PhD Position in

Microfluidic non-Newtonian droplets generation: experiments and numerical simulations

Context. **Microfluidic** is the science and technology devoted to systems that process and/or manipulate small amounts of fluids (10^{-9} to 10^{-18} litres) within channels with dimensions of 10μm to 100μm [1, 2]. One of its essential applications concerns the fabrication of micrometric objects (so-called microparticles) via stretching and breakup of **non-Newtonian fluids** in a flow-focusing microchannel (see figure 1): a dispersed phase (phase 1 in red) is stretched by a continuous phase (phase 2 in blue) leading to the dispersed phase breakup and then giving rise to microparticles (quasi-spherical red drops). Depending on the flow parameters (phase velocities U_1 and U_2) and the rheological properties of the considered fluids (viscosity, elasticity, plasticity, surface tension etc.), the obtained objects (red drop in the example illustrated by figure 1) can exhibit a **variety of final shapes**, from spherical mono or multiphase drops to filaments, passing through pearls, bowls, sombreros, bullet-like, capsules, and prolate microparticles [some of those shapes are shown in 3 and 4]. These objects can be subsequently used to encapsulate bioactive agents (such as drugs, proteins, and cells) in **applications like drug delivery**, **materials formulation**, **cell culture**, **tissue engineering**, and **bioassays** [3].

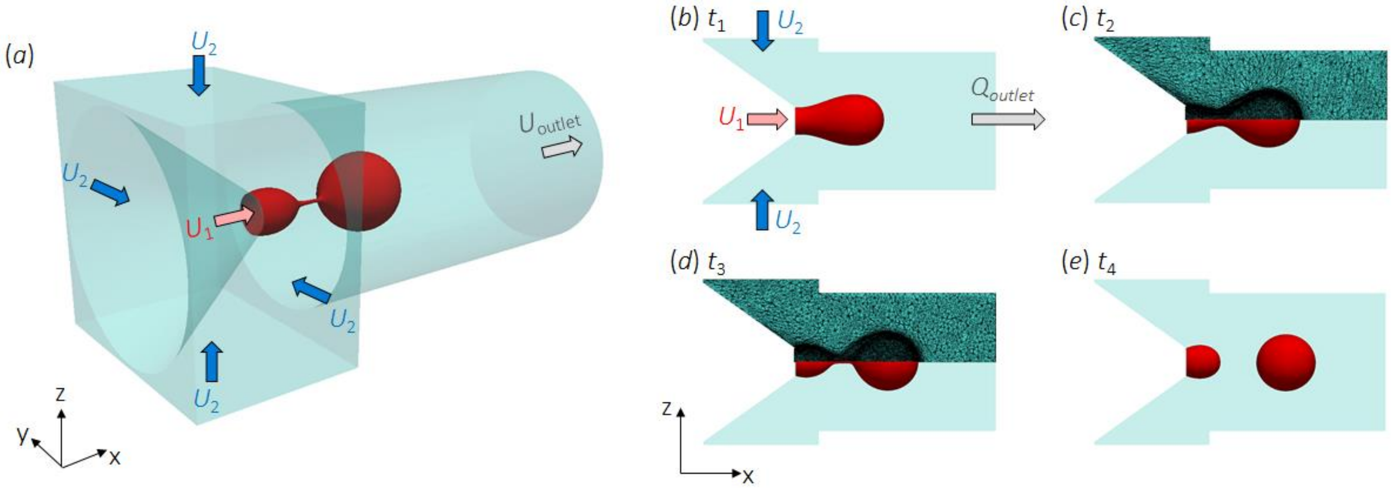

Figure 1. **Preliminary results** from the project team: a non-Newtonian **dispersed phase** (in red) is stretched by a **Newtonian continuous phase** (in blue), leading to the dispersed phase breakup and then giving rise to a droplet. (*a*) 3D simulation using a viscoplastic (Bingham) fluid in a 'Raydrop' geometry [6]. (*b*)-(*e*) Side-view snapshots of the simulation before and after the breakup (drop diameter ≈ 200μm).

Problematic. The fabrication of microparticles via microfluidics involves the stretching and subsequent breakup of non-Newtonian fluids [5] at very high strain-rate levels (≈ 10^5 s^{-1}), a fluid mechanics' problem that remains unclear up to now. Lacking a priori fundamental physical understanding of such a problem, the control of the above applications is often done by trial-and-error [3], and consequently it is far from optimal.

Objective. The current project aims to **highlight the physical mechanisms** driving the formation of **microparticles** via stretching and breakup of **non-Newtonian fluids** [5] in an axisymmetric flow-focusing is referred to as a **non-embedded co-flow focusing configuration** or simply **'Raydrop'** [see figure 1; 6]. It will be conducted using a mixed approach **combining experiments and numerical simulations**. The results will be analysed in light of filament stretching dynamics, energy transfer, and scaling laws [7, 8]. Finally, a good quantitative matching between experiments and numerical simulations would allow us to adequately describe the energy transfer during the stretching/breakup process and, thus, to precisely highlight the relevance of each rheological ingredient (viscosity, elasticity, plasticity, and surface tension) during the microparticles fabrication, as well as to predict their final shapes.

Participants. We are seeking a **highly motivated PhD researcher** interested in developing a mixed experimental-numerical profile in Fluid Mechanics to join our project. The former will be developed at the **CFL Research Group** at **CEMEF**, **Mines Paris - PSL**, which is ideally positioned to pursue this objective, as it gathers experts on **numerical and experimental** Fluid Mechanics. Furthermore, this research will be grounded on a solid **collaboration with industrial and academic European partners**.

Contacts. Dr. Anselmo PEREIRA (anselmo.soeiro_pereira@minesparis.psl.eu), and Dr. Edith PEUVREL-DISDIER (edith.peuvrel-disdier@minesparis.psl.eu).

References

[1] **G. M. WHITESIDES**, *Nature*, 2006 | [2] **P. TABELING**, *Oxford University Press*, 2005 | [3] **C. ZHANG et al.**, *Biomaterials Research*, 2021 | [4] **Q. JI et al.**, *Nature*, 2018 | [5] **P. SARAMITO** - *Journal of Non-Newtonian Fluid Mechanics*, 2009 | [6] **A. DEWANDRE et al.**, *Scientific Report*, 2024 | [7] **K. ISUKWEM et al.**, *Journal of Fluid Mechanics*, 2024 | [8] **A. PEREIRA et al.**, *Journal of Non-Newtonian Fluid Mechanics*, 2022