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High-fidelity numerical simulations of nucleate boiling

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We present an approach for three-dimensional high-fidelity numerical simulations of nucleate boiling at the bubble scale [1,2]. The incompressible Navier-Stokes equations for liquid and vapor phases are solved, as well as the heat equation. The interface mass transfer rate is computed ab initio from the difference in the local heat fluxes of both phases. All the physical discontinuities at the phase interface (velocity, pressure, heat flux) are retained sharply, without relying on adjustable parameters. The simulations are performed on tetrahedral unstructured grids, allowing to reproduce complex geometries, and the numerical developments are performed within the massively parallel YALES2 library [3]. The challenges of unstructured grids in terms of numerical accuracy have demanded several specific developments, including the use of high-order operators for the computation of the mass transfer rate at the liquid-vapor interface and close to the contact line. The use of dynamic mesh adaptation also contributes to achieve high numerical accuracy around the interface while limiting the numerical cost of the simulations. The proposed developments are extensively validated. Very good agreement is obtained with experiments of bubble growth and departure from the heated wall, in water at ambient pressure (Figure 1). Some important aspects will be discussed, as numerical convergence of the simulations, contact angle accuracy and modelling of the heat transfer at the contact line.

Keywords: Nucleate boiling – Bubble dynamics - Numerical simulation – High-performance computing

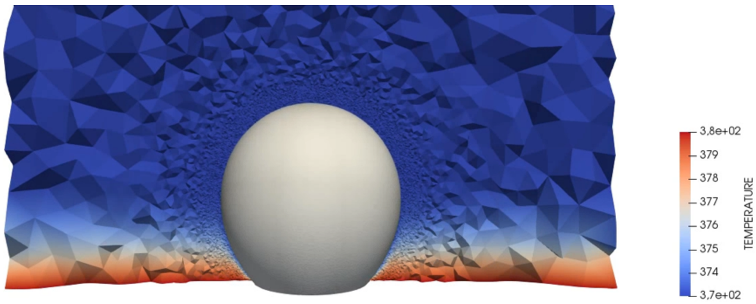

Figure 1: Simulation of a growing vapor bubble in water at ambient pressure in contact with a heated wall.

References

[1] G. Sahut, G. Ghigliotti, G. Balarac, V. Moureau & P. Marty, 2021, Numerical simulation of boiling on unstructured grids, *Journal of Computational Physics* 432, 110161.

[2] S. Pertant, M. Bernard, G. Ghigliotti & G. Balarac, 2021, A finite-volume method for simulating contact lines on unstructured meshes in a conservative level-set framework, *Journal of Computational Physics* 444, 110582.

[3] https://www.coria-cfd.fr/index.php/YALES2.