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Experimental Bullard-von Karman dynamo: MHD saturated regimes

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The dynamo instability, converting kinetic energy into magnetic energy, creates the magnetic fields of many astrophysical bodies for which the flows are highly turbulent.
Those turbulent fluctuations restricts the range of parameters of numerical and theoretical predictions. As laboratory experiments are closer from natural parameters, this approach is favored in this work. In the past decades, dynamo action has been observed in experiments involving laminar flows [1] or fully turbulent flows [2] in liquid sodium. Nevertheless, the saturation of the velocity field by the Lorentz force due to the dynamo magnetic field is weak in those experiment because the control parameter is always close to the threshold of the instability (which is not the case in astrophysical situations). The details of the mechanism of the back reaction of Lorentz force on the flow are not known.
We present here an experimental semi-synthetic dynamo, for which a fluid turbulent induction mechanism ('omega' effect) is associated to an external amplification applying a current into a pair of coils. The flow, called von-Karman, is produced by the counter rotation of two coaxial propellers in a cylindrical tank filled with liquid gallium. The resulting flow is highly turbulent (Re > 10ˆ5). The amplification, mimicking a turbulent 'alpha' effect, allow to observe the dynamo instability at low magnetic Reynolds number (Rm $\sim$ 2), far below the threshold of natural homogeneous dynamo. This experiment reaches non linear regimes, for which the saturation is a MHD process, at control parameter several times the critical value. The instability grows through an on-off intermittent regime evolving into a full MHD saturated regime for which the Lorentz force is in balance with the inertial one. The power budget is strongly modified by the dynamo magnetic field and we give an insight of the estimated rate of conversion of kinetic energy into magnetic one from experimental data.
Very rich regimes such as chaotic reversals of polarity are also observed and presented. Finally, a sub-critical instability has been observed under certain conditions, reminding some hypothesis formulated for geophysical situations.

[1] R. Stieglitz and U. Müller, Phys. Fluids, 13, 561 (2001); A. Gailitis et al., Phys. Rev. Lett. 86, 3024 (2001)

[2] Monchaux et al., Phys. Rev. Lett., 98, 044502 (2006).