Observation of a homogeneous dynamo in liquid sodium and transport of magnetic field with the VKS experiment.

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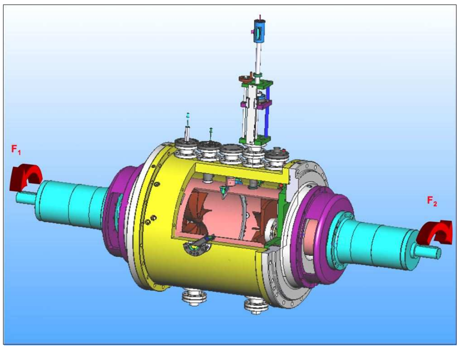
Some experimental results from a closed turbulent flow of liquid metal at very high Reynolds number are discussed in the context of magnetohydrodynamics (MHD). We study the coupling between hydrodynamic and magnetism, by induction effects. It is a subject of broad interest, as the magnetic fields of earth and of most astrophysical objects, result from turbulent flows of electrically conducting fluids : the kinetic energy of the flow is converted into magnetic energy, by the dynamo effect. This is an instability mechanism, which occurs when a threshold value of the control parameter the magnetic Reynolds number is reached. In september 2006 we observed this effect for the first time, in the experiment Von-Karman Sodium [1]. Contrary to existing laboratory dynamos, the flow is largely unconstraint the fluid and the electrical current being free to evolve in the experimental volume.

The bifurcation and the value of saturation have been studied, to understand the role of turbulence on a instability. A rich dynamical behavior of the magnetic field is also observed : for example a state with reversals of magnetic field similar to those of the Earth recorded on the geological time scale [2]. Moreover these experiments allow us to get a lot of results on the MHD turbulence.

The equation of evolution of the magnetic field $\mathbf{B}$, which expresses the electromagnetic induction due to the motion of a electrically conducting fluid in the presence of a magnetic field can be written as :

$$\frac{\partial \mathbf{B}}{\partial t} = \mathbf{curl}\,(\mathbf{v} \wedge \mathbf{B}) + \frac{1}{\mu_0 \sigma} \Delta \mathbf{B} \qquad (1)$$



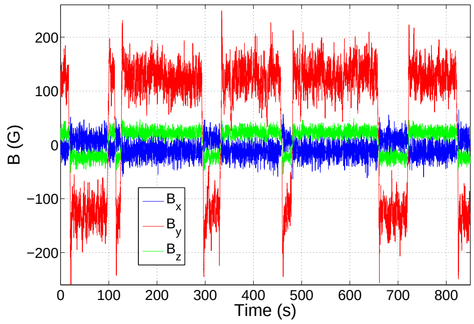


Figure 1: left : Experimental setup   right : Reversals of magnetic field

The right hand side of this equation has a part of advection $\mathbf{curl}\,(\mathbf{v} \wedge \mathbf{B})$ and a part of diffusion with the "magnetic diffusivity" $\nu_m = (\mu_0 \sigma)^{-1}$. We can define a dimensionless number which compares the respective importance of advection on the diffusion of $\mathbf{B}$, the magnetic Reynolds number : $R_m = \frac{LV}{\nu_m}$. For low enough amplitude of the magnetic field and especially below the dynamo threshold, the retroaction of the magnetic field on the flow is negligible and $\mathbf{B}$ evolves as a passive vector. So the magnetic field can be transported by the flow. This phenomena is important to understand the mechanisms leading to the dynamo instability, and also it can give some useful informations on the dynamic of turbulence itself. The first measurements in the experiment Von-Karman Sodium which observes this effect were published in 2006 [3] . The transport of magnetic field with an oscillating source was also studied. This setup could allow to better understand the behavior of magnetic field in spectral space and also to discuss the concept of turbulent magnetic diffusivity, which is often introduced in mean field theory.

References

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