CONVECTION IN NANOFLUIDS UNDER VARIOUS CONFIGURATIONS

ABSTRACT
of
THESIS

Submitted to
Babasaheb Bhimrao Ambedkar University
(A Central University)
Lucknow

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प्रज्ञा शील करुणा
ESTABLISHED 1996

for the Award of the Degree of

Doctor of Philosophy
in
APPLIED MATHEMATICS

Under the Supervision of
Prof. B. S. BHADAURIA

Research Scholar
AWANISH KUMAR
Enrollment No. 1059/17

DEPARTMENT OF APPLIED MATHEMATICS
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ABSTRACT

Nanofluid is a new type of fluid which is used for heat transfer enhancement in automobile industries, nuclear reactors, building heating, space and defence, etc. Since nanofluid is very useful in our life, therefore this is a very interesting topic for research. The researchers want to know how it will be more beneficial for us and what external effects need to be applied to nanofluids to advance the heat transfer capability. The researchers also want to know the behaviour of nanofluid in different types of enclosures because we use different shapes of instruments in our daily life. The term nanofluid was proposed by Choi in 1995; later on, many researchers worked in this area and also currently working by applying modulation, rotation, magnetic field, electric field, etc. In this thesis, our main focus is to investigate the onset of convection in different types of enclosures filled with a nanofluid under the influence of gravity modulation, throughflow, local thermal non-equilibrium condition, rotation, magnetic field, electric field, etc and the solution of the equations have been obtained by using normal mode technique, Galerkin's method, truncated Fourier series method and Runge-Kutta-Fehlberg Method(RKF-45) method. The thesis comprises seven chapter, which are describe as follows:

The **Chapter 1** is the introduction of the thesis, which contains the basic definition of matter, nanofluid, nanofluid formation, nanofluid applications, basic governing equations and a brief literature survey, etc.

In the **Chapter 2**, throughflow effect on thermal instability in a Hele Shaw cell filled with nanofluid has been studied under gravity modulation, and by performing the linear and nonlinear stability analyses. For linear stability analysis, normal mode technique has been used, while double Fourier series technique has been used for nonlinear stability analysis. Brinkman model for nanofluid has been considered, which incorporates the effect of Brownian motion along with thermophoresis. In linear analysis, it is observed that some parameters are having dual effect due to throughflow. In non-linear analysis, effects of throughflow, gravity modulation and Hele-Shaw number

play important roles in heat and mass transfer. An increment in the value of Hele-Shaw number decreases heat transfer but increases mass transfer in the system. Heat and mass transfer both increase on increasing throughflow.

In the **Chapter 3**, linear analysis was done to know about the onset of convection in the system and weakly nonlinear stability analysis was done to know about heat and mass transport in the system for both unsteady and steady case. Here we have taken temperature to be constant and nanoparticles flux to be zero at the upper and lower boundaries of the system. Normal mode technique is used for linear and truncated Fourier series method is used for nonlinear analysis, and also plot streamlines, isotherms and isohaline to visualize the conduction, convection and steady state. We found the behaviour of Hele-Shaw cell is same in the case of LTNE and local thermal equilibrium (LTE). The effect of Hele-Shaw number, interphase heat transfer coefficient, modified thermal capacity ratio, thermal diffusivity ratio, amplitude and frequency of modulation on the onset of convection, heat and mass transfer are depicted graphically. We found that the effect of LTNE can be seen only for the intermediate values of interphase heat transfer coefficient and this region is called LTNE region. We also discuss the result of thermal Nusselt number, streamlines and isothermals of fluid and particle phase for steady case and plot the graphs with respect to Hele-Shaw Rayleigh number. Rate of heat transfer for particle phase is higher than the fluid phase for both unsteady and steady state. In this research paper we find the result for both LTE and LTNE conditions with unsteady and steady cases, while in the previous study we analyzed only for LTE condition.

In the **Chapter 4**, a non-linear analysis is done to analyze the heat and mass transport in a composite nanofluid layer confined between two parallel horizontal plates, heated from below. The Nusselt number for temperature and nanoparticle concentrations is obtained as a function of time. It is observed that the suspension of two different nanoparticles in a base fluid significantly affects the heat and mass transport. We observe that the modified diffusivity ratios and the Lewis numbers for the first and second type of nanofluids only affect the mass transportation of the first and second type of nanofluids respectively.

In the **Chapter 5**, the stability analysis of tri-hybrid nanofluid is examined theoretically in the presence of three types of gravity modulation. Normal mode techniques have been carried out for linear stability analysis, and the truncated Fourier series method is used for non-linear analysis. We observe both stationary and oscillatory convection is possible in the bottom-heavy case, and the onset of convection gets delayed in stationary in comparison to oscillatory. We also observe the onset of convection is earlier in the case of top-heavy with respect to bottom-heavy. Heat and mass transport start earlier in the day-night profile in comparison to other profiles of gravity modulation. In the graph of Nusselt number, mass transfer of the first particle increases with an increase in Rn_1 value while other two concentration Rayleigh numbers(Rn_2, Rn_3) does not have any effect on first concentration Nusselt number. If we generalize the problem for n-different types of nanoparticles, then two cases may be possible (1)Top-heavy -ordinary nanofluids will be the most stabilizing case. (2)Bottom-heavy- nanofluids with n-type particles will be the most stabilizing case. The most stabilizing case is possible with the same ratio of Rn in the top-heavy, whereas the opposite result is found in the bottom-heavy.

In the **Chapter 6**, the combined effect of electric field and variable viscosity on the stability of dielectric nanofluid (CuO+ Water) within a Hele-Shaw cell is studied. The normal mode technique has been implemented for linear stability analysis and the truncated Fourier series method for nonlinear stability analysis. The effect of the Hele-Shaw number, Thermorheological parameter and alternating current(AC) electric Rayleigh number on the onset of convection and heat/mass transfer has been investigated analytically, graphically and using tables. It is observed that the effect of the Thermorheological parameter has a destabilizing effect, and the value of the parameter is always less than 2 for this study. We also found that the Hele-Shaw number has stabilizing effect, and it is always greater or equal to 1.6 for this study. The effect of AC electric Rayleigh number is destabilized. We observed that in the whole analysis, numerical results are better than analytical results.

In the **Chapter 7**, the stability analysis of Jeffrey fluid filled in Hele-Shaw cell is examined theoretically in the presence of magnetic field and rotation. We obtained that

the rotation parameter(Taylor number) directly affects the behaviour of the Hele-Shaw number and magnetic Chandrasekhar number. Here we also analyze the behaviour of two different types of Nanofluids (CuO+ Blood and Cu+ Blood) on the onset of convection and found that the onset of convection gets delayed in (Cu+ Blood) with respect to (CuO+ Blood). Heat and mass transfer in the system is analyzed by two different approaches, Mathematica NDSolve and Runge-Kutta-Fehlberg method(RKF-45), and found that the rate of heat and mass transfer is exactly the same in both cases. The Taylor number directly affects the behaviour of heat transfer and also found that the onset of convection gets advanced in Jeffrey fluid.

At last the thesis is concluded with the possible future scopes of the present work.

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1. B.S.Bhadauria, **Awanish Kumar**, Throughflow and gravity modulation effect on thermal instability in a Hele-Shaw cell saturated by nanofluid, *Journal of Porous Media*, 24(6):31-51 (2021).

2. **Awanish Kumar**, B.S.Bhadauria, Heat and mass transport in a nanofluid layer using a thermal non-equilibrium model confined within a Hele-Shaw cell under the effect of gravity modulation, *Journal of Porous Media*(Accepted).

3. **Awanish Kumar**, B.S.Bhadauria and Anurag Srivastava, Study of heat and mass transfer in a composite nanofluid layer, *Springer Proceedings in Mathematics & Statistics 410 (Book Series)*, FIAM-2021 Conference Proceedings, DOI: https://doi.org/10.1007/978-981-19-7272-0_17, 2023.

4. **Awanish Kumar**, B.S.Bhadauria and Shilpee, Instability analysis of tri-hybrid nanofluid under the influence of three types of gravity modulation, *Journal of Nanofluids* (Accepted).

Communicated/Under revision

1. **Awanish Kumar**, B.S.Bhadauria, Study the combined effect of electric field

and variable viscosity on the stability of dielectric nanofluid (CuO+ Water) within a Hele-Shaw cell (Under revision).

2. **Awanish Kumar**, B.S.Bhadauria, Effect of magnetic field on the instability of Jeffrey nanofluid (CuO+Blood and Cu+ Blood) filled in Hele-Shaw cell with rotation (Communicated).

References

Choi, S. (1995). Enhancing thermal conductivity of fluids with nanoparticles. In: Signier, D.A., Wang, H.P. (eds.) Development and Applications of Non-Newtonian flows, *ASME FED, vol. 231/MD vol. 66*, 99-105.