Effects of anisotropy and rotation on Rayleigh-Bénard convection of nanoliquid-saturated porous medium using general boundary conditions

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1. INTRODUCTION & OBJECTIVE

In literature, we come across many works that consider only a single boundary combination. However, with the availability of many sophisticated mathematical tools it is now possible to unify all existing boundary combinations into a single problem and the paper emphasizes on this fact. Such a very general study encompasses the results of all the boundary combinations on velocity and temperature. In the present problem the convection of nanoliquids in a porous medium has been studied using general boundary conditions with respect to velocity and temperature.

Convection problems in literature make use of specific boundary conditions (classical boundary conditions), viz., free-free isothermal, rigid-rigid isothermal and rigid-free isothermal. The current work involves the RBC in a nanoliquid-saturated porous medium using general boundary conditions (GBC) [1] where the velocity boundary conditions are obtained from the Beavers and Joseph (BJ) slip condition [2]. Taylor [3] conducted experiments in order to determine the extent to which the slip coefficient depends on the porosity of the material. The historical background and relevant concepts of the BJ velocity boundary condition is documented in an excellent paper on flow through porous medium by Nield [4].

Many works in literture concern study of the effect of rotation on convection in a porous medium ([5], [6], [7]) and so on.

Most of the previous studies concern a homogeneous and isotropic porous medium. In recent years, the effects of non-homogeneity and anisotropy in a porous medium are being investigated. Investigations on stability analyses in liquid-saturated anisotropic porous medium under various effects are reported by [8], [9], [10], [11] and references therein.

The objective of the study is to explore the following:

- Investigate the onset of RBC in a nanoliquid-saturated anisotropic porous medium subject to GBC.
- Extract the results on RBC of Newtonian base liquids from those of the current problem.
- Obtain results concerning various boundary combinations as a limiting case of the current problem.
- To propose a mechanism for increasing the stay-time of heat in the system.
- To propose a mechanism involving nanoparticles to enhance the heat transfer in the system.

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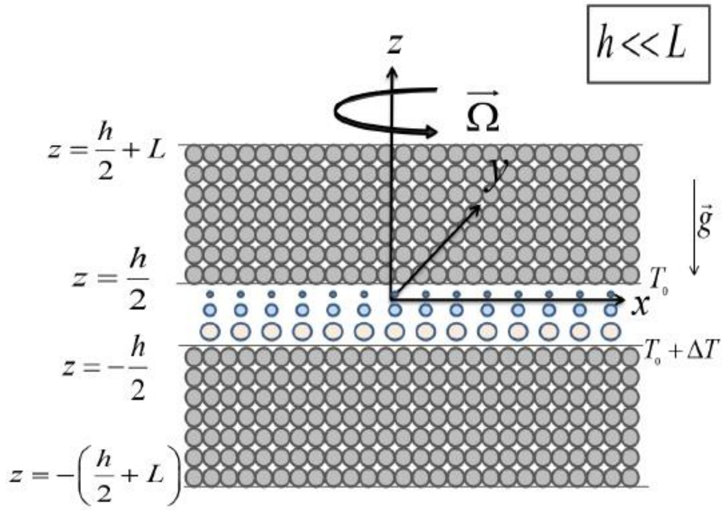
- To study the effect of Brinkman number, porous parameter, mechanical anisotropy parameter, thermal anisotropy parameter and Taylor number, on the onset of convection.

Figure 1. Schematic representation



The governing equations are:

$$\nabla.\vec{q}=0$$

$$\rho\left[\frac{1}{\phi}\frac{\partial\vec{q}}{\partial t}+\frac{1}{\phi^2}(\vec{q}.\nabla)\vec{q}\right]=\mu'\nabla^2\vec{q}-\frac{\mu}{K}\vec{q}+\rho\vec{g}-\nabla p+\frac{2\rho}{\phi}(\vec{q}\times\vec{\Omega})$$

$$M\frac{\partial T}{\partial t}+(\vec{q}.\nabla)T=M\alpha_{Tv}\left[\eta\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial z^2}\right]$$

$$\rho(T)=\rho(T_0)-(\rho\beta)(T-T_0),$$

where $(\rho\beta)=(\rho\beta)_{T=T_0}$

A linear stability using single term Galerkin method with a sophisticated choice of trial function is performed to estimate the critical Rayleigh number that characterises the onset of convection. We adopt a novel method of introducing additional constants in the Eigen function which are then evaluated using orthogonality conditions.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Results pertaining to 82 various problems are obtained as limiting cases of the current study. The effect of increasing the mechanical anisotropic parameter is to advance the onset of convection whereas increasing the values of thermal anisotropic parameter and Taylor number delays the onset of convection.

Instead of assuming several individual boundary combinations, one can examine an integrated problem including all limiting cases. Utilizing advanced mathematical softwares, it is now feasible to consider general boundary conditions and integrate many different problems into a single problem.

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