Atelier
« Problèmes complexes de frontières et d'interfaces —
modèles théoriques, applications et défis mathématiques »
4—8 juillet 2016

Workshop
"Complex Boundary and Interface Problems —
Theoretical Models, Applications and Mathematical Challenges"
July 4—8, 2016

A coupled level set and moment-of-fluid method for simulating drop impact and freezing

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Supercooled large droplets (SLDs) have the potential to bypass aircraft anti-freezing devices by splashing and then leading to ice accretion further downstream. In this presentation, we present a numerical method for simulating the impact and freezing of droplet(s) on solid surfaces. The thermal and wetting properties of water, ice, and substrate are taken into account in our numerical simulations. The interfaces separating water, ice, substrate, and air are represented sharply using a novel coupled level set and moment of fluid method. The moment-of-fluid method is coupled to the level set method so that interfacial curvature and interface slopes can be more accurately approximated by aid of the level set functions. The level set method is coupled to the moment-of-fluid method so that the overall method conserves volume. The level set functions are the exact signed distance to the multimaterial (two or more materials) tessellating reconstructed interface. We report results of our simulations in 3D axisymmetric coordinates and three dimensional coordinates for a liquid drop freezing on a substrate in air and a liquid drop impacting a substrate with a preexisting thin layer of ice and then possibly freezing. Contact line effects between substrate, ice and air, and between ice, water, and air are taken into account. We find in our simulations that the simulated volume of ice, including the effect of expansion, is correct up to a fraction of a percent throughout the freezing process. Comparisons are made between simulations and analytical results for rate of freezing with good agreement. Good agreement between simulations and experiments are obtained for the shape of freezing droplets.

This is joint work with Mehdi Vahab, M. Yousuff Hussaini, and Yongsheng Lian.

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