PhD position

Gelling non-Newtonian drops impacting reactive liquids

Context. One of the most challenging problems coupling interfacial hydrodynamics, soft matter rheology, and material phase change concerns the **impact of non-Newtonian drops** (polymer solutions, suspensions, emulsions etc.) **on a chemically reactive Newtonian liquid inducing drop gelation**, i.e., the drop, which is initially a weak gel, solidifies while penetrating the liquid, becoming then a strong gel (figure 1). **This fundamental** and **scarcely explored** physicochemical hydrodynamics topic is directly related to **essential health and industrial applications**, such as **encapsulation** processes (for the protection of transplanted pancreatic islets cells, for example), **3D-bioprinting** of cells, tissues, organs, prosthetics, and wound dressings; and **ceramic beads** and non-spherical solid particles **production** [1-5].

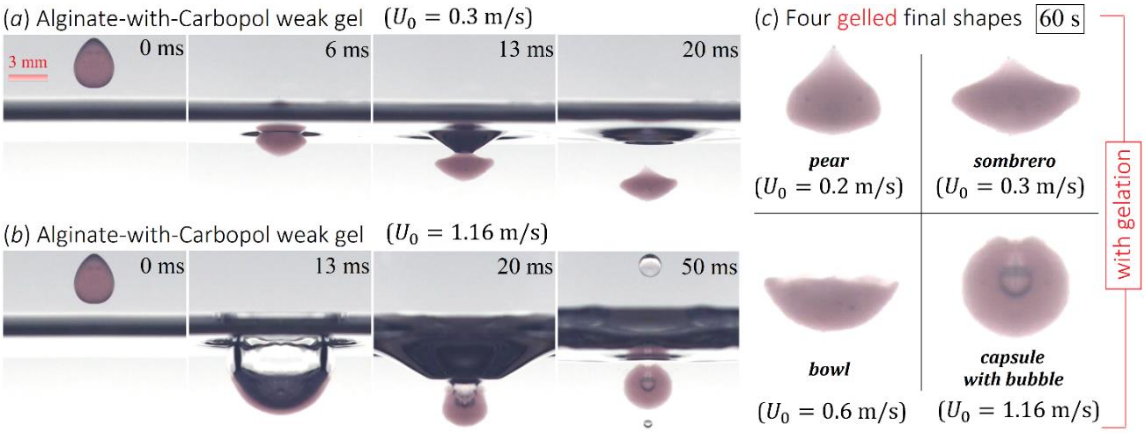

Figure 1. (*a-b*) Preliminary results: experimental snapshots showing Alginate-with-Carbopol drops (weak gel) falling into a water bath containing calcium ions (gelling agent). The drops solidify during the liquid-entry. (*c*) Four gelled (strong gel) final shapes as a function of U_0.

Key challenge. Typically, as illustrated by the snapshots in figures 1(*a*)-(*b*), a falling elasto-viscoplastic millimetric drop passes through a liquid/air interface and forms an air cavity, which later retracts, while the drop penetrates the liquid containing reactive compounds. The latter diffuses inside the drop, giving rise to a gelled elastic membrane (shell) in the outer part of the drop and ultimately turning it into a strong gel [solid-like material; 4, 5]. Hence, during the penetration, the drop undergoes both chemical-induced solidification (gelation) and deformation (impact and penetration), which leads to different final solid-like shapes (pears, sombreros, bowls, capsules with a bubble etc.; figure 1c) depending on the impact velocity U_0, gelation kinetics (polymers and gelling agent concentrations), drop/liquid hydrodynamic interactions, and the rheological properties of the drop. The key open challenge consists of predicting these final solid-like shapes.

Objective. This project seeks to **highlight** the **physical mechanisms** driving the **impact of non-Newtonian drops on a reactive liquid containing gelling agents**, reducing the gap between the fundamental understating of the problem and quantitative predictions for industrial applications. More specifically, the physical link between the hydrodynamic interactions between the drops and the liquid, the gelation-induced-time-evolution of the rheological parameters of the drops during the liquid entry, and their final solid-like shapes will be studied. The investigation will be conducted by **combining experiments** (rheometry techniques and drop impact captured with high-speed cameras) **and three-dimensional numerical simulations**.

Participants. We are seeking a **highly motivated researcher who has recently completed a master's degree in physics, chemical physics, rheology, mechanical engineering or chemical engineering**. Experience with rheology, experiments, and numerical are highly appreciated. This PhD candidate will be based at the **Centre for Material Forming (Cemef, Mines Paris - PSL), and will start ideally on October/November 2025**.

Collaboration. This project is funded by the MetaSoft Matter **program** from PSL University. The PhD candidate will join a collaborative project between the **CFL Research Group at Cemef, Mines Paris - PSL, and the SIMM Laboratory, ESPCI Paris - PSL**. Moreover, the candidate will have the opportunity collaborate with two other PhD students working on the same topic at Mines Paris - PSL and ESPCI Paris - PSL, respectively.

How to Apply. Please send your CV, letter of motivation, and bachelor/master transcripts to:

- Anselmo Pereira (anselmo.soeiro_pereira@minesparis.psl.eu), Cemef, Mines Paris - PSL;
- Loren Jørgensen (loren.jorgensen@espci.fr), SIMM, ESPCI Paris - PSL.
- Edith Peuvrel-Disdier (edith.peuvrel-disdier@minesparis.psl.eu), Cemef, Mines Paris - PSL.

References

[1] M. YUMOTO et al., *Nature - Scientific Reports*, **10**, 2020, Link
[2] S. V. MURPHY & A. ATALA, *Nature Biotechnology*, 2014, Link
[3] H. YUK et al., *Nature Reviews Materials*, **7**, 2022, Link
[4] M. A. BOCHENEK et al., *Nature Biomedical Engineering*, 2018, Link
[5] J. GODEFROID et al., *Soft Matter*, **19**, 2023, Link

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