Comparison of the results of Küppers - Lortz instability of electrically conducting mono and Hybrid Nanofluid layer

B Sirisha Reddy [a]

[a] Research Scholar, Department of Mathematics, CHRIST (Deemed to be University), Bengaluru, India

Paper for "Young Scientists Award"

1. INTRODUCTION & OBJECTIVE

In many heat transfer applications, including power generation, manufacturing, production, chemical processing, transportation, microelectronics, and more, fluid heating and cooling are essential challenging components. In many industrial applications, increasing the heat transfer rate can shorten processing times, improve equipment longevity, and save a substantial amount of energy. One way to increase the heat transfer rate is to increase the thermal conductivity of the fluid, which is achieved by adding nanoparticles to the base fluid. Nanofluids, the dispersion of nanosized metallic or non-metallic particles onto the base fluid, offer practical solutions to these challenges.

Nanofluids were first coined by Choi [1] in the year 1995. Many researchers have conducted detailed studies on nanofluid under different situations and found that the thermal conductivity of these fluids is greater than that of conventional fluids [2, 3]. When two nanoparticles are dispersed in base fluid, the thermal conductivity increases the heat transfer of the fluid.

In the case of a rotating Rayleigh–Bénard system, as the rotation, i.e., Taylor number increases, at a particular value of Taylor number, the convective system formed by the primary instability due to temperature disturbances is disturbed, and the resulting rolls form an angle with each other. This instability is called the Küppers–Lortz instability and is named after Küppers and Lortz [4]. Studies have reported that the two rolls' switching angle, approximately 58°, is a significant indicator of the instability [5, 6].

This novel study delves into the Küppers–Lortz instability problem for electrically conducting mono and hybrid nanofluid fluid layers. For mono nanofluids, we consider a single nanoparticle of 1% concentration suspended in the base fluid, whereas in hybrid nanofluids, two different nanoparticles, each with a concentration of 1 %, are suspended in the base fluid. The thermophysical properties of the mono and hybrid nanofluids are calculated using Phenomenological laws and mixture theory. The condition for the onset of primary and secondary instability for mono and hybrid nanofluids is compared.

[1] Further author information:
S.S.A.: E-mail: b.reddy@res.christuniversity.in, Address: Bengaluru, karnataka, India

Physical Configuration:

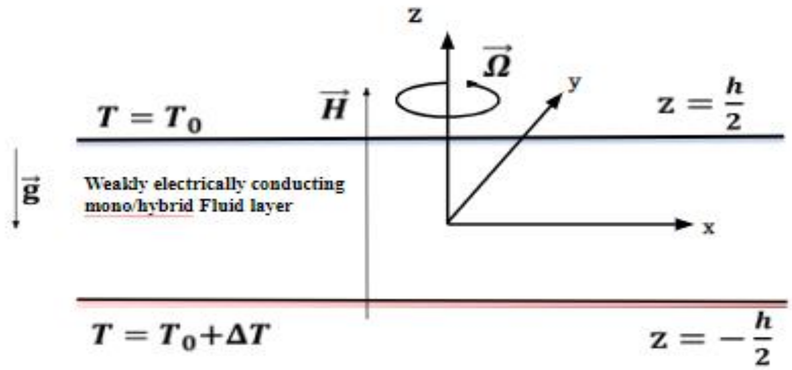

Figure 1: The physical configuration for Rayleigh - Bénard convection problem in a weakly electrically conducting fluid in presence of weak magnetic field.

Following are the governing equations to study the problem:

$$\nabla . \vec{q} = 0, \tag{1}$$

$$\rho_0 \left(\frac{\partial \vec{q}}{\partial t} + (\vec{q}. \nabla)\vec{q} + 2(\vec{\Omega} \times \vec{q}) \right) = -\nabla P + \mu_{nl} \nabla^2 \vec{q} + \rho_{nl}(T)\vec{g} + 2\rho_{0nl}(\vec{q} \times \vec{\Omega}) + \vec{J} \times \vec{B}, \tag{2}$$

$$\left(\frac{\partial T}{\partial t} + (\vec{q}. \nabla)T \right) = \alpha_{nl} \nabla^2 T, \tag{3}$$

$$\rho_{nl}(T) = \rho_{0nl}(1 - \beta_{nl}(T - T_0)). \tag{4}$$

Subjected to boundary condition:

$$\left. \begin{array}{l} w = \dfrac{\partial^2 w}{\partial z^2} = \dfrac{\partial \zeta}{\partial z} = 0,\ T = T_0 + \Delta T \text{ at } z = -\frac{h}{2} \\ w = \dfrac{\partial^2 w}{\partial z^2} = \dfrac{\partial \zeta}{\partial z} = 0, T = T_0 \text{ at } z = \frac{h}{2} \end{array} \right\}. \tag{5}$$

Where $\vec{q} = (u, v, w)$ is the velocity vector in *m/s*, t is the time in *s*, *T* is the temperature in *K*, p is the pressure in *Pa*, ρ is the density of the fluid in *Kg/m*^{3}, ρ_0 is the reference density in *Kg/m*^{3}, μ_{nl} is the dynamic coefficient of viscosity in *Kg/[m s]*, α_{nl} is the thermal diffusivity in m^2/s, $\vec{g}$ is the gravitational acceleration in m/s^2 $\vec{J}$ is current density in *A/m*, β_{nl} represents coefficient of thermal expansion in K^{-1}, T_0 represents reference temperature in *K*, $\vec{B}$ and is magnetic induction in Wb/m^2.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

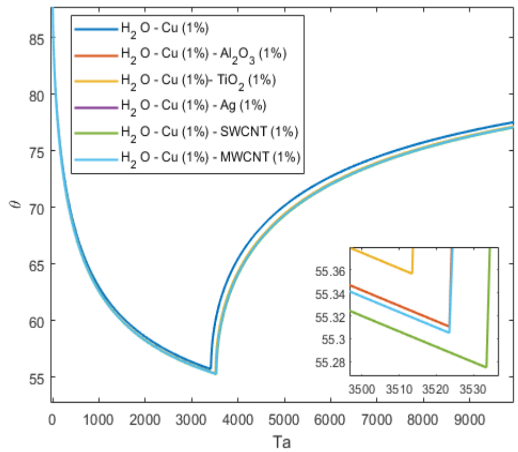

Figure 2: Plot of θ versus *Ta* for $M_1^2 = 5$ for Cu based nanofluids

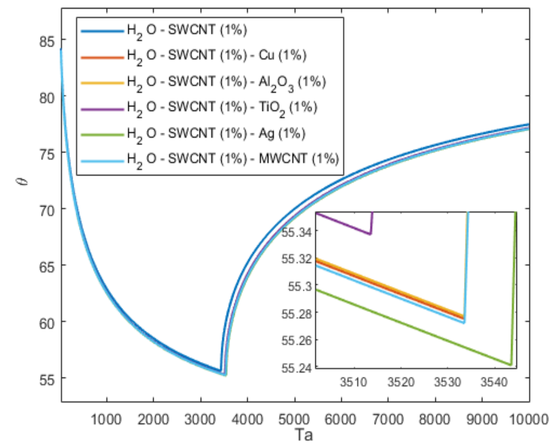

Figure 3: Plot of θ versus *Ta* for $M_1^2 = 5$ for SWCNT based nanofluids

CONCLUSION:

1. The comparison of weakly electrically conducting mono and hybrid nanofluids in KL instability is studied.
2. Addition of mono/hybrid nanoparticles advances the onset of convection.
3. Among mono liquids considered critical Taylor of H_2O - SWCNT is greater and H_2O - Cu is least.
4. In the Hybrid nanofluids, H_2O - SWCNT - Ag has lower critical Taylor number and H_2O - Cu - TiO_2 has the least.
5. Increase in Hartmann number delays the onset of Küppers–Lortz instability.

REFERENCES

1. S.U.S. Choi, Enhancing Thermal Conductivity of Fluid with Nanoparticles, Developments and Applications of Non-Newtonian Flow, ASME, FED 231/MD 66 (1995) 99-105.
2. S. Witharana, I. Palabiyik, Z. Musina, Y. Ding, Stability of glycol nanofluids-The theory and experiment, Powder technology 239 (2013) 72-77
3. P.K. Das, A.K. Mallik, A.K. Santra, R. Ganguly, Synthesis and characterization of TiO2–water nanofluids with different surfactants, International Communications in Heat and Mass Transfer, 75 (2016) 341–348.
4. G. Küppers, D. Lortz, *Tr*ansition from laminar convection to thermal turbulence in a rotating fluid layer, J. Fluid Mech. 35 (03) (1969) 609–620.
5. C. Kanchana, Yi Zhao, P.G. Siddheshwar, Küppers–Lortz instability in rotating Rayleigh–Bénard convection bounded by rigid/free isothermal boundaries, Applied Mathematics and Computation, Volume 385, 2020,
6. P.G. Siddheshwar, C. Siddabasappa, D. Laroze, Küppers-Lortz instability in the rotating Brinkman-Bénard problem, Transp. Porous Med. (2020) 1–29, doi:10.1007/s11242-020-01401-4.