Numerical Investigations and Simulations on Stability Problems in Non-Newtonian Nanofluids

UGC-MRP: 43-435/2014(SR), Dated: 30/09/2015

Final Progress Report

(01-07-2015 to 30-06-2018)

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&

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ANNEXURE-IX

UNIVERSITY GRANT COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002

FINAL REPORT OF THE WORK DONE ON THE MAJOR RESEARCH PROJECT

1. Title of the Project : Numerical Investigations and Simulations on Stability Problems in Non-Newtonian Nanofluids.
2. Name and Address of the Principal Investigator : Dr.(Mrs.) Veena Sharma, Professor, Department of Mathematics and Statistics, Himachal Pradesh University, Shimla-171 005 (H.P.) INDIA
3. Name and Address of the Institution: Himachal Pradesh University, Summerhill, Shimla-171 005, Himachal Pradesh, INDIA.
4. UGC Approval Letter No and Date : 43-435/2014(SR) Dated : 30th SEPTEMBER, 2015.
5. Date of Implementation: 01/07/2015.
6. Tenure of the Project: **Three Years.**
7. Total Grant Allocated: **Rs. 11,58,000/- (Rupees Eleven Lakhs and Fifty-eight Thousand only).**
8. Total Grant Received: **9,35,700/-**
9. Final Expenditure: **8,88,095/-**
10. Title of the Project: Numerical Investigations and Simulations on Stability Problems in Non-Newtonian Nanofluids.
11. Objectives of the Project: ANNEXURE-A
12. Whether Objectives were achieved: Yes. All the objectives of the Project have been achieved.
13. Achievements from the Project:
    - (i) One Project Fellow, Ms. Anuradha Chowdhary was appointed through proper procedure mentioned by the UGC- New Delhi.
    - (ii) The work done in the project has been published in National/International Journals of repute. Two papers are communicated and few manuscripts on Thermal Instability of non-Newtonian nanofluids under various parameters, separately and simultaneously, are under preparation for the publication in the Journals of repute.
    - (iii) The Project Fellow appointed in the project has been exposed to various scientific techniques related to the requirements of the work being done in the project.

14. Summary of the Findings: ANNEXURE-B
15. Contribution to the Society: ANNEXURE-C

16. Whether any Ph.D. enrolled/ Produced out of the Project: NO. However, the following three students have been awarded the Ph.D. Degree during this period:

1.	Renu Kumari	Awarded in 2016	Linear Stability Problems in Newtonian and Non-Newtonian Fluids

2.	Shaloo Devi	Awarded in 2018	Elastodynamic Problems in Modified Couple Stress Thermoelastic Media
3.	Radhe Shyam	Awarded in 2015	On Some Problems in Newtonian and Non-Newtonian Fluids in Porous Medium

17. **No. of Publications out of the Project**: **02**.
In addition to this, there are **06** more papers published during this project.
(See **ANNEXURE-D** for list of publications)

Veena Sharma
04.03.2019
(PRINCIPAL INVESTIGATOR)
Prof. Veena Sharma
(Principal Investigator)

Urvashi Gupta

(CO-INVESTIGATOR)

26/3/2019
(REGISTRAR/PRINCIPAL)
Registrar
H.P. University
Shimla-171005
(Seal)

ANNEXURE -A

Objectives

Nanofluids are mixtures of a regular fluid (base fluid) with a very small suspended metallic or metallic oxides of nitrides, sulphides) nanoparticles or nanotubes in the range of 1 to 100 nm, coined by Choi (1995). Rayleigh- Benard convection (Thermal instability) was studied first theoretically by Pellew and South well for classical Newtonian fluids in which the establishment of the non-occurrence of any slow oscillatory motions which may be neutral or unstable implies that validity of the principle of exchange of stabilities (PES) is proved. However, no such results existed for other more hydrodynamic configurations. The same research problem for classical Newtonian nanofluids was studied by Dhananjay Aggarwal and Bhargava and extensions were studied by many authors under different parameters analytically and numerically satisfying some conditions for oscillatory motions.

Surprisingly a large amount of literature was available on the viscous and Newtonian nanofluids. However, only a limited attention had been given to the study of non-Newtonian nanofluids. There are two major reasons responsible for this. The main reason is that the additional nonlinear terms arising in the equations of motion rendering the problem more difficult to solve. The second is that a universal non -Newtonian constitutive relation that can be used for all fluids and flows are not available. The oscillatory instability can set in before a stationary mode is achieved due to the inherence of the clastic behaviour in non- Newtonian regular fluids or nanofluids. It is found that the oscillatory motion is not possible in viscoelastic fluids under realistic experimental conditions. However, experiments with a DNA suspension showed that convection patterns take the form of spatially localized standing and travelling waves which exhibit small amplitudes and extremely long oscillation periods.

Therefore, the objectives of this research project was to promote the thermal instability investigations by solving the relevant governing partial differential equations defining any physical problem comprising of incompressible, viscous, viscoelastic nanofluids analytically as well as numerically, which are extensions of Benard Convection (1916). Viscoelastic nanofluids fall in the category of non-Newtonian nanofluids. The rheology of nanofluids can be described by a variety of models and is derived from the constitutive relations suitably modified. Some of these non-Newtonian models are proposed by Maxwell (1866) Rivlin-Ericksen (1955), Walters' (1962), Oldroyd (1958), Jeffrey and many others due to their diverse applications in various industries viz. (food processing, nuclear paints, physiology, biomechanics chemical and process engineering including coaxial mixtures, blood oxygenators, milk processing, steady state tabular reactors, dissolution processes etc.).

The research work done under this project was focussed on the rheological models proposed by Maxwell (1866) to include the effect of various parameters on the stationary as well as oscillatory modes of the perturbations applied due to the triggered new interest from experiments by applying fluid binary aspects to viscoelastic nanofluids.

ANNEXURE-B

Summary of the findings

Non-Newtonian nanofluids are unique colloidal suspensions in a non-Newtonian (viscoelastic) base liquid like polymer solutions. The viscoelastic nanofluids falls in the category of non-Newtonian Nanofluids. Due to the features of nanoparticles like suspension for much longer time, a much high surface area and 1000 times larger surface/volume ratio of nanoparticles than that of micro particles. The high surface area of nanoparticles enhances the heat conduction of nanofluids, since heat transfer occurs on the surface of the particles. The number of atoms present on the surface of nanoparticles, as opposed to the interior, is very large which may reduce erosion and clogging. These specific properties of nanoparticles help to develop stable and high thermal conductivity heat transfer fluids. Stable suspension of small quantities of tiny particles makes conventional heat transfer fluids cool faster and thermal management system smaller and lighter. The study of non-Newtonian fluids has many applications in various industries, such as oil recovery, food processing, spread of contaminants in the environment, nuclear paints, physiology, biomechanics, chemical and process engineering including coaxial mixtures, blood oxygenators, milk processing, steady-state tabular reactors and capillary column inverse gas chromatography devices, mixing mechanisms, bubble drop formation processes, dissolution processes and cloud transport phenomena, and technology. Since elastic behavior is inherent in non-Newtonian fluids, the oscillatory instability can set in before a stationary mode is achieved due to the inherence of the elastic behavior in non-Newtonian fluids. It is found that oscillatory motion is not possible in viscoelastic fluids under realistic experimental conditions. However, experiments with a DNA suspension showed that convection patterns take the form of spatially localized standing and traveling waves which exhibit small amplitudes and extremely long oscillation periods. New interest has been triggered from experiments by applying binary aspects to viscoelastic fluids.

We have studied some thermal stability problems in non-Newtonian fluids by applying various rheological models relevant to the research project. These are listed and explained in essence as follows:

1. **Veena Sharma, Anuradha Chowdhary and Urvashi Gupta, "Electrothermal convection in dielectric Maxwellian nanofluid layer'. Journal of Applied Fluid Mechanics, Vol. 11, No. 3, pp. 765-777, 2018 (Manuscript attached).**

   The influence of rheology behaviour on the natural convection in a dielectric nanofluid with vertical AC electric field is investigated. The rheology of the nanofluid is described by the Maxwell model for calculating the shear stresses from the velocity gradients. The employed model introduces the combined effects of movement of the molecules of the fluid striking the nanoparticles, thermophoresis and electrophoresis due to embedded nanoparticles. The exact solutions of the eigen model value problem for stress-free bounding surfaces are obtained analytically using one term Galerkin method to find the thermal Rayleigh number for onset of both non-oscillatory (stationary) and oscillatory motions. It is found that the oscillatory modes are possible for both bottom and top-heavy distributions of nanoparticles. It is observed that the value of critical Rayleigh number is decreased by a substantial amount with the increase in electric field intensity; whereas role of viscoelasticity (time relaxation parameter) is to hasten the occurrence of oscillatory modes appreciably. The thermal Prandtl number is found to delay the occurrence of oscillatory modes. These results are shown graphically.

2. **Veena Sharma, Anuradha Chowdhary, Urvashi Gupta and Abhishek Sharma, "Electro-Hydrodynamics Convection in Dielectric Rotating Maxwellian Nanofluid Layer", Journal of Nanofluids, Vol. 8, pp. 1-13, 2019, American Scientific Publishers (Manuscript attached**).
   The influence of rotation on the criterion of natural convection in a dielectric rheological nanofluid with vertical AC electric field has been investigated for stress free boundaries. The rheology of the nanofluid is described by Maxwell model for calculating the shear stresses from the velocity gradients. The employed model introduces the combined effects of movement of the molecules of the fluid striking the nanoparticles, thermophoresis, electrophoresis, Coriolis forces and angular velocity of nanofluid due to embedded nanoparticles. The exact solutions of the eigen model value problem for stress-free bounding surfaces are obtained analytically using one term Galerkin method to find the thermal Rayleigh number for onset of both non-oscillatory (stationary) and oscillatory motions. It has been observed that the rotation parameter make the system more stable since the critical Rayleigh number increases appreciably with variation in the Coriolis force parameter. It is found that the oscillatory modes are possible for both the bottom heavy/top-heavy distributions of nanoparticles with various values of the stress-relaxation time parameter. It is observed that the value of thermal Rayleigh number is decreased by a substantial amount with the increase in electric field intensity; whereas role of viscoelasticity (time relaxation parameter) is to hasten the occurrence of oscillatory modes. The stabilizing and destabilizing effect of electric Rayleigh number, stress relaxation parameter, thermal Prandtl number, Lewis number, thermal diffusivity ratio and concentration Rayleigh number under certain wave number bands have been discussed and shown graphically.

ANNEXURE -C

Contribution to the society

Nanofluids find diverse applications in developing an advanced cooling technique to cool crystal silicon mirrors used in high intensity X- ray sources (the thermal resistance of a disc shaped miniature heat pipe is reduced up to 40% in nanofluids) transfer cooling, cancer therapy etc.

Due to the increasing relevance and importance of non-Newtonian nanofluids now-a-days in tribological technology to develop better oil and lubricants, in biomedical sciences in which iron-based nanoparticles are being used as delivery vehicles drug or radiation without damaging nearby healthy tissue by guiding the particles up the bloodstream to a tumor with magnets. Moreover, there exits wide and unlimited areas of applications open for exploration. Therefore, the work done in this project will provide an up-to-date information to wide range of experts working in these above-mentioned fields.

ANNEXURE -D

(a) List of Publications

1. Gian Chand Rana, Ramesh Chand and Veena Sharma, “Stability analysis of double-diffusive convection in a couple stress nanofluid” Technische Mechanik, Vol. 38, No. 3, 246-255 (2018) (Manuscript Attached).
2. Jyoti Sharma, Urvashi Gupta and Veena Sharma, “Modified model for binary nanofluid convection with initial constant nanoparticle volume fraction”, Journal of Applied Fluid Mechanics, Vol.10 (5), 1387-1395, (2017) (Manuscript Attached).
3. Veena Sharma**,** Ashwini Kumar, Abhilasha and Abhishek Sharma, “Numerical Investigations of Electro-Thermal Convection in Dielectric Nanofluid Layer” Research Journal of Science and Technology; 9(1):184-188 (2017) (Manuscript Attached).
4. Gian Chand Rana, Ramesh Chand, Veena Sharma and Abhilasha Sharda**,** “On the onset of Triple-Diffusive Convection in a layer of nanofluid” Journal of Computational Applied Mechanics (JCAMECH), Vol. 47, No. 1, 67-77, (2016) (Manuscript Attached).
5. Urvarshi Gupta, Jyoti Sharma and Veena Sharma, “Instabilty of binary nanofluids with magnetic field” Applied Mathematics and Mechanics – Engl. Ed., Vol. 36 (6), 693-706 (2015) (Manuscript Attached).
6. Veena Sharma and Renu Kumari, “Overstable Convection in rotating viscoelastic nanofluid layer by a Darcy-Brinkman porous medium embedded by dust particles” Journal of Rajasthan Academy of Physical Sciences Vol.14, No. 3&4 ,295-308 (2015) (Manuscript Attached).

(b) Papers Communicated for Publication

1. Veena Sharma, Shweta, Anuradha Chowdhary and Urvashi Gupta, “Thermal Instability of Jeffrey Nanofluid layer saturating a porous medium”, (Journal of Porous Medium, USA).

2. Veena Sharma, Sumna Devi, Anuradha Chowdhary and Urvashi Gupta, “Onset of Electrothermal convection in Maxwellian Dielectric Nanofluid layer saturating porous medium”.