

HEAT TRANSFER IN NANOFLUIDS UNDER LTE & LTNE

ABSTRACT OF THESIS

Submitted to
Babasaheb Bhimrao Ambedkar University
(A Central University)

Lucknow

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SHILPEE

Enrollment No. 1713/20

Under the Supervision of

Prof. B. S. BHADAURIA

DEPARTMENT OF MATHEMATICS
SCHOOL OF PHYSICAL & DECISION SCIENCE
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ABSTRACT

Heat stored in a system or object can be thought of as the amount of energy that its molecules possess. This energy is what causes the molecules to vibrate. Heat is transferred from one object to another when they are at different temperatures, which is what creates the sensation of being hot or cold. There are three main ways that heat can be transferred: conduction, convection, and radiation.(see fig.1)

Thermal instability appears when the temperature (T_f) of the system crosses a

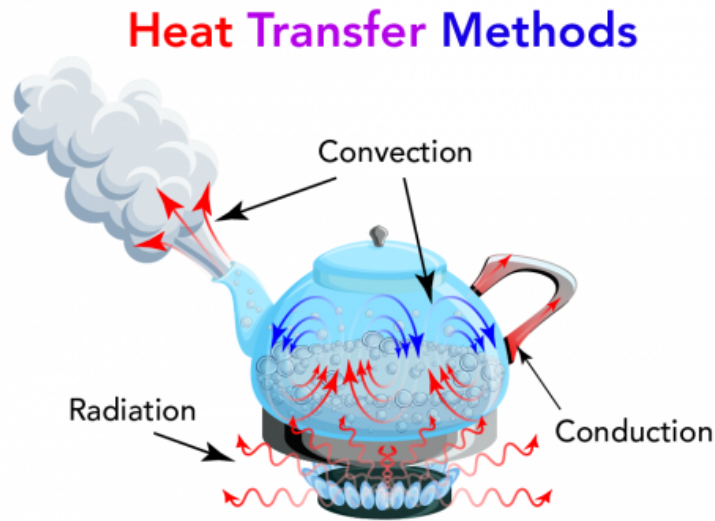


Figure 1: Modes of heat transfer

particular critical value. The temperature of the lower plate is higher than the upper plate. When the temperature across the boundaries is below the critical temperature (T_c), heat transport is due to conduction and the system is said to be *stable*. The process of convection sets in at the critical temperature, and the system is said to be *marginally stable*. Beyond the critical temperature, fully developed convection cells can be observed and the system is said to be *unstable* (Chandrashekar1961).

The objective of this thesis entitled “**HEAT TRANSFER IN NANOFUIDS UNDER LTE & LTNE**” is to investigate the heat/mass transfer in nanofluids under local thermal non equilibrium (LTNE) i.e. three different phases namely fluid, solid-matrix, and particle phases. Linear analysis is performed using normal mode

technique to analyse the onset of convection and non-linear analysis is performed using truncated Fourier series method to analyse heat/mass transfer in the considered system. Impact of various parameters like internal heating, AC electric field, gravity modulation, magnetic modulation and throughflow over convective instability is also obtained. Thermal instability of trihybrid nanofluid is studied in Hele-Shaw cell and Square enclosure. Because of enhance thermal conductivity of nanofluids it has application in many fields like engineering, industrial, energy savings, human blood circulatory system, medical applications, etc. This thesis comprises of seven chapters which are described as follows:

Chapter 1 describes the fundamental concepts and definition used in the entire thesis. The basic definition of nanofluids, their methods of preparation, mathematical models, porous medium, heat transfer, local thermal equilibrium and local thermal nonequilibrium, applications, different analytical and numerical methods used to solve the problems, literature survey, etc. are included in this chapter.

In **Chapter 2**, describes the combined effect of local thermal non equilibrium and internal heating of a micropolar nanofluid saturated in a porous medium layer. Zero flux boundaries have been taken for the analysis. Thermal difference between the nanofluid and solid matrix phase is not taken to be too high. All the three particles, fluid, and solid-matrix phases are at different temperatures i.e. a local thermal non equilibrium temperature model has been used. Gravity modulation is applied to investigate its effect on heat and mass transfer in the system. To investigate the onset of convection linear analysis and for heat/mass transfer, non-linear stability analysis have been performed respectively. It is concluded that convection in case of LTNE model advances in comparison to LTE model. In LTNE model increase in the porosity has a stabilizing effect on the system. In graph of a_c vs $\log_{N_{HS}}$, $\log_{N_{HP}}$ porosity shows opposite effect in LTNE region to the effect obtained in LTE region.

In **Chapter 3**, thermal instability of Jeffrey nanofluid is investigated under three temperature model i.e. local thermal non equilibrium. Internal heating and different gravity modulation is applied on the system to investigate the onset of convection and heat/mass transfer in the system. For gravity modulation three function namely

sinusoidal, sawtooth and day-night are used. Both linear and non-linear analysis is performed to study the onset of convection and heat/mass transfer in the system. Convection rate in LTNE (Local thermal non-equilibrium) model is earlier than rate of convection in LTE (Local-thermal equilibrium) model. Effect of rate of convection at $\varepsilon_p = 0.1$ is more earlier than convection at $\varepsilon_p = 0.4$ which is observed very near to stationary convection. Jeffrey parameter λ_3 , Internal heating Ri , enhances the stationary rate of convection. In graph of $\log N_{HP}$ vs a_c , with increase in ε_p delay in convection is observed for some time but as heat interface transfer coefficient increases convection gets earlier, while in graph of N_{HS} vs a_c increase in value of ε_p increases convection rate. Jeffrey parameter and internal heating enhances the convection in the system. On comparing the effect of three types of gravity modulation on the system day-night profile starts heat/mass transfer earlier in the system.

In **Chapter 4**, effect of internal heating/cooling in $(CuO + H_2O)$ nanofluid saturated with porous media is investigated. Different types of gravity/magnetic modulation is applied. Both linear and non-linear analysis is applied on the system to study the convection rate and heat/mass transfer in the system. In linear analysis internal heating shows destabilizing effect while internal cooling shows stabilizing behaviour. On comparing the four modulation day-night profile is found to advance heat/mass transfer in case of both gravity/magnetic modulation. On comparing the graph for four profiles of gravity and magnetic modulation, day-night profile advances in both the modulation. In non-linear analysis, in graph of Nu_{Tf} versus t , frequency and amplitude of gravity modulation delay the heat transfer while advances in Nusselt number for solid-matrix Nu_{Ts} and concentration phase Nu_ϕ respectively. In graph of Nu_{Tf} versus t amplitude of magnetic modulation delays the heat transfer while frequency of magnetic modulation advances heat transfer, whereas in Nusselt number for solid-matrix and concentration phase amplitude of magnetic modulation increases heat and mass transfer respectively.

Chapter 5 investigates the effect of throughflow in trihybrid nanofluid $(Cu + Ag + Al_2O_3)$ with (H_2O) as base fluid in Hele-Shaw cell. For trihybrid nanofluid nanoparticles of different shapes i.e. spherical, brick and cylindrical are taken. Lin-

ear and non-linear stability analysis is performed to obtain convection and heat/mass transfer in the system. The Hele-Shaw number shows the destabilizing behaviour. An increase in the concentration of different nanoparticle shows the increase in heat/mass transfer of the system. Fluid system with only alumina nanoparticles starts faster convection in linear analysis compared to the other two nanoparticles. The Hele-Shaw number (HS number) demonstrates destabilizing behavior. An increase in the concentration of nanoparticles leads to a noteworthy increase in heat and mass transfer ($Cu < Cu+Ag < Cu+Ag+Al_2O_3$) of the nanoparticles. Throughflow in opposite direction shows stabilising behavior. Streamline and isotherm are obtain for heat transfer. As time process all the three states i.e, conduction state, transition state and fully convection state is obtained in the graph.

In **Chapter 6** thermal instability of Oldroyd-B nanofluid saturated with porous medium is investigated with the effect of gravity modulation and AC electric field over it. Darcy-law is considered and Oberbeck-Boussinesque approximation technique is used. Linear stability analysis is performed to check the convection rate in the system while non linear stability analysis is performed to investigate the earlier heat/mass transfer in the system. Numerical uncertainty analysis is used to obtain the Accuracy goal, Precision goal, and error using different numerical methods. Porosity shows stabilizing behaviour on the system. R_{ae} shows destabilizing behaviour in stationary convection while very nominal effect is observe in heat/mass transfer of the system.

In **Chapter 7**, comparison of heat/mass transfer in trihybrid nanofluid ($Cu/Ag/Al_2O_3$ with H_2O) in Hele-Shaw cell and Square enclosure is performed. For this nanoparticles of different shapes namely spherical, brick and cylindrical is taken. The entire system is provided with the constant Throughflow. Both linear stability analysis and non-linear stability analysis is performed. Square enclosures are found to prevail in heat and mass transfer both. Throughflow shows the destabilising behaviour. Also increase in concentration of nanoparticle increases the heat/mass transfer in the system.

The list of publications is as follows:

Journals

1. **Shilpee**, B.S. Bhadauria, “Combined effect of local thermal non-equilibrium and gravity modulation on thermal instability in micropolar nanofluid saturated porous media”. *Journal of Porous Media*, 27(2), 81-99, 2024. (IF: **2.3**)(Published)
2. **Shilpee**, B.S. Bhadauria, “Local thermal Non-equilibrium and internal heating impact on thermal instability of Jeffrey nanofluid saturated porous media under different gravity modulations”. *Journal of Nanofluids*, (IF: **1.739**)(Published)
3. **Shilpee**, B.S. Bhadauria, Awanish Kumar, Anurag Srivastava “Effect of internal heating/cooling on heat transfer using different types of gravity/magnetic modulations in ($H_2O + CuO$) nanofluid saturated with porous media”. *Numerical Heat Transfer, Part B: Fundamentals* , (IF: **1.378**)(Published)
4. **Shilpee**, B.S. Bhadauria, Anurag Srivastava “ Study of Heat/Mass transfer of Trihybrid nanofluid($Cu + Ag + Al_2O_3 + H_2O$ (base fluid)) in Hele-Shaw cell with Through-flow”. *Journal of nanofluids* (SCI indexed)(IF: **1.329**)(Published).
5. **Shilpee**, B.S. Bhadauria, Awanish Kumar “Study of heat transfer in trihybrid nanofluid ($Cu/Ag/Al_2O_3$ with H_2O) in Hele-Shaw cell and Square Enclosure with throughflow”. *Numerical Heat Transfer, Part A: Fundamentals* (SCI indexed)(IF: **1.329**) (Published).

Book Chapter

1. **Shilpee**, B.S. Bhadauria, Ismail “Gravity Modulated thermal instability in Oldroyd-B Nanofluids”. *Computational Fluid Flow and Heat transfer: Advances, Design, Control and Applications* (Book Series), (Scopus indexed) (Published)

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