Rheological and microstructural characterization of non-Brownian hydrogel suspensions

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Non-Brownian suspensions, as out-of-equilibrium systems, exhibit a strong coupling between their rheological properties and their microstructure. The latter is strongly influenced by particle characteristics. In particular, it has been shown that, in dilute non-Brownian suspensions, the pair distribution function is directly related to the surface state, notably the roughness, of the constituent particles.

In this work, we investigate this coupling between rheology and microstructure for non-Brownian suspensions of hydrogel particles. The particles are commercial hydrogels Aquakeep 10SH-NFC (kobo products, Unipex) beads swollen either in water or in a water–glycerol mixture, with a Young's modulus ranging from 10 to 100 kPa. After sieving, the particles have a mean diameter of 300 μm and are dispersed in the fluid in which they were swollen. They are volume-labeled with a fluorophore (Nile Blue A). The suspensions are sheared in a transparent cylindrical Couette rheometer. The shear plane (velocity–velocity-gradient plane) is illuminated by a 30 μm thick laser sheet, which makes the intersected particles appear as bright disks. The laser sheet is mounted on a scanning system that allows its vertical position to be varied, providing a series of 2D images separated by a distance dz. From these image stacks, a three-dimensional reconstruction of the suspension is obtained (Figure 1).

An AI-based algorithm is used to detect the particles and to compute both the local volume fraction and the 3D pair distribution function for volume fractions ranging from 5% to 70%. The resulting pair distribution functions differ markedly from those measured in suspensions of more rigid spheres. Finally, the local rheology is investigated by particle tracking. We demonstrate the critical importance of measuring the local volume fraction in order to derive constitutive laws that accurately describe the rheological behavior of non-Brownian hydrogel suspensions.

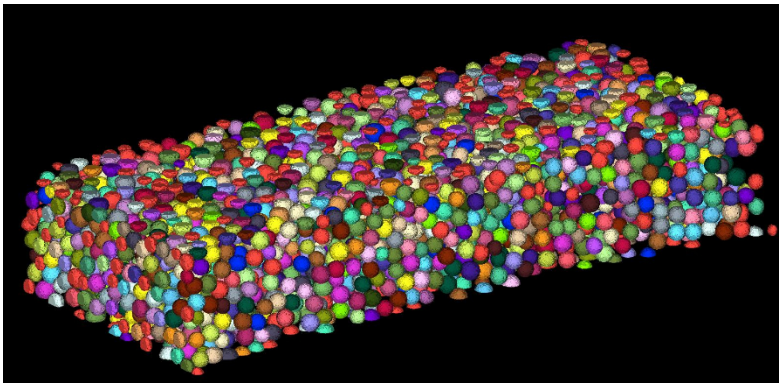

Figure 1. Three-dimensional reconstruction of the Aquakeep particle suspension at a volume fraction of 45%.

References:

[1] Frédéric Blanc. François Peters. Elisabeth Lemaire. Physical review letters, 107(20), 208302. 2011.

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