Modelling the deformation of liquid surfaces under impinging gas jets

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Primary host: Dr. Dmitri Tseluiko (Loughborough University)

Overview: Analysing the effect of impinging gas jets on liquid layers is not only of fundamental interest, but also presents great industrial importance, e.g. for metallurgical applications. The SRV brought together experimental and theoretical capabilities of the hosts and the visitor to synergistically develop a comprehensive understanding of this process. The close interaction during the week allowed rapid progress and generated a collection of exciting results that are to be extended into large scale studies over the coming months.

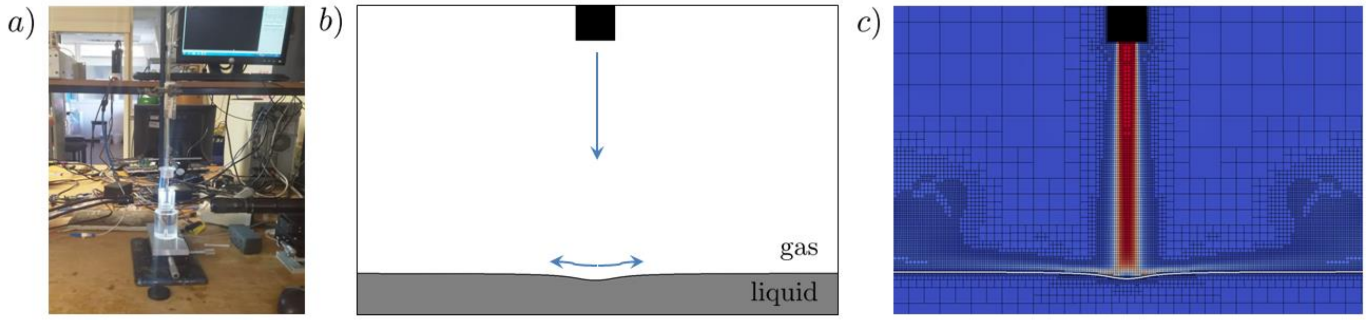

Figure 1. a) Experimental setup in the lab at Loughborough University, involving an impinging gas jet being ejected from a nozzle at moderate to large velocities, causing the deformation of the liquid interface below. b) Sketch of the multi-fluid system. c) Direct numerical simulation snapshot illustrating the norm of the velocity vector (background), the adaptive mesh refinement, as well as the fluid-fluid interface (white).

SRV Description: The physical setup was motivated by the interaction between plasma, an electrically charged gas, and a body of fluid underneath, of interest not only in large scale industrial devices, but also in medicine (skin treatment) and environmental applications (nitrite detection). While electric and chemical effects play an important role in these systems, the hydrodynamic component underlies the key dynamical processes at play and already includes a series of competing mechanisms such as inertia, gravity, surface tension and viscosity. Much of the focus in the past has been on the interfacial shape deformation only, with the flow patterns inside the liquid largely ignored, despite these being vital for the understanding of heat and mass transfer for example. The hosts, as part of the doctoral work of Juliet Chinasa Ojiako, had been building the following investigative toolkit for this purpose:

- an experimental apparatus (see Fig. 1a above) consisting of a gas injection mechanism with variable flow rate, a cylindrical container partially filled with liquid, a light source and a high speed camera to enable flow visualisation;
- an efficient reduced-order model operating under the thin film approximation to study the evolution of the liquid-gas interface;
- a numerical setup using a commercial package that would allow the capturing of further detail in the flow.

The latter was however shown to produce unexpected results or experience numerical convergence issues. To ensure the accuracy of the setup and before moving on to analysing previously unexplored flow regimes systematically, a more stable toolkit was required. In order to bridge the experimental work and analytical progress, the visitor implemented and validated a state-of-the-art direct numerical simulation platform based on the volume-of-fluid methodology (Fig. 1c) running both locally and on high performance computing clusters that has shown good versatility in addressing the target regimes. Through extensive comparisons while on site we found excellent agreement when compared to the commercial package for the available results, while at the same time enabling access to (previously) difficult test scenarios. Beyond the extraction of new quantities of interest, the study of more complex phenomena such as interfacial oscillations and eventual break-up is also within reach. As such, a systematic study of the parameter space is now under way and we are in the process of preparing a publication based on this work. Understanding the key challenges in the project and interfacing quickly between the experiment, model and computational platforms would not have been possible without the close contact over the respective week.

The SRV has also facilitated the strengthening of collaborative ties with other members of the Mathematical Modelling and Nonlinear Waves groups. Interesting discussions on drop dynamics with Dr. David Sibley, as well as the initiation of research activities together with Morgan Tudball and Dr. Dmitri Tseluiko on the topic of falling films down solid surfaces with large scale topographical structures are two such examples. Together with the main investigative effort on the effects of impinging gas jets, the SRV has had a decisive contribution towards cementing long-lasting and fruitful connections between the research partners.