Dynamics of the Cavity Generated in a Liquid Film by Drop Impact

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Abstract

The hydrodynamics of a drop impacting onto a liquid film are rather important when trying to understand and predict spray related processes like spray cooling or spray coating. The underlying physics essential for this understanding can be investigated well by examining a single drop impact onto a liquid film or layer, which is the subject of this study. Drop impact onto a liquid layer generates an expanding cavity which penetrates into the layer due to inertia. In some cases, if the initial velocity exceeds the splash threshold, drop impact leads to the formation of the uprising crown-like sheet and splashes. In the case of relatively deep liquid layers, the cavity growth is decelerated by the gravity and surface tension. If the initial thickness of the liquid layer is comparable with the drop diameter, the cavity expansion is significantly influenced by the bottom wall effects. As the distance between the cavity and the rigid bottom decreases with time after impact, the cavity penetration is increasingly influenced and damped by viscous forces. The residual thickness of the liquid film between the cavity and the bottom is one of the main parameters determining the heat transfer associated with spray impact and is therefore an interesting parameter to predict. For a hydrophobic surface, the residual thickness could also determine the condition for the rewetting of the substrate. The present study examines experimentally and theoretically the main geometrical parameters of the cavity, especially the residual, minimum film thickness. This thickness is much smaller than the drop initial diameter and the initial film thickness. Its determination experimentally is therefore a challenging task. In the experiments the shape of the penetrating cavity generated by drop impact is observed using a high-speed video system. Additionally, the thickness of the liquid layer between the cavity and the wall is monitored in time using an instrument based on chromatic confocal imaging (CHR optical sensor). Liquid properties, initial film thickness and drop impact parameters are varied in the experiments. The theoretical model for the cavity penetration is developed accounting for gravity, surface tension and liquid inertia. The equation of motion of the cavity tip is obtained from the linear momentum balance equation and the evolution of the film thickness during the viscous stage is described. The theoretical predictions agree well with the experimental data.

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