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NUMERICAL SIMULATION OF BUBBLE GROWTH INDUCED BY PRESSURE AND TEMPERATURE VARIATIONS UNDER MICRO-GRAVITY CONDITIONS

Abstract

The development of future cryogenic depots in orbit is characterized by multiple challenges among which the propellant loss that could be induced by phase change (boiling and cavitation). The main difficulty relies on the multi-scale nature of the problem, which is driven by small scales (nanometers to millimeters) but impacts large tank scales (meters). In particular, cavitation at the walls of a tank, which is characterized by a fast bubble growth in superheated liquid, can be a great concern for cryogenic fluids. In fact, one cooling strategy in order to condition the propellant before transfer is to depressurize the tank by venting the propellant. The tank thermal control is ultimately strongly affected by phenomena occurring at the bubble scale and in the contact line region that need to be understood. In order to study these phenomena, without making use of a sub-grid model for the phase change mass flow rate that would bring huge uncertainties on the results, thermal gradients at the interface need to be solved with a Direct Numerical Simulation (DNS). However, most of the DNS solvers for phase change phenomena are based on incompressible assumptions suitable for the description of boiling and condensation in isobaric conditions. On the other hand, for pool cavitation simulations, a compressible two-phase flow solver including phase change, is required and, to the author knowledge, these approaches are only partially addressed in the literature. The objective of our work is to fill this modeling gap introducing an innovative numerical algorithm for the DNS of compressible two-phase flows with phase change. The solver is based on a level set/ ghost fluid approach, solves the complete set of Navier-Stokes conservation equations making use of a semi-implicit projection scheme. A cubic equation of state is employed for the description of both the liquid, the vapor and the saturation conditions at the interface. In the present paper, the solver formalism will be introduced. Several validation test cases will be described. Finally, the focus will be on the analysis of the cavitation of a bubble at the wall under micro-gravity conditions in a closed tank considering different depressurization levels.