Hydrodynamic stability of convection in porous medium with chemical reaction effect and generalised boundary conditions

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Abstract

We study solutal convection in a Brinkman porous layer with generalized Robin boundary conditions for solute concentration and two-sided Navier slip for velocity. The linear onset threshold (Ra_L) and the global energy threshold (Ra_E) are determined using a new Chebyshev collocation algorithm coupled to a pseudoinverse–eigenvalue formulation and a golden–section search. Accuracy is assessed through residual evaluation, as no analytical solutions are available for this problem. The results reveal that the Brinkman coefficient λ exerts a nearly linear stabilizing influence on both Ra_L and Ra_E, while the slip coefficients N_L and N_U act asymmetrically to destabilize the system. In addition, the interaction between the reaction parameter ζ and the concentration ratio η produces non-monotonic shifts in the stability thresholds. These findings clarify how reaction, solute exchange, and interfacial slip reshape both linear and nonlinear stability boundaries in Brinkman porous media, and they establish a high-accuracy computational framework for analyzing stability regimes relevant to reactive transport.

Keywords: Brinkman equation; Chemical reaction; Slip boundary conditions; Linear instability; Nonlinear stability; Energy function method; Chebyshev collocation approach

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1. Introduction

Simulating chemical reactions within porous materials, under the influence of fluid movement, is essential for a comprehensive understanding of natural and industrial processes in scientific and engineering fields. These processes include environmental remediation, groundwater pollution, enhanced oil recovery, and catalytic reactors [1–4]. In particular, the chemical reactions within porous materials that result from variations in salt concentration in a

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