PHD position at ISAE-Supaero

Title :
Cavitation in cryogenic fluids in microgravity conditions.

Starting date: October 2026

Supervisors :
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Technological context and scientific questions
During depressurization for propellant preconditioning (and cooling) prior to engine ignition or propellant transfer (in the context of space depots), bubbles can form and grow due to cavitation [1] (see Fig.1). This is a problem due to vapour accumulation under microgravity conditions and the impact on wall heat transfer. More generally, cavitation, under conditions where phase change predominates, is important for many applications (including nuclear power plants) and raises many questions that are not understood at the small scale. This justifies the development of the SCREAMH2 microgravity wall cavitation experiment (currently in phase A/B development under an ESA contract), in which ISAE-Supaero is participating as part of the scientific team.
There are several scientific open questions regarding pool cavitation. **It is unclear how the contact line phenomena (nano-region, wall roughness, cavity shape…), the level and dynamics of depressurization, and the nature of the fluid (pure or in the presence of non-condensable gas) impact the growth of these bubbles and the associated wall heat flux.**
This thesis project aims to answer these questions by developing numerical models capable of accurately simulating pool cavitation, in parallel with the development of the SCREAMH2 experiment. The results will serve, on the one hand, as support for the experiment and, on


a) Upper stage (credits: Ariane Group)


b) Bubbles in 0g from the SOURCE experiment (credits: IMFT)

Figure 1: Context : phase change in 0g

the other hand, for its extension, particularly to configurations with multiple bubbles and in the presence of non-condensable gases.

Background

The present project is a continuation of the team's recent work on the development of a solver for the direct numerical simulation of two-phase flows with phase change [2,3,4]. The originality of the solver, based on a semi-implicit compressible projection method, lies in its thermodynamic consistency, which allows it to describe liquid, vapor, and saturation conditions at the interface for a generic fluid.

The solver has recently been extended to phase change in the presence of a contact line (solid, vapor, liquid) and validated for the simulation of nucleate boiling and pool cavitation [4]. It has thus enabled parametric studies and models developments for bubble cavitation in microgravity at the wall (see Fig. 2). The models will be extended and generalized in this project.

a) H2O bubble cavitation in a convergent duct

a) Cavitation of CH4 bubble in a tank

c) Cavitation on CH4 bubbles

Figure 2: Direct numerical simulations of cavitation

Project development

This project aims to further develop the numerical solver and to use it to answer the scientific questions raised.

1. *Numerical development of the immersed boundary method* [5] to include conjugate heat transfer and contact lines. After validation on basic test cases, configurations with complex geometries will need to be addressed. Initially, the simulation of CH4 pool cavitation used for validation in [4] will be reconsidered with the complex geometry (cylindric support and cavity for the bubble).
2. *Incondensable gas.* The solver will be extended to account for the presence of multi-species vapor and incondensable gases adsorption in the liquid while ensuring thermodynamic consistency at the interface. A surface tension model dependent on local composition will be developed, and the jump conditions will be adapted to take thermo-capillary effects into account. The model will need to be validated for simulation in the presence of Marangoni currents (using existing experimental data).
3. *Pool cavitation in micro-gravity.* Several objectives will be pursued. The first will be to support the SCREAM H2 project with detailed numerical simulations. The second will be to extend the study of pool cavitation to many fluids, considering non-condensable gases and various geometric configurations. In particular, the phase change models

developed in [4] will be extended and used to simulate multi-bubble configurations, the interaction between bubbles and their impact on wall heat transfer in microgravity.

Impact

While this project focuses on pool cavitation in microgravity, it is important to note that the developments envisaged are also intended to simulate and study other phenomena involving phase change in compressible flows in the presence of contact lines. These include 1) sloshing in tanks and 2) hydrodynamic cavitation with the development of cavitation pockets. It is planned to study such configurations towards the end of the thesis project, depending on how the project progresses.

Work environment

The PhD will be funded by CNES and will be hosted in the Space Advanced Concepts Laboratory at ISAE Supaero in collaboration with IMFT.

Application

- Profile: Master of Science (or equivalent) in aerospace or mechanical engineering (or equivalent). Required scientific background: fluid mechanics, numerical methods for computational fluid mechanics, thermodynamics.
- To apply send a cv, transcript of marks and a motivation letter and specify the name and contact of a referent, by email to annafederica.urbano@isae-supaero.fr
- Deadline for application: **1/03/2026**

Références

[1] A. Simonini, M. Dreyer, A. Urbano, F. Sanfedino, T. Himeno, P. Behruzi, M. Avila, J. Pinho, L. Peveroni and J.-B. Gouriet, "Cryogenic propellant management in space : open challenges and perspectives", NPJmicrogravity Nature,10:34(2024)

[2] A. Urbano, M. Bibal and S. Tanguy, "A semi-implicit compressible solver for two-phase flows of real fluids", Journal of Computational Physics, 456:111034 (2022)

[3] M. Bibal, M. Deferrez, S. Tanguy and A. Urbano, "A compressible solver for two phase- flows with liquid-vapor phase change. Applications to bubble cavitation." Journal of computational physics , 500:112750 (2024)

[4] M. Deferrez, S. Tanguy, C. Colin and A. Urbano, "Direct Numerical Simulation of Bubble Cavitation at a Wall in Micro-Gravity". Int. J of Heat and Mass Trans.. 254, p127612 (2026)

[5] S. Coseru, S. Tanguy, P. Freton,J.-J. Gonzalez, A. Urbano, M. Bibal, G. Bourdon, "An Immersed Boundary Method for Pressure Based Compressible Solvers with Applications to Free-Convection flows, Acoustic Wave Propagation and Thermal Plasma".
J. of Comput Phys. 524, p.113714 (2025). (2025).