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MICRORHEOMETRIC STUDY OF DAMAGE AND RUPTURE OF CAPSULES IN SIMPLE SHEAR FLOW

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Microcapsules, which are fluid droplets enveloped by a thin elastic membrane, are widely used in industry to protect and transport active substances, aromas, cells, etc. When subjected to an external flow, they undergo strong deformations, which can potentially lead to their breakup. Since the 1990's, capsule membrane properties have been studied until breakup subjecting the particles to various flow conditions: simple shear flow [1], hyperbolic flow [2], spinning flow [3], tube flow [4], etc. But hardly any study provided a comprehensive set of experimental data on rupture or investigated the underlying damage phenomena that eventually lead to breakup. To overcome the lack of experimental data in the literature, we have conducted a microrheometric study of microcapsules, subjecting them to simple shear flow conditions leading to their damage and rupture. Our objectives are to characterize the impact of damage on the mechanical properties of the capsule membrane and determine the occurrence of rupture depending on the parameters of the problem.

Suspensions of ovalbumin microcapsules are prepared using an interfacial cross-linking technique [5]. This technique provides spherical deformable capsules with radii ranging from a few dozens to a few hundreds of microns. To avoid any osmotic prestress in the membrane caused by differences in concentration between the internal and external fluids, capsules are suspended in a glycerol solution containing 3% (w/v) of ovalbumin. They are then sheared in a counter-rotating microrheometer (Figure 1) under increasing values of shear rate and exposure time to shear. They are visualized using a high speed camera in the mid-plane of the shear flow in order to determine whether each of the capsules entering the shear flow mid-plane has been damaged or not by hydrodynamic forces. The surface shear modulus of observed capsules is identified using the inverse analysis method of Wang *et al* [4]: it consists in comparing the measured capsule profiles with those computed by a full numerical model solving the capsule-flow interactions and in finding the best fit. For time exposures above 2 minutes, a significant decrease in surface shear modulus is observed over time for capsules of radius larger than 50 μm .

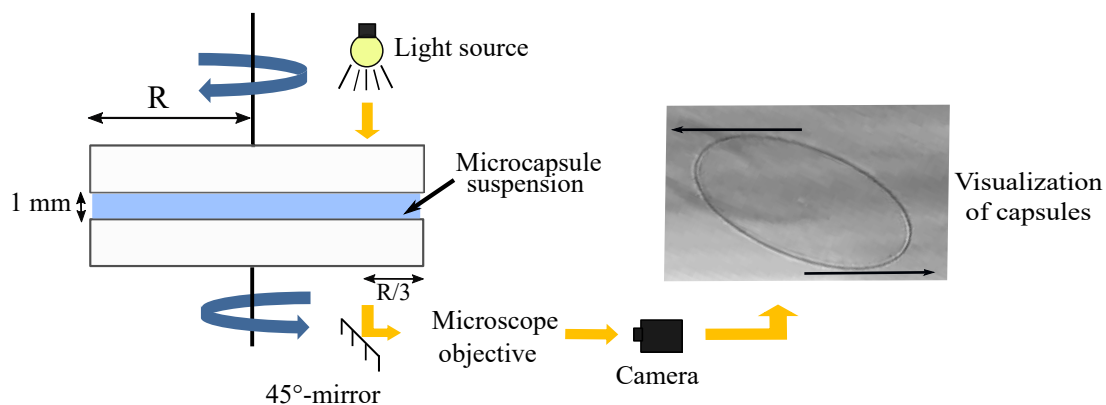


Figure 1. Microrheometry set-up.

The study of rupture is based on the quantification of the number of capsules present before and after shear exposure for different values of shear rates and exposure times to shear. The difference between both is assumed to be the number of ruptured capsules. The percentage of broken capsules increases with their radius. A phase diagram is obtained varying the capillary number (ratio of the viscous to the elastic characteristic forces) and the exposure time to shear. For a given exposure time to shear, increasing the capillary number increases the probability of rupture. And as the exposure time to shear increases, the capillary number required to observe capsule breakup decreases.

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