Pneumo-Hydrodynamic Droplet Generation

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Abstract

Introduction
Droplet-based microfluidics is a large source of research for scientists of new biotechnologies, aerosols or other 2D-Microfluidics devices. Here, we will focus on an industrial application of a 3D microfluidic device : the PH2DG, Pneumo-HydroDynamic Droplet Generator. The aim of the process is to produce mono-disperse, regular pattern of droplets, with a minimum size. To use it in an industrial way, one need the more control over the physical phenomenon occurring.
The geometry used is based on the work of [1] and [2]. The inner radius of the nozzle exit and the discharge orifice are about 100µm. The distance between these two orifices is adjustable (50-500µm). The range of pressure is 103 -105 Pa, and the liquid flow rate varies around 10-9 m3/s.

Use of COMSOL Multiphysics®
This paper presents the method & results of numerical simulation : COMSOL Multiphysics® software is used with the help of the COMSOL Microfluidics Module to model the two-phase flow with the Phase Field approach. Thanks to a rotational symmetry, a 2D-axisymmetric model is built. It allows to reduce the number of finite linear elements down to 10k, without decreasing the numerical quality of the results in terms of mass conservation and interface diffusion. A parametrical study is performed on the Cahn-Hilliard coefficients to improve numerical convergence.

This modeling puts light on the different types of flow regimes happening with this device. Moreover, the numerical experimental design allows us to put forward a characterization of the physical phenomenon by dimensional analysis.

In summary, the Pneumo-HydroDynamic Droplet Generator offers a great control over the droplet generation and the numerical simulation is helpful to identify the different modes of an industrial tool showing promising results.

Reference

[1] A. Ganan-Calvo, “Generation of steady liquid microthreads and micron-sized monodisperse sprays in gas streams”, Physical Review Letters, 80-2 p.285 (1998).

[2] S. N. Jayasinghe and N. Suter, “Aerodynamically assisted jetting : a pressure drive approach for processing nanomaterials”, Micro & Nano Letters, Vol. 1, Iss. 1 p 35 (2006).