IFPRI Project Abstract

Drying Wet Powders With Shear to Prevent Agglomerate Formation

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Project Objective:

The objective of this project is to characterize how the mode and intensity of shear imposed during the drying of wet powder or grains affect the final size distribution of the agglomerates once dried. This physical configuration is highly complex due to its intrinsic multiscale nature in space (from the size of the particles to the size of the reactor) and in time (fragmentation in a few milliseconds and drying over the timescales of minutes or more). To this end, one of the goals of this project is to develop different laboratory experimental tools that will allow easy implementation and testing of various powders and liquids while controlling the input energy and/or shear rate. An underlying objective is also to develop physical models of the fragmentation and coalescence of wet and dry aggregates under shear.

Approach:

The approach for this project is to develop laboratory-scale experimental tools for studying the drying of wet powders with shear and characterizing the evolution of the size distributions of agglomerates. To study a broad range of shear conditions, we are developing two lab-scale setups: a humidity-controlled rotating drum that imposes steady low-to-moderate shear, and a quasi-2D impinging-jet cell that delivers strong localized high shear rates. We rely on model cohesive granular materials, alongside representative industrial powders. In parallel, we develop particle-scale and aggregate-scale experiments to (i) develop a framework to link particle-cohesion to macroscopic behavior and (ii) study the fragmentation or coalescence of wet/cohesive agglomerates under different shear conditions. Such microscale/agglomerate modeling will then allow us to rationalize the measurements in the lab-scale setups.

Recent Results:

During the past year, and following the input from IFPRI members at the last AGM, we have obtained the following results:

- We conducted an extensive literature review on experimental approaches to study model cohesive granular materials (publication in Soft Matter). We now have a catalog of experimental models of cohesive grains for which the inter-particle adhesive forces are well-characterized. These model systems will be beneficial for future investigations in our group and in the community in general.

- Low-Shear Rotating Drum Experiments: we characterized the features of cohesive granular flows in a rotating drum. We have then been able to perform experiments to determine the size distribution of aggregates made of grains bonded together by brittle bonds.
- We performed shear-cell tests on wet grains to correlate the measured particle-particle force with macroscopic cohesive yield stresses. This insight is crucial for bridging the gap between micro-scale interactions and macro-scale outcomes in our experiments.
- We initiated experiments of fragmentation of cohesive (wet) agglomerates by one turbulent jet subjected to varying shear intensities. This experiment aims to bring more quantitative insight into the impinging-jet cell setup.

Next Steps:

Our next steps in the coming months are to:
- Gather more experimental data in the rotating drum with various rotation rates (and thus shear) and agglomerates made of brittle bonds. We will characterize the average aggregate size and the shape of the distribution under different operating conditions.
- Gather experimental data on the fragmentation of cohesive aggregate in a turbulent jet and characterize the size distribution.

These two experiments will give us important information on the fragmentation of model cohesive grains under shear and will provide much-needed benchmarks for numerical models. Such experiments will also allow us to develop fundamental models of the fragmentation of cohesive aggregates.

If the project were to be renewed, the next steps would be to:
- Look at the time evolution of dried agglomerate under shear. Since we know the inter-particle force, the experiments in the air jets setup and in the rotating drum setup will allow us to fine-tune the value of the peak shear in our system before adding the complexity brought by the drying.
- Develop further the experiments at the aggregate scales of fragmentation using brittle bonds and also more realistic powders (fragmentation by air jet and by impact)
- Measure the evolution of the inter-particle force during drying, as it will give us the microscopic adhesive force.
- Consider drying in the rotating drum setup and the air jet setup, since we would now have a balance of aggregate coalescence and fragmentation until reaching a final dry dispersion of agglomerates.

These different steps will lead to laboratory-scale tools with controlled shear, for which we could vary the humidity and temperature, and measure the final size distribution of powders and industrial materials.