Tuning flow properties and microstructure of colloidal suspensions via bubble dynamics for smarter suspension formulations

Supervisor: Valeria Garbin (TP) v.garbin@tudelft.nl
Daily supervisor: Yu-Fan Lee (TP) y.f.lee@tudelft.nl
Research group website: https://garbinlab.org/

Suspensions of solid particles in liquid media are often found in formulated products, such as paint, ink, and cements. Successful industrial suspensions require tailored flow (rheological) properties for better consumer applications and easier industrial processes. Usually, ink-jet printing, spraying, pumping in a pipe, and many other production processes require fast flow of suspensions, where shear thickening and jamming may occur and causes deleterious effects on equipment. Therefore, the study of active tuning of the microstructure and rheology of suspensions that exhibit shear thickening or jamming in such extreme flow conditions remains a great topic of interest in both academia and industry.

Tuning the rheological properties via acoustic waves has been proposed for dethickening the thickened suspensions by the disruption of shear-induced force chains through application of an oscillatory acoustic waves orthogonal to the primary flow direction [1]. Similar tuning techniques using ultrasound-activated bubbles, as shown in Fig. 1(a-c), have also been developed in our group with visual confirmation monitoring the change in local order of microstructure [2]. With proper inclusions of bubbles, an on/off switch for shear thickening would be achievable for suspensions by the techniques of ultrasound-activated deformable inclusions. However, so far only smooth spherical colloidal gel has been studied in these experiments, suspensions of rougher particles (e.g. raspberry-like particles in Fig. 1 (d)), which are more likely to induce shear thickening [3] with richer features of jammed microstructure, has not yet been investigated. Therefore, we aim to examine the effect of ultrasound-activated bubbles on shear thickening suspensions with different surface roughness in the fast flow conditions.

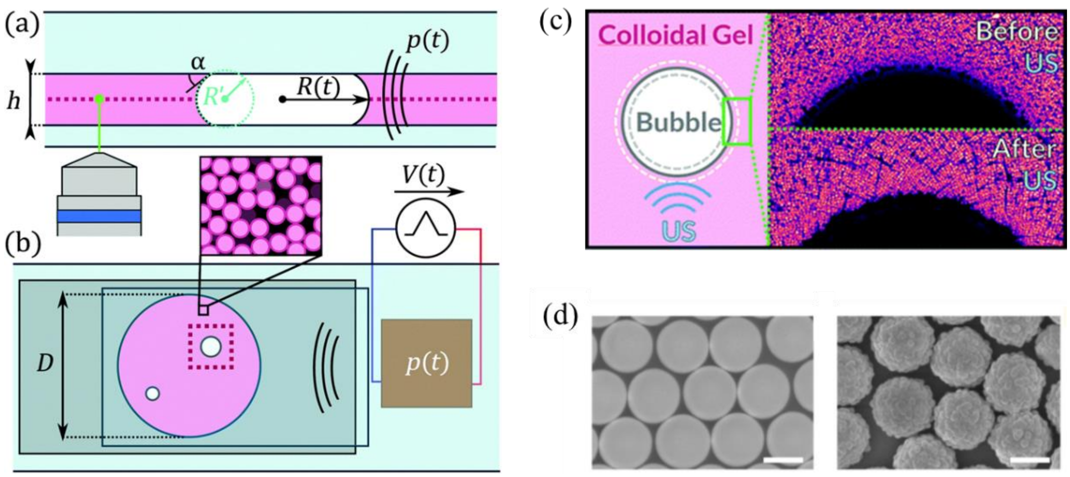

Figure 1: Schematic of the experimental setup (a) in side view and (b) in bottom view. (c) Schematic of changes in colloidal microstructures after ultrasound-activation. (d) SEM image of the smooth (left) and raspberry-like (right) silica particles with scale bars of 500 nm. Reproduced from [2] and [3].

You will perform microstructural investigations on the concentrated smooth/rough silica colloidal suspensions after the ultrasound activation by monitoring the in-situ confocal images. These experiments can be complemented with measurements of bulk rheology. The expected outcomes and impact of this project include better strategies for tuning local microstructure and rheology for colloidal suspensions and deeper understanding of micromechanical mechanisms for shear thickening and jamming. Potential findings in this work can contribute to a promising route towards smarter suspension formulations leading to controllable industrial processes and coating applications.

Background reading:

1. Sehgal, P., et al., *Using acoustic perturbations to dynamically tune shear thickening in colloidal suspensions*. Physical Review Letters, 2019. **123**(12): p. 128001.
2. Saint-Michel, B., G. Petekidis, and V. Garbin, *Tuning local microstructure of colloidal gels by ultrasound-activated deformable inclusions.* Soft matter, 2022. **18**(10): p. 2092-2103.
3. Hsu, C.P., et al., *Roughness-dependent tribology effects on discontinuous shear thickening.* Proceedings of the National Academy of Sciences of the United States of America, 2018. **115**(20): p. 5117-5122.