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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.

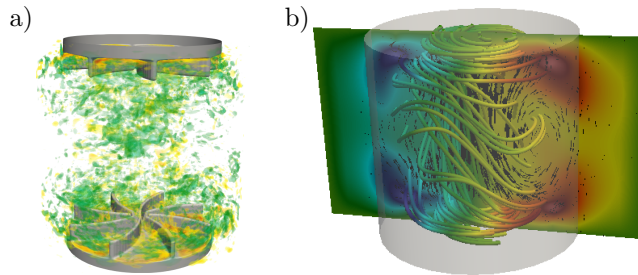


Figure 1: (a) Snapshot of the kinetic helicity at kinetic Reynolds number $Re = 10^5$ with impellers colored in grey. (b) Streamlines and slice of the time-averaged magnetic field at kinetic Reynolds number $Re = 10^5$ and magnetic Reynolds number $Rm = 10^2$.

*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

‡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)