A note on Onset of Benard – Marangoni ferroconvection

Meghashree G R

Assistant Professor ,Mathematics Department ,New horizon college of Engineering ,Marathalli outer ring Road,Bangalore,560103

Abstract

A review has been done on an onset of Benard – Marangoni ferroconvection in the presence of magnetic field viscosity, temperature dependent viscosity, internal heat generation and Coriolis force in a rotating ferrofluid layer with MFD Viscosity.

Key words

Benard – Marangoni ferroconvection, Magnetic field Viscosity ^{A} *, internal heat generation parameter* N_s *, temperature dependent viscosity B, coriolis force* $\aleph$*, Biot number* B_i*, non-linearity of fluid magnetization* M_3*, Magnetic number* M_1*, Taylors number Ta.*

I. INTRODUCTION

Heat transfer in a medium can be done by three ways Conduction, Convection and Radiation. Convection is known to be heat transfer method in fluids. In particular a ferrofluid is a liquid that becomes strongly magnetized in the presence of external magnetic field. Ferrofluids are colloidal liquid made of nanoscale ferromagnetic particles suspended in a carrier fluid which are non-conducting in nature like heptanes, kerosene water etc. The ferrofluid is a type of functional fluid whose flow and energy transport is controlled by external magnetic field due to its property it as variety of application in various fields Bio medical, Electronic packing, Mechanical engineering, aerospace and thermal engineering. Ferrofluids usually do not retain magnetization in the absence of an externally applied field. The magnetization of ferromagnetic fluids depends on the magnetic field, temperature and the density of the fluid. Any variation in these quantities can induce a change in body force distribution which leads to convection in the presence of magnetic field gradient known as ferroconvection. Convection can be induced if surface tension forces are the function of temperature. In accordance to that if the ferrofluid layer has an upper surface open to atmosphere then the instability is due to the combined effects of the buoyancy as well temperature dependent surface tension forces known as Benard – Marangoni ferroconvection.

II. ANALYSIS

BENARD – MARANGONI FERROCONVECTION WITH MAGNETIC FIELD DEPENDENT VISCOSITY

One of the astonishing physical properties of thermal convection in ferromagnetic fluid is the viscosity of the ferromagnetic fluid. The viscosity of the ferromagnetic fluid is predicted by dimensionless analysis of a function of hydrodynamic stress to magnetic stress. The magnetic field dependent viscosity in the study of Benard – Marangoni ferroconvection helps in understanding the control of ferroconvection which is useful in many heat transfer problems .The Benard – Marangoni ferroconvection with magnetic field dependent viscosity are dependent upon the parameters Ma, Ra, R_m, M_3, B_i, and ^{A} which has its influence on Benard – Marangoni ferroconvection. The magnetic field dependent viscosity is predominant variable where the above parameter depends on. Through the study of Benard – Marangoni ferroconvection reveals that M_{a_c} and R_{a_c} as a strong coupling between each other and further increase in the critical rayliegh number R_{a_c} as a destabilizing effect on the system indicating that if surface tension force is predominant than the buoyancy force is negligible and vice-versa. And as magnetic field dependent viscosity increases, M_{a_c} and R_{a_c} also increases indicating the effect of stability on the system with increase in both parameters M_{a_c}, $R_{a_c}$and magnetic field dependent viscosity. Thus the onset of Benard – Marangoni ferroconvection is delayed with increasing magnetic field dependent viscosity. Further by increasing B_i at the top free surface leads to a better heat transfer makes the system more stable and hence delays the onset of Benard – Marangoni ferroconvection. In the case only when buoyancy force is an effect mean M_1=0. Further the system becomes unstable when the destabilizing magnetic force $M_1 \neq 0$. Ferrofluids acquire larger magnetization due to increase in the non-linearity parameter M_3 which in turn reacts with smaller temperature gradient and advance the Benard – Marangoni ferroconvection. With the increase in magnetic field dependent viscosity, which is the predominant variable where $R_m, M_3, and\ B_i$ depends on and results in the delay of onset of Benard – Marangoni ferroconvection and the width of convection cells decreases with further increase of $R_m, M_3, and\ B_i$.

BENARD – MARANGONI FERROCONVECTION WITH TEMPERATURE DEPENDENT VISCOSITY

The study says the effect of temperature dependent viscosity on the onset of Benard – Marangoni ferroconvection under microgravity conditions in a horizontal ferrofluid layer in the

presence of a uniform vertical magnetic field.Where the lower rigid surface and the upper horizontal free boundaries are considered to be perfectly insulated to temperature perturbation. Viscosity varies analytically with temperature. The results thus obtained is dependent on the M_{a_c}, R_{m_c}, B, M_3.The stability of the system in the onset of Benard – Marangoni ferroconvection is strongly influenced by the presence of the predominant variable temperature dependent viscosity B where the presence of non-linearity magnetization parameter M_3 as no effect on the system. In the absence of temperature dependent viscosity B or B=0 the R_{m_c} attains the maximum value and further decreases with increase of temperature dependent viscosity $B \neq 0$ indicating the less effect of viscosity with temperature use to hasten the onset of Benard – Marangoni ferroconvection because of increase in destabilizing surface tension force use to advance the onset of ferroconvection. There exists a strong influence on the onset of Benard – Marangoni ferroconvection as the $M_{a_c}$is considered as a function of temperature dependent viscosity B as a results it leads to a dual effect $R_m = 0$ ($R_m = 0$ corresponds the ordinary viscous fluid). That is M_{a_c} T attains its maximum value initially with B and further decreases with increasing value of B and the same continuous with increasing values of R_m as the destabilizing magnetic field increases and results in hasten the onset of Benard – Marangoni ferroconvection. Thus their exists both stabilizing and destabilizing influence on the onset of Benard – Marangoni ferroconvection. That is initial increases in B shows stability effect and results in destabilizing effect with further increase in B. In the absence of surface tension forces results in destabilizing effect and $M_{a_c} < R_{m_c}$ up to some values of B and with further increase in temperature dependent viscosity B results in coalescing of M_{a_c} and R_{m_c}.

BENARD – MARANGONI FERROCONVECTION WITH INTERNAL HEAT GENERATION

The study helps to understand the control of Benard – Marangoni ferroconvection affected by non-uniform temperature gradient that arises due to internal heating in the presence of combined buoyancy and surface tension forces driven in a horizontal layer of ferrofluid. In which lower rigid surface and upper free boundary at which the temperature dependent surface tension forces are accounted are considered to be perfectly insulated to temperature perturbation. The results thus obtained by the study reveals that there exists a large deviation in the basic temperature distribution due to the increase in the dimensionless internal heat source strength N_s leading to temperature disturbance in fluid to hasten the onset of ferroconvection. The increase in $N_s$with decrease of both M_{a_c} and R_{m_c} indicates their exits the non-linear temperature distribution of heat sources thus it is to advance the onset of ferroconvection. Further the increase in destabilizing magnetic force hastens the onset of ferroconvection due to increased value of $M_1$and decreased value of R_{t_c}. Thus the increasing N_s is to drive the flow with more vigour and thus is to hasten the onset of ferroconvection.

EFFECT OF CORIOLIS FORCE ON BENARD – MARANGONI CONVECTION IN A ROTATING FERROFLUID LAYER WITH MFD VISCOSITY

All ferrofliuds possesses a MFD Viscosity, the rotation of the fluid is due to increase in the viscous dissipation of the applied magnetic field. The study was done to know the effect of coriolis, buoyancy, magnetic and surface tension forces on the linear stability of ferroconvection under the influence of MFD Viscosity. Further it was based on the stability analysis of the influence of rotation and MFD Viscosity on Benard – Marangoni ferroconvection in a rotating ferrofluid layer where the lower boundary is rigid, while the upper free boundary is open to the atmosphere at which the temperature dependent surface tension effect is considered. As mentioned above a tight coupling exists between buoyancy, surface tension, magnetic and coriolis force that is R_{t_c}, M_{a_c}, R_{m_c}, M_3, B_i and M_1 for different values of Taylors number Ta, . with a increasing M_3, R_{m_c}decreases but only marginally and thus results in destabilizing effect on the stability of the system because larger magnetization interacts with the imposed magnetic field and releases more energy to drive the flow faster, thus the system becomes unstable with a smaller temperature gradient and with the increasing values of M_3 increases the presence of coriolis force due to rotation is to suppress the Benard – Marangoni ferroconvection .The thermal disturbances can easily dissipate into the surrounding with increasing B_i and higher heating is required to make the system unstable. The region of stability decrease with the increase in M_1 and M_3 and N with decreasing B_i A and Ta. The heat transfer is done more efficiently with increase in M_1 alone with M_3 constant. And on the other when M_3 increases R_{m_c} decreases and the results reduces to the class of Benard – Marangoni ferroconvection of ordinary viscous fluid. The resistive type force arises with increase in the MFD Viscosity, R_{t_c} and M_{a_c} slows down motion of the fluid thus decreasing the heat transfer. This decrease in the heat transfer delays the onset of Benard – Marangoni ferroconvection.

III. CONCLUSION

Onset of Benard – Marangoni ferroconvection in the presence of magnetic field viscosity, temperature dependent viscosity, internal heat generation and Coriolis force in a rotating ferrofluid layer with MFD Viscosity is discussed that the presence of the above parameter stabilizes or destabilizes the System by considering the critical values of various parameters that is to hasten the onset of ferroconvection.

IV. REFERENCES

1) Vidal, A., Acrivos, A.: The influence of Coriolis force on surface tension driven convection. J. Fluid Mech. 26, 807–818 (1966)

2) Finlayson, B.A.: Convective instability of ferromagnetic fluids. J. Fluid Mech. 40(4), 753–767 (1970)

3) Shliomis, M.I.: Magnetic fluids. Soviet Phys. Uspekhi (Engl Trans.) 17, 153–169 (1974)

4) Gotoh, K., Yamada, M.: Thermal convection in a horizontal layer of magnetic fluids. J. Phys. Soc. Jpn. 51, 3042–3048 (1982)

5) Rosensweig, R.E.: Ferro hydrodynamics. Cambridge University Press, New York (1985)

6) Odenbach, S.: On the stability of a free surface of a magnetic fluid under microgravity. J. Magn. Magn. Mater. 170, 309–316 (1997)

7) Auernhammer, G.K., Brand, H.R.: Thermal convection in a rotating Layer of a magnetic fluid. The European Phys. J. B 16, 157–168 (2000)

8) Vaidyanathan, G., Sekar, R., Ramanathan, A.: Effect of magnetic field dependent viscosity on ferroconvection in rotating medium Indian. J. Pure Applied Phys. 40, 159–165 (2002)

9) Shima, P.D., Philip, J., Raj, B.: Magnetically controllable nanofluid with tunable thermal conductivity and viscosity. Appl. Phys. Letts. 95, 1331121-3 (2009)

10) Nanjundappa, C.E., Shiva kumara, I.S., Arunkumar, R.: Bénard– \Marangoni ferroconvection with magnetic field dependent viscosity. J. Magn. Magn. Mater. 322, 2256–2263 (2010)

11) Nanjundappa, C.E., Shivakumara, I.S., Arunkumar, R.: Onset of Bénard-Marangoni ferroconvection with internal heat generation. Microgravity Sci. Technol. 23, 29–39 (2011)

12) Nanjundappa, C.E., Shivakumara, I.S., Arunkumar, R.: Onset of Marangoni–Bénard ferroconvection with temperature dependent Viscosity. Microgravity Sci. Technol. 25, 103–112 (2013a)

13) Shivakumara, I.S., Rudraiah, N., Nanjundappa, C.E.: Effect of Coriolis force on the Bénard–Marangoni convection in a rotating Ferrofluid layer with MFD Viscosity. Microgravity Sci. Technol. 27, 27-37(2014)