Numerical Simulations of the Bouncing Behavior of Porous Dust Aggregates

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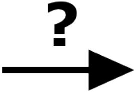
Bouncing Barrier

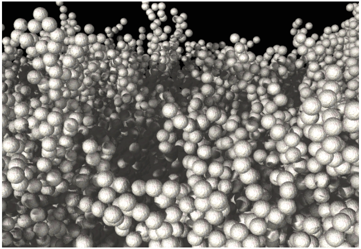


- In laboratory experiments bouncing is observed for rather low filling factors (e.g. Heißelmann *et al.*, 2007, Langkowski *et al.*, 2008)
- Bouncing collisions may or may not prevent growth of larger aggregates (Zsom *et al.*, 2010, Windmark *et al.*, 2012a)
- In molecular dynamics simulations bouncing is observed only for highly compact aggregates (Wada *et al.*, 2011)

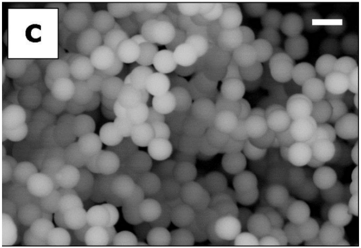
Physical Model

Method

We use a molecular dynamics / soft sphere discrete element (SSDEM) approach featuring a detailed micro-mechanical model of the particle interaction.



Simulation



Laboratory

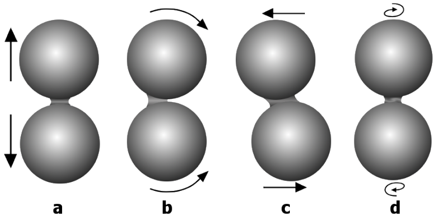
Particle-Particle Interaction

(a) Repulsion/Adhesion (Johnson *et al.*, 1971)

(b) Rolling (Dominik & Tielens, 1995)

(c) Sliding (Dominik & Tielens, 1996)

(d) Twisting (Dominik & Tielens, 1996)



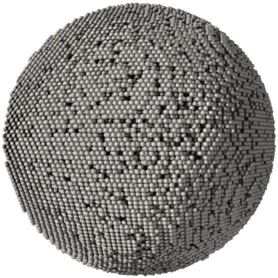
Forces and torques can be derived from *corresponding potentials* (Wada *et al.*, 2007)

Interaction model has been *calibrated* using compression experiments (Seizinger *et al.*, 2012)

Aggregates

We use different types of aggregates for our studies:

Hexagonal lattice with extraction



$n_c = 9.93$

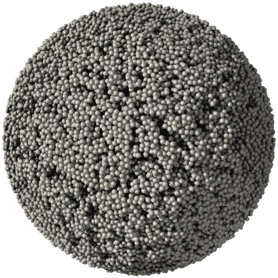
$\varphi = 0.59$

Static compression with relaxation

$n_c = 3.50$

$\varphi = 0.49$

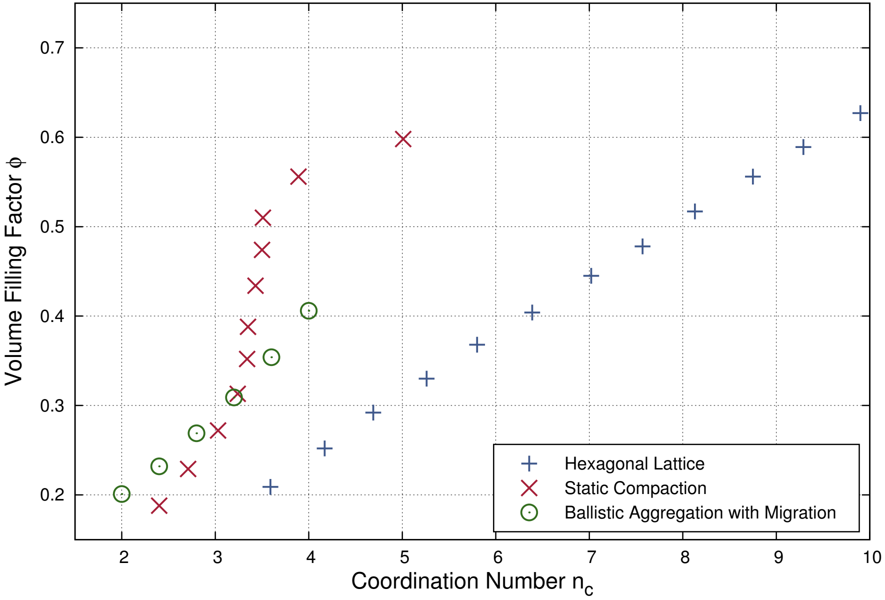
Ballistic aggregation with migration



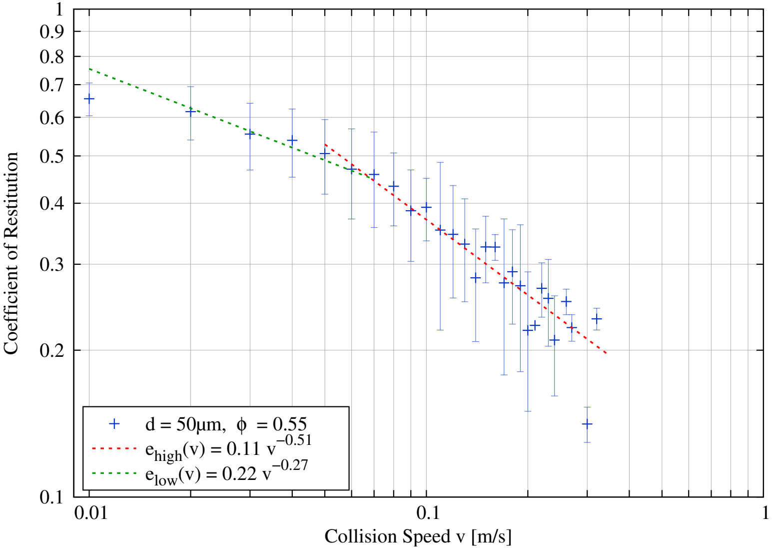
$n_c = 3.98$

$\varphi = 0.40$

Filling Factor vs. Coordination Number



Coefficient of Restitution

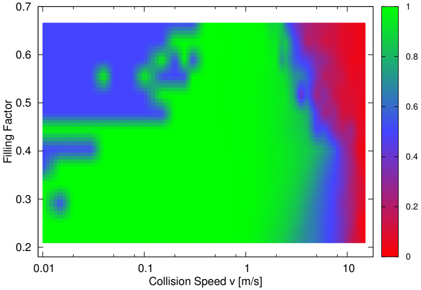


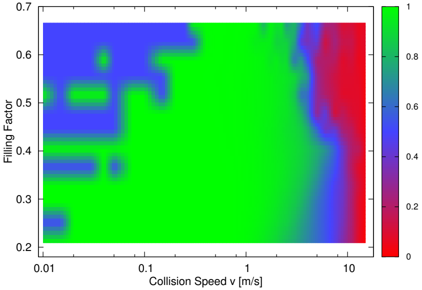
from Schräpler, Blum, Seizinger & Kley (2012)

Influence of Orientation

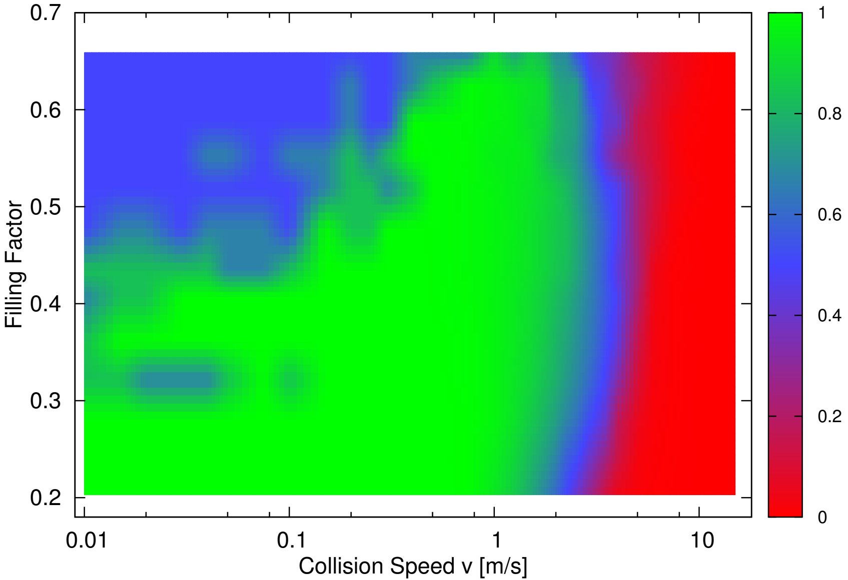
Problem

For hexagonal lattice type aggregates, the bouncing behaviour is greatly influenced by their orientation.

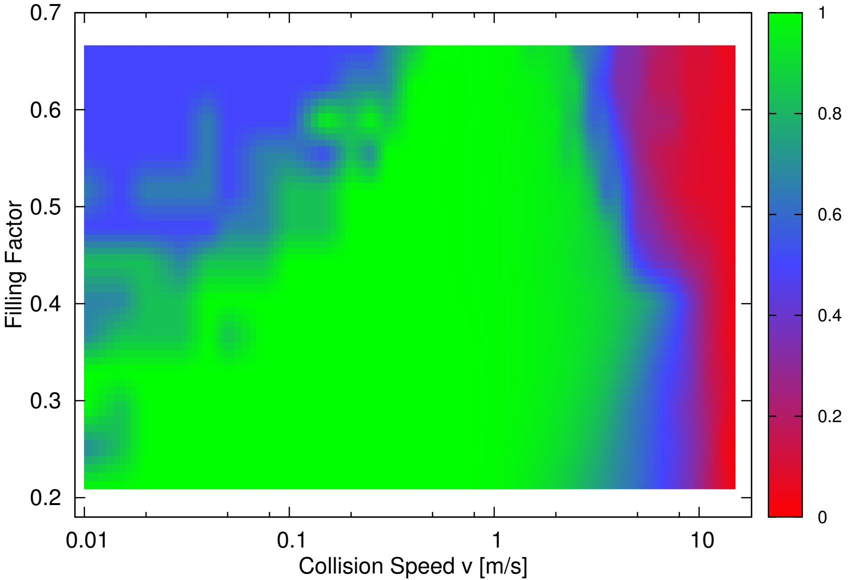




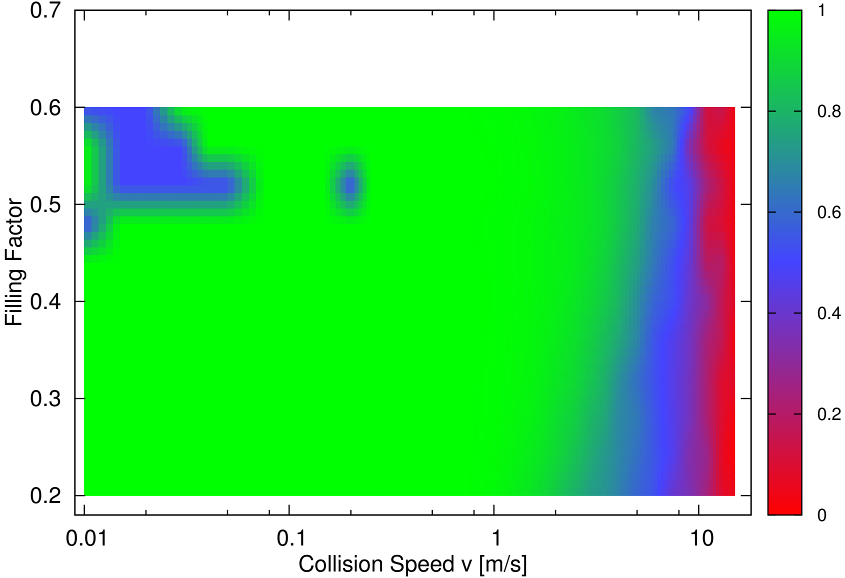
Hexagonal Lattice, $d = 30\ \mu\mathrm{m}$



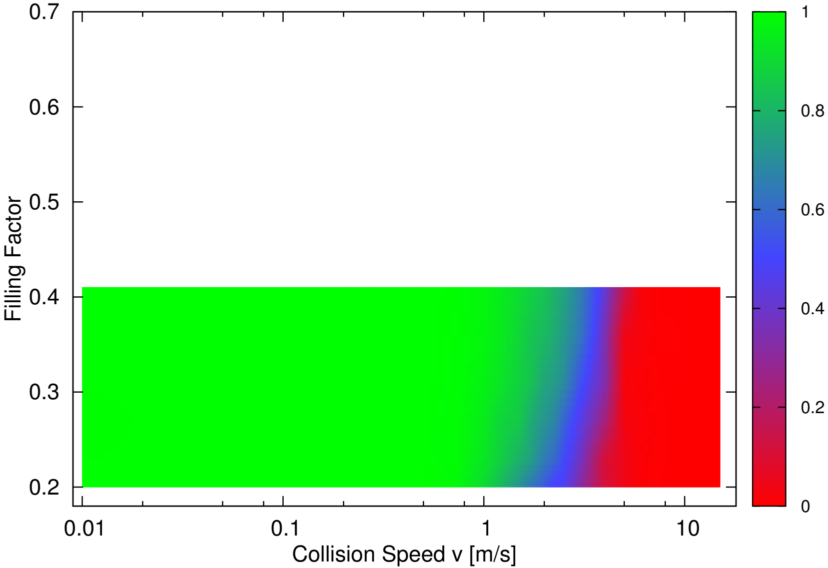
Hexagonal Lattice, $d = 60\ \mu m$



Static Compaction, $d = 60\,\mu\mathrm{m}$



Ballistic Aggregation with Migration, $d = 30\ \mu\mathrm{m}$



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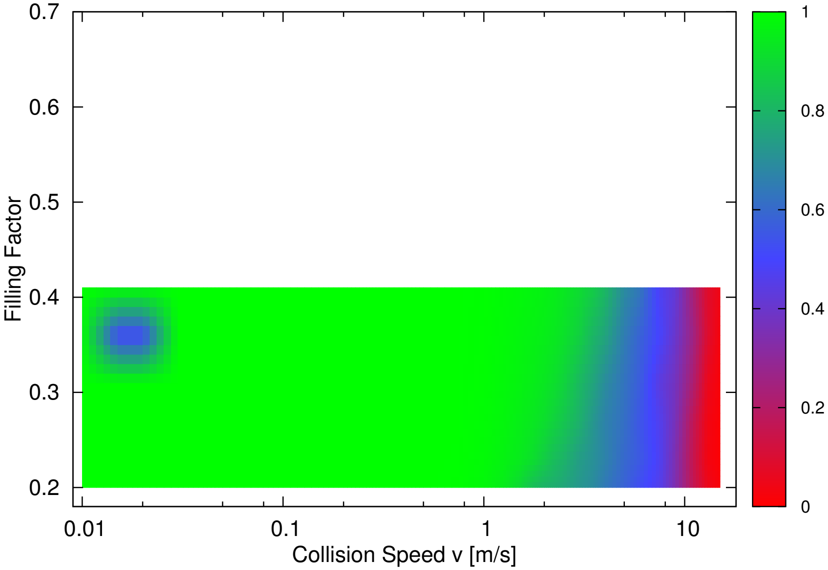

Conclusions

- Coefficient of restitution agrees well with theoretical predictions of Thornton & Ning (1998)
- Coordination number of aggregates with similar filling factor may vary considerably
- For hexagonal lattice aggregates bouncing behaviour depends strongly on orientation
- Size dependency of bouncing not yet clear
- For low porosity aggregates sticking increases with the size of the aggregates

Outlook

- Generate more compact BAM aggregates
- Study influence of impact parameter
- More simulations with aggregates of $\geq$ 100 $\mu\mathrm{m}$ diameter
- Some examples: Collision 0.1 $\mathrm{m/s}$, Collision 0.2 $\mathrm{m/s}$, Collision 2 $\mathrm{m/s}$, Collision 5 $\mathrm{m/s}$

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Thank you very much for your attention!