Dynamo action in a precessing cylinder

- BIFD2011 -

C. Nore*, J. Léorat[1], J.-L. Guermond[2,3] and F. Luddens[2,3]

* LIMSI, CNRS, UPR3251, BP 133, 91403 Orsay cedex, France, Université Paris-Sud 11 and Institut Universitaire de France,
e-mail: nore@limsi.fr, web page: http://www.limsi.fr/Individu/nore

[1]Luth, Observatoire de Paris-Meudon, place Janssen, 92195-Meudon, France,

[2]Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, USA,

[3]Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur, CNRS, UPR3251, Orsay cedex, France

ABSTRACT

The possible contribution of precession to dynamo action is a long-standing debate (see for example [1]). Modern astrophysical observations of some planetary dynamos can contribute to resolving this issue, although definite evidence is still lacking. Because of the large computing resources required, it was only recently that numerical computations could demonstrate that dynamo action occurs in two different precessing containers: spherical [2] and spheroidal [3] ones. Since neither shape is convenient for large-scale experiments, it is instructive to investigate whether similar results can be obtained in cylindrical containers. We use a nonlinear magnetohydrodynamics (MHD) code denoted SFEMaNS (for Spectral / Finite Elements for Maxwell and Navier-Stokes equations, [4]), which is able to integrate nonlinear MHD equations for incompressible fluids in heterogenous domains (with spatial distributions of electrical conductivity or magnetic permeability) with axisymmetric interfaces embedded in a vacuum. SFEMaNS is based on a spectral method in the azimuthal direction and involves finite elements in meridional planes. Five parameters govern the flow: the aspect ratio of the container, the precession angle and precession rate (forcing parameters), and the Ekman and magnetic Prandtl numbers (fluid parameters, E and Pm). Choosing the container length equal to its diameter, a precession axis orthogonal to the rotation axis and a precession rate of 0.15, the non-magnetic flow breaks its central symmetry when the Ekman number becomes small enough (E is then about 10^{-3}). The nonlinear MHD problem starts after a small magnetic seed field is added. When the magnetic dissipation is small enough, i.e. for magnetic Prandtl numbers Pm above a critical value $Pm^*(E)$, dynamo action appears after symmetry breaking of the flow, as was also observed in the spherical and spheroidal dynamos. An experimental approach could be relevant to natural dynamos and seems within reach using a cylindrical container (cf. DRESDYN proposal in Germany, F. Stefani, personal communication).

References

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