Fluid dynamics model accurately predicts how bubbles impact on solid surfaces

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Bubbles are an essential part of many industrial applications including foam formation, water purification, and oil and gas extraction. To understand the effects of bubbles in these systems, A*STAR researchers have developed a computer model that predicts exactly how they rise through liquids and impact on solid surfaces.

The dynamics of bubbles are surprisingly complex, influenced by processes on micrometer to millimeter length scales, and on timescales ranging from milliseconds up to several seconds. The interface between the air inside a bubble and the surrounding liquid, and the terminal velocity of rising bubbles both change considerably depending on the composition of the liquid. Then, when a bubble hits a solid surface, the film of liquid that drains off the solid can form complicated shapes that are difficult to predict.

A full solution of this problem would require solving the non linear Navier-Stokes equations—a task that even a supercomputer would take weeks to complete. So, Rogerio Manica at the A*STAR Institute of High Performance Computing and co-workers developed a simpler 'force balance model' in which forces such as buoyancy and drag are considered along with lubrication theory to model the draining liquid film.

"We aimed to provide the simplest model that can capture the physics of the problem," explains Manica. "In fluid dynamics, more often than not, it is the knowledge of which effects can be neglected and which effects should be included, rather than brute computer power, that determine if a model can represent experimental data accurately."

They used real data from high-speed camera observations of bubbles to provide some boundary conditions on their simulations and were able to run their simplified model in seconds using a regular desktop computer.

"Our model contains all the major physical ingredients of the system, and in fact we were surprised by how well it performed when compared to experimental data," says Manica. "It also has great predictive power, because the parameters are not fitted to any one dataset."

The team is hopeful that their results will open up possibilities for future research, for example modeling the interaction between bubbles and deformable surfaces. This would include bubbles colliding with the separation boundary between oil and water, a pressing problem for the oil industry. The team will also extend their model to consider oblique impacts of bubbles, and the effects of bubbles sliding along a surface.

More information: Rogerio Manica et al. Force Balance Model for Bubble Rise, Impact, and Bounce from Solid Surfaces, *Langmuir* (2015). DOI: 10.1021/acs.langmuir.5b01451

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