Stage M2: Compressible viscous flow simulation of collapsing bubbles

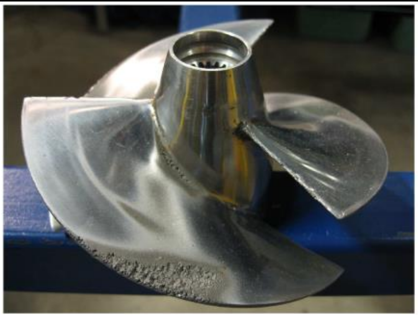

Figure 1: Erosion due to cavitation.

Figure 2: Jet formation at for a collapsing bubble relatively far from a wall (which is at the bottom of the picture). From Lauterborn & Ohl (1998).

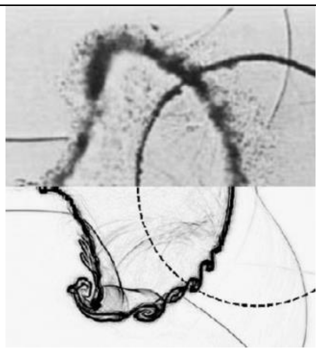

Figure 3: Comparison between numerics (bottom) and experiment (top) of an R22 bubble in air hit by a shock wave (from the right). From Capuano, Bogey & Spelt (2018).

Collapsing bubbles near surfaces can erode surfaces, which may be undesirable, such as in the erosion of ship propellers (see figure 1), or be desirable, such as in medical applications that include targeted drug delivery, enhanced sonoporation, and lithotripsy (destruction of kidney stones). Small bubbles may collapse individually (e.g. Figure 2), or a cloud of bubbles may collapse, either of which can result in shock waves that impact the solid material.

Visual observations such as in Figure 2 of the rapidly evolving bubble shape are available from prior experimental work (in fact, several distinct flow regimes are known), but the sequence of physically rich events, and how these result in cavitation damage, remains unclear, thus in practice one relies on empiricism.

The proposed stage subject is to conduct a computational study of these flows, which will also form a basis for future work on other compressible gas-liquid flows. This requires challenging numerical simulations, and the method for these has novel aspects in their own right, but the in-house numerical code to be used in this stage has been developed previously to provide a suitable starting point. It is a generalization of the well-established computational method for aeroacoustics at the Centre Acoustique at Lyon (Bogey & Bailly 2004) to flows of two different fluids. The project is therefore to use the pre-existing code to conduct numerical simulations of collapsing bubbles, and to interpret the results.

The computational method that will be used is based on that developed in our prior work, for the simulation of compressible flows of two ideal gases (Capuano, Bogey & Spelt 2018). The results of comparisons in that earlier work with experiments was found to be satisfactory. These included the detailed evolution of a gas bubble in another gas that is hit by a shock wave - a sample result obtained from these simulations is presented in Figure 2. Recently, this method has been extended such that gas-liquid flows can also be simulated (Capuano 2018).

The project offers opportunities for a talented, motivated student to work on a highly interdisciplinary subject. The stage may form the basis for a subsequent PhD subject, possibly involving other compressible two-phase flows such as jets.

The stage will be supervised by Christophe Bogey (CNRS, LMFA, christophe.bogey@ec-lyon.fr) and Peter Spelt (UCBL, LMFA, peter.spelt@univ-lyon1.fr), and will be at École Centrale de Lyon.

References:

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