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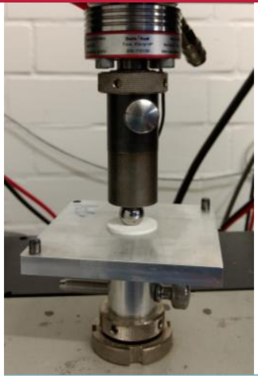

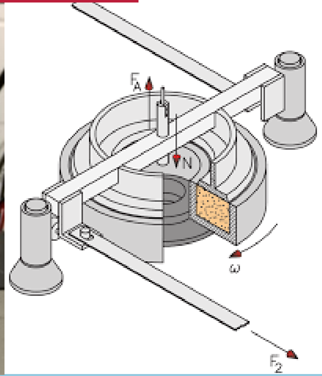

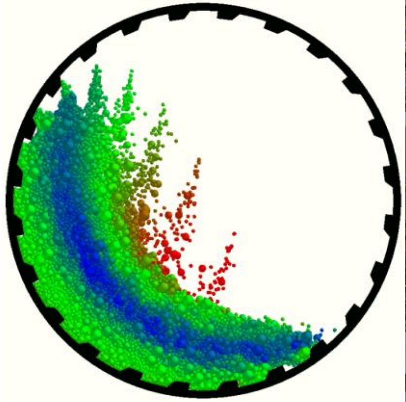

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A Systems Engineering Approach to Dry-Milling with Grinding Aid Additives

Anderson Chagas, Sandra Breitung-Faes, Arno Kwade

Team at Institute for Particle Technology (iPAT)

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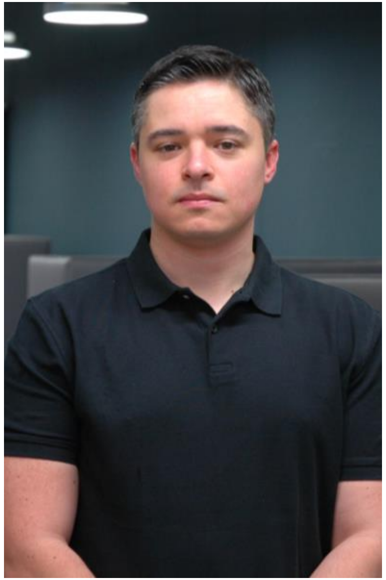


M.Sc. Anderson Chagas

Dr. -Ing. Sandra Breitung-Faes

Prof. Dr. -Ing. Arno Kwade

Project introduction

Long term objectives:

I. Obtain qualitative/quantitative effect of grinding aid additives on material behaviour, process aspects and energy flows.

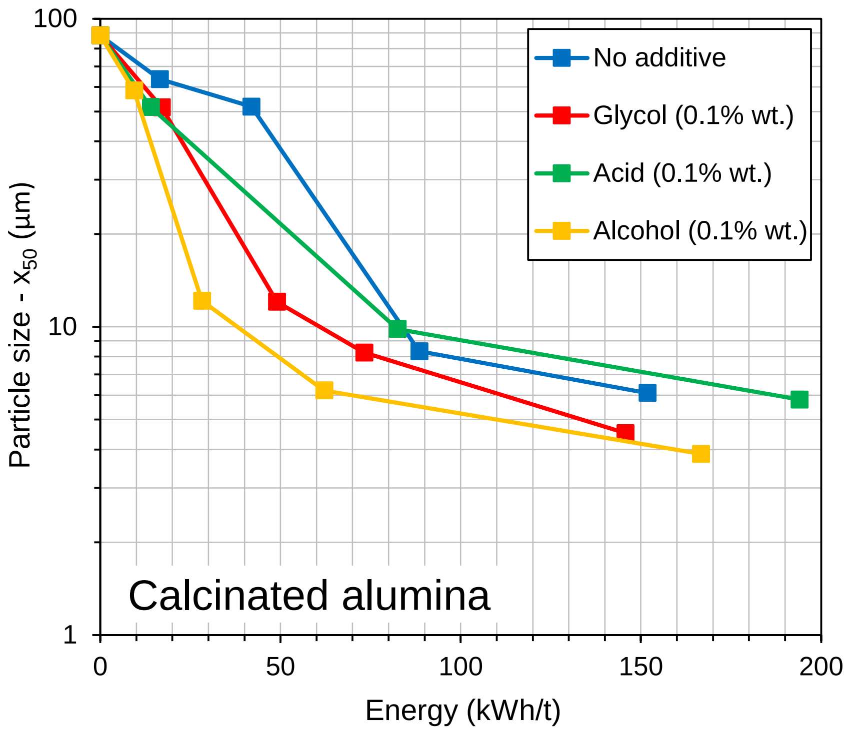
II. Develop a system engineering approach for optimizing and scaling industrial dry fine grinding processes.

First phase (3+1 years period):

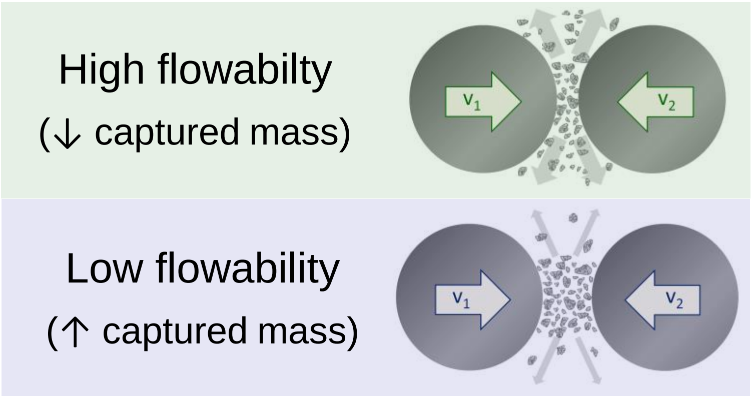
I. Focus on the grinding aid impacts on the grinding aspects inside the ball mill, and the transfer of batch grinding results to closed circuit processes.

II. Those information will be used to predict particle size distributions and energy consumptions.

Batch ball milling



- <u>Batch ball milling</u> – no powder transport
  - Different classes of G.A. promote increase in powder flowability in different intensities
  - Flowability determines the amount of powder stressed per ball impact and grinding efficiency



Open-circuit milling: Diethylene glycol (low flowability)

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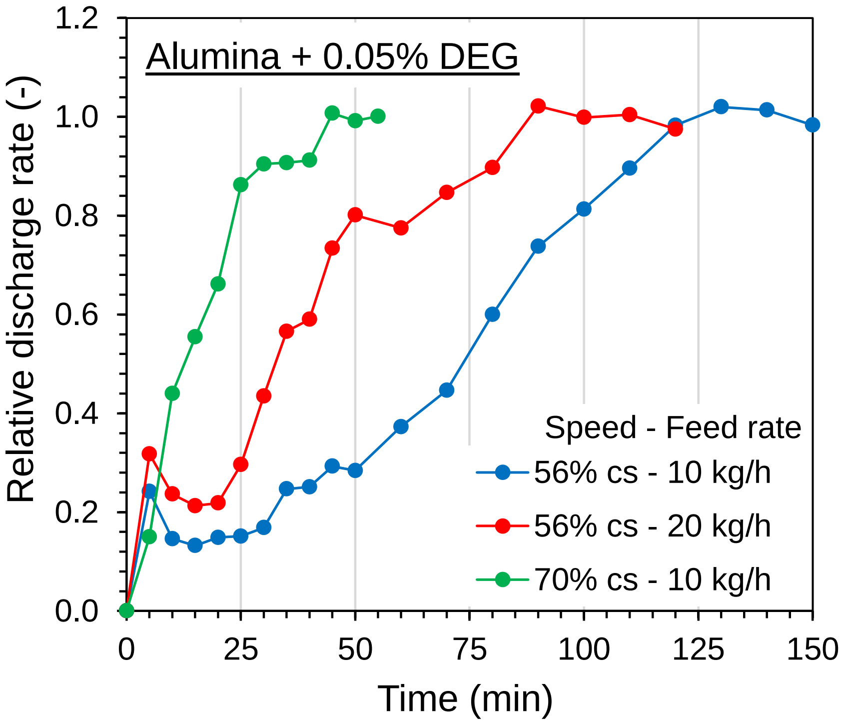

- Observations:
  - Mill holdup is directly related to stabilization time
  - Higher speed:
    - Faster stabilization - lower holdup
    - Slightly higher product size
  - Lower feed rate:
    - Longer stabilization – higher holdup
    - Smaller product size

Speed (% cs)	Feed rate (kg/h)	x_{50} (µm)
56	10	9.2
56	20	33.1
70	10	35.9

Open-circuit milling: Heptanoic acid (high flowability)

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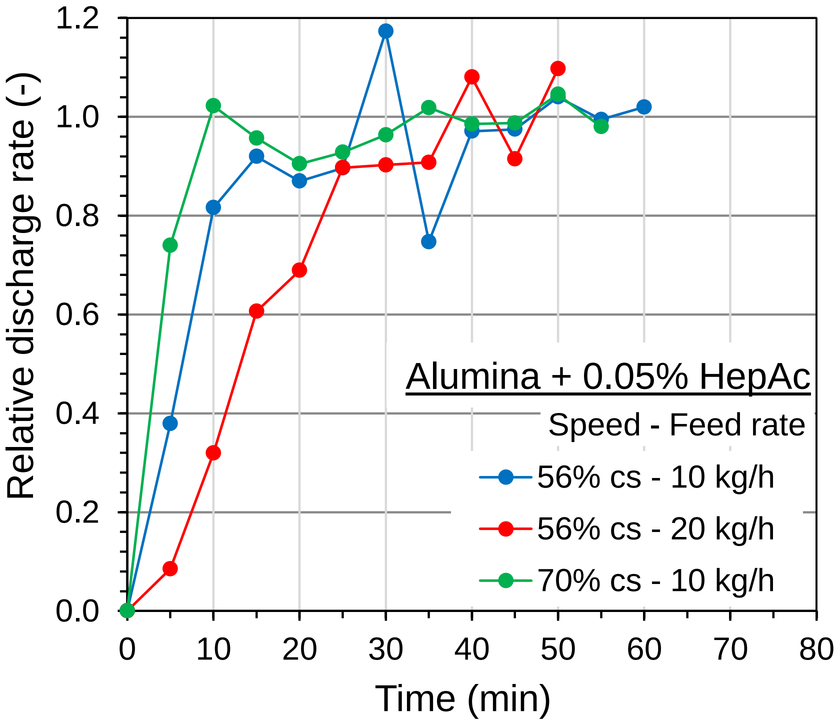

- Observations:
  - Mill holdup is directly related to stabilization time
  - Higher speed:
    - Faster stabilization - lower holdup
    - Higher product size
  - Lower feed rate:
    - Faster stabilization – lower holdup
    - Higher product size

Speed (% cs)	Feed rate (kg/h)	x_{50} (µm)
56	10	24.6
56	20	13.8
70	10	67.9

Open-circuit milling: Ring shear test results

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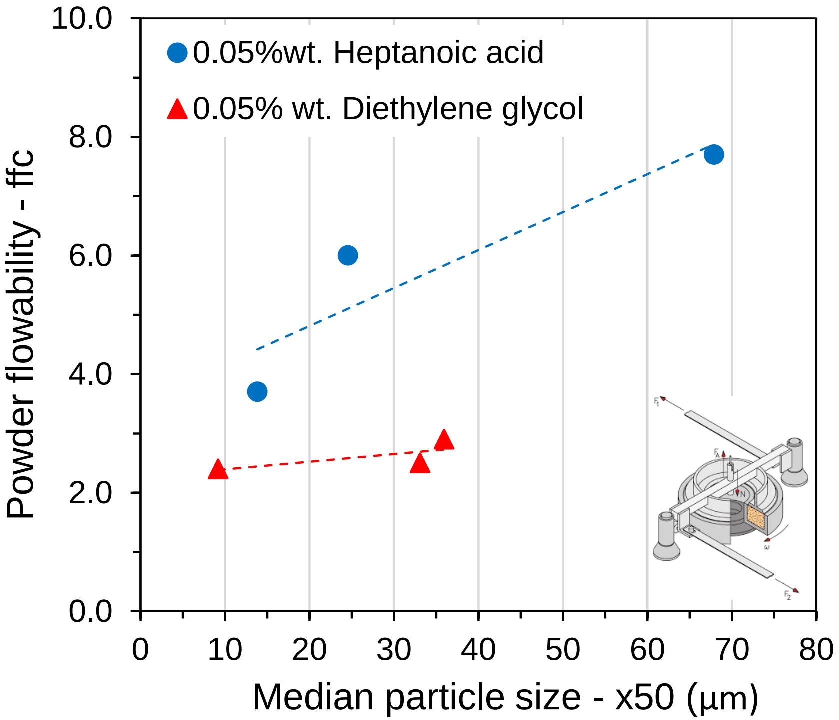
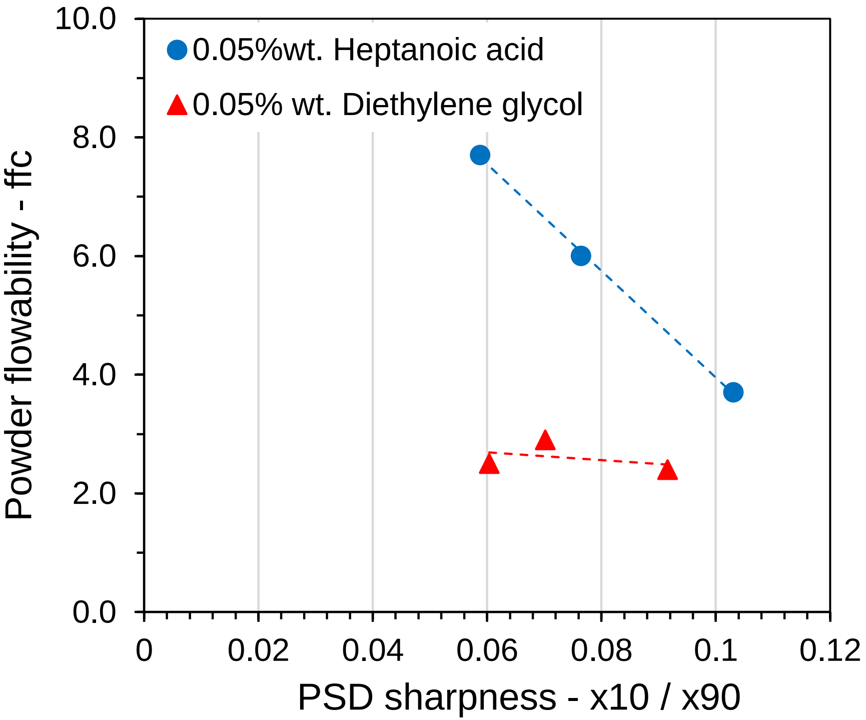


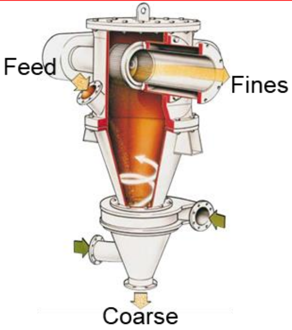


Air classification with additives

Equipment available:

Lab-scale classifier

Industrial-scale classifier



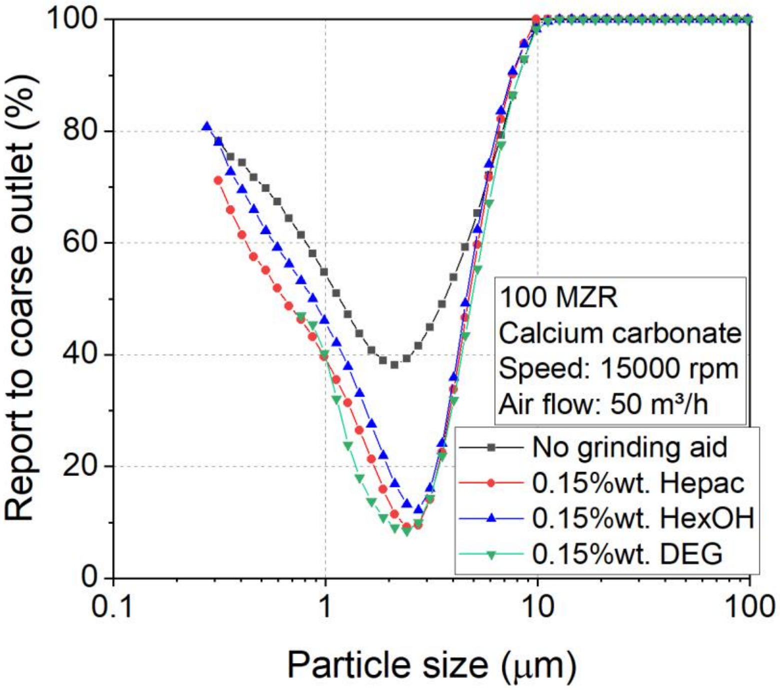
Process variables:

- Classifier wheel speed
- Air flow rate through the wheel
- Classifier scale and geometry
  - Hosokawa MZR – 100 x 2,2 mm
  - Hosokawa ATP – 100 x 67 mm

Outcomes:

- Efficiency curve:
  - Cut size
  - Fine particles <u>bypass</u> to coarse outlet
  - Fish-hook effect
- Possible scale-up procedure

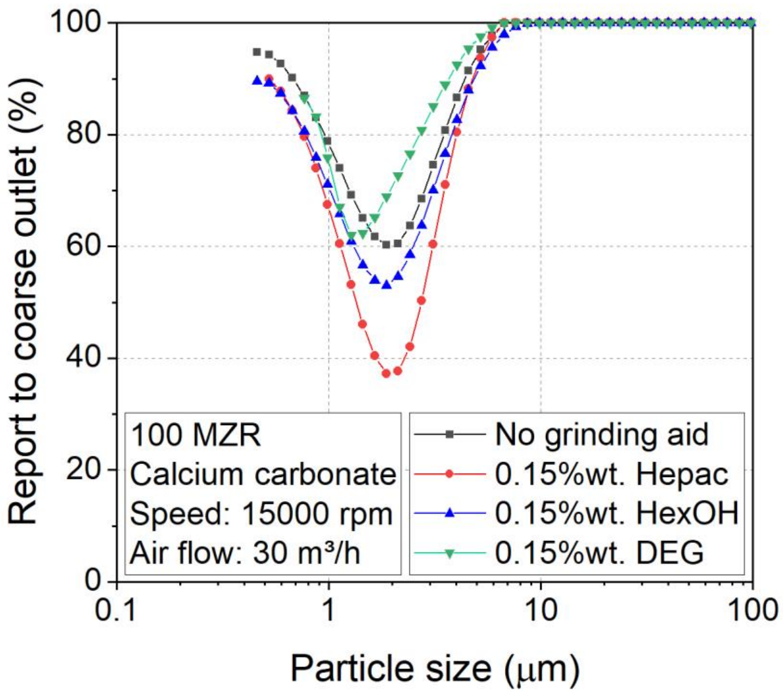
Air classification
Hosokawa Alpine MZR



<u>Lab-scale classifier – MZR 100:</u>

- Condition:
  - High wheel speed
  - High air flow rate
- Cutsize – Neglegible effect
- Bypass – Considerable reduction for all G.A.
- Fish-hook – No reduction with G.A
  - due to classifier design

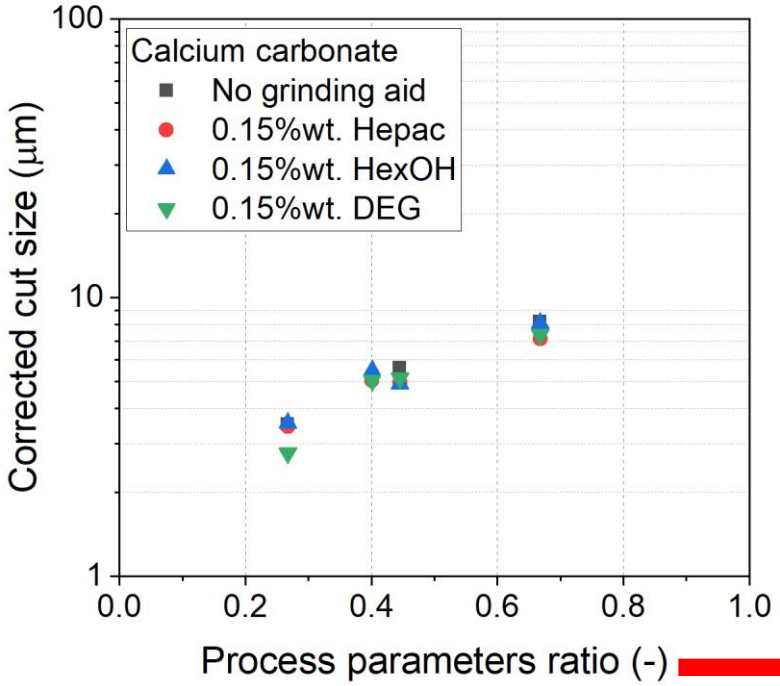
Air classification
Hosokawa Alpine MZR



Lab-scale classifier – MZR 100:

- Condition:
  - High wheel speed
  - Low air flow rate
- Cutsize – Small effect
- Bypass – High even with G.A.
- Fish-hook – No reduction with G.A.
  - Due to classifier design

Air classification
Hosokawa Alpine MZR



Lab-scale classifier – MZR 100:

- Corrected classification curve:

$$c(d_p) = \frac{e(d_p) - bypass}{100 - bypass}$$

- Cutsize – No effect of G.A. (When bypass is removed)
- Bypass – Highly effected by G.A.

$$\frac{Proc.param.}{ratio} = \frac{Air\ flow}{Wheel\ speed \cdot Open\ area}$$

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Air classification
Hosokawa Alpine MZR

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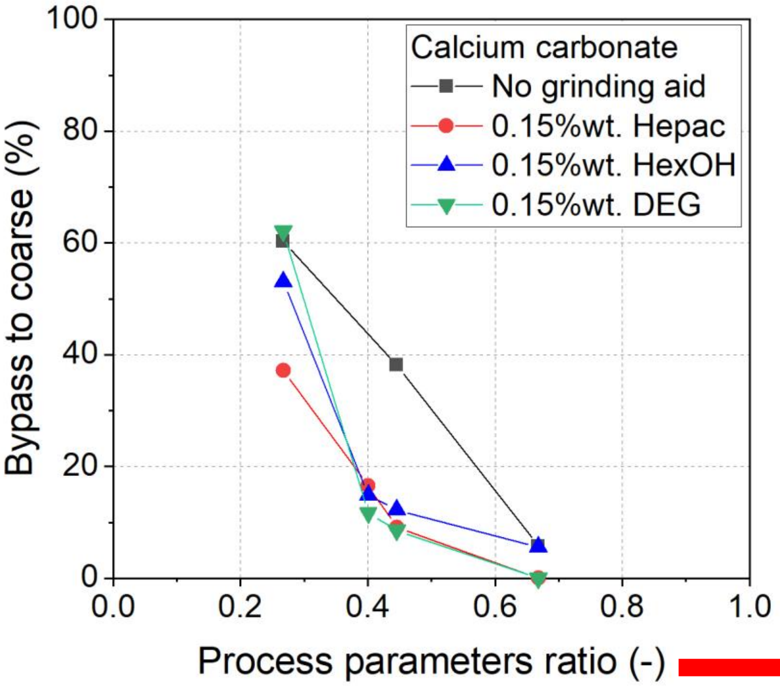

Lab-scale classifier – MZR 100:

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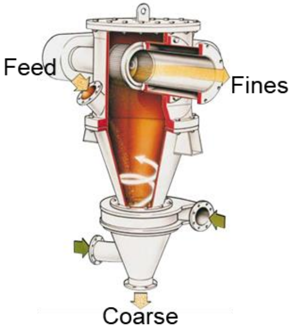
Air classification with additives

Equipment available:

Lab-scale classifier

Industrial-scale classifier



Process variables:

- Classifier wheel speed
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  - Hosokawa MZR – 100 x 2,2 mm
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Outcomes:

- Efficiency curve:
  - Cut size
  - Fine particles bypass to coarse outlet
  - Fish hook effect
- Possible scale-up procedure

Air classification

Caking on internal walls – Hosokawa Alpine ATP 100

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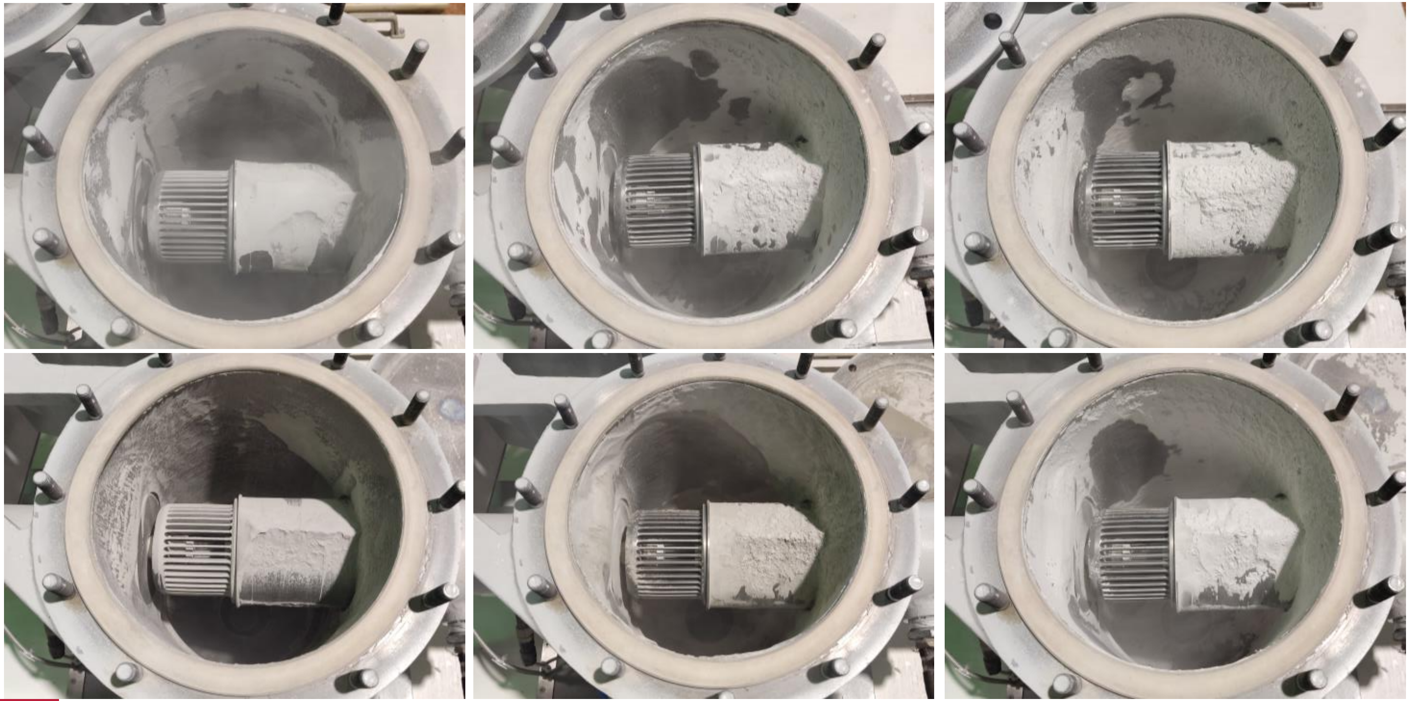
	4000 rpm	7000 rpm	10000 rpm

Without additive

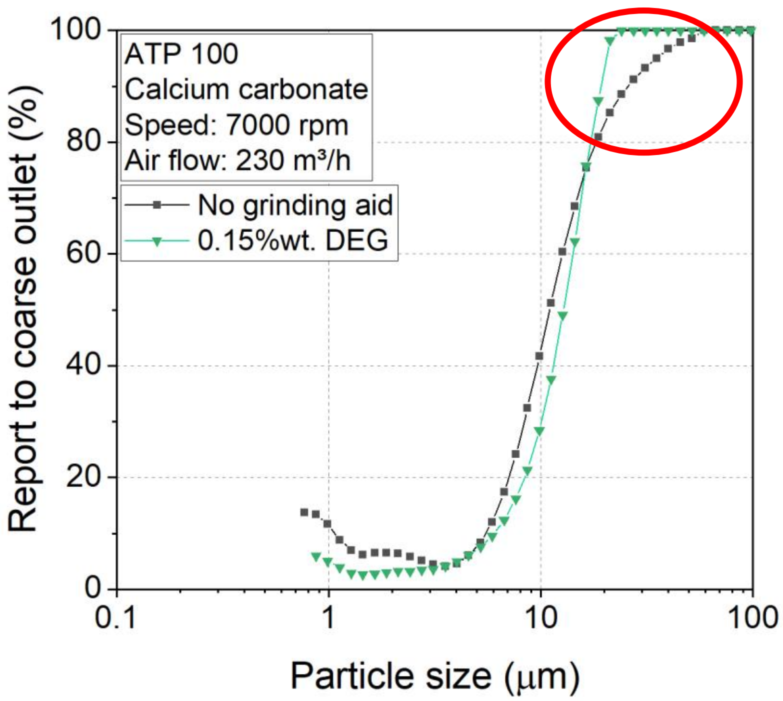
0.15%wt. DEG



Cut size reduction and bypass increase

Air classification

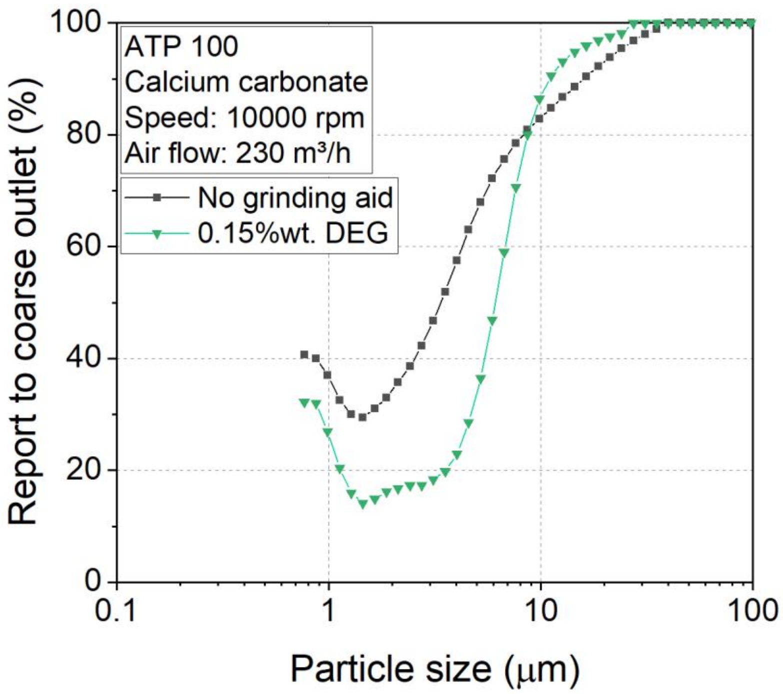
Hosokawa Alpine ATP – Mid range cutsize



Industrial-scale classifier – ATP 100:

- Condition:
  - Mid range wheel speed
  - High air flow rate
- Cutsize – Small effect of G.A.
- Bypass – Small effect of G.A.
  - More intensive effect for very small cutsizes
- Fish-hook – Some reduction with G.A
- Sharper separation for coarser sizes

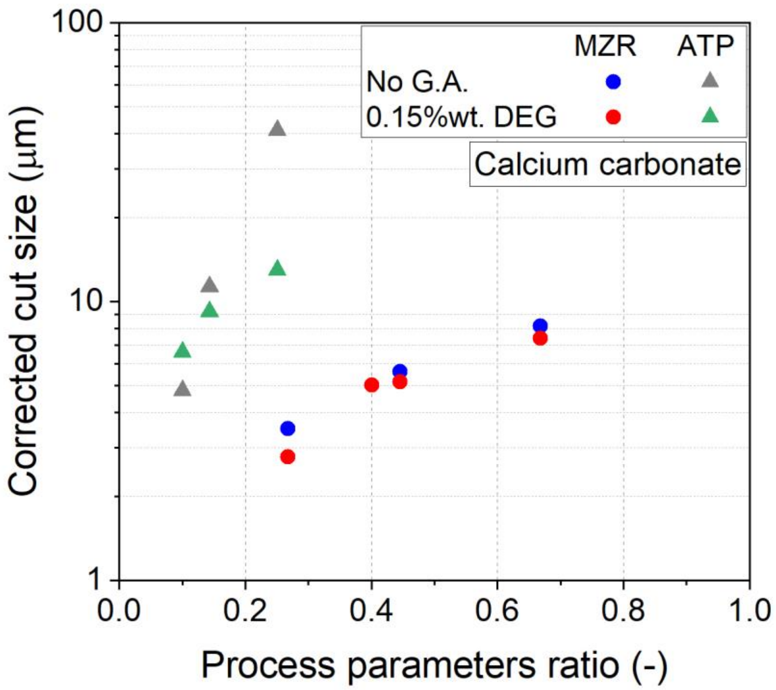
Air classification
Hosokawa Alpine ATP – Small cutsize



Industrial-scale classifier – ATP 100:

- Condition:
  - High wheel speed
  - High air flow rate
- Cutsize – higher effect of G.A.
- Bypass – Small effect of G.A.
- Fish-hook – No reduction with G.A
  - Due to classifier design

Air classification
Comparison between scales

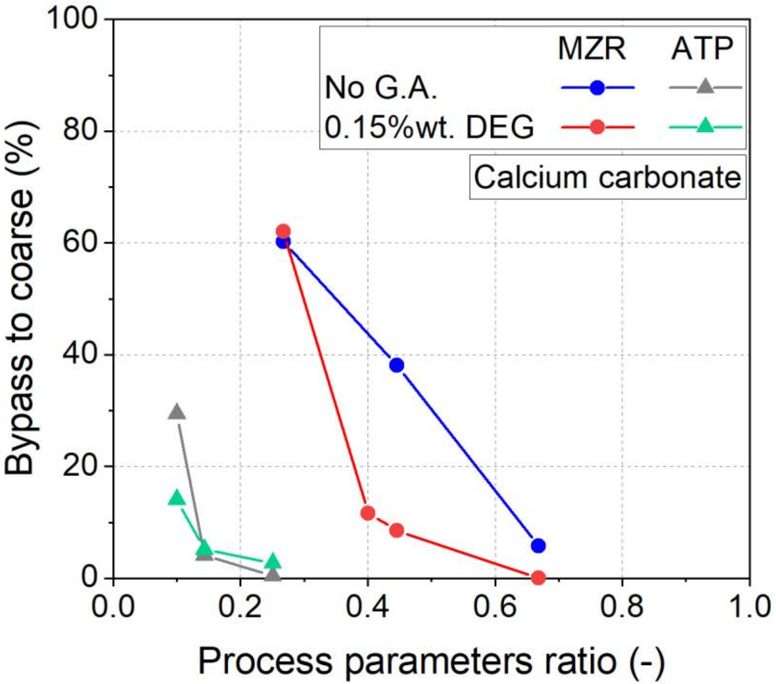


In terms of grinding aid effectiveness:

- Cutsize:
  - Design of classifier play a big role
- Bypass:
  - G.A. are more relevant for very small cutsizes
- Fish-hook:
  - Classifier design seams to be more important than grinding aids
  - Altough some reduction is observed

$$Proc.param.\ ratio = \frac{Air\ flow}{Wheel\ speed \cdot Open\ area}$$

Air classification
Comparison between scales



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  - Although some reduction is observed

$$\begin{matrix} Proc.param. \\ ratio \end{matrix} = \frac{Air\ flow}{Wheel\ speed \cdot Open\ area}$$

Future steps

Closed-circuit ball milling

- Variables:
  - Mass feed rate
  - Classifier cut size
  - Additive class
- Results:
  - Process energy consumption
  - Product size
  - Powder recirculation factor

Material characterization procedure

- Proposal of a standardized powder characterization procedure

Process flowsheet simulation

- Inclusion of project findings on population balance model
- Flowsheet simulation of individual process units and of multiple circuit arrangements

Acknowledgements

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International Fine Particle Research Institute

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- Oliver Gutsche (FMC)
- Eric Gulliver (Lincoln Electric)
- Frits van der Westerlaken (Alteo-Alumina)

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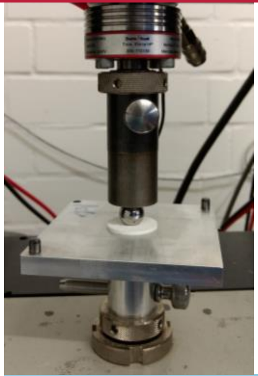

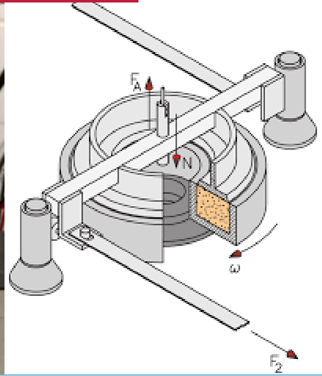

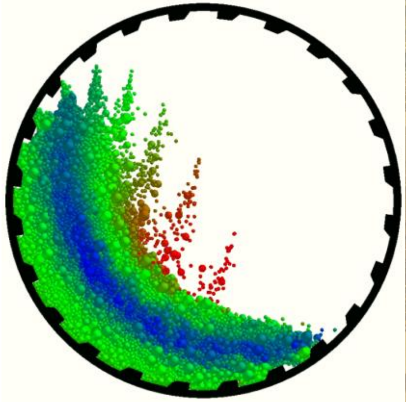

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