Onset of magneto convection in an inclined porous layer using LTNE model

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1. INTRODUCTION & OBJECTIVE

Understanding the instability and stability of fundamental stationary solutions in magnetic fluid movements, especially in the presence of heat, is crucial for a wide range of scientific applications. These include geophysics, astronomy, and medicine. In particular, fluid convection or the movement of a fluid-saturated porous layer plays a significant role in many practical applications such as filtration systems, soil erosion control, geotechnical and biomedical engineering, the oil and gas industry, as well as solar desalination and irrigation systems.

One of the key factors that influence fluid movement in these systems is the inclination of the porous layer. When the layer is tilted relative to the horizontal plane, the dynamics of fluid convection undergo significant changes. This phenomenon can be viewed as an extension of the classical Darcy-Bénard problem, where a flat porous layer is inclined. The foundational studies exploring this scenario have been presented in seminal works, including those by Bories and Combarnous [1], Weber [2], and Caltagirone et al. [3]. These studies highlight that the inclination primarily affects thermal instability, with the Darcy-Rayleigh number being defined as $4\pi^2 / \cos(\gamma)$ where γ denotes the angle of inclination. The critical wave number remains unchanged, but thermal instability becomes more pronounced as the angle of inclination increases.

Most studies on this topic have assumed the local thermal equilibrium (LTE) model, where the fluid and solid phases are always in thermal balance. However, this assumption may not accurately capture the complexities of non-equilibrium heat transfer phenomena, especially in systems where there is a significant temperature difference between the phases. To address this limitation, the local thermal non-equilibrium (LTNE) model can be employed. Unlike the LTE model, the LTNE approach uses two distinct energy equations—one for the fluid phase and one for the solid phase—allowing for a more detailed investigation of heat transfer dynamics.

Despite the extensive research conducted on thermal convection in porous media, the effects of an external magnetic field on convection in inclined porous layers have not been thoroughly explored in the literature. To fill this gap, the present study focuses on investigating the onset of convection in an inclined porous medium under the influence of a magnetic field.

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Linear analysis is used to examined the onset og convection using the LTNE model, providing a more comprehensive understanding of the system's behavior under varying conditions. This analysis is crucial for advancing knowledge in the field and addressing the limitations of previous model.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

The study investigates the onset of magneto convection in an inclined porous layer with a temperature difference between adjacent regions. The perturbed linear system is addressed using the normal mode technique. Numerical solutions are obtained using the Runge-Kutta method combined with the shooting method for analyzing longitudinal and traveling rolls. This study investigated the impact of several key parameters on the critical Rayleigh number (Ra_c), including the interphase heat transfer parameter (H), the porosity-modified conductivity ratio (τ), the Hartmann number (Ha^2), and the inclination angle (**γ**). We made comparisons between linear and nonlinear analyses for longitudinal and transverse rolls.

The important results from the study are, the non-dimensional parameters like the Hartmann number and the inter-phase heat transfer parameter stabilize the fluid flow in the system. An inclination angle also plays a vital role in delaying the onset of convection. The angle at which the transverse rolls disappear depends on the Hartmann number. An elevation in the Hartmann number correlates with an increased disappearance angle for transverse rolls.

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