Cavity collapse near porous plates

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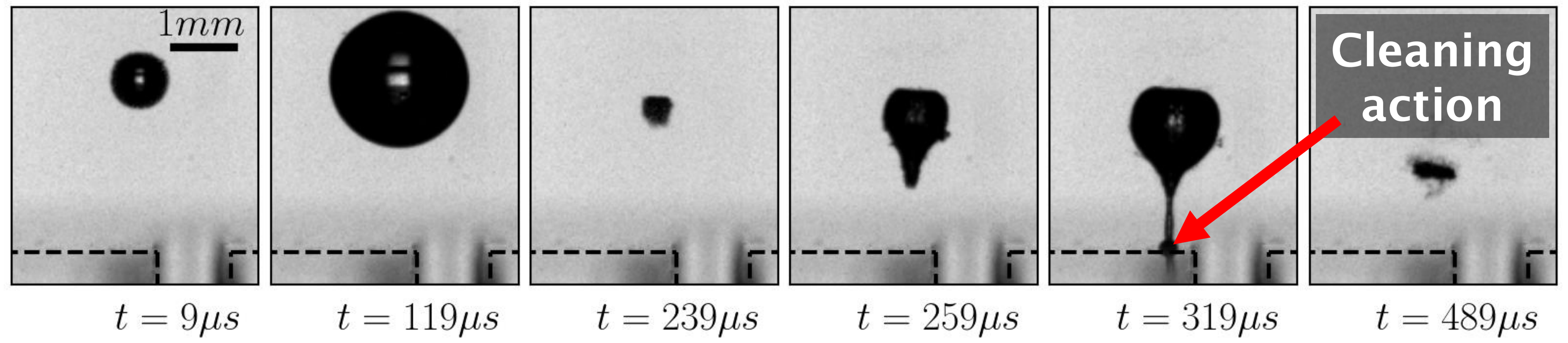
Introduction

Collapsing bubbles can be used as a practical cleaning method[1] for complex geometries that are now more common due to developments of new manufacturing methods such as 3D printing. A collapsing bubble forms a high-speed jet that can be used to clean a surface.

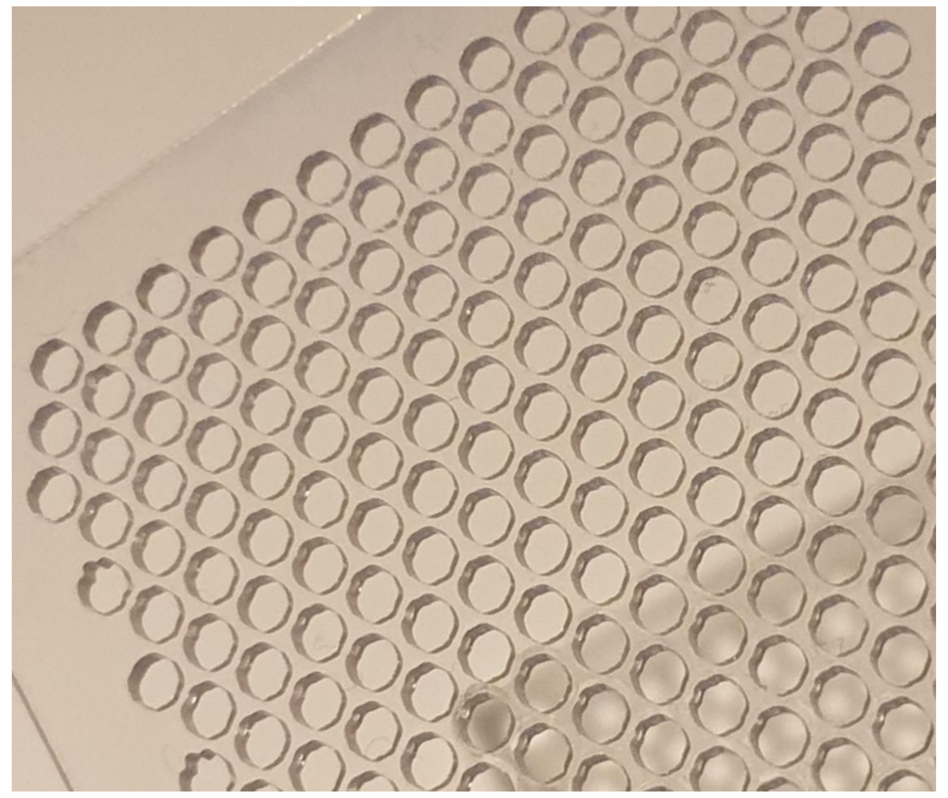


It is well understood how bubbles collapse near flat boundaries and other simple geometries. However, the understanding of how complex geometries affect bubble collapse is still limited. Here, we investigate how bubbles collapse near a flat boundary with through-holes.

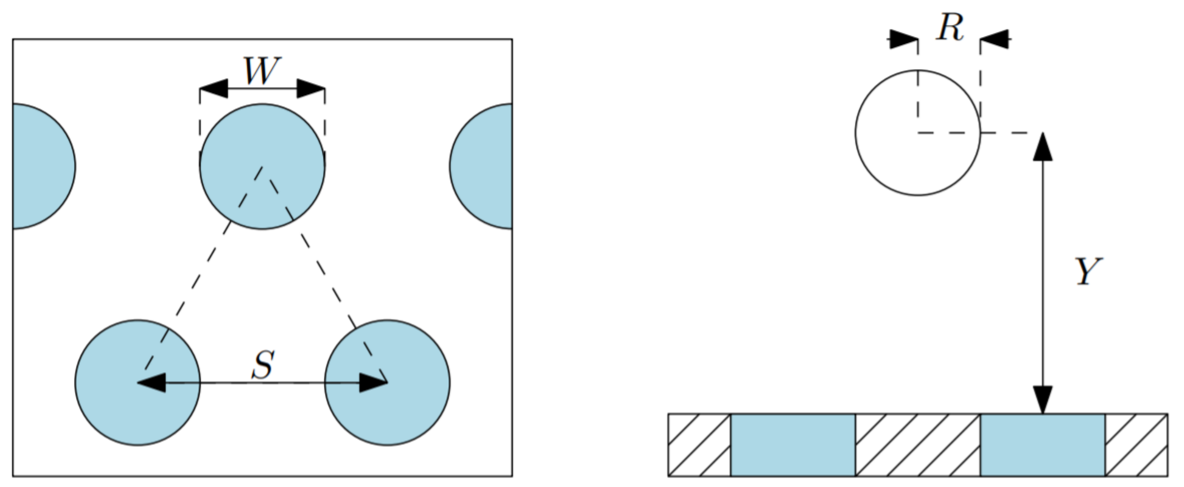
Problem Definition

Porous materials, such as filters, are common and can be treated with ultrasonic cleaning[2].

We investigate the simplest form of porous material: a thin plate with circular through-holes (pictured right).



We assume that the plate thickness is negligible and thus the system can be described by the four parameters shown in the diagram below.



Boundary void fraction ϕ

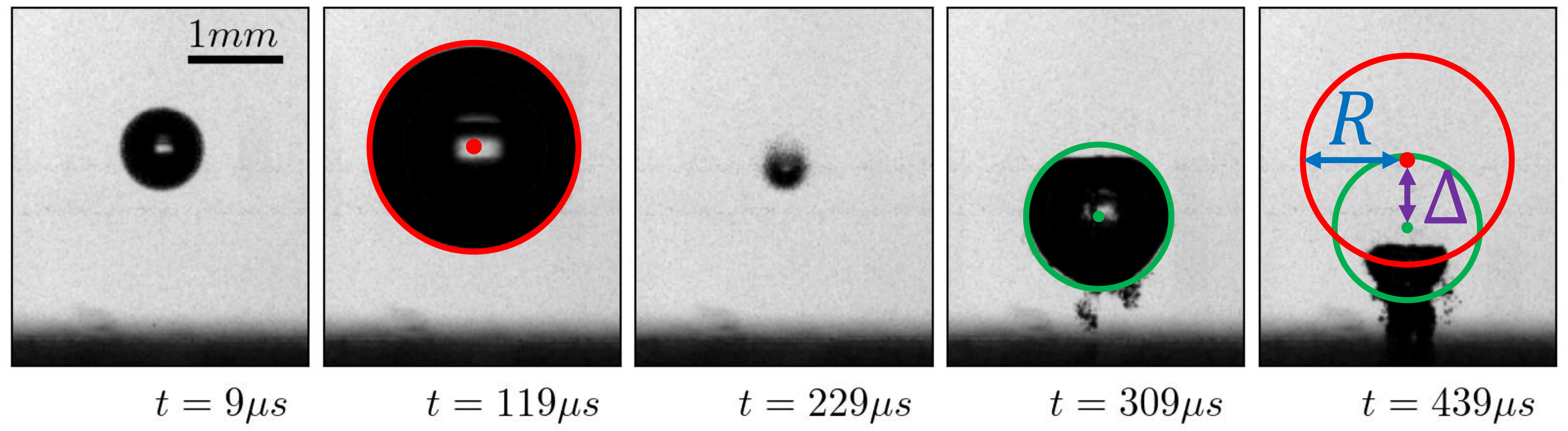
$$\phi = \frac{\pi\sqrt{3}}{6}\left(\frac{W}{S}\right)^2$$

Bubble standoff distance γ

$$\gamma = \frac{Y}{R}$$

Measuring Collapse Strength

Bubble collapses close to boundaries are stronger than collapses far from boundaries. We measure the strength as the displacement (Δ) of the bubble between its first (R) and second radius maxima.

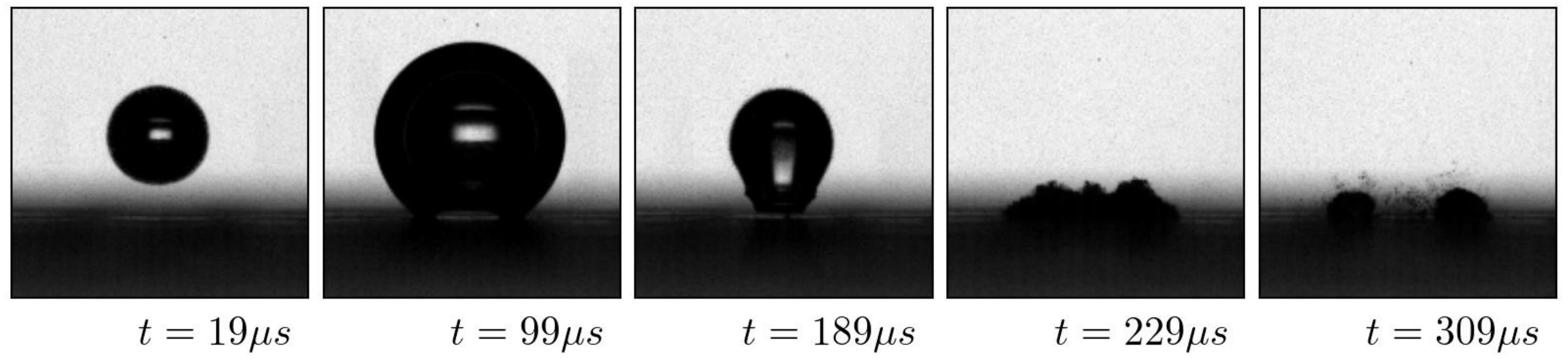


Effect Of Horizontal Position

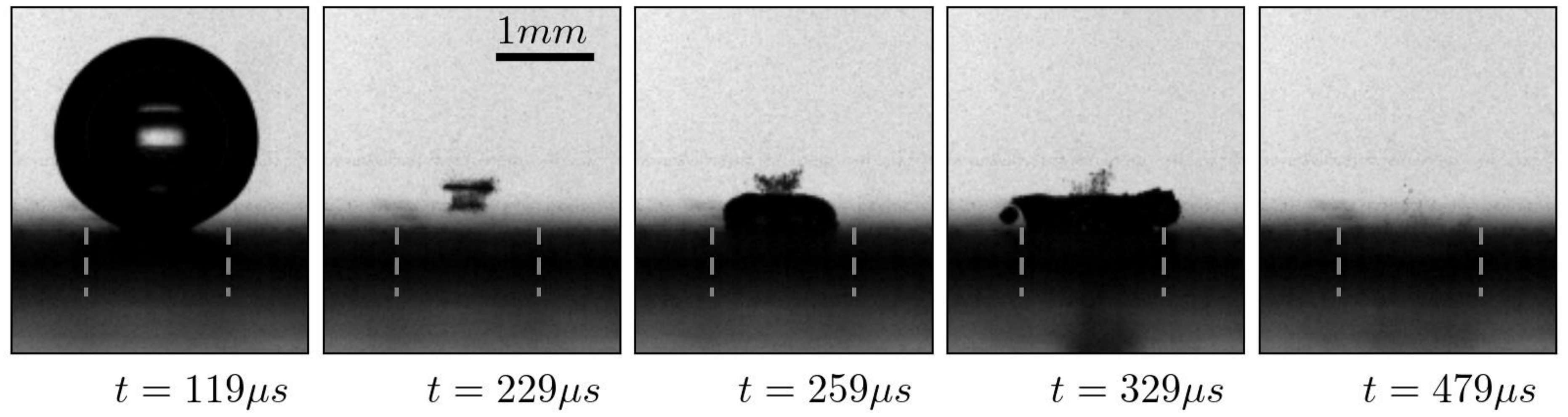
At the extremes, bubbles can be above a hole or between three holes. Surprisingly, these two cases produce indistinguishable collapse displacements.

However, there are some interesting collapse dynamics when the bubble is close to the boundary.

When the bubble collapses above the boundary between two holes, the bubble expands more towards the holes. After impacting the boundary, it separates into two sections, both moving apart.

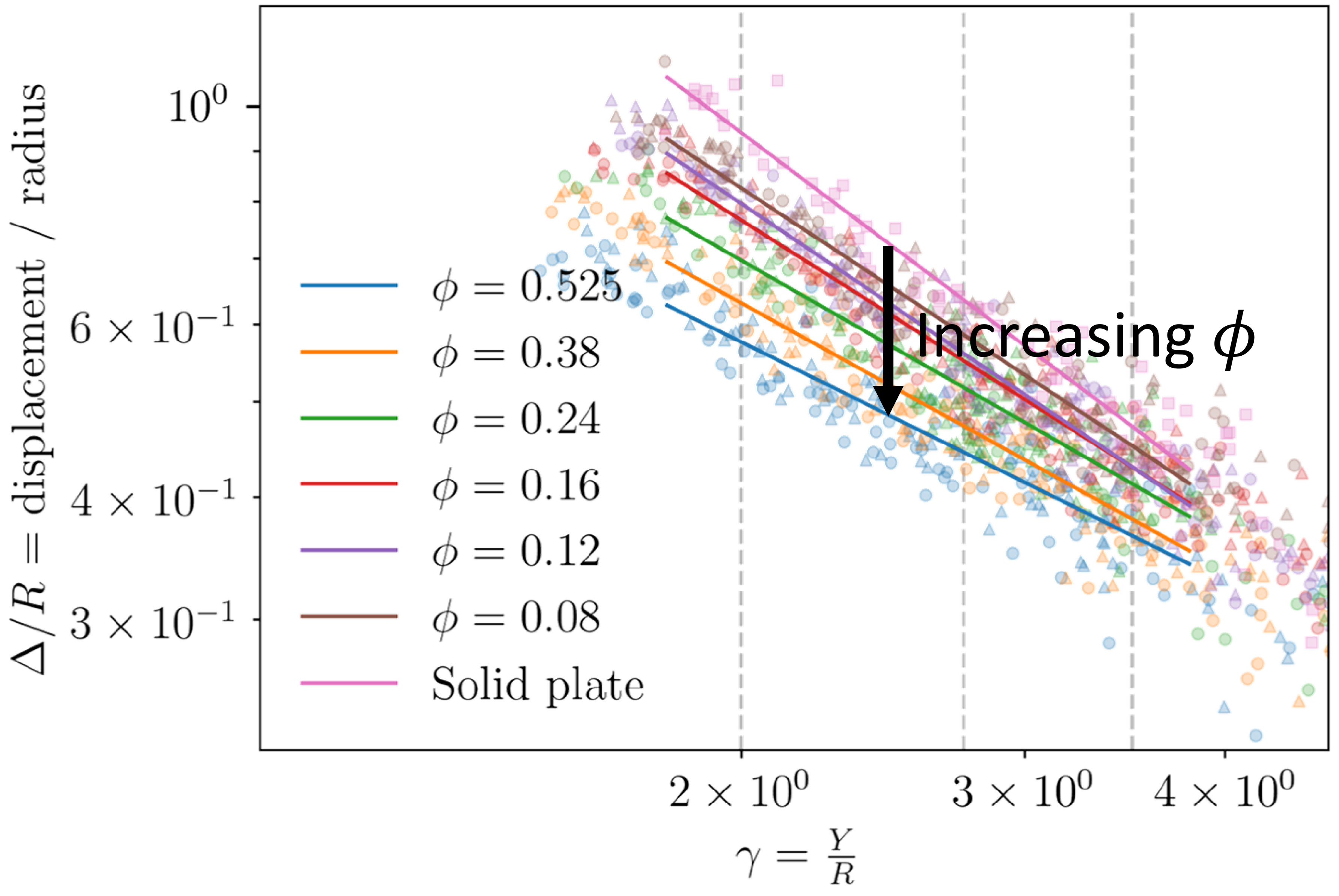


When the bubble is above a hole, it collapses through the hole.



Effect Of Standoff And Void Fraction

This plot shows the variation of dimensionless displacement with standoff distance.



For each plate, as the standoff distance increases, the bubble displacement decreases.

A solid plate causes the highest bubble displacements, with the bubble displacement decreasing as the void fraction of the plate, ϕ, increases.

Essentially, the less plate there is, the weaker the bubble collapse.

Conclusion

In this work, we have shown that holes in a boundary reduce the strength of bubble collapse. Surprisingly, the horizontal position of the bubble does not have a significant effect.

In our upcoming research, we will characterise how the displacement varies with standoff and void fraction, as well as the effect of the shape of the holes.

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[1] B. Verhaagen, T. Zanderink, D. Fernandez Rivas, Ultrasonic cleaning of 3D printed objects and Cleaning Challenge Devices. *Applied Acoustics*. **103**, 172–181 (2016).
[2] F. Reuter, S. Lauterborn, R. Mettin, W. Lauterborn, Membrane cleaning with ultrasonically driven bubbles. *Ultrasonics Sonochemistry*. **37**, 542–560 (2017).