USING WAGNER THEORY TO PREDICT EARLY-TIME JET PROPERTIES IN LIQUID-LIQUID IMPACT PROBLEMS

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Droplet impact problems have a wide range of applications throughout real-world phenomena and industrial processes ranging from inkjet printing to aerosol formation to soil erosion. Due to the violent displacement of liquid free surfaces and the associated rapid topological changes on short timescales and disparate lengthscales, impacts are notoriously difficult to model theoretically, numerically and experimentally.

With the advent of ever more powerful cameras and computers, we have a wealth of resources at hand to investigate impact phenomena in greater detail and at earlier times. However, since impact problems are highly nonlinear and complex, it is desirable to use mathematical modelling to help predict certain properties, such as the location of the root of the splash jet (or ejecta), enabling us to focus our numerical or experimental investigations on a subset of the full impact problem.

Wagner theory – an inviscid, incompressible model that neglects the roles of surface tension, gravity and the surrounding air – was developed in relation to ship-slamming applications. However, much of the model is readily extended to droplet impacts. In this analysis we perform a comprehensive Wagner analysis of droplet impacts for general droplet radii and impact speeds. We derive leading-order predictions for the location, thickness and velocity of the root of the high-speed jet, as well as predictions for the leading-order jet thickness and velocity.

We compare the predictions to direct numerical simulations performed in the open-source software package Gerris, which allows for a high-level of local grid refinement, necessary for problems with such a wide range of spatial scales. We discuss what the theory predicts well, as well as where it struggles to predict the impact dynamics. In the former cases, we discuss possible uses for the theory, while in the latter cases, we discuss extensions to Wagner theory to improve the predictions.

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