

Direct Numerical and Large Eddy simulations of the Von-Kármán-Sodium dynamo experiment

Caroline Nore, D. Castanon Quiroz, L. Cappanera, J.-L. Guermond

▶ To cite this version:

Caroline Nore, D. Castanon Quiroz, L. Cappanera, J.-L. Guermond. Direct Numerical and Large Eddy simulations of the Von-Kármán-Sodium dynamo experiment. EFMC12 – 12th European Fluid Mechanics Conference, Prof. Hendrik Kuhlmann, Sep 2018, Vienna (AUSTRIA), Austria. hal-04402800

HAL Id: hal-04402800 https://hal.science/hal-04402800

Submitted on 18 Jan2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Direct Numerical and Large Eddy simulations of the Von-Kármán-Sodium dynamo experiment

C. Nore^{*}, D. Castanon Quiroz[†], L. Cappanera[‡] and J.-L. Guermond[§]

Hydrodynamic and magnetohydrodynamic (MHD) simulations of liquid sodium flows in the Von-Kármán-Sodium (VKS) setup are presented. The soft iron counter-rotating impellers that were used in the successful 2007 experiment¹ are modelled by means of a pseudo-penalty method. High kinetic Reynolds number hydrodynamic simulations are performed using a Large Eddy Simulation technique. The results compare well with the experimental data: at small angular frequencies of the impellers, the flow is stationary and laminar or slightly fluctuating; at large angular frequencies, small scales invade the bulk (see Fig. 1a) and a Kolmogorov-like spectrum is obtained. Near the tips of the blades the flow is expelled and forms intense helical vortices. MHD computations are also conducted: at fixed kinetic Reynolds number, increasing the magnetic permeability of the impellers reduces the critical magnetic Reynolds number above which a magnetic field is generated and maintained, i.e. for dynamo action; at fixed magnetic permeability, increasing the kinetic Reynolds number also decreases the dynamo threshold. Our results support the conjecture that the critical magnetic Reynolds number tends to a constant as the kinetic Reynolds number tends to infinity. The resulting magnetic field generated by dynamo action is a mostly axisymmetric axial dipole with an azimuthal component concentrated near the impellers (see Fig. 1b) as observed in the VKS experiment². We propose a speculative mechanism for dynamo effect in the VKS experiment.



Figure 1: (a) Snapshot of the kinetic helicity at kinetic Reynolds number $Re = 10^5$ with impellers colored in grey. (b) Streamlines and slice of the time-averaged magnetic field at kinetic Reynolds number $Re = 10^5$ and magnetic Reynolds number $Rm = 10^2$.

^{*}LIMSI, CNRS, Univ. Paris-Sud, Université Paris-Saclay, Bâtiment 508, rue John von Neumann, Campus Universitaire, F-91405 Orsay, France

[†]BCAM, Mazarredo 14 E48009 Bilbao, Basque-Country, Spain

 $^{^{\}ddagger}\mathrm{Dep.}$ Computational and Applied Mathematics, Rice University 6100 Main MS-134, Houston, TX 77005, USA

[§]Dep. Mathematics, Texas A&M University 3368, College Station, TX 77843-3368, USA.

¹Monchaux et al., Phys. Rev. Lett., **98**, 044502 (2007)

²Nore et al., EPL, **114(6)**, 65002 (2016)