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Investigation of dominating DEM parameters for multi-component segregation during heap formation, hopper discharge and chute flow

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Introduction

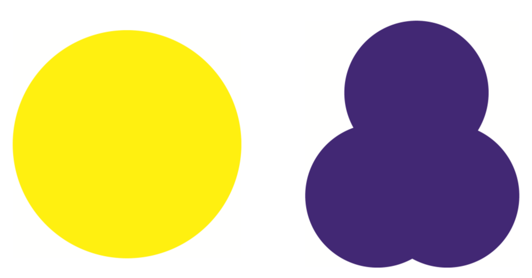
- Granular **segregation** is a **critical phenomenon** in various industries, such as food processing, pharmaceuticals, and mining.
- DEM is an **effective tool** for gaining insight into granular segregation since it provides **particle-level information** that is often **difficult or impossible to obtain through experiments**.
- To ensure realistic material behaviour and **correct representation of segregation**, it is essential to **systematically calibrate** the model against experimental results.
- In the context of **multi-component segregation**, it is extremely challenging and computationally **expensive** to **consider all parameters** in the calibration procedure.

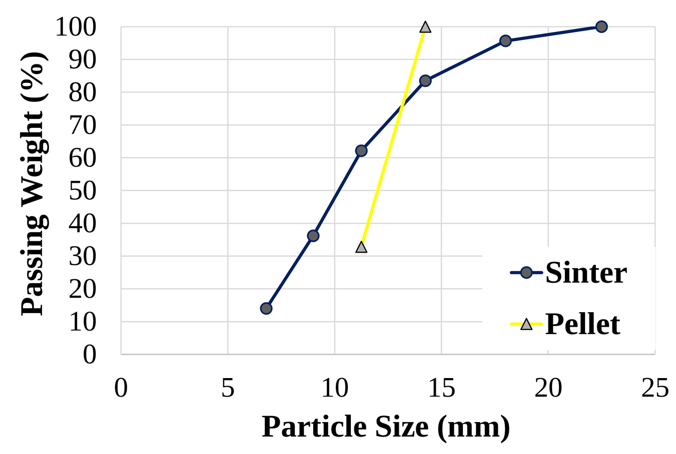
Objective

- **This work aims to identify the most influential DEM parameters for modelling multi-component segregation during heap formation, hopper discharge, and chute flow.**
- Our findings will aid researchers in calibrating DEM models for multi-component segregation more efficiently.

DEM model

- Contact model: Hertz-Mindlin with rolling friction type C





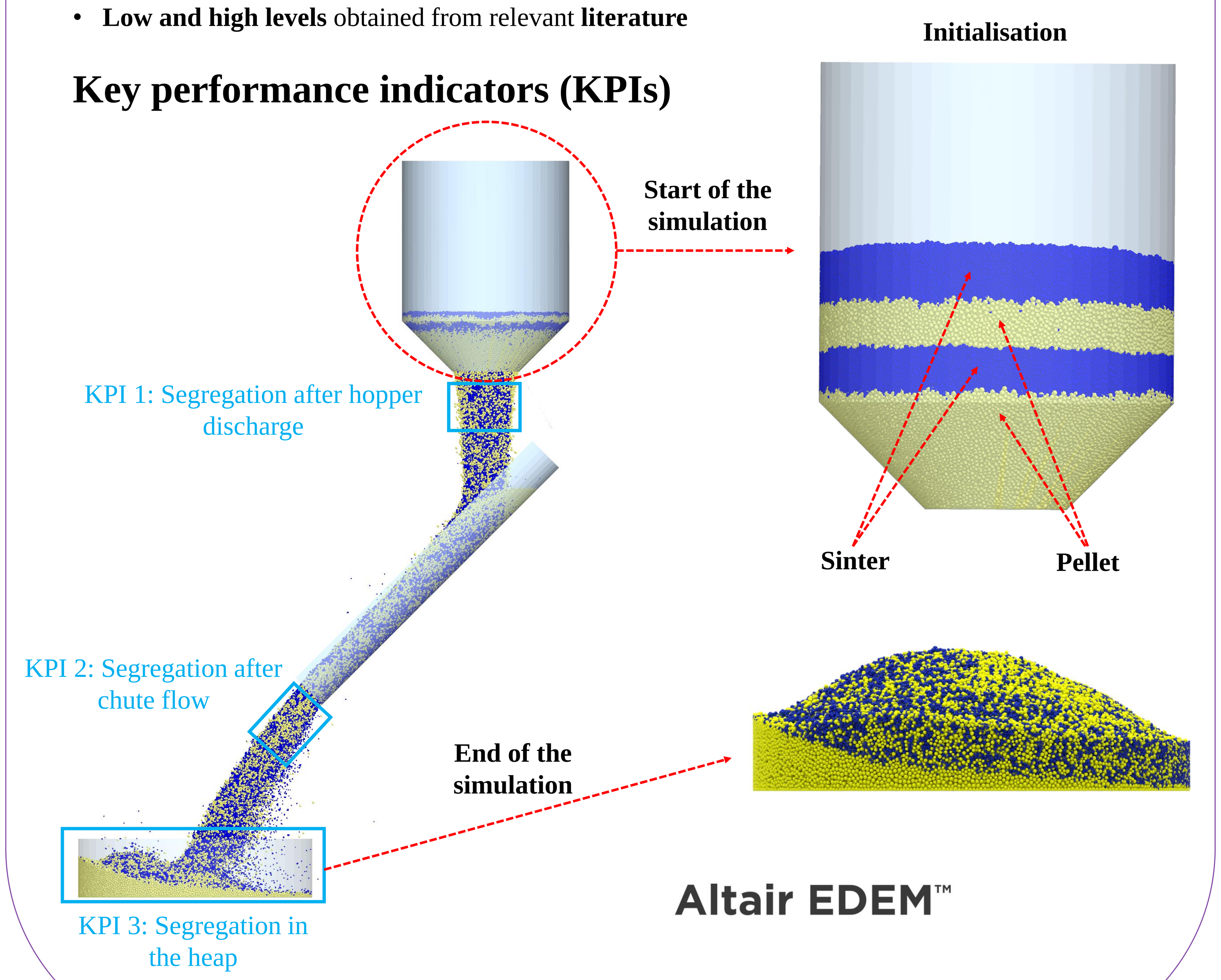
- 50%-50% mass ratio of pellets and sinter (500 kg each)
- Parameters of interest (interaction parameters):

	Coefficient of restitution	Coefficient of sliding friction	Coefficient of rolling friction
Pellet-pellet	$C_{r,p-p}$	$\mu_{s,p-p}$	$\mu_{r,p-p}$
Pellet-sinter	$C_{r,p-s}$	$\mu_{s,p-s}$	$\mu_{r,p-s}$
Sinter-sinter	$C_{r,s-s}$	$\mu_{s,s-s}$	$\mu_{r,s-s}$
Pellet-geometry	$C_{r,p-g}$	$\mu_{s,p-g}$	$\mu_{r,p-g}$
Sinter-geometry	$C_{r,s-g}$	$\mu_{s,s-g}$	$\mu_{r,s-g}$

Design of experiment (DoE)

- **Definitive screening design (DSD)**
- The number of runs: $N = 2k + 3$; given $k = 15 \ggg N = 33$
- Adding **four extra runs** to make the screening design more powerful
- **Three repetitions** to capture the standard error
- **Low and high levels** obtained from relevant **literature**

Key performance indicators (KPIs)



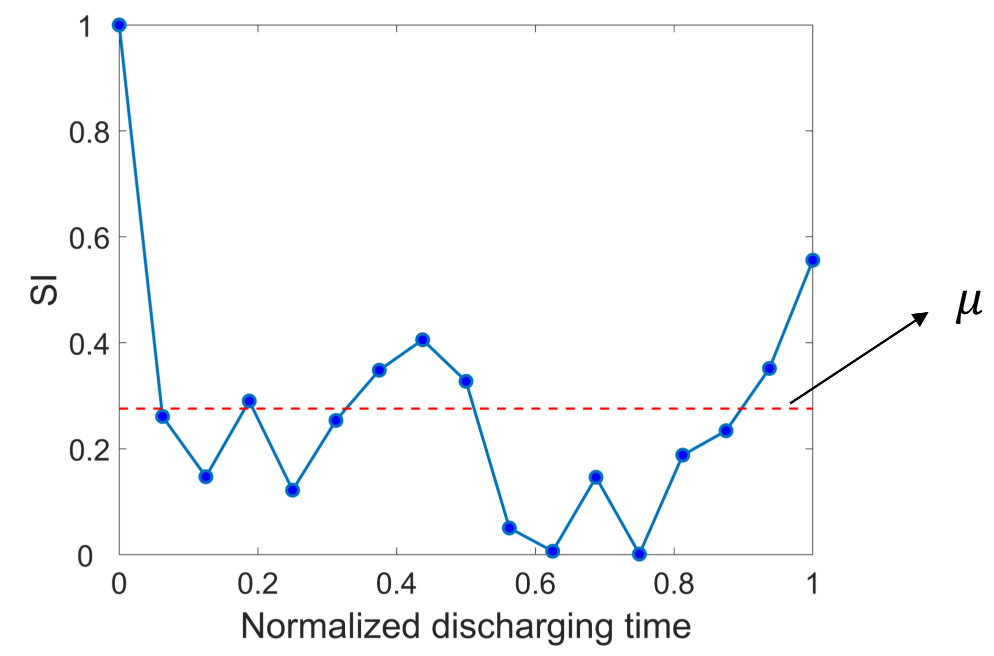
Quantifying segregation:

I. Segregation index (SI) for KPI 1 and KPI 2:

$$SI = \frac{|MR_P - MR_{mixed}|}{|MR_{max} - MR_{mixed}|}$$

- SI = 0 >> Fully mixed
- SI = 1 >> Fully segregated

where MR_P is the instantaneous mass ratio of pellets. A typical time evolution example of SI during discharge is given in Figure below:



We need to transform this graph into a **single value** for use as a response in definitive screening design. We employ relative standard deviation (RSD) as follows:

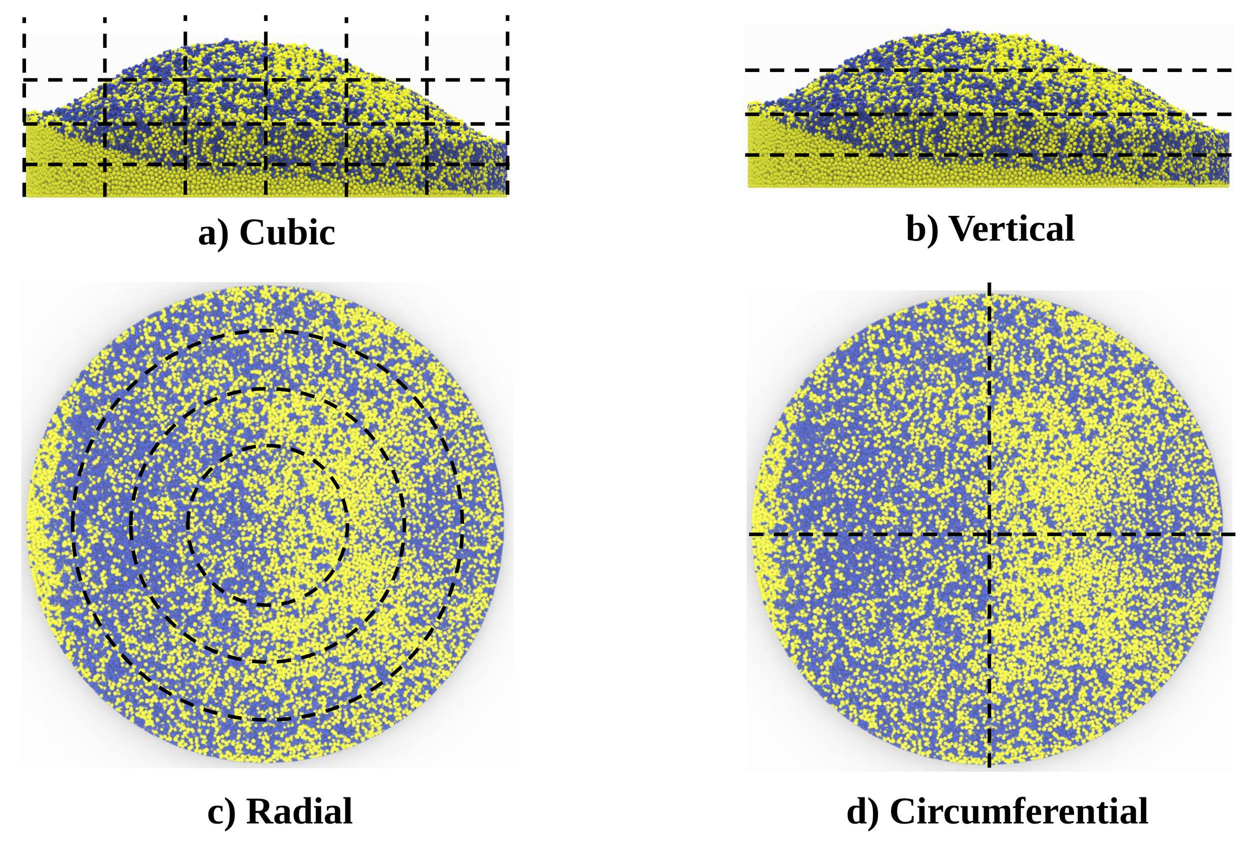
$$RSD = \frac{\sigma}{\mu}$$

where

- σ is the standard deviation of the points
- μ is the mean of the points (showing as the red dashed line)

II. KPI 3

- We divided the heap into a number (m) of bins in different directions:



- We then measured the mass ratio of pellets (or sinter) in each bin (C_{P_m}).
- We calculated the mean (μ_P) and standard deviation (σ_P) of C_{P_m}.
- Segregation index (i.e., relative standard deviation (RSD)) is calculated using the equation above.

Screening Results

Significant parameters for each KPI.

		Pellet-Pellet			Sinter-Sinter			Pellet-Sinter			Pellet-Geometry			Sinter-Geometry		
		C_r	μ_s	μ_r	C_r	μ_s	μ_r	C_r	μ_s	μ_r	C_r	μ_s	μ_r	C_r	μ_s	μ_r
KPI1												*	*			
KPI2													*		*	
KPI3	**Cubic**		*		*	*										
	Radial					*	*							*		
	Vertical		*	*												*
	Circumferential			*		*									*	

Conclusion

- Segregation occurring after discharging from hopper and chute is mainly affected by particle-geometry interactions.
- Segregation in the heap is mostly affected by pellet-pellet and sinter-sinter interactions.
- The influence of pellet-sinter interactions on segregation is negligible.
- Future work will include conducting the sensitivity study for spherical sinter particles, different pellet-sinter mass ratios and different mixture compositions (e.g., mixed) in the hopper.

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