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 additives and humidity on material behaviour, process aspects and energy requirements.

Approach:

In its first 4-year-period, the project selected a dry ball mill and air classifier closed circuit system as case study for the identification of process aspects which are affected by the use of grinding aid additives in the product powder. The system is studied in three process scales, namely:

❖ Micro scale –Particle surface modification, agglomeration and breakage

❖ Meso scale – Powder stressing and related energy dissipation, powder transport

❖ Macro scale – Milling and air classification process aspects, plant circuit aspects, energy efficiency and flowsheet simulation

Recent Results:

The first three years of this project focused on mapping which mechanism (powder flowability, stressing and transport) and process aspects of batch and continuous ball milling as well as of the air classification process are impacted by grinding aids (GAs). It was also considered how to implement those impacts into already established population balance models. This last project year focused mainly on ball mill and classifier closed circuit trails and implementation of material and process findings into a population balance model and flowsheet tool.

Previously it was observed that the main contributions of GAs to powders were the increase in flowability and easily dispersion in air. However, some GA formulations presenting a

more intense increase in flowability and dispersibility than others do. During open circuit ball milling (with no classification), high powder flowability resulted in extremely small residence time and less effective and efficient grinding. On the other hand, the same GA formulation, while promoting better particle dispersion during air conveying and classification, resulted in more efficient size classification and smaller bypass of fine classes to the course outlet. Interestingly, although detrimental to isolated milling, the powders with high flowability (with heptanoic acid as GA) presented better results during closed circuit grinding, especially in criteria such as product recirculation and production rate in relation to classifier cut size (Figure 1). In this case, better particle dispersion during classification allow readily discharge of fine particles to the circuit outlet, without unnecessary recirculation back into the mill. For the coarse fraction leaving the mill, the low residence time is compensated by the recirculation, which increases also the hold-up in the mill sufficiently. Therefore, less energy is spent regrinding fine particle when comparing with low flowability and dispersibility formulations.
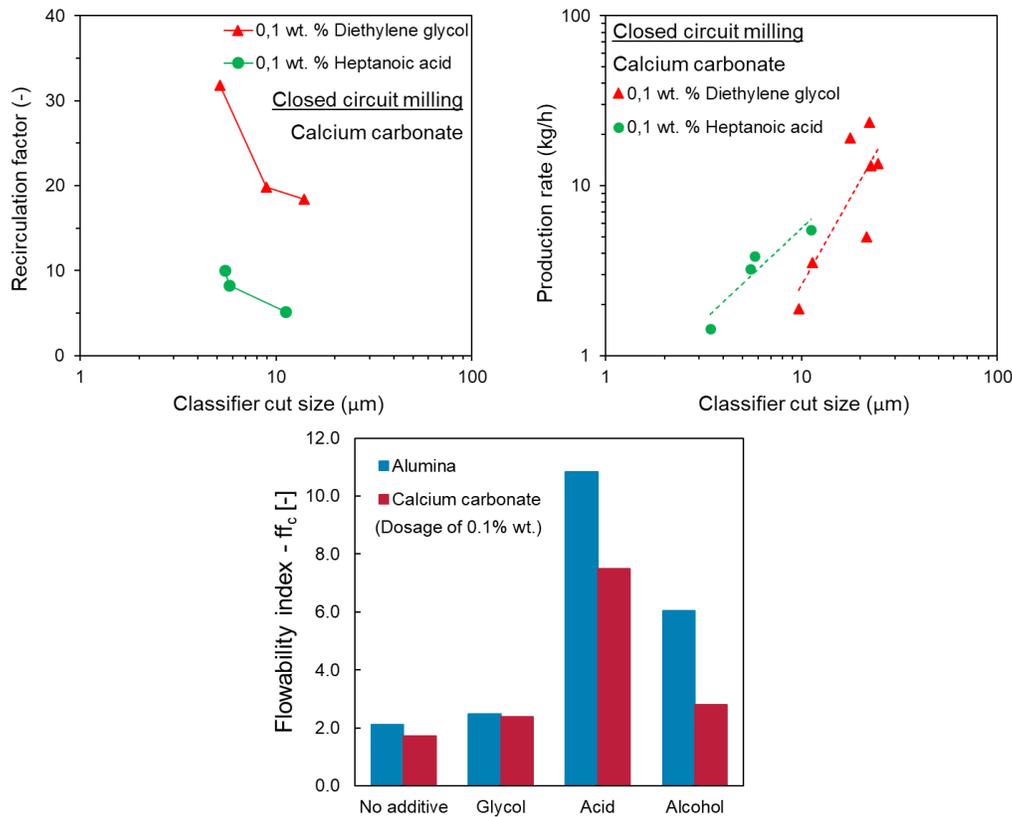

Figure 1: Product recirculation and production rate of closed circuit milling with grinding aids in relation to classifier cut size (upper) and impact of GA on powder flowability (lower).

For the systems approach beside the experimental trials, models for the milling and classification processes and product streams are implemented in an open source flowsheet simulation tool named "Dyssol". The calibration of the model parameters is fulfilled in element tests without directly running the milling operation. By this, an prediction of process results and energy efficiency is possible.

Next Steps:

Here is a summary of the main open questions that remain at end of the first funding phase of the project and are the subject of the project renew proposal:

From micro to macro: Although the influence of powder flowability and particle dispersion on many process aspects has been described during the project, it is still unclear how GAs act at the micro, i.e. molecular, level and how the combination of the chemical formulation of the grinding aid, particle surface properties and particle size distribution determine the mesoscopic and macroscopic bulk behaviour of the powder.

Powder transport modelling and dynamical modelling: The current mill model and flowsheet simulation tool implemented describes well stressing, breakage mechanisms and product particle size. However, it still relies on the assumption of process stability and requires process inputs such as, residence time, hold-up and throughput. In order to allow process optimization strategies, understanding of powder transport and residence time distribution as well as developing a new dynamical formulation, which accounts for bulk behavior, particle size and grinding aids, is beneficial. Strategies faster equipment unloading in case of change between different products by use of GAs can also be studied.

Validation with industrial data: The experimental work done so far for this project was conducted in a pilot scale mill-classifier circuit. Hence, the conduction of sampling campaigns on industrial grinding plants for validation of project findings and simulation on the flowsheet tool is proposed.