Paper ID: 52088
oral
student

IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Science Results from Ground Based Research (4)

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FREE SURFACE RECONSTRUCTION OF OPAQUE LIQUIDS FOR EXPERIMENTAL SLOSHING ANALYSES IN MICROGRAVITY

Abstract

Liquid level measurement techniques are needed in liquid sloshing research. Lateral cameras, pressure gauges, ultrasonic transducers and laser displacement sensors have traditionally been employed for this purpose. Although these limited approaches provide enough data for most applications, the three-dimensional nature of sloshing sometimes requires more powerful alternatives. Optical methods, such as fringe reflectometry, image distortion, tracking of markers or stereo-imaging have arisen with the increase of computational power. However, they often involve expensive devices, complex post-processing or large and delicate setups.

We present an inexpensive, non-invasive and flexible alternative for opaque liquids, such as ferrofluids. Its working principle is based on simple trigonometric calculations. A set of laser diodes with known position and orientation are directed towards the fluid surface. The vertical displacement of the liquid produces an apparent horizontal movement of the laser pattern which is due to the inclination of the laser diodes and the relative position of the observer (a single video camera). This displacement can be easily correlated with the real height of each point, hence obtaining a set of measurements. The surface elevation, computed through modal summation, is finally approximated based on the experimental data.

A cylindrical container with 20 laser diodes and a high-resolution camera composed the setup. The 3D printed PLA structure ensures an easy adaptation to the workspace and, if needed, a high structural resistance. These properties are particularly interesting for microgravity research and space applications, where highly demanding geometrical, structural and automation constraints are common.

The instrument was designed to study the lateral sloshing of ferrofluids in microgravity and was tested on ground. A sufficient degree of autonomy was achieved by means of simple electronic components. In order to minimize laser reflections in the walls of the container, neutral filters and a post-processing algorithm were successfully employed obtaining accuracies of less than 0.2 mm. The resulting measurements are used to validate semi-analytical and CFD models of the sloshing dynamics of ferrofluids.