VII ECCOMAS Young Investigators Conference
YIC2023
19-21 June 2023, Porto, Portugal

Effect of Vapour Bubble Initial Displacement on Droplet Impact onto Liquid Films

Daniel Vasconcelos*, André Silva*, Jorge Barata*

*AEROG/LAETA
Universidade da Beira Interior
Covilhã, Portugal
e-mail: daniel.vasconcelos.rodrigues@ubi.pt

Abstract: Heat and mass transfer mechanisms regarding droplet impact have been extensively studied for dry surfaces, and in terms of droplet evaporation/combustion during free-fall. On the contrary, the droplet impact phenomena onto heated liquid films is a topic overlooked in the literature and requires further understanding in terms of hydrodynamics and phase change. Therefore, this work focuses on numerically simulating droplet impact onto liquid films in the presence of vapour bubbles. The crown height, diameter and overall development are analysed as a function of the position of the bubble related to the axis of symmetry. Results show that the crown overall growth is affected if the vapour bubbles detach and contact the crown wall. The size of the vapour bubbles also influences the detachment from the surface.

Keywords: Droplet Impact, Numerical Model, Bubble Formation, Crown Disintegration

1 Introduction

The mathematical and numerical comprehension of multiphase flows are topics both extensively studied and far from understood. Specifically, the droplet impact phenomena and associated interfacial phenomena, such as surface tension, evaporation and condensation, are difficult to implement in euler-euler formulations, along with the underlying fluid dynamics of the droplet-liquid film interactions. These are found in practical applications such as internal combustion engines, heat exchangers, and electronic cooling devices, in which temperature plays a major role. If a heated surface is covered by a liquid film, local boiling effects will occur, leading to the appearance of vapour bubbles on the impact surface, which affect the impact phenomena.

The influence of the bubble size and spacing on the crown formation and disintegration has been studied in previous works [1]. However, the initial bubble displacement (which refers to the vapour bubble closest to the symmetry axis) was not varied during the experiments, which may be an important factor in determining the crown overall development. Therefore, this work focuses on numerically simulating droplet impact onto liquid films in the presence of vapour bubbles, in which the first bubble positioning in relation to the axis of symmetry is varied.

2 Numerical Model

The numerical model consists on solving the Navier-Stokes equations coupled with the VOF method for liquid-gas interface tracking, which has been fully detailed [1]. Basilisk [2] was the open-source software adopted for the numerical simulations. Figure 1 displays a schematic of the physical setup. A single droplet impacts vertically onto a liquid film of a certain thickness. Vapour bubbles are positioned in the impact surface to represent boiling effects. These are defined by their diameter, D_v, spacing, x_v, and the positioning of the first bubble, x_s, meaning the displacement of the vapour bubble in relation to the axis of symmetry. This last parameter will be modified to verify its influence on the impact outcome.

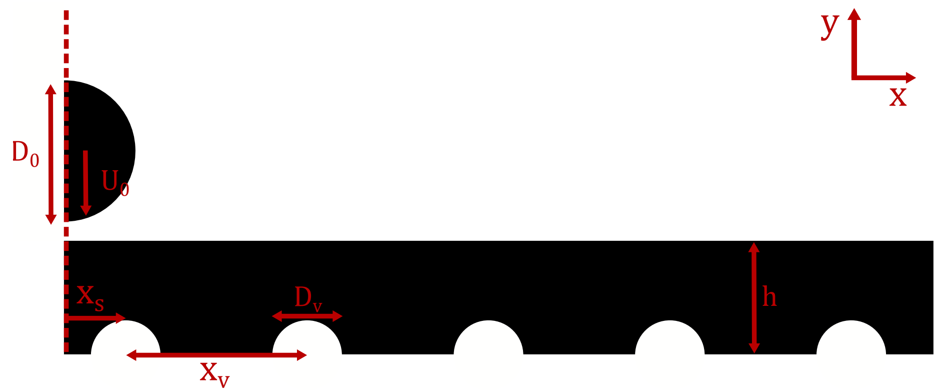

Figure 1: Numerical setup: x_s - Initial vapour bubble displacement from axis of symmetry; D_0 - Droplet diameter; U_0 - Droplet impact velocity; D_v - Vapour bubble diameter; x_v - Vapour bubble spacing; h - Liquid film thickness.

3 Conclusions

Numerical simulations of droplet impacting onto a heated liquid film in the presence of vapour bubbles were performed. Results show that the crown overall growth is affected if the vapour bubble detaches from the impact surface and contacts the liquid crown wall, leading to disintegration. The size of vapour bubbles is also a factor, as smaller bubbles tend to stick to the impact surface, not disturbing the crown walls.

4 Acknowledgements

The present work was performed under the scope of Aeronautics and Astronautics Research Center (AEROG) of the Laboratório Associado em Energia, Transportes e Aeronáutica (LAETA) activities, supported by Fundação para a Ciência e Tecnologia (FCT) through the project number UIDB/50022/2020 and by the Ph.D. scholarship with the reference SFRH BD/143307/2019

References

[1] Vasconcelos D, Silva A, Barata J. Influence of Vapour Bubbles Size and Spacing on Droplet Impact Outcomes under Subcooled Boiling Regimes. ILASS–Europe 2022, 31st Conference on Liquid Atomization and Spray Systems.

[2] Popinet, S. Basilisk flow solver and PDE library. http://basilisk.fr.