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AXISYMMETRIC BUBBLE GROWTH AND DETACHMENT SUBJECT TO INHOMOGENEOUS MAGNETIC FIELDS IN MICROGRAVITY

Abstract

Understanding the dynamics of interfacial flows in microgravity is of key importance for fundamental and applied research. Due to its major impact on several space technologies, such as electrolysis or boiling, the study of bubble growth, detachment, and displacement has traditionally gathered significant attention. This process presents unique characteristics in space due to the absence of strong buoyancy forces and the overwhelming role of surface tension.

Major technical challenges arise during the operation of multiphase devices in microgravity. A layer of gas bubbles is generated over the nucleation surfaces due to the weak buoyancy force, shielding the active surface area and reducing the efficiency of the device. Forced water convection is usually employed to overcome this effect, but it requires complex, heavy, and noisy liquid management devices. The detachment of gas bubbles may be instead induced by making use of magnetic buoyancy. This approach follows from the application of a sufficiently strong inhomogeneous magnetic field to the fluid, whose susceptibility may be enhanced by employing colloidal suspensions of magnetic nanoparticles (ferrofluids).

A very limited number of works have explored the influence of inhomogeneous magnetic fields on the dynamics of gas bubbles within magnetic liquids. Recent experiments report significant correlations between contact angle, surface tension, and critical volume with the applied field intensity when a ferrofluid is employed. Attempts have been made to offer analytical estimations of some of these parameters (e.g. by extending the departure diameter equation, known as Fritz formula, to the magnetic case). However, the strong coupling between fluid-dynamic and magnetic problems must be considered in order to produce accurate estimations. The study of this coupled magnetohydrodynamic problem requires a dedicated numerical simulation framework but, to the best knowledge of the authors, none has yet been developed. Such a tool would support the design of new magnetohydrodynamic devices in microgravity, like the recently introduced magnetically enhanced water electrolysis concept.

This paper presents a numerical interface-tracking model addressing the growth and detachment of axisymmetric gas bubbles from flat surfaces while subject to inhomogeneous magnetic fields in microgravity. The model considers a fully coupled magnetohydrodynamic framework of analysis and implements a highly efficient numerical approach for interfacial flows. Preliminary results are reported for the shape and departure volume of the bubble under different fluid-magnetic configurations, showing that the magnetic interaction has a significant effect in this process.