Numerical simulation of an impact pin mill with DEM-PBM coupling model

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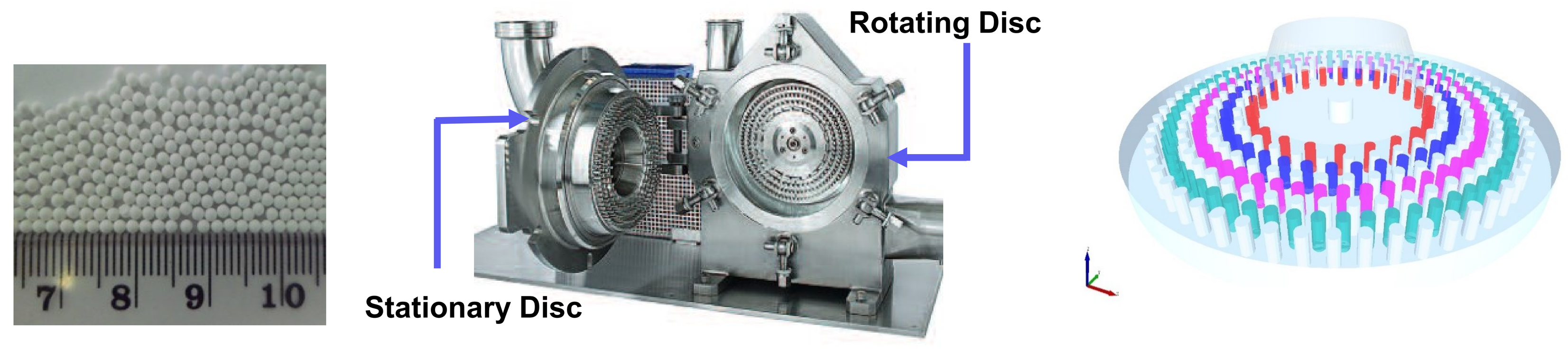
1. Introduction

Milling is known to be an energy intensive and highly inefficient process. The design and operation of mills still rely on empirical methods, experience, trial and error rather than sound scientific principles. Population balance model (PBM) has been extensively used to model milling processes. However, the main criticism on PBM is it does not realistically consider the characteristics of a mill environment. On the other hand, discrete element method (DEM) is a powerful tool to reproduce the microscopic impact events of individual particle inside a mill. *The aim of this project* is perform multiscale analysis of DEM simulation results to inform PBM to get more convincing predictions.

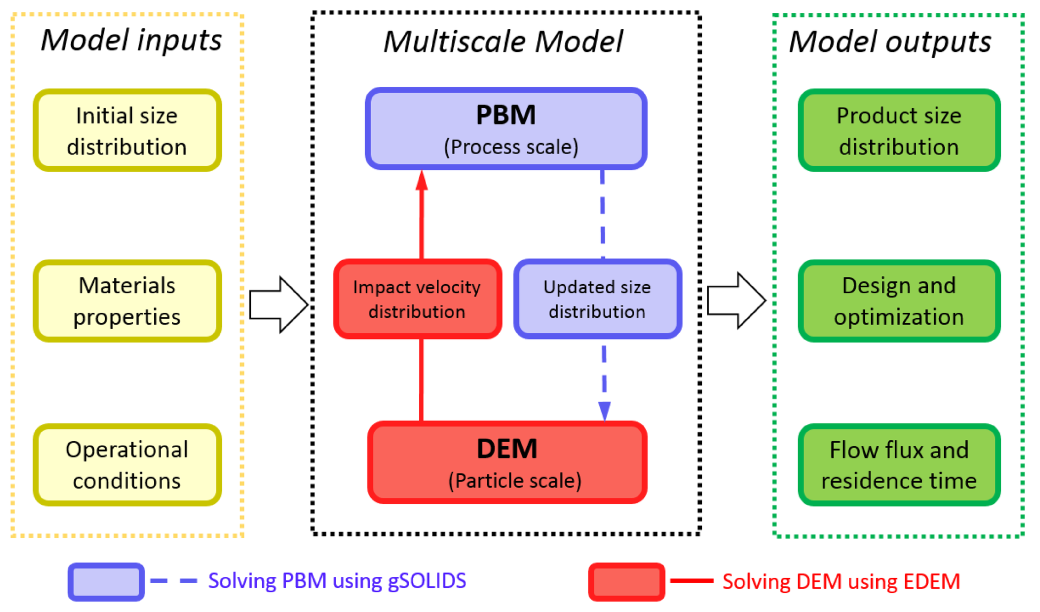
2. Simulation of UPZ mill



Alumina particle | Impact pin mill (UPZ 100) | DEM simulation layout

- milling Experiments were conducted at Hosokawa utilizing the high velocity impact mill UPZ100 with Alumina and zeolite as milling material and DEM simulations were conducted on the same system.

3. DEM-PBM multiscale modeling



Framework of PBM-DEM multi-scale coupling method

Population balance model

$$\frac{\partial M_p(x,t)}{\partial t} = -S_M(x)M_p(x,t) + \int_0^x S_M(y)M_p(y,t)b_M(x,y)dy$$

Breakage rate

$$S_M(x) = Sc_M\left[1-\exp\left(-f_{mat}x\left(W_{m,kin}-W_{m,\min}\right)\right)\right]$$

Cumulative breakage Distribution

$$B_M(x,y) = \frac{1}{2}\cdot\left(\frac{x}{y}\right)^q\cdot\left(1+\tanh\left(\frac{x-x'}{x'}\right)\right)$$

Blue variables---material dependent
--- from single particle breakage

Red variables---machine dependent
--- from DEM simulation of mill

4. Results and discussions

4.1 Particle dynamics from DEM

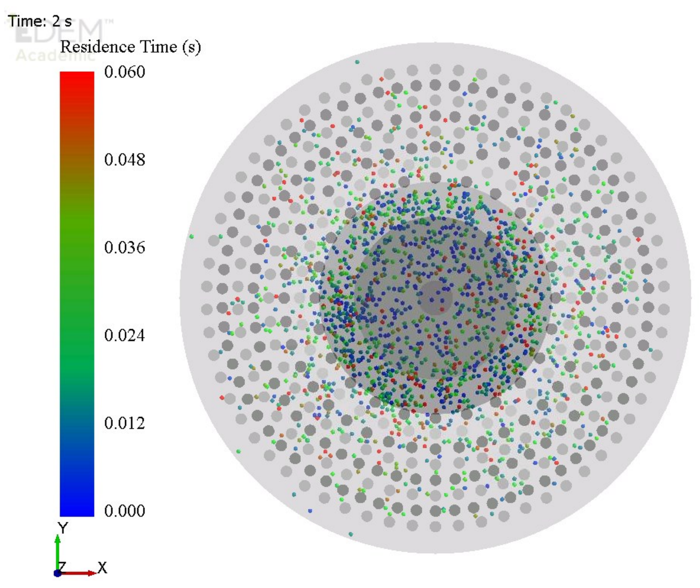


Fig 1. Instantaneous particle residence time distribution

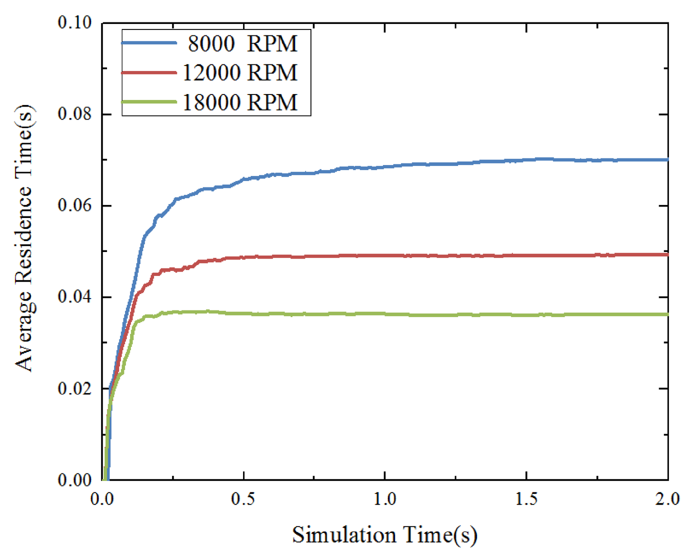


Fig 2. Average particle residence time

- Average particle residence time decreases with increasing pin rotating speed

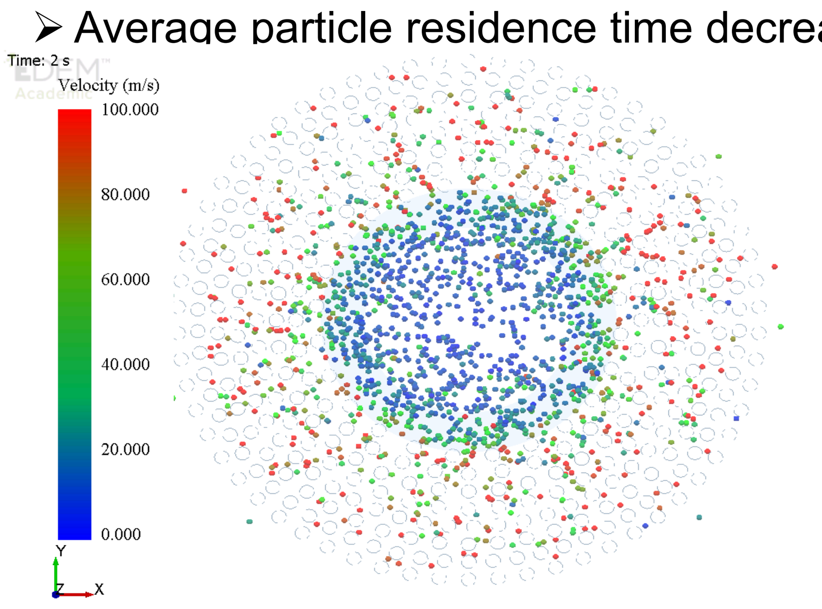


Fig 3. Instantaneous particle velocity distribution

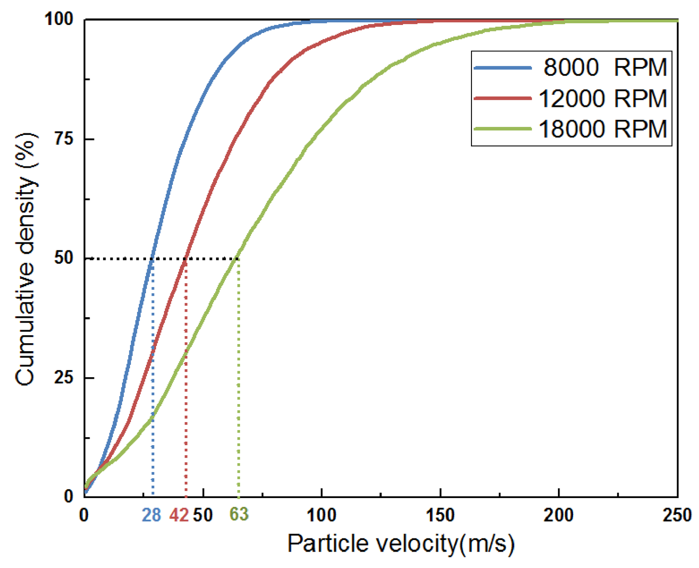


Fig 4. Particle velocity cumulative distribution

- Average particle velocity increases with increasing of pin rotating speed

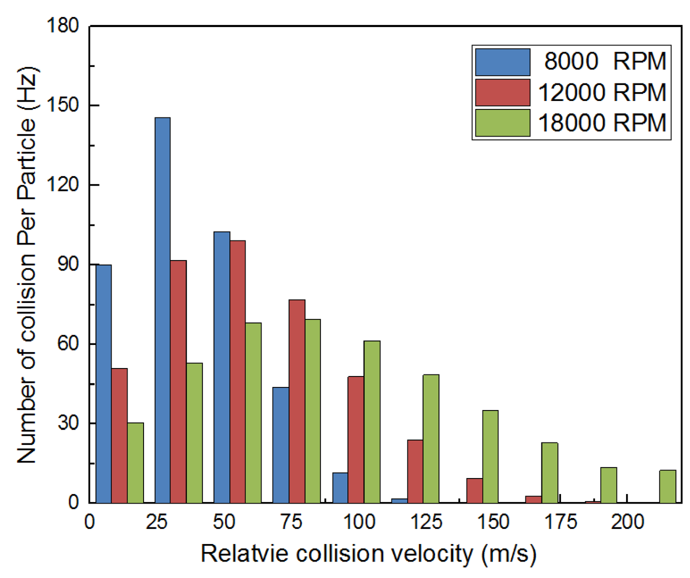


Fig 5. Impact velocity and number distribution

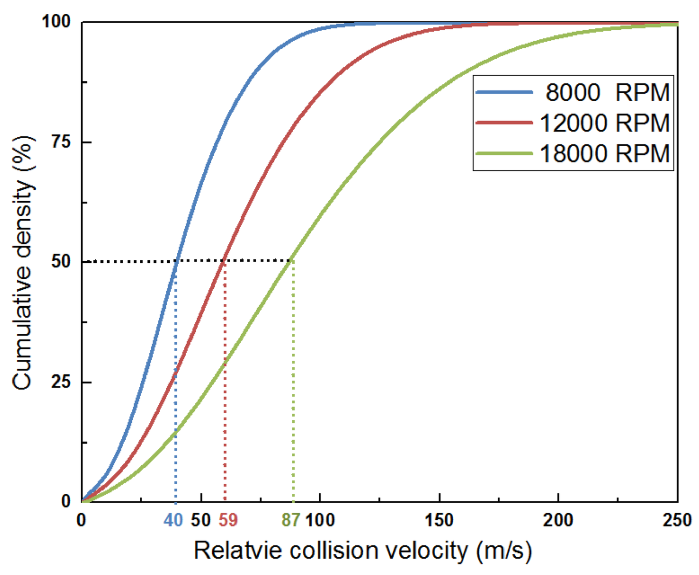


Fig 6. Impact velocity cumulative distribution

- Particle impact velocity increases with increasing of pin rotating speed

4.2 PSD predicted by PBM

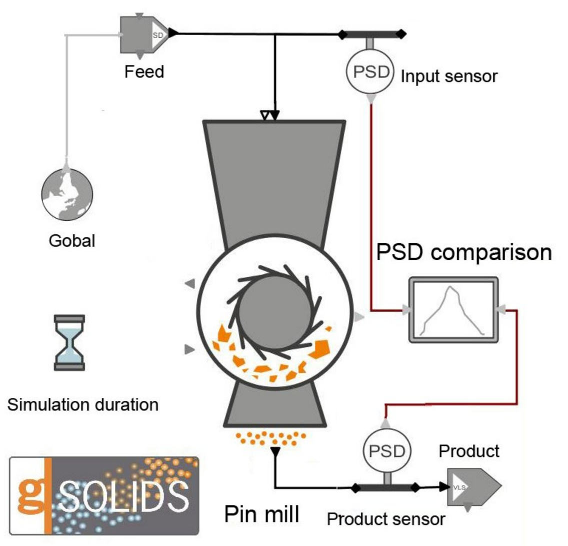


Fig 7. Flowsheet simulation of milling process

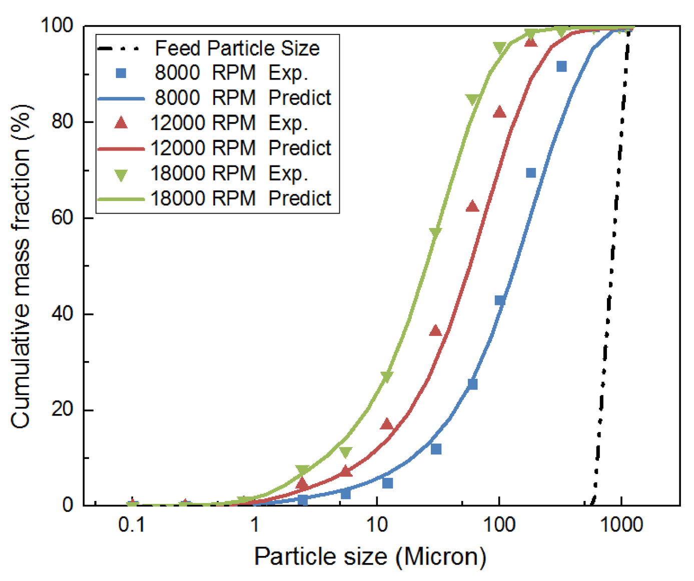
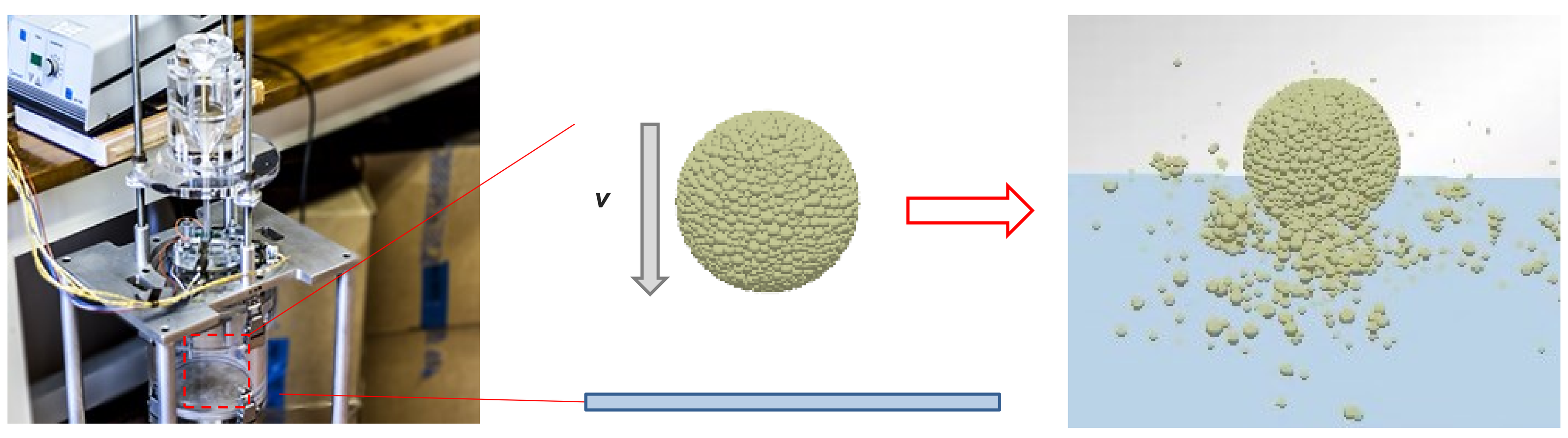


Fig 8. Product particle size distribution predictions

- Particle material dependent parameters in the breakage kernel were estimated based on 18000 RPM case and then used to predict 8000 RPM and 12000 RPM cases
- With the impact velocity distribution from DEM, the gSOLIDS prediction results have a good agreement with experimental product size distribution measurement

5. Ongoing Work



Single particle impact experiment | Single particle impact DEM simulation using Edinburgh Bonded model

- Calibration of Edinburgh bonded model based on single particle impact experiment
- Using DEM simulations to obtain particle breakage material dependent parameters
- Once finished, no more fitting parameters are required in gSOLIDS

6. Conclusions

a) A multiscale DEM-PBM coupling approach is proposed to predict the milling behaviour of alumina particles in an impact pin mill.

b) DEM provides the particle dynamics and stress events in a centrifugal impact pin mill.

c) PBM coupled with DEM information was used to predict the product size distribution under varying operational conditions.

d) PBM coupled with DEM simulations sheds more physical insights into material grindability prediction under varying grinding conditions.

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