Numerical simulations of swirling electrovortex flows in cylinders

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We study swirling electrovortex flows in a cylinder filled with GaInSn alloy by using axisymmetric and three-dimensional simulations. For this purpose, we use the massively parallel code SFEMaNS [1], in which the azimuthal direction is decomposed using Fourier modes and the representation in the meridional plane uses finite elements. The set-up is a cylinder symmetrically connected to two copper wires, one at the top and one at the bottom of the cell. The electrical connection is established through those wires, which have a radius lower than the one of the cylinder. This yields a deviation of the current. An external vertical magnetic field is applied. The interaction between this magnetic field and the current creates a Lorentz force which drives a convection motion. The resulting flow is called swirling electrovortex flow and is very similar to the Von-Karman flow [2].

We vary different parameters in order to investigate their influence on the flow. We first study the impact of the current density and the magnetic field. Four regimes are identified : the viscous, the boundary-layer and the inertial regimes, which are all three induction-less. The last one is the inductive regime (high magnetic fields). We provide for each of them scaling laws for the velocity, numerically observed and theoretically explained. Moreover, we compare axisymmetric and three-dimensional simulations and discuss the validity of the axisymmetric approximation with respect to the velocity of the flow and the spatial distribution.

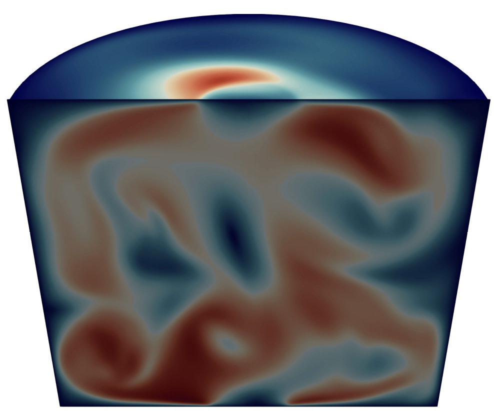

Figure 1. Velocity magnitude in the cylinder for a current density J=500 $\mathrm{A\,m^{-2}}$.

Références

1. J.-L. Guermond, R. Laguerre, J. Léorat & C. Nore, Nonlinear magnetohydrodynamics in axisymmetric heterogeneous domains using a Fourier/finite element technique and an interior penalty method, *J. Comput. Phys.*, **228**, 2739–2757 (2009).
2. C. Nore, L. Tuckerman, O. Daube & S. Xin, The 1 :2 mode interaction in exactly counter-rotating von Kármán swirling flow, *Journal of Fluid Mechanics*, **477**, 51–88 (2003).