Numerical Study of the Physics of assisted Atomization to Control its Efficiency

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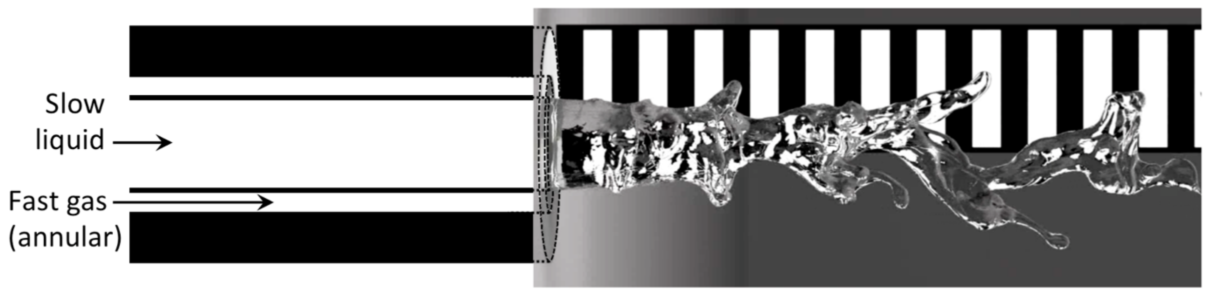
Context:

Liquid sprays play a key role in many environmental flows (e.g., breaking waves) and engineering devices (e.g., food processing, coating, printing, fire safety). In combustion applications, a widespread fuel atomization strategy consists in assisting liquid fuel break-up using a fast surrounding air stream. A major objective of combustion engineers is to optimize such systems in order to limit pollutant emission and increase fuel efficiency. A promising but under-exploited route for achieving this optimization is to modify liquid jet atomization dynamics via inflow conditions control. **The goal of this project is then to deepen our understanding of the mechanisms leading to air-blast liquid jet atomization to pave the way towards control.**

To engineers, atomizing liquid-gas flows present major challenges for control and optimization in comparison to single-phase flows. In addition to the large viscosity and density differences between the two phases, leading to discontinuous pressure and velocity gradients, the liquid-gas interface exchanges kinetic energy with the flow via surface tension. Moreover, spray formation involves frequent topology changes, usually through the formation and rupture of liquid ligaments and sheets. Consequently, **the detailed understanding of liquid atomization physics that would be needed to enable spray control simply does not exist today.**

In this context, **numerical simulations appear as an ideal tool to obtain an exhaustive description of the atomization process**. This is crucial to better understand the interplay between nozzle flow conditions, growth of interfacial instabilities, and evolution of downstream flow structures: the necessary first step needed to make spray control possible. Such simulations have to deal with various difficulties (large viscosity and density ratio, discontinuities, large range of scales, …). Simulation capabilities have been recently advanced, such that **the opportunity now exists to accurately simulate these complex multiphase flows**.



Numerical simulation of coaxial air-blast liquid atomizer. Low velocity liquid is issued from the round middle pipe, while a high velocity gaseous annular co-flow is injected around it, promoting liquid break-up. The image illustrates the type of behavior expected from the liquid jet.

PhD work

The scientific approach in this project is to employ high-fidelity simulations of the air-blast liquid atomization process in a canonical geometry in order to rapidly improve our understanding of the dynamics of air-blast liquid destabilization. **These first-principles simulations will allow access to an exhaustive description of the atomization process.** This can now be achieved due to the recent development of accurate numerical methods specifically dedicated to the simulation of this complex multiphase flow and the important growth of computational resources in the context of high-performance computing (HPC). This leads to the opportunity to generate a numerical database by considering various inflow conditions to simulate various regimes of the air-blast liquid jet dynamics. **This is the goal of the PhD work.** Specifically, we propose to focus on two types of inflow conditions. The first inflow condition will consist of an analytical mean velocity profile where perturbations, to which small amplitude are added. The second type of inflow will be generated from coupled simulations of straight long pipes, in order to generate realistic fully turbulent inflow conditions. This PhD work will be performed under the guidance of Dr. G. Balarac (LEGI, Grenoble) and Dr. O. Desjardins (Cornell University, USA). Specifically, 18 months of the PhD work will be performed at LEGI lab (Grenoble, France) and the other 18 months will be performed at CTFLab (Cornell University, USA).

Simulations will be synergistically augmented with experimental diagnostics and theoretical stability analysis to provide additional guidance and opportunities for validation, in collaboration with Dr. J.-P. Matas (LMFA, Lyon) and Dr. A. Cartellier (LEGI, Grenoble).