Modelling the interaction of Rayleigh-Bénard convection and Electro-vortex flow in Liquid Metal Batteries

Declan Finn Keogh,[a] Victoria Timchenko,[a] John Reizes,[a] Chris Menictas*[a]

[a] *School of Mechanical and Manufacturing Engineering, UNSW Sydney, NSW, Australia.*
E-mail: c.menictas@unsw.edu.au

Liquid Metal Batteries (LMBs) are a relatively new electrochemical storage solution with the potential to supply grid-scale storage of electricity. The batteries consist of three layers; two molten metals and a molten salt electrolyte kept separate by differences in their densities only. Since the anode and cathode are separated by the molten salt and have no physical barrier between them, the hydrodynamic stability of Liquid Metal Batteries is a focus of the field. Fluid flow in the anode is dominated by Electro-vortex flow (EVF) and Rayleigh-Bénard convection. Determining how these fluid phenomena interact, and which is dominant, is crucial for estimating the stability bounds of LMBs.

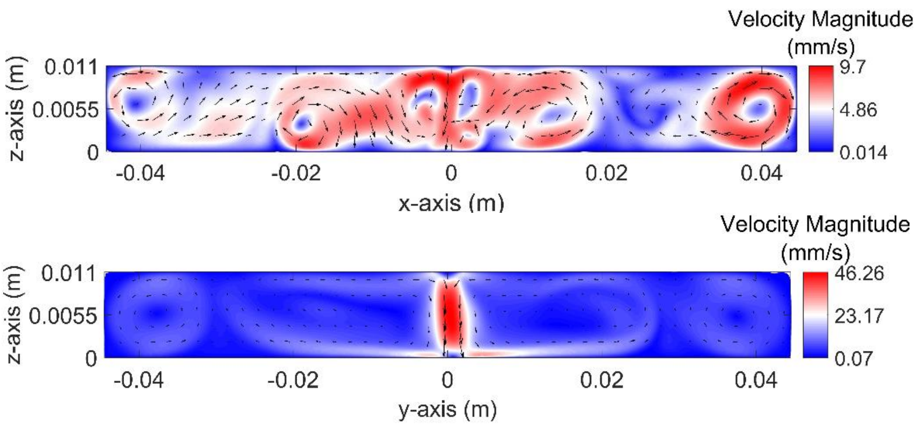

Figure – Rayleigh-Bénard convection and Electro-vortex flow in a PbBi electrode with current supplied at densities equivalent to a LMB discharging at 0.25 A/cm^2 (top) and 1 A/cm^2 (bottom)

The recently developed computational fluid dynamics (CFD) model of a single layer PbBi liquid metal electrode has shed light on how these fluid phenomena interact. It has been found that at high current densities EVF dominates flow in the anode while at low current densities convection dominates. Previous studies have shown that convection is not expected to cause instability in LMBs with a radius smaller than 1.33m[1] while EVF could cause electrolyte layer rupture in batteries with radius' as small as 0.1m[2]. Therefore, finding the transition from buoyancy dominant flow to EVF dominant flow is important for evaluating the stability of LMBs.

References

[1] Shen, Y. & Zikanov, O. Thermal convection in a liquid metal battery. *Theor. Comput. Fluid Dyn.* **30**, 275–294 (2016).
[2] Herreman, W. *et al.* Numerical simulation of electrovortex flows in cylindrical fluid layers and liquid metal batteries. *Phys. Rev. Fluids* **4**, 113702 (2019).