IFPRI Project Abstract

Dynamic and structural investigation of capillary suspensions

Erin Koos
KU Leuven
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Project Objective:

Structure and function and inherently related. Using a model system for dense and capillary suspensions, we will investigate the microstructural changes during interesting rheological transitions, e.g. yield, using confocal microscopy. Capillary suspensions, particles suspended in a bulk fluid with a small amount of immiscible secondary fluid added to form a percolating network of capillary bridges between the particles are of particular interest as they show a wide range of rheological behavior.

Approach:

We investigate changes to the microstructure of capillary (nano)suspensions containing fluorescently labeled silica spheres and glass micro-rods using a confocal microscope. By using particle detection and semi-local measures, we compare the structure of the samples with their bulk rheological response.

Recent Results:

This year, we published work on the investigation of the dewetting dynamics of suspension, capillary suspension, and capillary nanosuspension. During dewetting, the Saffman–Taylor instability induces fingering patterns which grow from the rim of the sample towards the center. Meanwhile, due to high acceleration and high pressure drop, cavitation appears from the center and grows outwards. By introducing a yield stress to the suspension system, the dewetting fingering pattern becomes more complicated and unpredictable, but the probability of cavitation is positively correlated with the initial sample diameter. When nanoparticles are incorporated, the sample structure becomes more homogenized, and the sample-to-sample variation decreases greatly. Meanwhile, nanoparticles can reduce the force chains in capillary suspension systems, inducing earlier breakage during stretching, changing the failure type during sample deposition. This work is published as an open-access paper in *Langmuir* (doi: 10.1021/acs.langmuir.4c04939). Additionally, we finalized the work regarding anisotropic particles in capillary suspensions, where we discovered that rod-based capillary suspensions change contact type from point-to-point to side-to-side contact as secondary liquid increases, and unlike spheres, the clustering coefficient of rods decreases with increasing coordination number. Under external shear forces, higher side-to-side contact probability increases viscoplastic fragility, and particle clusters rotate and translate in different directions during yielding. The paper is currently under revision by the *Journal of Colloid and Interface Science*; the preprint arXiv version can be found under the link (10.48550/arXiv.2503.18744). Finally, we delve deeper into the recovery rheology of capillary (nano)suspensions by decomposing amplitude sweeps and studying the physical meaning of the specific ranges within a cycle. By combining rheological studies with optical observations, we have set a baseline for understanding the yielding behavior of capillary suspensions.

Next Steps:

The rheo-confocal setup will not be upgraded to have a better resolution and alignment. We aim to focus on the particle movement during shear (recovery) rheology. We believe that the obscure behavior of capillary suspensions is related to their vorticity direction of movement, especially before the structural breakdown.