Understanding the growth of vapour bubbles

by Rohit Pillai, senior lecturer at University of Edinburgh

Abstract

Vapour bubble formation has been attributed as the driving factor behind natural phenomena such as geyser formation and volcanic eruptions. The explosive failure of pressurised containers and wear of turbomachinery caused by cavitation bubbles highlight the deleterious effects of vapour bubbles on industrial processes. On a different note, the high heat fluxes dissipated from surfaces during bubble formation and growth has seen pool boiling attracting significant interest in thermal management systems. Understanding the formation and growth behaviour of vapour bubbles is therefore an important open problem for both scientific and engineering applications, but a fundamental understanding is still lacking.

Our theoretical understanding of vapour bubble growth is currently restricted to asymptotic descriptions of their limiting behaviour. While attempts have been made to incorporate both the inertial and thermal limits into bubble growth models, the early stages of bubble growth have not been captured. By accounting for both the changing inertial driving force and the thermal restriction to growth, we present novel inertio-thermal models of both homogeneous and heterogeneous vapour bubble growth, capable of accurately capturing the evolution of a bubble from the nano- to the macro-scale.

For homogeneous bubbles, our results show improved agreement with experiments - and our own molecular simulations - when compared to previous theoretical models. By accounting for the effect of the surface on both the geometry of the bubble and on the available thermal energy, we can additionally study the effect of surface wettability on heterogeneous vapour bubble growth. Using molecular simulations, we investigate not only how the strength of fluid-solid interaction affects the growth rate, but also how the non-continuum nature of the fluid under the bubble on hydrophilic surfaces plays a vital role in determining the bubble shape and subsequent dynamics.

Short Bio

I am Senior Lecturer (equivalent to Associate Professor) in the Institute of Multiscale Thermofluids at the University of Edinburgh. I have a background in computational modelling of micro/nano-scale fluid dynamics and heat transfer, and my current research interests lie in topics such as ice nucleation, interfacial thermal resistance, and vapour bubble growth. I currently lead a group comprising of 1 Research Fellow and 3 PhD students and am part of a wider research group that focuses on multiscale modelling of a range of problems relevant to health, transport, water, and energy (see multiscaleflowx.ac.uk).

I obtained my PhD from the University of Melbourne in 2017, was appointed as Lecturer in Edinburgh less than a year later, and promoted to Senior Lecturer earlier this year. In the last 5 years, my research has featured in prominent top-quality journals (such as *Physical Review Letters* and *Nano Letters*), the press (*BBC, Times, Metro*), led to keynote talks at international conferences as well as a radio interview *on BBC Scotland Newsnight* programme. I have also obtained €270,000 of research funding from internal and external sources in that time.