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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.

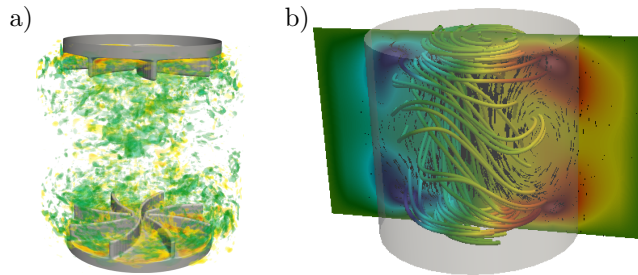


Figure 1: (a) Snapshot of the kinetic helicity at kinetic Reynolds number $Re = 10^5$ with impellers colored in grey. (b) Streamlines and slice of the time-averaged magnetic field at kinetic Reynolds number $Re = 10^5$ and magnetic Reynolds number $Rm = 10^2$.

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

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