Connecting recovery rheology to structural rearrangement in capillary suspensions

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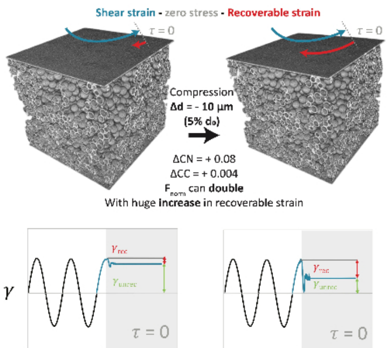
Capillary suspensions, particle gels in a bulk fluid with small amounts of a secondary immiscible fluid forming liquid bridges at particle contacts, demonstrate unique behavior due to the strong capillary forces. Recovery rheology offers new tools to understanding the material response to deformation and distinguishing between contributions from different physical mechanisms. By measuring strain evolution after stress removal, the total strain can be decomposed into recoverable and unrecoverable components. Unlike conventional materials where the recoverable strains consist of instantaneous elastic recoil with slow relaxation, obscuring the true elastic response, capillary suspensions exhibit distinctive strain decomposition under oscillatory shear. Kinetic arrest imposed by capillary bridges constrains particle mobility during stress-free periods. Since capillary suspensions maintain their deformed network configuration over experimentally relevant timescales, enabling clean separation of elastic response originating from bridge stretching and bending, these can be used as an ideal model system to correlate the relevant physical processes to the network microstructure.
Using iterative zero-stress recovery under oscillatory shear combined with rheo-confocal microscopy, we isolate the elastic recoil of the capillary network and correlate macroscopic strain recovery with particle-scale displacements and liquid bridge morphology. Below the flow point, particles demonstrate more collective movement, and the rate at which recoverable strain is acquired increases dramatically, approaching the oscillatory cycle beginning. As amplitude increases towards and beyond the flow point, this behavior progressively disappears with trajectories becoming increasingly smooth and particle displacements becoming more local. This systematic evolution reflects the interplay between network elastic deformation and structural rearrangement onset and establishes a correlation between elastic response and recoverable microstructural deformation during the yielding transition in capillary suspensions.

Keywords:
Capillary suspensions, Recovery rheology, capillary force, yielding



Slight changes to the network caused by compression can lead to drastic changes in the recovered strain