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Effect of throughflow and magnetic field on Marangoni convection in micro-polar fluids

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Abstract

The effect of throughflow and uniform magnetic field on the onset of Marangoni convection in a horizontal layer of micro-polar fluid bounded below by a rigid isothermal surface and above by a non-deformable free adiabatic surface, for marginal state is studied. The conditions for the onset of instability occurring via stationary convective modes are obtained with the help of Galerkin method. It is observed that both stabilizing and destabilizing factors due to constant vertical throughflow can be enhanced by magnetic field.

Keywords: Throughflow; Magnetic field; Marangoni convection; Micro-polar fluid

1. Introduction

Surface tension plays a major role in micro-gravity environment and new impetus in analyzing its influence on material processing stems from space

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programme. Although the micro-gravity environment reduces the convection driven by buoyancy force, the free surface of liquid may generate convective flows or unstable cellular flows. The convective phenomena arising due to non-uniformities in surface tension is known as Marangoni convection.

Metal melting experiments in SKYLAB gave evidence of surface tension driven convection. It is speculated that the Marangoni flow will be of great importance in micro-gravity experiments in view of the solidification processes taking place in moulton zones with strong temperature gradients.

Marangoni convection is suppressed to make decisive effect on crystal growth in space. This has been an active area of research in recent years. Convection could be controlled either by external constraints like Lorentz force due to electro-magnetic field and Coriolis force due to rotation or by non-uniform temperature gradient due to transient heating or cooling at the boundaries. These forces are less effective at the terrestrial environment, but become more effective in the micro-gravity environment. Such forces may be used to suppress or augment convection. Several authors [1–10] discussed the effect of surface tension driven convection.

Another simple and elegant way of controlling the convective instabilities is by the adjustment of constant vertical mass discharge called throughflow. This is of recent origin, which may be effectively used to control convection. The problem of convective instabilities with throughflow is of interest because of the possibility of controlling the convective instabilities by the adjustment of throughflow. Several authors [11–14] analyzed the problem of Marangoni convection with throughflow in viscous fluids.

By including the internal rotation to the particles viz., micro-rotation, Eringen [15] proposed the theory of micro-polar fluids. There has been several investigations dealing with the thermal instability of micro-polar fluids. In these the authors have not discussed the effect of surface tension driven convective instabilities in their work. Murty and Rao [16] initiated the work in this direction in which they discussed the effect of throughflow and non-uniform temperature gradient on Marangoni convection.

The objective of this paper is two fold. Firstly to determine the effect of throughflow and magnetic field on the convection induced by surface tension in micro-polar fluids inorder to understand the control of Marangoni convection by the adjustment of throughflow. Secondly we wish to suggest some modifications to the results given by Murty and Rao [16] in the absence of magnetic field.

2. Formulation of the problem

Consider an infinite horizontal layer of depth d of an electrically conducting micro-polar liquid permeated by a uniform vertical magnetic field H_0 and a