Linear Stability Analysis of Ferrofluids in Porous and Non porous Medium

Final Progress Report
(01-07-2015 to 30-06-2018)

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FINAL REPORT OF THE WORK DONE ON THE MAJOR RESEARCH PROJECT
1. Title of the Project: Linear Stability Analysis of Ferrofluids in Porous and Non Porous Medium
2. Name and Address of the Principal Investigator: Dr. JYOTI PRAKASH, Professor, Department of Mathematics and Statistics, Himachal Pradesh University, Shimla-171005 (H.P.)
3. Name and Address of the Institution: Himachal Pradesh University, Summerhill, Shimla-171005
5. Date of Implementation: 01/07/2015.
6. Tenure of the Project: Three Years.
7. Total Grant Allocated: Rs. 10,90,000/- (Rupees Ten Lakhs and Ninety Thousand only)
8. Total Grant Received: 7,70,379/-
9. Final Expenditure: 7,13,345/-
10. Title of the Project: Linear Stability Analysis of Ferrofluids in Porous and Non Porous Medium
11. Objectives of the Project: See Annexure-A
12. Whether Objectives were achieved: Yes. All the objectives of the Project has been achieved.
13. Achievements from the Project:
   (i) Two Project Fellows were appointed subsequently. First Project Fellow, Miss Kultaran Kumari got regular job in between the project, so she resigned. Then new Project Fellow, Mr. Pankaj Kumar was appointed. Both the Project fellows working on the project are already registered for the Ph.D. with the Principle Investigator. The Ph. D. degree will be awarded to the Project fellows on the basis of the work done in the project. Mr. Pankaj Kumar has submitted the Ph. D. thesis and final thesis written work of Miss Kultaran Kumari is in progress.
   (ii) The work done in the project has been published (five papers) in National/International journals of repute. Two papers are communicated and few manuscripts on ferroconvection and double diffusive ferroconvection are under preparation for the publication in the journals of repute.
   (iii) The Project Fellows 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: See Annexure-B
15. Contribution to the Society: See Annexure-C
16. Whether any Ph.D. enrolled/Produced out of the Project: Yes.
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<th>Name</th>
<th>Status</th>
<th>Research Topic</th>
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<td>1.</td>
<td>Shweta Manan</td>
<td>Awarded In 2017</td>
<td>On Some Stability Problems In Triply/Multi Diffusive Convection And Ferromagnetic Convection In Porous And Non-Porous Medium</td>
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<td></td>
<td>(Project Fellow-II)</td>
<td>(Regd. in 2016)</td>
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<td>3.</td>
<td>Kultaran Kumari</td>
<td>Synopsis approved. Thesis writing work is in progress (Regd. in June-2014)</td>
<td>ON Some Instability Problems In Triply Diffusive, Ferromagnetic And Double Diffusive Binary Viscoelastic Fluids Configurations In Porous And Non Porous Medium</td>
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<td>(Project Fellow-I)</td>
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17. No. of Publications out of the Project: 05.
In addition to this there are 07 more papers in which the financial aid of the project has been acknowledged.
(See Annexure-D for list of publications)
ANNEXURE – A

OBJECTIVES

Banerjee et al. (1981) formulated a noble way of combining the governing equations and boundary conditions for double diffusive convection problem so that a semicircle theorem is derivable and which in turn yields the desire bounds. They also used this technique to derive sufficient conditions for the validity of ‘the principle of the exchange of stabilities’ in different hydrodynamic and hydromagnetic stability problems. Banerjee et al.’s technique together with its appropriate modifications to suit applications in our problems has been used to handle more complex problems in ferromagnetic convection. Since some result involve Rayleigh number which is an eigenvalue, therefore some numerical calculations has also been performed by using software Scientific Work Place.

This research will provide the up-to-date information to wide range of fluid professional, including mechanical, chemical, nuclear and aeronautical and civil as well as physicists and mathematicians interested in fluid dynamics and transport phenomenon.

References

ANNEXURE-B

SUMMARY OF THE FINDINGS

Ferrofluids (also known as magnetic fluids) are unique colloidal suspensions of magnetic nanoparticles which are coated with a surfactant in an organic or non-organic carrier liquid like water, kerosene, hydrocarbon etc. The surfactant prevents particle agglomeration. The nature of the surfactant, the carrier liquid and magnetic particle size are the determining parameters for the stability of magnetic fluids. Due to high magnetization and liquidity, magnetic fluids have vast applications e.g. liquid cooled loud speakers, energy conversion devices, novel-zero leakage, rotary shaft seals used in computer disc drives, liquid sealing in chemical and biochemical reactors and medical sciences (drug targeting, endoscopic analysis, magnetic separation of cell and magnetic resonance imaging (MRI))(Rosensweig (1985), Odenbach (2002)).

We have studied some stability problems in ferromagnetic convection relevant to the project which have been published in National/ International Journals of repute. The work done has been listed and explained in essence as follows:


   In this paper it is proved analytically that the complex growth rate \( \omega = \omega_r + i\omega_i \) (\( \omega_r \) and \( \omega_i \) are respectively the real and imaginary parts of \( \omega \)) of an arbitrary oscillatory motion of growing amplitude in ferromagnetic convection, with magnetic field dependent viscosity, in a rotating sparsely distributed porous medium for the case of free boundaries, must lies inside a semicircle in the right half of the \( \omega_r,\omega_i \) - plane whose centre is at the origin and \( (radius)^2 = \) greater of \( \left\{ \frac{RM_1}{Pr},\, T_a \right\} \), where \( R \) is the Rayleigh number, \( M_1 \) is the magnetic number, \( Pr \) is the Prandtl number and \( T_a \) is the taylor number. Further, bounds for the case of rigid boundaries are also derived separately.

In this paper the effect of magnetic field dependent (MFD) viscosity on the thermal convection in a ferromagnetic fluid in the presence of a uniform vertical magnetic field has been studied for a fluid layer saturating a sparsely distributed porous medium by using Darcy Brinkman model. A correction is applied to Vaidyanathan et al. (Ind. J. Pure Appl. Phys., 40(3), (2002), 166) which is very important in order to predict the correct behavior of MFD viscosity. A linear stability analysis has been carried out for stationary modes. The critical wave number and critical Rayleigh number for the onset of instability, for the case of free boundaries, are determined numerically for sufficiently large values of the magnetic parameter $M_1$. Numerical results are obtained and are illustrated graphically. It is shown that magnetic field dependent viscosity has stabilizing effect on the system, whereas medium permeability has a destabilizing effect.


In this paper ferromagnetic convection in a rotating porous medium has been studied by using Darcy-Brinkman model. It is proved that the complex growth rate $\omega = \omega_r + i\omega_i$ ($\omega_r$ and $\omega_i$ are respectively the real and imaginary parts of $\omega$) of an arbitrary oscillatory motion of growing amplitude in ferromagnetic convection, in a rotating sparsely distributed porous medium for the case of free boundaries, must lies inside a semicircle in the right half of the $\omega_r, \omega_i$ - plane whose centre is at the origin and $(radius)^2 = \text{greater of} \left\{ \frac{RM_1}{P_r}, T_a \right\}$, where R is the Rayleigh number, $M_1$ is the magnetic number, $P_r$ is the Prandtl number and $T_a$ is the Taylor number. Further, bounds for the case of rigid boundaries are also derived separately.


In this paper the effect of magnetic field dependent (MFD) viscosity on thermal convection in a horizontal ferromagnetic fluid layer has been investigated numerically. A correction is applied to Sunil et al. (Chem. Eng. Comm., 195(2008), 571) which is very important in order to predict the correct behavior of MFD viscosity. Linear stability analysis has been carried out for stationary convection. $\delta$, the MFD viscosity parameter as well as $M_3$, the measure of nonlinearity of magnetization both have stabilizing effect on the system. Numerical results are also obtained for large values of magnetic parameter $M_1$ and predicted graphically.

In this paper the effect of magnetic field dependent (MFD) viscosity on the thermal convection in a ferromagnetic fluid in the presence of a uniform vertical magnetic field has been investigated for a fluid layer saturating a densely packed porous medium by using Darcy model. A correction is applied to Sunil et al. (*Z. Naturforsch*. **59**, 397 (2004)), wherein they have resolved the MFD viscosity into components along the coordinate axes which is not correct since viscosity, being a scalar quantity, cannot be resolved in such a manner. So this correction is very important in order to predict the correct behaviour of MFD viscosity. A linear stability analysis has been carried out for stationary modes. The critical wave number and critical Rayleigh number for the onset of instability, for the case of free boundaries, are determined numerically for sufficiently large values of the magnetic parameter $M_1$. Numerical results are obtained and are illustrated graphically. It is shown that magnetic field dependent viscosity has stabilizing effect on the system, whereas medium permeability has a destabilizing effect.
Annexure-C

Contribution to the Society

Ferrofluids have several applications in mechanical engineering, analytical instrumentation, heat transfer, electronic devices, pressure seals for compressors and blowers, aerospace etc. and are widely used in rotating X-ray tubes, sealing of computer hard disk drives and high-speed, inexpensive, noiseless printing systems. Ferrofluids are also used as lubricants in bearing and dumpers. In medical sciences these are used in drug target ring, endoscopic analysis, magnetic separation of cells and Magnetic Resonance Imaging (MRI).

Ferrofluids are also used in liquid cooled loudspeakers that employ mere drops of ferrofluids to conduct heat away from the speaker coils. Magnetic field can pilot the path of a drop of ferrofluid in the body, bringing drugs to a target site and ferrofluid serves as a tracer of blood flow in noninvasive circulatory measurements. Ferrofluids are also used in the industries to separate mixtures of industrial scrap metals such as titanium, aluminium and zinc and also used to sort diamonds. Moreover, there exist wide and unlimited areas of application open for exploration. The work done in the project will provide an up-to-date information to wide range of fluid professional working in the above mentioned areas.
LIST OF PUBLICATIONS

(a)  

(b)  
**Papers Communicated for Publication**


In addition to the above publications there are 07 more papers in which the financial aid of the project has been acknowledged. These are as follows:


