Instabilities of conducting fluids in cylindrical cells under external forcing

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ABSTRACT

Flows created in neutral conducting fluids remain one of the less studied topics of fluid dynamics, despite their importance both in fundamental research (dynamo action, turbulence suppression) and applications (continuous casting, aluminum production, biophysics). One of these challenging topics is the interaction between electrolytes and high magnetic fields. This point is relevant in biophysics, because of the secondary effects reported by patients in MRI devices. Between these effects are vertigoes, i.e. the sensation of motion or spinning when the body is at rest. The equilibrium in the human body is controlled by the inner ear, in the vestibular cavity, by three toroidal channels filled with endo- and perilymph (K^+ or Na^+ electrolytes). When an alternating magnetic field is applied to one of these channels it behaves as a coil, an induced current is produced and a radial Lorentz force acts on the fluid.

Having in mind this application, but with a simpler geometry, we present the effect of a time-dependent magnetic field parallel to the axis of circular cavities. The radial Lorentz force produces the destabilization of the static fluid layer, and a flow may appear. The geometry of the experimental cell is a disc layer with external diameter smaller than 94 mm, with or without internal hole. The layer is up to 20mm depth, and we use an In-Ga-Sn alloy as conducting fluid. There are no external currents applied on the problem, only an external magnetic field. This field evolves harmonically with a frequency up to 10Hz, small enough to not to observe skin depth effects. The magnitude ranges from 0 to 0.1 T. With a threshold of 0.01T a dynamical behaviour is observed, and the main characteristics of this flow have been determined: different temporal resonances and spatial patterns with different symmetries (azimuthal wavenumbers m=3,4,5,8,...).

To our knowledge there are very few experimental works on this field. Only the group of Y. Fautrelles in Grenoble has performed some measurements but in a strongly non-linear regime [1]. On the other hand, our system allows a much more precise threshold determination and spatial symmetry description, so we can compare with the theory that predicts the instability without threshold [2].

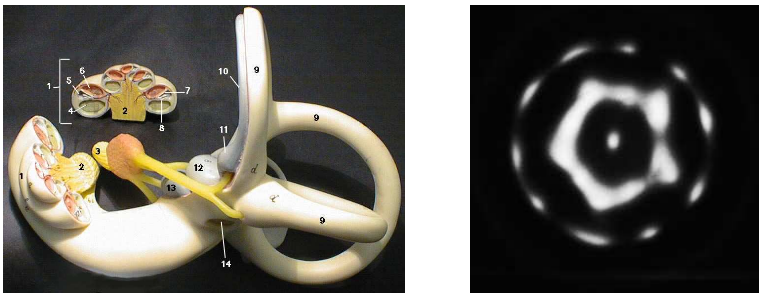
(a)  (b)

Figure 1: (a) Inner ear model. The equilibrium (spinning) is controlled by the three circular channels placed on the right side. (b) Top view of the fluid layer. The surface is deflected presenting an azimuthal $m = 5$ mode.

REFERENCES

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[2] Y. Fautrelle, A.D. Sneyd, European Journal of Mechanics B/Fluids 24 (2005) 91-112