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PHASE-FIELD SIMULATION OF DROP IMPACT ON A LIQUID FILM: THE CRITICAL ROLE OF INTERFACIAL MIXING ENERGY

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In internal combustions engines and in systems for exhaust aftertreatment, sprays interact with liquid wall films. Fundamental understanding of this interaction and its proper modelling are essential to increase efficiency while reducing emissions. Here, we assess and validate a phase-field method for the impact of a single droplet on a thin wall film of the same liquid (silicone oil) by dedicated experiments exhibiting different dynamics of axisymmetric corona formation.

In the experiments, a drop (diameter 1.4 mm) accelerates by gravity and impinges onto a stagnant horizontal film of defined thickness (0.5 mm). By altering the falling height of the drop, the impact speed U is varied between 1 and 3 m/s. To observe the drop impingement, a high-speed camera system with a framerate of 20000 fps is utilized. With the help of image processing, the temporal evolution of the corona top and base diameter as well as its base angle are determined. These parameters serve for comparison with the numerical results.

For the numerical simulations with the phase-field method, the two-phase flow is described by the coupled Cahn-Hilliard-Navier-Stokes equations, which are solved using the open source C++ library OpenFOAM (code phaseFieldFoam). Since the impingement and corona formation process in the experiment are rotationally symmetric, an axisymmetric set-up in combination with adaptive mesh refinement is used. Different mixing energy and mobility (standard and degenerate) formulations will be critically assessed with focus on accuracy and boundedness.

For $U = 1$ m/s and 2 m/s, simulations with standard mixing energy formulation reproduce the experimental corona formation reasonably well. This is not the case for $U = 3$ m/s where the corona base angle in the experiment is about 90° (Fig. 1), while in the computation it is about 120° (Fig. 2). The application of a (yet empirical) non-equilibrium mixing energy formulation demonstrates the potential to correctly reproduce the experimental corona formation also for high impact velocities. These results indicate that for multiphase flows with highly dynamic fresh interface formation, out-of-equilibrium interfacial mixing energy modelling is required.

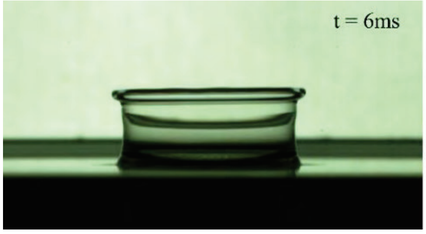

Fig. 1: Snapshot of experiment ($U = 3$ m/s).

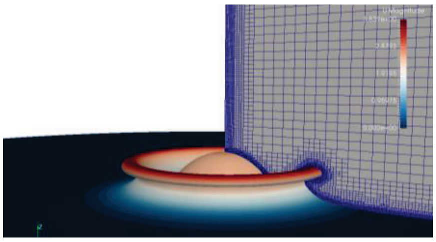

Fig. 2: Snapshot of simulation ($U = 3$ m/s).