Computational modelling of gas focused thin liquid sheets

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ABSTRACT

Formation of liquid sheets has been demonstrated as a critical capability needed in many different research fields. Many different types of liquid sheets have been produced experimentally, its thickness ranging from few tens of nanometres to few micrometres. Due to the small size of such systems, where physical parameters such as thickness, velocity and temperature are difficult to measure, a need for numerical simulation of liquid sheets arises. In this paper we demonstrate such capability with sheets that can be used in experiments with synchrotrons, x-ray free electron lasers or lab sources. A modified gas dynamic virtual nozzle (GDVN) design is used in order to generate micrometre thin sheets. The system is characterised by a strongly coupled problem between the focusing gas flow and the liquid sheet flow. Investigation of varying physical properties of liquid is performed in order to demonstrate the effects on the sheet production. It was found that the variation of liquid viscosity and density have minimum negligible effects on the primary sheet thickness. On the other hand, the variation of surface tension force greatly affects the thickness and width of a primary sheet, such as expected in flows where surface tension is the dominating force. Findings demonstrate that lowering the surface tension of a liquid, i.e. changing liquid from water to alcohol for example, would produce thinner and wider sheets. Simulations were produced with an open source computational fluid dynamics code OpenFOAM using a multiphase solver “compressibleInterFoam”, capable of simulating free surfaces. Mixture formulation of a multiphase system consists of an incompressible liquid phase along with a compressible ideal gaseous phase. Interface position is determined by the algebraic volume of fluid method. Such model was also used in GDVN micro-jet simulations preformed in previous work. Due to the need for 3D simulations and huge computational resources needed, an adaptive approach was chosen. This made the simulations of liquid sheets of thicknesses down to 500 nm possible. Roughly half a million cells were used and calculated on 36 cores, each running at 2.93 GHz, which took approximately one day to compute.

KEYWORDS: Microfluidics, Liquid Sheets, Multiphase System, Surface Tension Driven Flow

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