IFPRI Project Abstract

A Systems Engineering Approach to Dry-Milling with Grinding Aid Additives

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Project Objective:

1. Develop a system engineering approach for optimizing and scaling industrial dry fine grinding processes.
2. Obtain numerical relations about the effect of grinding aid (GA) additives on material behaviour, process aspects and energy requirements.

Approach:

In its second 3-year-period, the project will continue the work started during the first phase to build a digital twin for dry ball mill and air classifier systems with special focus of predicting the effect of grinding aids. The first phase focused on identifying the impacts of grinding or flow aids on macroscopic aspects of such processes. It was identified which mechanisms on both milling and classification are directly affected by GA and where the current models should be improved.
The second phase focuses on bridging the gap between dynamical changes on product microscopic properties (particle size and surface) and powder bulk behavior. Moreover, the findings are to be implemented into the current flow sheet model structure to dynamically account for flowability changes. This second phase was divided in the following steps:

- Determine a proper powder microscopic property to represent the combination of material and GA type and dosage
- Relate measurable microscopic particle properties with powder bulk behavior
- Design a characterization procedure to obtain the model parameters required for axial transport simulation
- Model powder internal axial transport during milling
- Validate all developed models and flowsheet simulation with industrial data

Recent Results:

In order to develop a digital twin for predict not only product size but also energy consumptions and product flows in dry milling systems, a flowsheet simulation tool with a population balance model (PBM) framework was selected. The traditional PBM applied to such system aims in tracking product size changes and this is the main variables that this project focus on simulating. However, since powder cohesion, agglomeration and flowability are by nature surface related, particle size does not typically relates well with bulk behavior. Therefore, we adopted the powder surface area as a single value to represent the product fineness. In Figure 1 (left) the flowability measured in a Schulze Ring Shear Tester is related to the BET specific surface area of calcium carbonate. The product was ground using GAs within a batch ball mill. As expected, the results shows that observed flowability is the results of the combination of product finesses and GA. Additionally, the results shows that a power function can be adopted as empirical model.

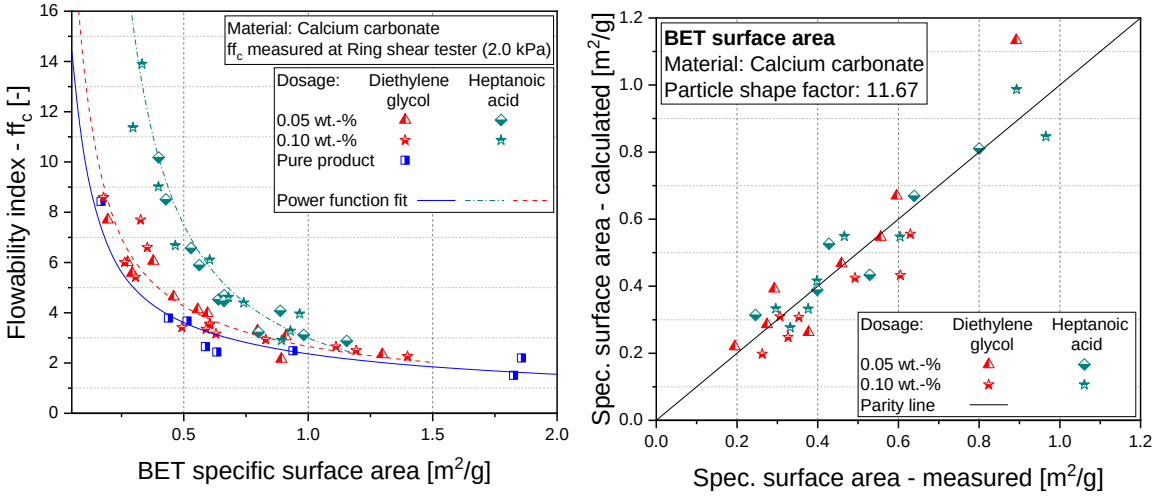

Figure 1: Powder flowability as a function of specific surface area and grinding aid (left) and comparison between surface area measured and calculated from size distribution (right).

Considering that a population balance model based on particle size is used on this project, the powder surface area should be calculated based on the particle size distribution. Therefore, figure 1 (right) compares the measured specific surface area to a specific surface area calculated from the particle size distribution. Using the solids density of the product, the calculation was done by multiplying by a shape factor the area of equivalent spheres. That way, the model framework can track flowability variation during grinding.

Next Steps:

Over the next months, the sub-models that relate powder flowability with powder bed stressing and particle capturing between approaching balls will be improved. This step will allow the implementation of a breakage rate function that accounts for both particles properties and GAs.

In parallel, it is between discussed with IFPRI members the selection of a dry milling production plant for future validation of the Digital Twin. Ideally, the selected plant already adopted GAs, possess multiple sensors to allow process and product tracking and also allow multiple product sampling points.