Hessisches Kompetenzzentrum
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Numerical Investigation of Drop Impact, Coalescence and Evaporation on Superheated Surfaces IV

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Clusters
Lichtenberg II Cluster Darmstadt

Software
OpenFOAM

Institute
Institute for Technical Thermodynamics

University
Technische Universität Darmstadt

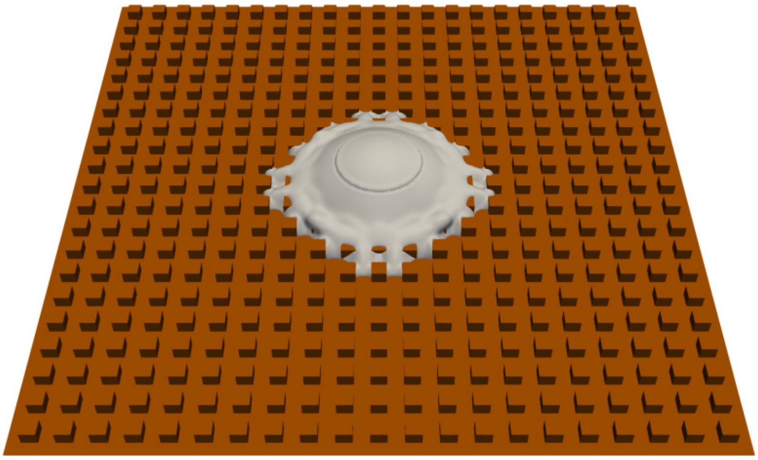

Figure 1: Drop impact onto a structured wall.

Introduction

Spray cooling is a very effective method for cooling of electronic devices. The study of the impact of single and coalescing drops onto a superheated wall contribute to a better understanding of the complex hydrodynamics and heat transfer mechanisms during spray cooling. Special consideration is given to the three-phase contact line, where solid, liquid and vapor meet and high evaporation rates are observed. Accurate calculations of the hydrodynamics and heat transfer require large computational effort.

Methods

The governing equations of the numerical model describe the conservation of mass, momentum and energy for incompressible fuid flow. Heat and mass transfer at the liquid-vapor interface is accounted for in source terms. To track the interface, the volume-of-fluid method is used. A subgrid model accounts for hydrodynamics and heat transport mechanisms on a microscale in the vicinity of the three-phase contact line. The results from this sub-grid model are implemented in the form of correlations in the overall numerical model.

Results

The solver is used for two different studies. The first study addresses several drops impacting consecutively centrally onto each other onto a smooth, superheated wall. This scenario is referred to as drop train impact. Next, it has been shown that texturing of the surface can enhance the heat transfer during drop impact. Hence, in a first step, the hydrodynamics during the single drop impact onto a textured wall under isothermal conditions is studied.

Discussion

During the impact of the drop train the maximum contact line radius increases and both the spreading and receding phases of the drop impact process are prolonged with each consecutive drop impact. After the impact of ten drops the so-called puddle thickness, which describes the thickness of a large sessile drop in case where gravitation dominates, is reached. Just after the impact of the initial drop, the wall temperature decreases to the contact temperature. All further drops lead to a lower decrease in wall temperature compared to the first drop. For our study, the liquid film thickness, formed by the previous impacted drops, has no influence on the wall temperature decrease. By comparing drop train configurations with different drop generation frequencies and drop sizes, but each drop train with the same total kinetic energy and flow rate, it has been shown that large drops impacting with low drop frequency transfer more heat than small drops impacting with high drop frequency. This can be attributed to the drastic changes in Reynolds and Weber numbers. The final drop shape depends only on the total liquid volume and not on the drop train configuration. The study of the single drop impact onto textured surfaces shows that the textures prevent a receding of the drop. This results in a large wetted are over a long time period and hence heat transfer is expected to be high. Additionally, the final liquid height matches the texture height. As a consequence, small and low textures lead to larger wetted areas as large and high textures. Drop impact onto grooves leads to asymmetric drop spreading. The drop spreading in the grooves is driven by capillary forces and follows a power law.

Publications

Sontheimer, H.; Schlawitschek, C.; Batzdorf, S.; Stephan, P.; Gambaryan-Roisman, T.: "Numerical Simulation of Heat Transfer and Evaporation During Impingement of Drops onto a HeatedWall", Fluid Mechanics and Its Applications, 124, in Droplet Dynamics Under Extreme Ambient Conditions, p. 269-289, Cham, Springer International Publishing, ISBN 978-3-031-09008-0 https://doi.org/10.1007/978-3-031-09008-0_14

Sontheimer, H.; Gholijani, A.; Stephan, P.; Gambaryan-Roisman, T.: "Hydrodynamics and heat transport during the vertical coalescence of multiple drops impacting successively onto a hot wall", International Journal of Heat and Mass Transfer, 204, Elsevier, ISSN 0017-9310 https://doi.org/10.1016/j.ijheatmasstransfer.2023.123856

Sontheimer, H.; Gholijani, A.; Stephan, P.; Gambaryan-Roisman, T.: "Coalescence of Drops Impacting a Hot Wall: Hydrodynamics and Heat Transport", DIPSI Workshop 2022 - Droplet Impact Phenomena & Spray Investigations, Bergamo (Italy), July 1, 2022

Sontheimer, H.; Gholijani, A.; Stephan, P.; Gambaryan-Roisman, T.: "Heat Transfer and Evaporation during the Impingement of a Single Drop and of a Drop Chain onto a Superheated Wall", Gordon Research Conference - Micro and Nanoscale Phase Change Phenomena, Barga (Italy), January 8-13, 2023

Sontheimer, H.; Elsäßer, L.; Stephan, P.; Gambaryan-Roisman, T.: "Numerische Simulation der Hydrodynamik beim Tropfenaufprall auf strukturierten Wänden", Jahrestreffen der DECHEMA-Fachgruppen Computational Fluid Dynamics und Wärme- und Stoffübertragung, Frankfurt (Germany), March 6-8, 2023

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