Onset of Convection in Bidisperse Porous Medium in presence of Viscous dissipation and Vertical throughflow

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1. INTRODUCTION & OBJECTIVE

Over the decade, bidisperse porous media(BDPM) attracts researchers attention significantly due to its versatile application in engineering and science domains such as geological reservoirs [1, 2], heat exchangers, filtration, water transport [3, 4, 5], biomedical engineering (specifically in drug delivery systems), landslides [6], civil engineering, and bone studies. It plays a vital role in energy storage devices such as optimizing the transport of reactants, products, and overall performance. This is due to its standalone ability to delay the onset of convection compared to mono-porous media [7]. It makes BDPM a go-to choice for thermal engineering systems. Chen et al [8] studied the thermal conductivity of BDPM and stated BDPM as clusters formed by large particles aggregated together by small particles. Nield and Kuznetsov [9] modeled a two-velocity two-temperature model for BDPM. Using the extended Brinkman model, the same authors extended the work from the Hortan-Rogers Lapwood problem to BDPM [10].

When a fluid passes through the micropores of BDPM, it possesses intriguing phenomena. Whereas macroscopic flow is unidirectional and local flows exhibits three dimensional character [11]. The friction at the microscopic level generates heat due to the viscous dissipation effect. Hence, it is crucial to consider viscous dissipation in BDPM, especially in scenarios where it dominates such as on larger planets with a stronger gravitational field, large deceleration, larger masses of gas in space, internal cooling of turbine blades (i.e., high rotative speed devices), and geophysical flows with larger characteristic lengths. Gebhart [12] studied the effect of viscous dissipation in natural convection and established that the viscous dissipation effect is appreciated more than the heat transferred amount. Gebhart and Mollendorf [13] studied its impact on external natural convection flow. Hadhrami et al. [14] deduced the theory for viscous dissipation term in the Brinkman equation. Nield et al. [15] modeled viscous dissipation in a saturated porous medium. Barletta et al. [16] discussed its effects in plane Poiseuille flow.

We aim to fill the existing gap in the literature by investigating the effects of viscous dissipation in bidisperse porous media with throughflow. We investigate BDPM confined between two horizontal infinite planes of distance ‘d’ and a cartesian coordinate system considered with horizontal axes denoted by ‘x’ and ‘y’, and the vertical axis by ‘z’. The lower and upper plane temperatures are ‘T_L’ and ‘T_U’ respectively. Also, we operate the model under the below assumptions:

- The system obeys Darcy’s law,
- Oberbeck-Boussinesq approximation,
- Local thermal equilibrium considered between solid and fluid phases,
- The effects of Viscous dissipation.

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2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

We studied the onset of convection in a BDPM with the effects of viscous dissipation and throughflow using Linear stability analysis. The eigenvalue problem is solved numerically using the bvp4c routine in MATLAB R2023a via the normal mode technique. The primary findings of the paper are:

- In the absence of viscous dissipation, the critical Rayleigh number maintains symmetry over upward and downward throughflow.
- Convection sets early for a significant effect of viscous dissipation with upward throughflow, whereas convection delays with downward throughflow.
- The coefficient of moment transfer and permeability ratio stabilize the system.
- The effective permeability ratio has more stabilizing nature with upward throughflow than downward throughflow.

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