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 with a special focus on grinding aid application.
2. Obtain deep knowledge and numerical relations about the effect of grinding aid additives and humidity on material behaviour, process aspects and energy transfer.

Material and Methods:

- ✓ **Material:** Calcinated alumina from the company Almatis Inc. and Calcium Carbonate from the company IMERYS Minéraux Belgique SA.
- ✓ **Grinding aid additives:** Diethylene glycol (DEG), Heptanoic acid (HepAc) and 1-Hexanol (HexOH).
- ❖ **Test equipment:** For the first project period a 4 liters batch ball mill as well as a 47 liters continuous ball mill and an ATP 100 Air classifier from Hosokawa Alpine, which can be operated alone or in a circuit, were employed.
- ❖ **Approach:** The current process models, adopted at the iPAT, will be modified to quantitatively include the effect of grinding aid additives on breakage mechanisms, material transport, energy dissipation and air classification during batch and closed circuit operations. The final process model will be able to predict product size distributions, throughput and energy consumption.

Recent Results:

Previous studies indicate that grinding aid additives mainly affect the product in terms of powder flowability and tendency to agglomeration of particles. The powder flowability influences directly the grinding mechanism, such as mass of particles captured between balls and, thus, stress intensity and energy dissipation during collisions: A higher flowability reduces the captured mass and increases the stress intensity and, therefore, the specific energy transfer within one collision to the product particles. Moreover, it will also impact the material transport through a continuous operated mill and, by consequence, mill holdup and process efficiency.

A preliminary flowability measurement in relation to additive type was conducted as shown in Figure 1. The feed material was pre-mixed with the additive using a Turbula mixer for 20 minutes and ground within the batch ball mill for 240 minutes in order to reach median size in the scale of a closed circuit product. In a first glance, this results indicate that the additives influence the powder flowability very differently, such as found for glycol and acid, and additives such as glycol may have a very small effect on the grinding efficiency.

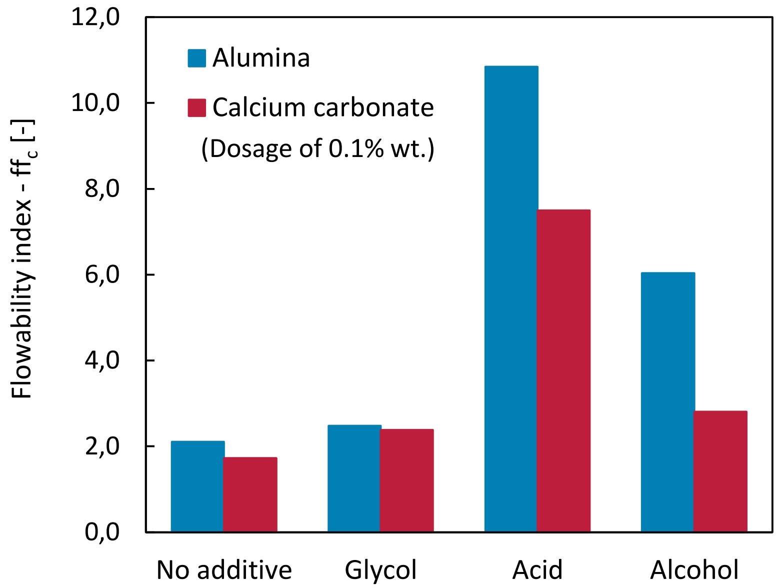

Figure 1: Flowability index of ground product in relation to additive type, measured with a ring shear tester with pre-consolidation at 1.0 kPa.

In parallel a batch grinding test with additives at same dosage are conducted. Figure 2 compares the grinding results (fineness as function of specific energy). The advantage of the batch test is that material transport can be ignored, so that effect of flowability on grinding itself is more evident. In the case of the alumina additives providing a medium flowability are best (alcohol), whereas the acid with the best flowability results in a relatively poor result. The reason is that with rising flowability the stress intensity increases but the stressing frequency decreases. On the other hand, for the calcium carbonate, the additives improve the result in a similar manner compared to no additive. However, the stress intensity provided by the small laboratory ball mill seems to be not high enough to produce a finer product without removing the fine particles. These two results demonstrate necessity of understanding separately the influence the additive type on the, above cited, many mechanisms of a grinding process. Additionally, the effect of dosage and moisture content should also be accounted quantitatively.

Potentially, the modelling of the ball motion and of the material capture between the balls under influence of different product flowabilities in combination with a population balance model shall provide a useful tool for optimization of product quality and energy efficiency.

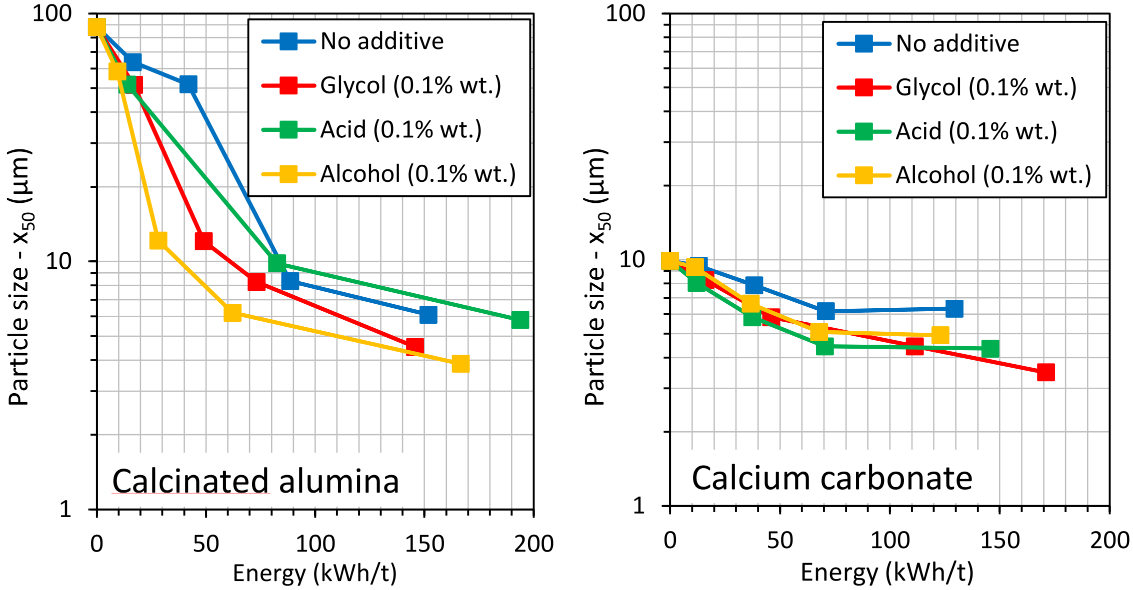

Figure 2: Impact of additive type on the batch grinding results at 70% of critical speed, 30% media filling and 100% media void filling by product.

Next Steps:

Quantitative description of additive effects on stress intensity, powder size reduction and energy dissipation by drop-weight-test, slow compression and hardgrove test, in all cases with grinding media and product, as well as characterization of bulk properties by a powder rheometer and rotating drum (dynamic angle of repose) beside shear tests.

In terms of grinding, additional batch grinding tests, in both 4 and 47 liters' mills as well as open and closed circuit milling tests with air classifier.