Colloidal Suspensions can have Non-Zero Angles of Repose below the Minimal Value for Athermal Frictionless Particles

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Résumé

Classical granular materials are known to have a finite angle of repose: under gravity, an inclined pile stop flowing below a critical inclination angle A. The value of this angle is typically around 30 degrees and comes from different contributions: the friction and confinement of the grains, plus a purely geometric interlocking of the particle networks that sets a minimal value for the angle of repose A $\geq$ 5.8 degrees (1). While this description applies to athermal systems, the situation changes when particles are submitted to an external perturbation that helps to overcome the arrested state. Macroscopic grains under mechanical vibration can exhibit creep flows below their athermal angle of repose (2), and the same phenomenon has been observed for dense colloidal suspensions where thermal agitation cannot be fully neglected (3). However, no study has investigated whether such systems creep indefinitely (i.e. whether their repose angle becomes zero) or, instead, can reach a lower non-zero repose angle.

In this work, we experimentally probe the long-time relaxation and arrest dynamics of dense colloidal suspensions by using a microfluidic rotating-drum setup. To do so, we tilt sedimented piles of almost frictionless silica microparticles to an initial angle of 5 degrees and we monitor their flow over timescales reaching up to one month. We repeat the experiment with particles of different diameters (2 μm $\leq$ d $\leq$ 7μm) and we report the angles of repose as a function of the gravitational Péclet number Pe, which quantifies the balance between thermal agitation and particle weight. For low Péclet (i.e. small particles), we retrieve piles that have a zero repose angle and always becomes completely flat after a given relaxation time. However, above a critical Péclet (i.e. for bigger particles), we observe creep flows that stop at a non-zero angle of repose, whose value grows non-linearly with Pe but always remain below the minimal expected value for athermal systems 0 $<$ A $<$ 5.8 degrees. Finally, we compare our experimental results with the predictions of a recent rheological model, which considers contributions of both the glass and jamming transitions to describe the non-linear arrest dynamics at the crossover between colloidal (thermal) and granular (athermal) regimes (4). In particular, we find a quantitative agreement between the model and our measurements with a single fitting parameter.

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(3) Bérut et al. "Brownian Granular Flows Down Heaps", *Phys. Rev. Lett.* **123**, 248005 (2019).
(4) Billon et al. "Transition from granular to Brownian suspension: An inclined plane experiment", *Phys. Rev. Fluids* **8**, 034302 (2023).