Instabilities triggered in different conducting fluid geometries due to slowly time-dependent magnetic fields

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The existence of non-linearities in fluid dynamics is a challenge for the scientific community because is the source of the complex behavior that appears in many physical processes. These processes cover different scales from extended natural systems (e.g., atmospheric phenomena, ocean flows, stellar flows) to many other applied systems (e.g., aerodynamics, navigation, medicine, microfluidics). There are many factors that affect the fluid dynamics, being two of them the geometry and the boundary conditions. These boundaries can be very different, from solid physical walls to interfaces where the boundaries are defined by the liquid densities, chemical barriers or magnetic fields. In despite of the diversity of the different physical processes, generic behaviors can be found in those problems with different forcing systems and confinements [1].

In this work we are interested in the study of one of these forcing mechanisms, the non-linearities produced by oscillating magnetic fields in conducting fluids. The critical parameter in this problem is called the interaction parameter N, that basically represents the ratio between the electromagnetic forces on the fluid (Lorentz force), compared to inertia.

In a previos work Burguete and Miranda [2] observed symmetry breaking patterns for very small values of the bifurcation parameter N. They forced an InGaSn droplet with an oscillating magnetic field with non-zero mean. They characterized the presence of non-axisymmetric patterns close to the threshold. Based on this experimental approach, we have previously characterized the existence of patterns for small values of the bifurcation parameter N in an InGaSn droplet using a zero-mean time oscillating magnetic field [3].

In these experiments the vertical time-dependent magnetic field produces an oscillating radial Lorentz force that periodically expands and contracts the fluid drop. An axisymmetric pattern is created that can destabilize for specific regions of the parameter space. In some cases various patterns can coexist for the same experimental parameters and we could observe cycles and other complex dynamics. In order to clarify the mechanisms involved in the pattern formation, the temporal evolution was split into harmonic and sub-harmonic of the Lorentz forces frequencies. There are two different mechanisms that trigger the instabilities associated with each set of modes: surfaces waves generated by the beating of the droplet, that correspond to harmonics of the forcing mechanism frequency; and oscillations for sub-harmonics frequencies that obey a first order Mathieu-Hill equation.

The main objective of this work [4] is the influence of different geometries on the bifurcation induced by oscillating magnetic fields in a conducting fluid. Depending on the geometry different surface patterns that break the symmetries have been observed. First, an InGaSn drop of fluid where the system breaks the azimuthal and radial symmetries depending on the volume. Second, we extend the study to an InGaSn annular configuration where the presence of patterns open the door to discuss the possibility to extend these results to other configurations as biological systems, where the conducting fluid is an electrolyte. This configuration has an added interest, as it has been proposed that vertigoes triggered on patients in an MRI test could be generated by the interaction of the magnetic field with the electrolyte present in the inner ear.

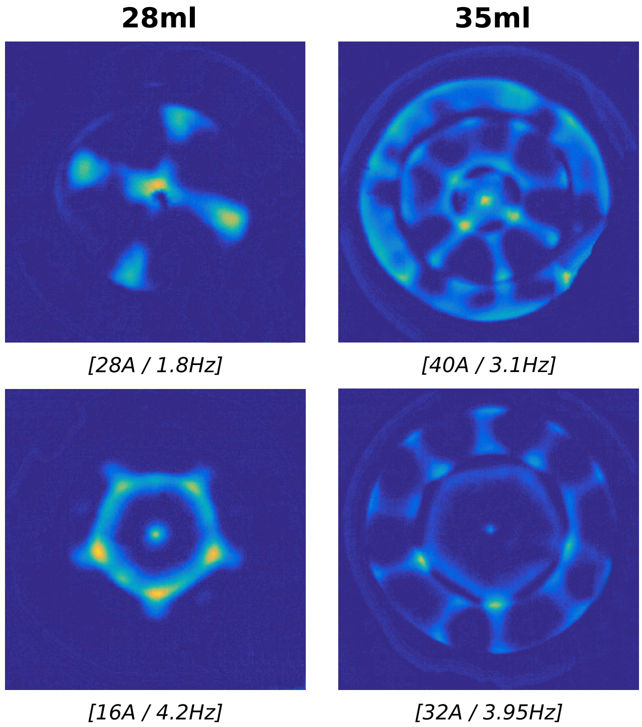

Fig. 1. Snapshots of the surface of the beating liquid metal drop for two sizes and frequencies. Different azimuthal and radial wavenumbers were observed.

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[2] J. Burguete and M. A. Miranda, Magnetohydrodynamics **48**, 69-75 (2012).

[3] I. Cortés-Domínguez and J. Burguete, Phys. Rev. E **96**, 013103 (2017).

[4] I. Cortés-Domínguez and J. Burguete, Chaos (in press).