SPH-DEM Simulations of Grain Dispersion by Liquid Injection

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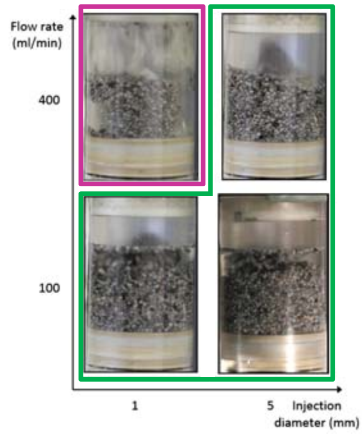
Objective: Understand the **dispersion patterns of a packed powder/granular bed initially at rest, upon impact by a liquid jet.** Experiments and numerical simulations are jointly used.

Abstract: We consider a model system where **a liquid jet is injected below a granular bed at rest, in a cylindrical cell.** Two different initial conditions are considered: **i) a two-phase case where the bed is initially fully immersed in the liquid; ii) a three-phase case where the bed and cell are completely dry preceding the injection of the liquid.** Different qualitative dispersion patterns are observed experimentally depending on the bed height, jet flow rate and diameter and grain wettability. The focus of this contribution is the **simulation of these model problems using a two-way coupled SPH-DEM granular liquid method [1].** This is a purely particle-based method without any prescribed mesh, well suited for this and other problems involving a free (liquidgas) surface and a partly immersed particle phase.
Our simulations capture well the effect of injection flow rate and injection diameter on the dispersion pattern of wettable grains, predicting whether the granular bed is impregnated bottom-up or a jet is formed.

I. Experimental study: dispersion by liquid injection

Three different qualitative patterns are observed when injecting water below a static bed of powder, depending on powder wettability:

Jet Formation (Any Wettability) | **Bed Lift (Non-Wettable Grains)** | **Impregnation (Wettable Grains)**



DISPERSION OF WETTABLE POWDERS

Dispersion patterns of 4g dry poppy seeds by a wetting liquid (LEFT). Images are taken after the injection of 7ml of liquid from the bottom.

With high flow rate and small injection diameter a jet is formed and the granular bed is wetted from top to bottom, while in all other cases bottom-up impregnation occurs.

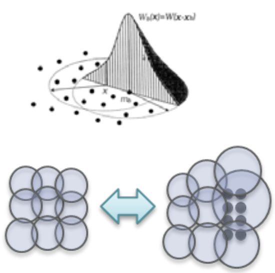
A shallow powder bed or wider cell also favour the formation of a jet.

II. SPH-DEM granular-liquid simulations and validation

Smoothed Particle Hydrodynamics is a Lagrangian scheme to solve the locally averaged N-S equations and simulate fluid flow problems [2].

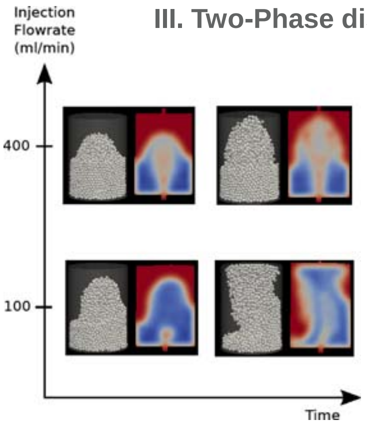
SPH-DEM is a **novel, meshless, particle-based method suitable for granular-liquid flows, also in presence of a free surface.**

We let SPH resolution (smoothing length) depend on superficial density (porosity).



Three validation cases were studied [1,3]: Single Particle Sedimentation, Constant Porosity Block sedimentation and Rayleigh-Taylor Instability.

III. Two-Phase dispersion simulations

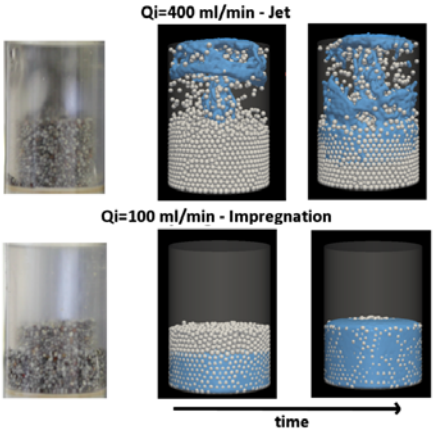


In the Two-Phase dispersion simulations [4], **the grains are initially fully immersed in the liquid**.

For all the flow rates considered (Qi= 50-600 ml/min), **the injected liquid immediately fluidizes a central column of grains above the inlet forming a jet.**

For lower injection flow rates, jet oscillations are observed.

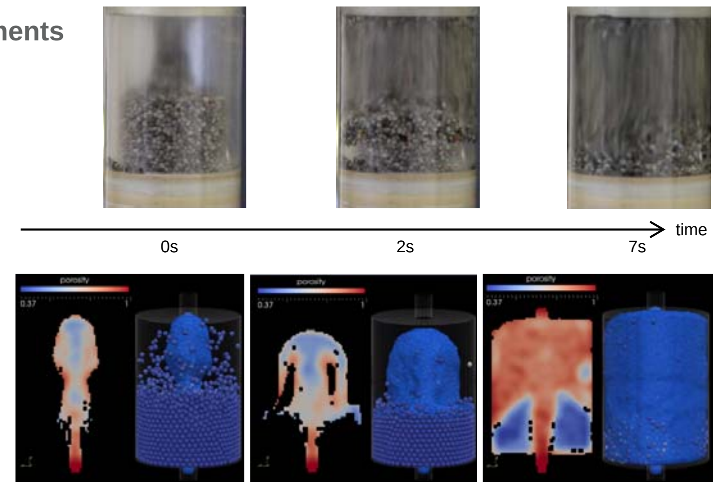
IV. Pseudo-Three-Phase dispersion simulations & experiments



In the Pseudo-Three phase case, **the grains are initially surrounded by air and water is injected.**

The air is neglected in SPH-DEM simulations and accounted for, implicitly, by the absence of liquid.

Dispersion simulations show dispersion patterns (jetting vs. impregnation) in good agreement with experiments [4].



[1] M.Robinson, M.Ramaioli and S.Luding. Fluid-particle flow and validation using two-way-coupled mesoscale sph-dem. Submitted, preprint available at http://arxiv.org/abs/1301.0752, 2013
[2] R.A. Gingold and J.J. Monaghan, "Smoothed particle hydrodynamics: theory and application to non-spherical stars," Mon. Not. R. Astron. Soc., Vol 181, pp. 375–89, 1977
[3] M.Robinson, M.Ramaioli, and S.Luding. Grain Sedimentation with SPH-DEM and its validation. In Proc. of Powders and Grains, 2013
[4] M.Robinson, S.Luding and M.Ramaioli. SPH-DEM simulations of grain dispersion by liquid injection. In Proc. of Powders and Grains, 2013

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