

## SIMULATION OF LIQUID METAL BATTERIES

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The increasing deployment of highly fluctuating renewable energy sources, as e.g. wind and solar power plants, demands for stationary energy storage. Pumped storage hydro power, which is the only technology widely used today, can not be applied in all places; new technologies are therefore required. A promising alternative is the liquid metal battery (LMB) [1, 2]. Easy scale-up, low priced raw materials, a simple set-up, long life-time and extremely high current densities make



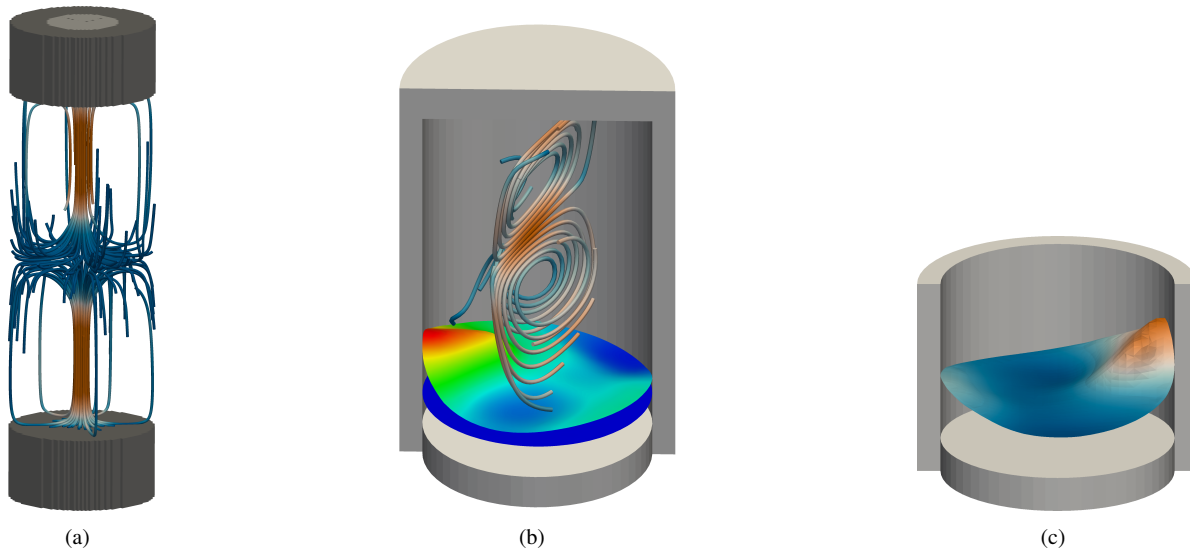
**Figure 1:** Sketch of a liquid metal battery with typical inventory (a) and short circuit due to strong fluid flow (b).

it a promising candidate for grid-scale energy storage. Liquid metal batteries are built as a stable density stratification of two liquid metals, separated by a likewise liquid salt (figure 1a). During discharge, the upper metal will lose electrons; the ion will diffuse through the electrolyte layer and alloy there with the cathode metal. In order to build such batteries cheap, they have to be large; however, this implies currents in the order of kilo-amperes. The battery current and its interaction with magnetic fields may be the source of different instabilities, leading to a fluid flow in the liquid metal battery. Stirring the cathode may be advantageous by mixing or removing reaction products from the salt-cathode interface. However, very strong fluid flow may even wipe away the electrolyte layer and lead to a short-circuit (figure 2b). This must be avoided.

We present a numerical model implemented in OpenFOAM, coupling the Navier-Stokes equation with Maxwell's equations [3]. The electric potential is determined by solving a Poisson equation; the current by Ohm's law and the magnetic field by Biot-Savart's law. This model is used to simulate the Tayler instability in the batterie's anode [4]. A multi-region model, similar to chtMultiRegionFoam, is used to model electro-vortex flow [5] (figure 2a). Finally, a multiphase model, based on multiphaseInterFoam, allows to simulate deformation of the electrolyte layer (figure 2b) as well as metal pad rolling [6, 7], known from aluminium reduction cells [8] (figure 2c).

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**Figure 2: Fluid flow in liquid metal batteries may be driven by rotational Lorentz forces (electro-vortex flow) as well as other mechanisms: (a) shows electro-vortex flow, (b) the Tayler instability and (c) metal pad rolling as known from aluminium reduction cells.**

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