INTERNSHIP 6 MONTHS

Direct Numerical Simulation of Hydrogen Bubbles Cavitation

Context

The development of upper stages featuring long coasting phases and in-space cryogenic depot reveal important issues associated with cryogenic propellant management in micro-gravity. During long ballistic phases, saturation conditions are reached in the tank. Prior to engine re-ignition or transfer, the propellant is cooled down by venting vapour. Bubbles can be formed by cavitation at the wall and growth under micro-gravity conditions. The consequences are the modification of wall heat transfer and the development of vapour pockets in the liquid. For engine applications, after the tank the propellant is sent to the turbo-pump and formation of cavitation bubbles or pockets can occur. This can lead to a loss of efficiency and damage the blades. Bubbles growth induced by pool cavitation and their impact on the wall heat transfer is difficult to characterize experimentally at a fundamental level because of the small scales involved that drive the phenomena. Direct numerical simulations can be performed to study the phenomena at the bubble scale. This has been recently achieved using a fully compressible solver [1,2] based on a pressure projection method integrated in the DIVA code. The solver has been validated against experimental data [3] and the phenomena of single bubble cavitation has been investigated. The solver has then been used to derive models for the phase change mass flow rate allowing to carry out 3D simulations of multiple bubbles at an acceptable cost (see Figure1).

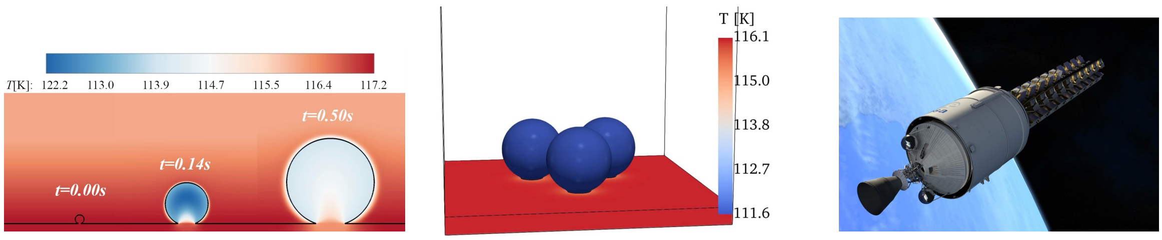

Figure 1: Left: single CH4 bubble growth induced by cavitation. Middle: multiple 3D bubbles growth induced by cavitation. Right: upper stage (credits: Ariane Group)

Goals of the internship

The objective of the present internship will be to use the DIVA code to carry out a parametric analysis on the influence of the distance between different bubbles over the wall heat transfer.

Work plan

- Bibliography study on models for bubble cavitation at the wall, heat transfer correlations and compressible methods for two phase flows simulations with phase change
- Formation on using the DIVA code for the DNS of two-phase flows with phase change
- Simulations of single and multiple bubble cavitation at the wall: study of the impact of the distance between the bubbles on the wall heat transfer

Supervisors: Prof. A. Urbano (annafederica.urbano@isae-supaero.fr)
Duration: 6 months. Starting: 2026
Requirements: Master 2 student or equivalent interested in pursuing with a PhD thesis. Basics in computational fluid dynamics, thermodynamics, programming
Hosting team: the internship will be hosted at the Space Advanced Concepts Laboratory (DCAS) at ISAE-SUPAERO

References

[1] A. Urbano, M. Bibal, and S. Tanguy. A semi-implicit compressible solver for two-phase flows of real fluids. J. Comput. Phys. , 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." J. of Comp. Physics, 500:112750 (2024).
[3] 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)