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Flow of a wet granular system in a Couette shear-cell geometry: a complete optical characterization

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Wet granular materials are made of solid grains immersed in a viscous fluid. Fresh concrete or wet sand are standard examples of such materials in common life. These materials currently are at the focus of an intense research effort to understand how they can flow. Here we report experiments aimed at evidencing 3-dimensionnal flows [1] in a model granular suspension, sheared between coaxial cylinders (Couette geometry), at low Reynolds/Taylor numbers. Both the flow cell (cylinders radius ratio $\alpha = 0.75$, height to gap ratio $\Gamma = 6$) and the solid grains (spheres, 200 µm diameter) are made of PMMA. The Newtonian immersion fluid is index-matched to PMMA. As a result the whole sample and shear-cell is optically transparent, allowing us to view particle distributions and fluidization effects. In our system, the fluid is not density-matched to the spheres ($\Delta\rho$ = 0.3 g/cm^3), then the suspension is sensitive to gravity. Below we report results from three types of experiments, all of them technically innovating: motion of a single particle (SPT), following a group of particles (video-trajectography) and optical measurements of concentration fields.

Single Particle Tracking (SPT)

The experimental procedure is based on tracking a single fluorescent particle used as a tracer within the granular suspension. The fully automated technique is based on a two-motor Couette cell and on a mobile microscope, including an auto-focus function to track the tracer. The angular rotation speed ω_1 and ω_2 of inner and outer cylinders are changed automatically so as to keep the differential speed $\Omega=\omega_1-\omega_2$ constant and to retain the tracer always in the field of view of the tracking system. The experiment yields information about primary and secondary flows inside the sheared material. We investigate radial, vertical and tangential position fluctuations of the tracer in the granular suspension due to random collisions and the resulting sheared-induced diffusive processes at short and long time scale. Complex secondary flows are evidenced in a meridian plane.

Concentration Field and Trajectography Experiments

Conversely to the above experiments with a single fluorescent tracer, here the immersion fluid is made fluorescent. Using a laser sheet that excites the fluid fluorescence, we observe full diametric cuts of the granular sample, and obtain particles spatial distributions and azimuthal velocity profiles under shear. In line with previous reports [2], we observe that the flow is localized near the inner cylinder for very small average shear rate ω_2-ω_1, resulting in a sheared layer only a few particle diameters in thickness, in a way very similar to sheared dry granular materials. At high enough angular velocity ω_2-ω_1 we observe that the system behavior crosses over to full fluidization: in this regime the granular suspension nearly behaves as a density-matched suspension. Gathering SPT, trajectography and concentration measurements reveals the main features of the granular flow mechanism, based on the coupling between local particle volume fraction, local shear rate and diffusion processes.

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References

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