Instability of a Swirling Bubble Ring

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A toroidal bubble or a cylindrical gas jet are known to be subjected to the Rayleigh-Plateau instability[2]–[3]. However, air bubble rings produced by beluga whales and dolphins are observed that remain stable for long times [5]. In the present work [1], we analyze the generation of such toroidal bubbles via numerical simulations, in particular how the process depends on surface tension with solver Basilisk[4]. In addition we examine the instability when the toroidal bubble is formed.

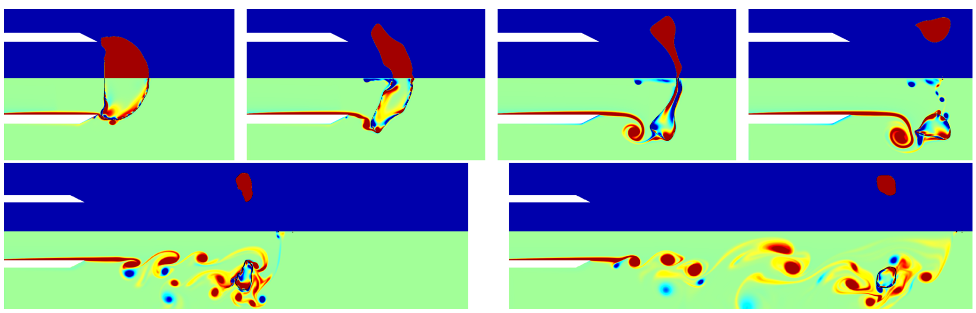

Figure 1. Simulations snapshots of a toroidal bubble generation at different time. From left to right, first row to second row: $\bar{t} = 4.4$, 5.6, 9.6,$t = 20$, 30. The upper half displays phases and interfaces (red is gas and blue water) and the lower half the vorticity field.

For the generation process, one considers an idealized axisymmetric nozzle containing initially a gas bubble which is rapidly expelled. Simulations show that during the initial production of such bubble, vorticity trailing from the nozzle or from the opening rolls up into a toroidal vortex ring. It traps gas in its core by overcoming surface tension which would favor the formation of a single spherical bubble. In a second period, the bubble ring is stretched. The core radius is highly reduced, the swirl is enhanced, and the vorticity in the gas tends to become uniform. These features are important since a linear stability study shows that a rotating columnar vortex in the gas eventually is capable to stabilize the Plateau instability as swirl increases above a well-defined critical value.

References

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