

# Swirling electrovortex flows in cylinders: how do the parameters influence the flow's intensity?

S. Bénard<sup>a</sup>, W. Herreman<sup>a</sup>, C. Nore<sup>a</sup> and J. L. Guermond<sup>b</sup>

We investigate swirling electrovortex flows in a cylinder filled with liquid metal. For this purpose, we use axisymmetric and three-dimensional simulations, conducted with the massively parallel code SFEMaNS<sup>1</sup>. This code uses a Fourier decomposition in the azimuthal direction and a finite element representation in the meridional plane. The set-up used is a cylinder filled with GaInSn eutectic alloy, symmetrically connected to two copper wires and immersed in an external vertical magnetic field. The current enters and exits through these wires. The radius of the wires is lower than the one of the cylinder, which deviates the current lines. The interaction between the deviated current and the magnetic field creates a Lorentz force which drives a flow called swirling electrovortex flow, very similar to the Von-Karman flow<sup>2</sup>. We first study the influence of the current density, the magnetic field and the viscosity on the flow. We identify four regimes. Three of them are induction-less regimes: the viscous regime (low velocities), the boundary-layer regime (intermediate velocities) and the inertial regime (high velocities). The last one is the inductive regime, for high magnetic fields. We present for each of these regimes scaling laws for the velocity. We then vary the geometry of the set-up, i.e. the radius of the wire, the height of the cylinder and the way the current enters the cell (asymmetrical or symmetrical wires). We find that the scaling laws previously obtained highly depend on the geometry. We provide a simple model in order to explain the dependency of the flow's intensity on the wire's radius. Furthermore, we compare axisymmetric and three-dimensional simulations and discuss the validity of the axisymmetric approximation with respect to the flow's intensity and spatial distribution.

<sup>a</sup> Université Paris-Saclay, CNRS, LISN, 91400 Orsay, France

<sup>b</sup> Dep. Mathematics, University of Houston, Houston, Texas 77204-3008, USA

<sup>1</sup> Guermond et al., *J. Comput. Phys.* **228**, 2739 (2009).

<sup>2</sup> Nore et al., *J. Fluid Mech.* **447**, 51 (2003).

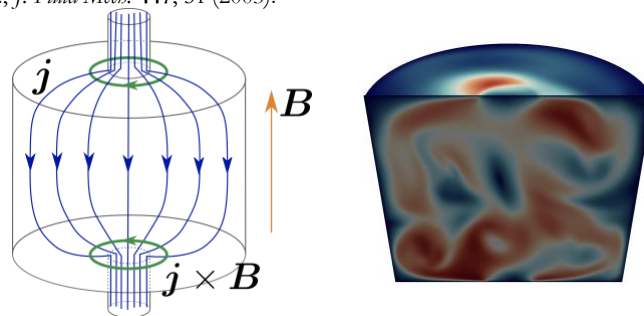


Figure 1: (left) Sketch of the set-up: current lines in blue, external magnetic field in orange, Lorentz force in green. (right) Velocity distribution in the cylinder for a current density of 500 A m<sup>-2</sup>.