Non-axisymmetric Resonant Modes under Oscillating Magnetic Fields for very low Interaction Parameter Values

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It is well known that the application of large external magnetic fields that evolve in time produce surface waves or instabilities in conducting fluid layers [1], [2]. This effect depends mainly on two sets of parameters, the fluid layer characteristics (electrical conductivity, layer depth, diameter) and the magnetic field (frequency and intensity). Many experimental works have been done for the large frequencies regime, where the instabilities appear due to forces localized near the surface. Plenty of industrial applications rely on high frequencies ranges. On the other hand, in the range of low frequencies, there is a lack of results close to the threshold because of its limited potential applications.

In this work we will focus on this range of frequencies, where the magnetic field may penetrate and produce a bulk force destabilizing the fluid layer. Specifically, we will study the range between 0.1Hz and 10Hz. An eutectic InGaSn alloy is placed on a Teflon® cylindrical cavity. The alloy adopts the form of a thin circularly-shaped fluid layer (a large drop of fluid) on the bottom of the container, with free surface. No external current is applied on the fluid. The force only appears through a purely vertical time dependent magnetic field perpendicular to the free surface. The field evolution is slow enough to avoid skin effects. The magnetic field is induced by modulating an electric current on an external coil. The power source that drives the coil can deliver up to 60A producing magnetic fields up to 70mT.

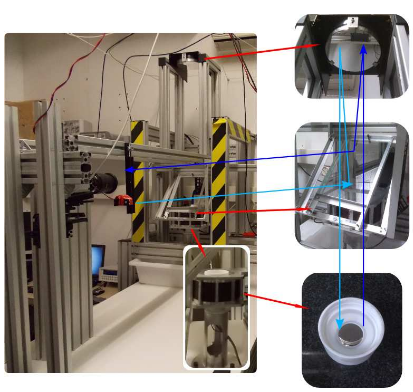

FIG. 1. Experimental setup.

This electrical current can be modulated, in a extremely low frequency range. This field generates in the fluid an azimuthal current due to Lenz's law that interacts again with the magnetic field producing a radial force (Lorenz's forces) if we assume that the system is axisymmetric. Any perturbation that deviates the system from the axisymmetry can produce an azimuthal force that can destabilize the fluid and will generate spatial patterns. So, depending on the experimental parameters, a flow is created that can be axisymmetric or not, and different resonances appear in the time domain and different spatial patterns are created associated to azimuthal wave numbers that break the symmetry of the system.

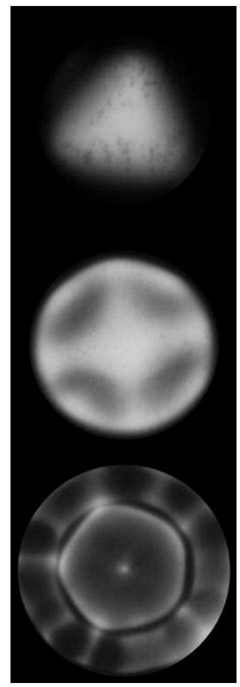

FIG. 2. m=3,4,5 azimuthal wavenumbers

Using Fourier analysis tools, we have observed patterns appearing on different regions. For the same parameter values, the azimuthal wavenumbers can even coexist and we have identified various sets of harmonics that evolve slaved. For large values of the exciting frequency we have observed that a radial wave number can be identified. These instabilities have been observed for interaction parameters as low as $N = 0.001$, and up to know these structures appear without threshold.

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[2] Y. Fautrelle, A.D. Sneyd. Surface waves created by low-frequency magnetic fields. *European Journal of Mechanics B/Fluids. Vol.24, pp.91-112* (2005).