Large Amplitude Oscillatory Shear (LAOS) Rheometry of wet and dry granular matter and their non-linear dynamics

Rishab Handa, Jorge Fisca, Christian Wagner
Experimental Physics, University of Saarland

Introduction:
Dry and wet granular materials exhibit rich non-linear dynamics under confinement, causing uncanny flow behaviour when sheared at large deformation rates during industrial processing operations. In this study, we have investigated granular flow dynamics in a conventional rheometer, and with the help of METLAOS framework, we have identified three dynamical regime for grains, namely, linear, non-linear and stick-slip. We revealed scaling relationship between non-linearity (quantified in terms of Chebyshev coefficients of higher order harmonics) and the dissipated energy.

Experimental Details:
- Materials:
  1. Dynoseeds (DySy): 140 μm - 500 μm, Dry and wet (1-3 % Silicon oil)
  2. Lactosa Powder: 140 μm, Dry and wet (3 % H2O)
- Rheometer:
  1. Cup-Plate gap: 10mm
  2. Frequency: 1.5 Hz
  3. Strain amplitude range: (0.001-200) ε
  4. Number of repetitions per cycle: 10

Results:

Fig. 1 Experimental system: (a) HAAKE MARS 2 Rheometer with capillary geometry and the RheoSoft software. (b) Schematic image of capillary geometry, where the cap is fixed to the bottom, and upper plate shears the grains. (c) Schematic representation of capillary assembly. (d) Close-up image of glass beads, packed in the cap before they undergo shear stresses, and (e) Vertical view of wet Dynoseeds forming a cellular-like structure, while the upper plate is going to its initial position, defining gravity.

Fig. 2 Micrographs, displaying different states of granular media, were obtained from (Nikon Microscopy) with bright field settings. (a) Dry granular media, negligible cohesion. (b) Partially saturated grains, cohesive grains. (c) Formation of dimers, trimers and pentamers. (d) Maximum number of contacts and (e) Capillary bridge between two Dynoseeds. Images were inspired from Kudrolli et al. Images at the bottom shows dynamical action in dry and wet grains, respectively (left to right). Plot on the right shows, Stress-Strain during a cycle for different materials.

Fig. 5. Large amplitude oscillatory shear test of dry (closed symbols) and wet (open symbols) Dynoseeds, analyzed within the new METLaOS framework. (a) elastic modulus: minimum-strain (circles) and large-strain (triangles) elastic moduli compared to first harmonic (squares) elastic modulus. (b) Dissipated energy per unit volume $E_{\gamma}$ vs strain amplitude $\gamma_{max}$ for dry (closed symbols) and wet (open symbols) granular materials.

Conclusion & Outlook:
- Identified three regimes on account of granular rheology, with critical strain, $\gamma_{c}$ (approx. the size of one grain) to push the system to non-linear regime.
- Unilising confinement pressure, tuned the viscosity (measure of dissipation energy) of granular materials.
- The plot on the right shows the inter-grain transitional process for granular matter under confinement, which is yet to be quantified.
- We are also working on tuning properties of grains via wetting agents of varying surface tension, to invoke phenomenal surface features.
- Also, setting up the experimental assembly for complex flow pattern formation in vibrating granular matter.

References:

http://www.uni-saarland.de/ fak7/wagner
http://powderreg.com/