$W = DW = \theta = Z = \emptyset = 0 \; at \; z = 0,\ 1 \tag{37}$$

At the free-free,

$$W = D^2W = \theta = DZ = D\emptyset = 0 \; at \; z = 0,\ 1 \tag{38}$$

At the lower rigid surface ($z = 0$),

$$W = DW = \theta = Z = \emptyset = 0 \tag{39}$$

At the upper free interface ($z = 1$),

$$W = D^2W = \theta = DZ = D\emptyset = 0 \tag{40}$$

2.4 Numerical Solution

In this study, we focus on the case of steady onset by setting ω = 0 in Eq. (27) to Eq. (30). The Galerkin approach is employed to solve the eigenvalue problem since an exact solution is impossible. Consequently, the variables are formulated as follows:

$$W = \Sigma A_i W_i \quad \theta = \Sigma B_i \theta_i \quad Z = \Sigma C_i Z_i \quad \emptyset = \Sigma D_i \emptyset_i \tag{41}$$

W_i , θ_i , Z_i and $\emptyset_i$ are the respective boundary conditions that satisfy the power series functions and A_i, B_i , C_i and D_i are the constants. Using Eq. (41) into Eq. (27) to Eq. (30) (after noting ω = 0), multiplying the resulting Eq. (34) (momentum equation) by $W_j(z)$, Eq. (35) (vorticity equation) by $Z_j(z)$, Eq. (36) (energy equation) by $\theta_j(z)$, (electric potential equation) using the boundary conditions and acting the integration by parts with respect to z between $z = 0$ and $z = 1$, we get the following system of linear homogeneous algebraic equations:

$$A_i E_{ji} + B_i F_{ji} + C_i G_{ji} = 0 \tag{42}$$

$$-\mathrm{A_i H_{ji}} + \mathrm{C_i I_{ji}} = 0 \tag{43}$$

$$A_i J_{ji} + B_i K_{ji} = 0 \tag{44}$$

where,

$$E_{ji} = [\rho_e w + 1]\left\{\frac{w}{pr} + Da^{-1}\left(1 - \frac{\Gamma \mathrm{p}}{pr}w\right)\right\} W_j (D^2 - a^2) W_i$$
$$F_{ji} = [\rho_e w + 1](R_t a^2 W_j \theta_i - R_{ea} a^2 W_j D\theta_i)$$
$$G_{ji} = [\rho_e w + 1] Ta^{1/2} W_j D Z_i$$
$$H_{ji} = Ta^{1/2} Z_j D W_i$$
$$I_{ji} = \left\{\frac{w}{pr} + Da^{-1}\left(1 - \frac{\Gamma \mathrm{p}}{pr}w\right)\right\} Z_j Z_i$$
$$J_{ji} = \theta_j\, f(z) W_j$$
$$K_{ji} = \theta_j \left[w - \left((D^2 - a^2)\right)\right] \theta_i$$

where the inner product is $(\dots\dots\dots.) = \int_0^1 (\dots..)dz$.

The above set of homogeneous algebraic equations can have a non-trivial solution if and only if:

$$\begin{bmatrix} E_{ji} & F_{ji} & G_{ji} \\ H_{ji} & 0 & I_{ji} \\ J_{ji} & K_{ji} & 0 \end{bmatrix} = 0 \tag{45}$$

The suitable boundary conditions are as follows:

(i) rigid-rigid boundaries

$$W_i = (2z^4 - 5z^3 + 3z^2)T^*{}_{i-1}, \quad \theta_i = (z - z^2)\, T^*{}_{i-1} = Z_i \tag{46}$$

(ii) free-free boundaries

$$W_i = (z^4 - 2z^3 + z)T^*{}_{i-1},\ \theta_i = (z^2 - z^3)\, T^*{}_{i-1}, Z_i = (z^3 - 3z^2/2 + 3/2)T^*{}_{i-1} \tag{47}$$

(iii) rigid-free boundaries

$$\mathrm{W_i} = (\mathrm{z}^4 - 5\mathrm{z}^3/2 + 3\mathrm{z}^2/2)\mathrm{T}^*{}_{\mathrm{i}-1},\ \theta_\mathrm{i} = (\mathrm{z} - \mathrm{z}^2)\,\mathrm{T}^*{}_{\mathrm{i}-1}, \mathrm{Z_i} = (\mathrm{z}^3 - \mathrm{z}^2 - \mathrm{z})\mathrm{T}^*{}_{\mathrm{i}-1} \tag{48}$$

By employing the abovementioned trial functions, namely the modified Chebyshev polynomials of the i^{th} order with f(z) = 2z and z^2 which represents the temperature gradient, Eq. (46) to Eq. (48) are solved. The determinant obtained from expanding the equation yields the characteristic equation, which provides the thermal Rayleigh number (R_t) or the DC electric Rayleigh number (R_{ed}) as a function of the wave number (a) and other parameters. Additionally, depending on the considered boundary combinations, the Rayleigh number (R_{ed}) can be expressed as a function of the wave number (a) and parameters such as Da^{-1} and Ta. To ensure accuracy in the numerical integration, the inner products involved in the determinant are evaluated analytically rather than numerically.

3. Results and Discussions

The study investigates the influence of a uniform DC electric field and temperature gradients on the initiation of thermal convection in a rotating viscoelastic fluid layer, considering three different velocity boundary conditions. The Galerkin approach is employed to solve the problem.

Figure 2 shows that increasing the DC electric Rayleigh number results in a decrease in the thermal Rayleigh number, indicating that it has a stabilising effect for rigid-free, free-free boundaries, while increasing the thermal Rayleigh number suggests that it has a destabilising effect for rigid-rigid boundaries. Furthermore, it is also obvious that free-free boundaries are stabilising compared to rigid-free boundaries, and the least boundaries are rigid-rigid.

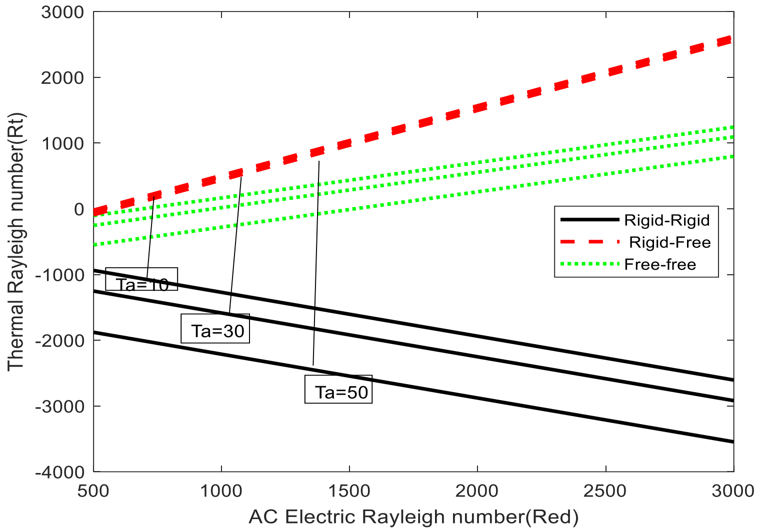

Fig. 2. $\mathrm{R_{ed}}$versus $\mathrm{R_t}$at $\mathrm{Da}^{-1} = 10, \mathrm{Ta} = 10, 30, 50$ for Rigid-Rigid, Free-Free and Rigid-free boundaries

Figure 3 specifically focuses on the case of rigid-rigid boundaries. It demonstrates the impact of different Ta values on R_{ed} and R_t. An increase in the value of R_{ed} leads to a decrease in R_t, indicating a destabilising effect on the system for rigid-rigid boundaries. Furthermore, it is observed that linear temperature profiles exert a stronger stabilising effect on the system compared to parabolic temperature profiles.

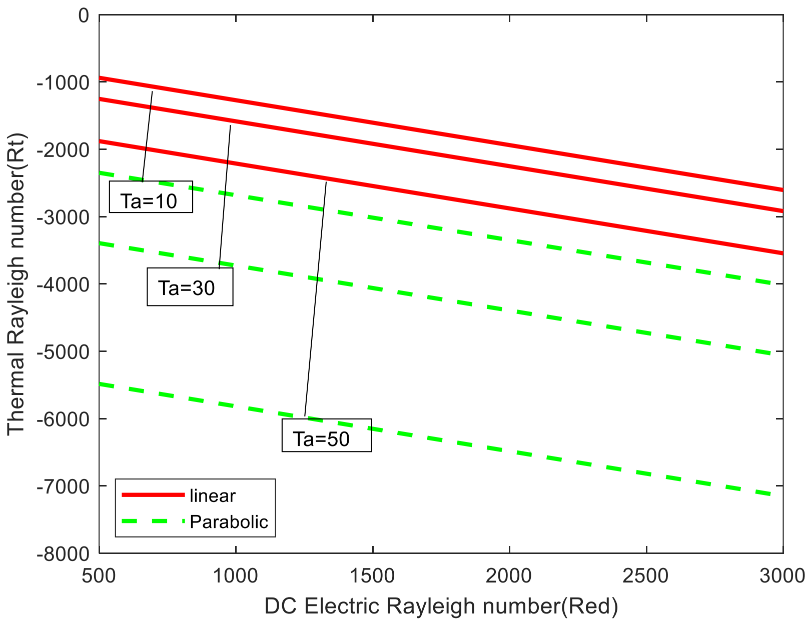

Fig. 3. Variation of $\mathrm{R_{ed}}$ with $\mathrm{R_t}$ for linear and parabolic temperature profiles for rigid-rigid boundaries when $\mathrm{Ta} = 10,30,50$

Figure 4 focuses on the case of free-free boundaries. For any different value of Ta, an increase in the value of R_{ed} amounts to decrease in the R_t, implying that its effect is stabilising for free-free boundaries. It can also be noted that the linear temperature profiles offer a more stabilising effect on the system than parabolic temperature profiles.

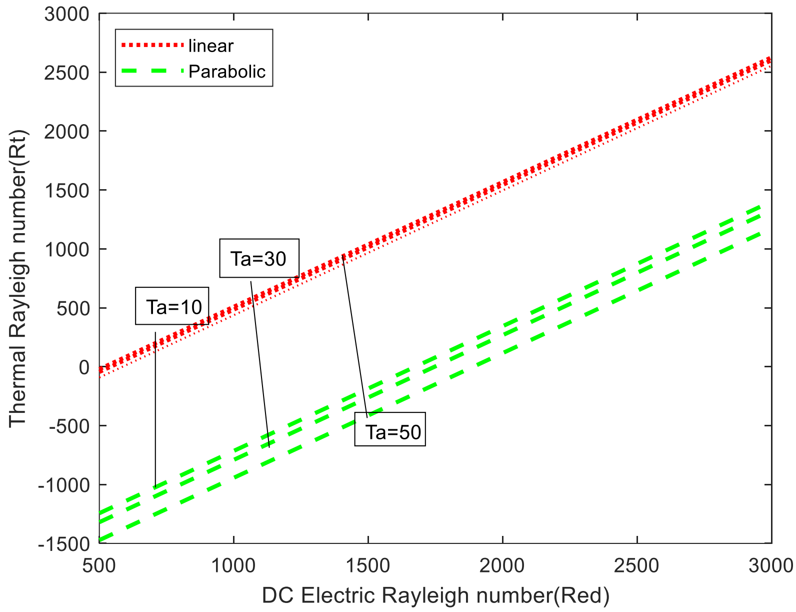

Fig. 4. Variation of $\mathrm{R_{ed}}$ with $\mathrm{R_t}$ for linear and parabolic temperature profiles for free-free boundaries when $\mathrm{Ta} = 10{,}30{,}50$

Figure 5 indicates for rigid-free boundaries. For any different value of Ta, an increase in the value of R_{ed} amounts to an increase in the value of R_t, indicating that its effect is stabilising for linear temperature profiles. Moreover, an increase in the value of R_{ed} amounts to decrease in the R_t, demonstrating its effect is destabilising for parabolic temperature profiles. It is also observed that the linear temperature profiles are more stable than parabolic temperature profiles.

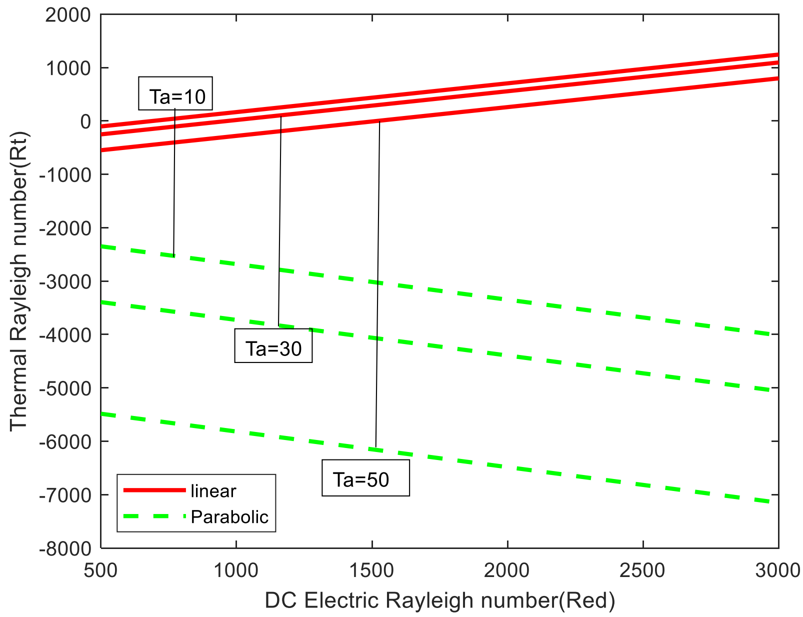

Fig. 5. Variation of $\mathrm{R_{ed}}$ with $\mathrm{R_t}$ for linear and parabolic temperature profiles for rigid-free boundaries when $\mathrm{Ta} = 10{,}30{,}50$

Figure 6 illustrates the relationship between R_t and *a* for rigid-rigid boundaries. For different fixed values of Ta, an increase in the value of wave number amounts to a decrease in the R_t indicating its effect is to increase the size of convection cells. It is also observed that the R_t for linear temperature profile is higher than the parabolic temperature profile.

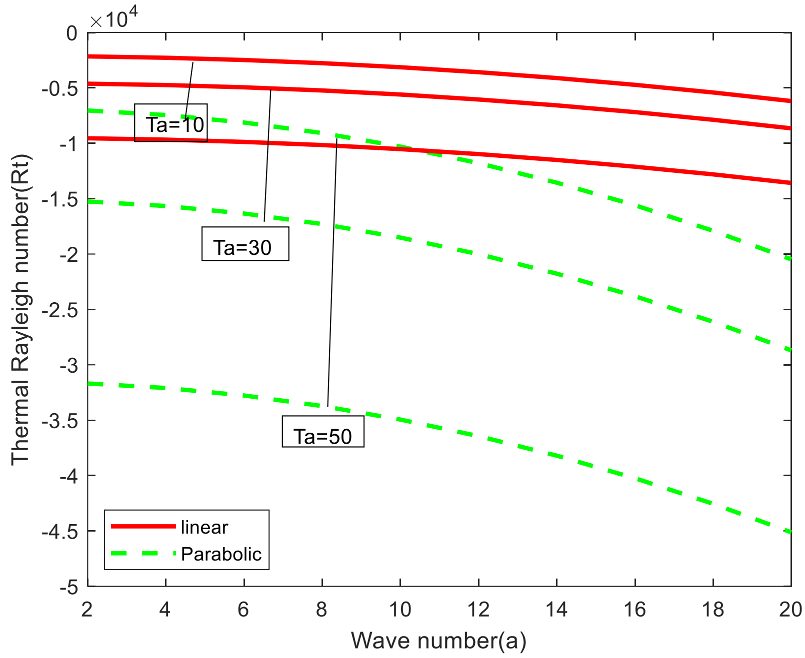

Fig. 6. Variation of a with $\mathrm{R_t}$ for linear and parabolic temperature profiles for rigid-rigid boundaries when $\mathrm{Ta} = 10,30,50$

Figure 7 indicates the plot for free-free boundaries. For any different value of Ta, increasing the value of the wave number amounts to a decrease in the R_t indicating its effect is to increase the size of convection cells. It is also observed that the R_t for linear temperature profile is higher than the parabolic temperature profile.

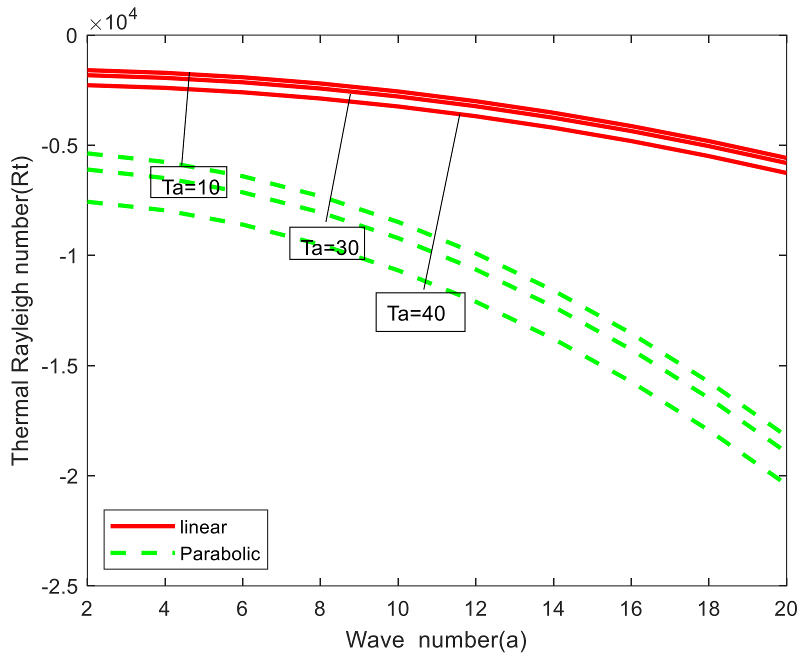

Fig. 7. Variation of a with $\mathrm{R_t}$ for linear and parabolic temperature profiles for free-free boundaries when $\mathrm{Ta} = 10,30,50$

Figure 8 indicates the plot for rigid-free boundaries. For any different value of Ta, increasing the value of the wave number amounts to a decrease in the $R_t$thermal Rayleigh number, indicating its effect is to increase the size of convection cells. It is also observed that the R_t for linear temperature profile is higher than the parabolic temperature profile.

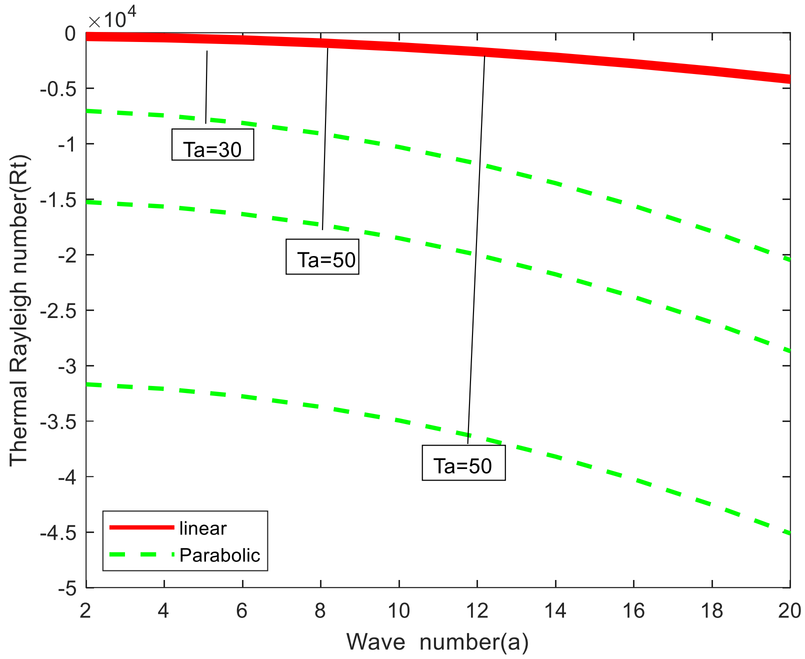

Fig. 8. Variation of a *with* $\mathrm{R_t}$ for linear and parabolic temperature profiles for rigid-free boundaries when $\mathrm{Ta} = 10{,}30{,}50$

Figure 9 compares the *R*$_t$-*a* relations for rigid-rigid, rigid-free, and free-free boundaries. Despite differences in R_{ed}, increase in the value of wave number amounts to a decrease in the R_t indicating its effect is to increase the size of convection cells. It is also observed that the R_t for free-free is higher than rigid-free and rigid-rigid boundaries.

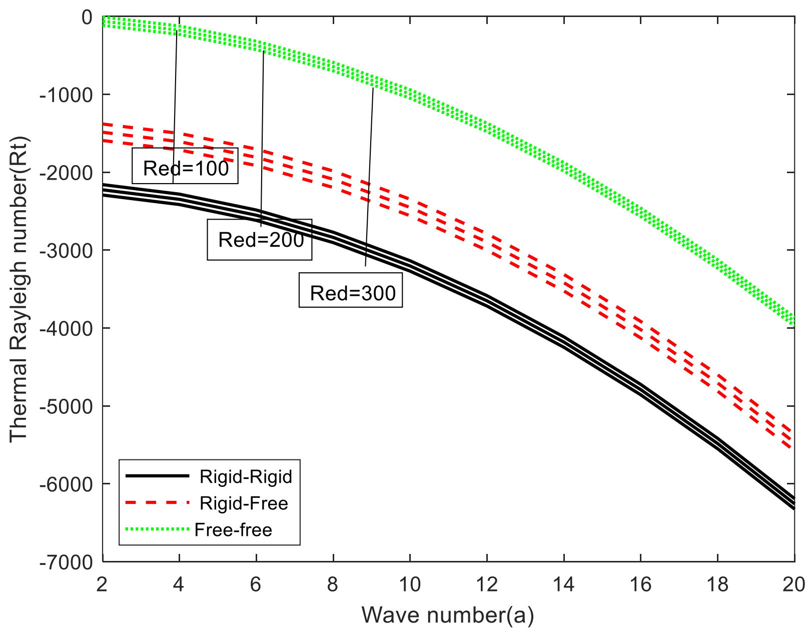

Fig. 9. a versus $\mathrm{R_t}$ at $\mathrm{Da}^{-1} = 10$, $R_{ed} = 100{,}200{,}300$ for Rigid-Rigid, Free-Free and Rigid-free boundaries

4. Conclusions

The study investigates the influence of different temperature profiles, namely linear and parabolic temperature profiles, on the initiation of electrohydrodynamic instability in a rotating viscoelastic fluid layer (Walter's B) subjected to a DC electric field. The study can contribute to gain insight into the CONTROL OF ELECTROHYDRODYNAMIC INSTABILITY. The summarised findings of the study are the effect of a DC electric field can augment or suppress convection depending on the nature of velocity boundary conditions and basic temperature profiles. Increasing the strength of rotation can delay the onset of electrothermal convection. The influence of a DC electric field on the system's stability is observed to have a stabilising effect for free-free boundaries compared to rigid-free and rigid-rigid boundaries. Linear temperature profiles exhibit more stabilising effects than parabolic temperature profiles, irrespective of the velocity boundary conditions. In future we are thinking of exploring the influence of other aspects like rotation temperature gradients etc., in the control of stability with the presence of electric field.

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