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Thermomagnetic instability of Taylor-Couette flow in ferrofluids

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The increasing importance of ferrofluids in technologies such as energy harvesters, fusion reactors, and rotating machinery employing magnetic liquid seals [1–3] highlights the need for a thorough understanding of their flow behaviour, commonly referred to as ferrohydrodynamics (FHD). Research in FHD has explored thermomagnetic convection, which arises from the interaction between imposed temperature gradients and magnetic fields. More specifically, studies on thermomagnetic convection have examined key flow phenomena including convective instability, pattern formation, and turbulence [4–6]. These complex flow phenomena of ferrofluids have often been studied in the canonical Taylor–Couette configuration, which consists of fluid confined between two concentric cylinders rotating independently. Radially heated Taylor–Couette flow of ferrofluids has particularly been studied as a model system to explore thermomagnetic convection and its associated instability [6–8].

Meyer et al. (2022) [7] considered a ferrofluid in the Taylor–Couette system with a rotating and heated/cooled inner cylinder consisting of a vertical stack of magnets. In this configuration, radial heating combined with magnetic fields drives thermomagnetic instability, which is further enhanced by the inner cylinder rotation. Their analysis considers narrow-gap cases, allowing the magnetic field to be treated as purely radial while neglecting axial variations. In this conference, we will present our work that extends the approach of Meyer et al. (2022) [7] by relaxing these assumptions. We consider a wide gap between the cylinders and the vertical variation of magnetic fields. We demonstrate how these factors influence the onset and pattern of thermomagnetic instability. Furthermore, we examine the progression of the flow beyond primary instability, including transition to secondary instability or other chaotic or turbulent states.

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