Phd project : Metal pad roll, electro-vortex flow and short-wavelength instabilities in liquid metal batteries.

Le Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur (LIMSI) is a laboratory funded by CNRS (UPR3251) and associated with Université Paris-Sud, Bâtiment 507, 91405 ORSAY (website: [www.limsi.fr).](www.limsi.fr)

Intermittent electrical energy sources, such as wind or solar energy, will not become dominant players unless we have cheap large scale storage devices to level production with demand. Amongst the different options that are studied, liquid metal batteries (LMBs) are viable candidates. These all liquid galvanic cells ressemble shallow pools filled with three distinct layers of fluid: a light molten metal on top, a salt electrolyte in the middle, heavier alloy in the bottom. Prototypical devices have already been built and commercialization is in its early stages (www.ambri.com).

Since 2013, we study how fluid flows may spontaneously arise in the different layers of these cells. This may be due to thermal convection but, since intense electrical currents will run through the battery, magnetohydrodynamical phenomena may also drive flows (Tayler instability, Metal pad rolling, electro-vortex flow, ...). In close collaboration with several european laboratories, we conduct a research program that aims to map out how important these flows are and how they may affect battery safeness and future design.

The PhD candidate will learn to master our in-house, massively parallel numerical code SFEMaNS. Since 2015, this code can now solve complex multi-phase magnetohydrodynamical flows such as those we encounter in liquid metal batteries. A first mission of the candidate will be to perform numerical simulations of the metal pad roll instability in liquid metal batteries and to compare these to a novel theory that we propose. In a second study, the candidate will need to quantify how electro-vortex flow helps mixing the bottom alloy. Insufficient mixing in the alloy is a principle obstacle to designing more performing batteries. This will require both numerical and theoretical skills. Finally, the Phd candidate will also participate in improving our numerical solver so that it can account for subtle capillary effects near moving contact lines. This should allow us to perform more realistic simulations of a variety of multiphase magnetohydrodynamical phenomena that have only been rarely considered in literature.

More information on our research on liquid metal batteries may be found on the website perso.limsi.fr/wietze/lmbs.html.

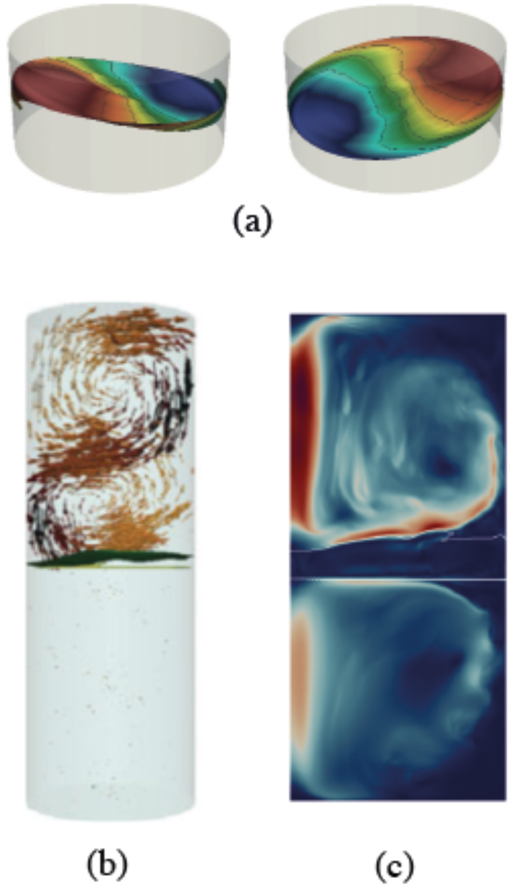

Figure: Examples of numerically simulated multi-phase flows in liquid metal batteries using our code SFEMaNS. (a) Metal pad roll instability. (b) Tayler instability.(c) Electro-vortex flow (meridional plane)

Keywords: Numerical analysis, fluid mechanics, magnetohydrodynamics, multiphase flows, HPC.

Candidate profile : Fluid mechanics, numerical methods, computational mechanics.

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International collaborations :

The massively parallel numerical code SFEMaNS is being developed in collaboration with Jean-Luc Guermond, guermond@math.tamu.edu (full professor of applied maths, TAMU, USA).