



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

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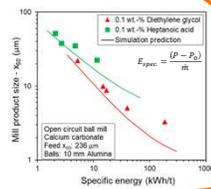
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Project summary

Second phase (3 years period):

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

- **Main goal:** Adapt a mechanistic Population Balance Model (PBM) from the literature to account for GA's
- **Model inputs influenced by GA's:**
 - Mill holdup and residence time
 - Material internal flow
 - Discharge rate
- **Current limitations:**
 - Increase in cohesion is not simulated
 - Material flowability is assumed to be constant

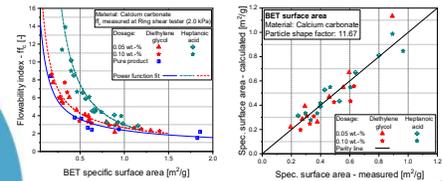


$$S_i(t) = \int_0^\infty \frac{m_{capt}}{m_{holdup}} \cdot N_{col}(E, t) \cdot \left[\int_0^1 F_i(E) \cdot p(e) \cdot de \right] \cdot dE$$

[Breakage rate for energy E] = [Amount of material captured by energy E] · [N^o of stresses of energy E] · [fraction of material that breaks with E]

Breakage and P.B.M.

- **Main goal:** Relate microscopic particle properties with macroscopic powder behavior
- Flowability is a function of both particle size (or surface area) and grinding aids
- Once pre-characterized, a size population balance model can dynamically estimates the changes in flow during grinding



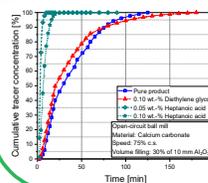
From Micro to Macro

- **Main goal:** Sampling campaign on an industrial grinding plant for later simulation and validation of the flowsheet tool.
- **Minimum requirements:**
 - Ball or stirred mill in open-circuit with GAs
 - Product sampling at in- and outlet
 - Measurement of throughput and power consumption
 - Estimation of ball charge and liners profile
- **Flowsheet simulation capabilities:**
 - Estimation of product size distribution in multiple points
 - Estimation of milling specific energy consumption
 - Simulation of potential process improvement scenarios

Validation

Powder transport

- **Main goal:** Implementation of transport model to allow flowsheet simulations
- Outcome of the previous WP will be used to model the powder axial flow, mill holdup and discharge rate
- A one-dimension transport model will be adopted:



$$\frac{\partial Q}{\partial t} = D_x \frac{\partial^2 Q}{\partial x^2} - u_x \frac{\partial Q}{\partial x} \quad Pe = L \frac{u_x}{D_x}$$

$$Q(t) = \frac{1/\theta}{2\sqrt{\pi \cdot Pe \cdot (t/\theta)^3}} \exp\left[-\frac{(1-t/\theta)^2}{4 \cdot Pe \cdot (t/\theta)}\right]$$

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