Effect of Particle Shape on The Particle Dynamics in Pin Mill

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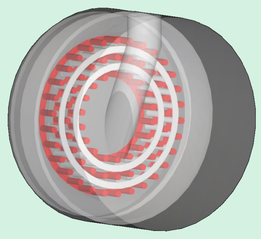
Introduction

- Milling is commonly used in a wide range of manufacturing operations to tailor desired product specifications and quality attributes.
- The milling performance is dictated by the mechanical properties of the material and the operating conditions of the chosen mill, such as geometry , process condition, etc.
- In this work, we simulate a commercially-available pin mill, PicoPlex of Hosokawa Micron using the Discrete Element Method (DEM).
- The effect of particle shape on the particle dynamics in the pin mill is analysed and reported, in addition to the effect of rotation speed of the mill.

Simulation Setup

PicoPlex Mill



Geometry Composition
3 rotating Rings - RED
2 Stationary Rings - WHITE

Operating Conditions Simulated
3000, 6000, 10000 and 30000 RPM
Mass flow rate: 2 g/s

Particle Representation

Faceted Polyhedron
26 faces

Sphere

Software Platform
ROCKY DEM

Material Properties

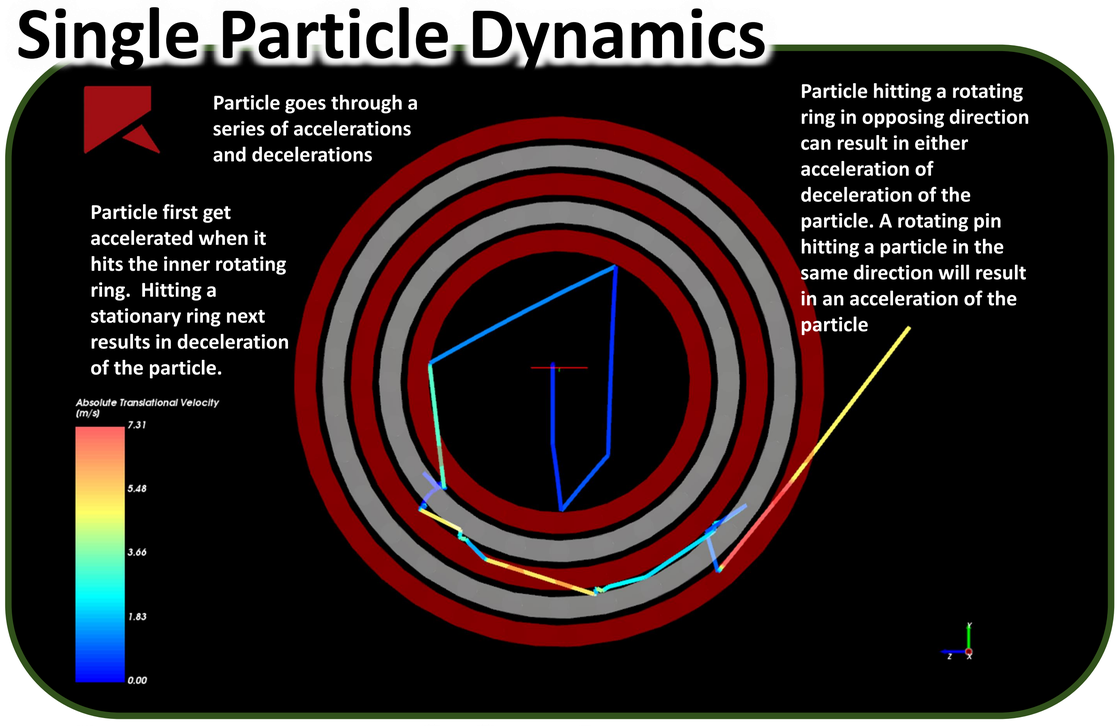
Material	Paracetamol	Stainless Steel
Young's Modulus, *E* (Pa)	* 5.7 x 10^9	2 x 10^{11}
Density, ρ (kg/m^3)	1290	7800
Poisson Ratio, v (-)	0.3	0.3

Material Interactions

Material Interaction	Paracetamol - Paracetamol	Paracetamol - Stainless Steel
Static Friction (-)	0.3	0.25
Dynamic Friction (-)	0.3	0.25
Coefficient of Restitution (-)	0.3	0.35

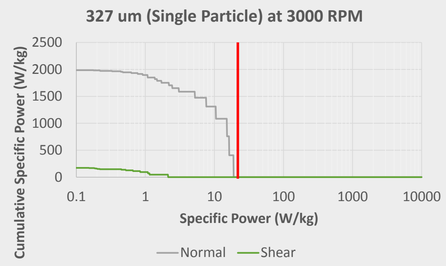
* Reduced to 5.7 x 10^7 to speed up the simulation

Single Particle Dynamics

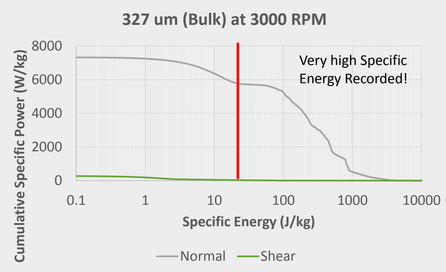


Breakage Mechanism

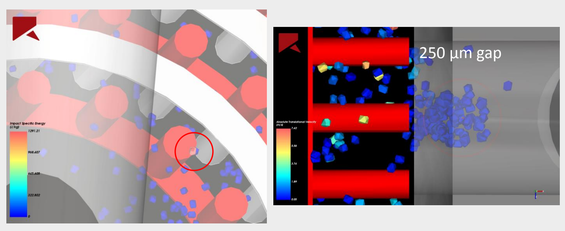
Contribution of impact and Shear on breakage mechanism in pin milling



Rotational Speed (RPM)	Outer Ring Linear Speed (m/s)	Corresponding Specific Impact Energy (J/kg)
30000	53.4	1425.78
10000	17.8	158.4
6000	10.7	57.2
3000	5.3	14.0



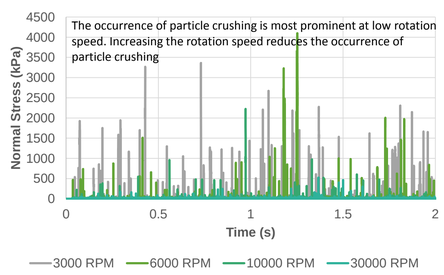
The clearance gap of pins from the side wall plays an influential role in particle crushing

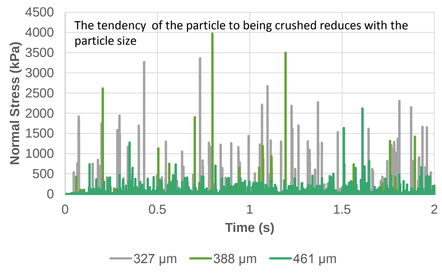


Spheres vs Polyhedra

What's the significance of particle shape?

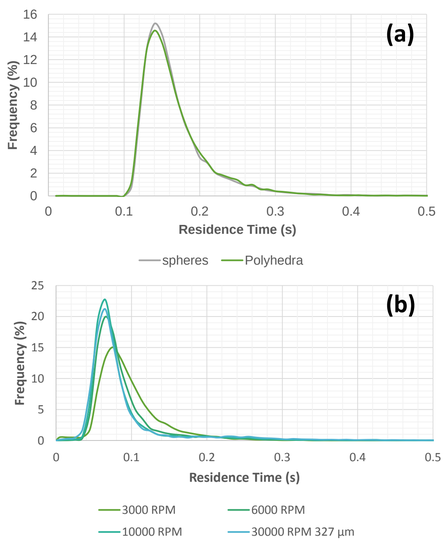
- Previous work [1] on predicting particle breakage in a pin mill used spheres on EDEM platform. Particle nipping was not reported and that could be attributed to the fact that the tendency of spheres to get nipped between the pin and side wall is less compared to faceted particles.





[1] Bonakdar, T. and Ghadiri, M. 2018. Analysis of pin milling of pharmaceutical materials. *International Journal of Pharmaceutics*. [Online]. **552**(1–2),pp.394–400. Available from: https://doi.org/10.1016/j.ijpharm.2018.09.068.

Residence Time



- Particle Shape does not affect the residence time of the particle much (Figure a).
- Rotation speed has a more prominent influence on the residence time of the particles (327 µm) (Figure b).
- At lower speeds, particles tend to stay longer in the mill (Figure b).
- Bigger particles stay longer in the mill, albeit the difference is small (30000 RPM) (Figure c).

Conclusions

- The particle dynamics inside a pin mill is analysed using DEM and two different particle shapes.
- The analysis of the dynamics of single particles in the pin mill reveals that the particles undergo a series of acceleration of deceleration events.
- Particle crushing is observed when the particles are being fed in bulk between the pin and the side wall. The clearance gap is influential.
- The residence time of particles is affected by the rotation speed of the mill and the size of the particle. The effect of shape on the residence time however is insignificant.

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