
Wall modes and pattern formation in molten-salt magnetoconvection

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Abstract

Magnetoconvection in electrically conducting fluids under strong imposed magnetic fields is central to heat extraction in fusion reactor cooling blankets. Most canonical results and many blanket-relevant studies focus on liquid metals, however, several proposed concepts use molten salts whose thermal diffusion is comparatively weak, with Prandtl numbers (Pr) in the range 10-30. While linear theory for wall-mode and bulk onset is Pr -independent for most relevant working fluids, little is known about nonlinear effects even in a Rayleigh-Bénard setup, such as near-onset pattern formation, wall-mode selection with increasing Rayleigh number (Ra), and the transition to turbulence. Recent results from numerical linear stability analysis in cylindrical domains show that multiple wall modes with different azimuthal wavenumbers are closely spaced at onset (1). This near-degeneracy, which results in transitions between wall-mode states of different azimuthal structure as observed in the liquid metal case (2), implies strong modal competition and potential multistability. Here, we present direct numerical simulations of magnetoconvection in cylindrical domains of aspect ratio 1 and 2 subject to a vertical magnetic field in the high- Pr molten-salt regime. We investigate (i) the nonlinear selection, potential coexistence, and transitions between competing wall-mode branches, and (ii) the sequence of pattern changes across Ra from steady wall modes towards time dependence and eventually turbulence. In contrast to the liquid metal case, we observe high-wavenumber wall-mode patterns to emerge with increasing Ra , that remain dynamically relevant beyond bulk onset. Preliminary results suggest the co-existence of wall modes with different wavelengths close to onset.

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(2) Xu, Y., Horn, S., Arnou, J.M., Transition from wall modes to multimodality in liquid gallium magnetoconvection, *Phys. Rev. Fluids* 8, 103503 (2023)

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