Collision dynamics of colliding wet solids: Rebound and rotation analysis

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Collision dynamics of colliding wet solids: rebound and rotation analysis

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Motivation
Micro processes

Macro process
Granulation
Agglomeration
Spray drying etc.

Consist of
Micro processes
Wetting
Particle collision
Liquid transfer
Drying, etc.

Describe
Granulation
Agglomeration
Spray drying
etc.

Particle collision
Wetting

droplets
wetting
droplet collisions
rebound
Rupture of liquid bridge
breakage
drying of binder liquid

sticking, agglomeration
Motivation
Particle collisions

- \( \sim 10^9 \) collisions/s in laboratory spouted beds [1]
- Collision behaviour of wet systems fundamentally different from dry systems (bed collapse)

- Characterisation by **Coefficient of restitution**: 

\[
e = \frac{v_R}{v} = \sqrt{\frac{E_{kin,R}}{E_{kin}}} = \sqrt{1 - \frac{E_{diss}}{E_{kin}}}
\]

Goal:
- \( e_{\text{wet}} = f(e_{\text{dry}}, v_{\text{rel}}, \alpha, \delta, \eta, \sigma, \rho, d_P, \rho_P) \)
- Application of correlation in DEM simulations

[1] Sutkar, Deen, Mohan, Salikov, Antonyuk, Heinrich, Kuipers; Chemical Engineering Science 104 (2013), 790-807
[2] Antonyuk, Heinrich, Deen, Kuipers; Particuology 7 (2009), 245-259
Joint project
Particle collisions

Experiments

Crüger et al., Particuology 25 (2016), 1-9
Crüger et al., Chemical Engineering Research and Design (2016), in press

Modelling via force balance

Antonyuk, Heinrich, Deen, Kuipers; Particuology 7 (2009), 245-259

Dimensional analysis

Crüger et al., Particuology 25 (2016), 1-9

VOF/IB simulation

Presentation of Yali Tang:
Tuesday 18:00, room 1
Direct numerical simulations of collision dynamics of wet particles

Jain, Deen, Kuipers, Antonyuk, Heinrich; Chemical Engineering Science 69 (2012), 530-540
Methods

Setup

Distinction between normal, tangential and rotational components:

\[ e_n = \frac{v_{n,R}}{v_n} \quad e_t = \frac{v_{t,R}}{v_t} \quad e_\omega = \frac{\omega_R}{\omega} \]

Cameras:
- 7000 fps
- Confocal sensor:
  - \( \delta_l \pm 1 \mu m \)

\( v_n = 1 \text{ m/s} \)
Methods
Initial rotation

Without initial rotation

With initial rotation
Particles:

$\gamma$-Al$_2$O$_3$
- $d_{50} = 1.74$ mm
- sphericity = 0.98
- porosity $\approx$ 70%
- rough surface ($\mu$m-range)

Target plate:

Glass
- smooth surface

Liquids: (23 °C, 1 atm)

Tween 20 – water solution
- 60 mg/L
- $\sigma = 37.3$ mN/m
- $\eta = 0.82$ mPa s
Results
Without initial rotation

- \( e_n \neq f(\alpha) \)
- \( \delta_l \uparrow \Rightarrow e_n \downarrow \)
- \( e_t \) weak dependence on \( \alpha \)
- \( e_t \neq f(\delta) \)

\( v_n = 1 \text{ m/s} \)

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\[ \nu_n = 1 \text{ m/s} \]
Results
Without initial rotation

Rotational velocity

- $\alpha \uparrow \Rightarrow \omega \uparrow$

![Graph showing rotational velocity vs. collision angle for different particle sizes](image)

- 0 µm (dry)
- 100 µm (wet)

Without initial rotation

[Diagram showing collision angle and rotational velocity]
Results
Initial particle rotation

- $e_n$ independent of initial rotation
- $e_t < 1$ if no initial rotation
- $e_t > 1$ if with initial rotation

$\Rightarrow$ conversion of energy between tangential movement and rotation?

$v_n = 1 \text{ m/s}$
Results
Rotational coefficient of restitution

- ~ 30% of rotation is converted to translational movement

With initial rotation

rotational CoR \( e_\omega = \frac{\omega_R}{\omega} \) [\( \cdot \)]

[Graph showing rotational CoR vs. collision angle \( \alpha \) [\( \degree \)] with data points for 0 \( \mu \)m (dry) and 100 \( \mu \)m (wet).]
Summary & Outlook

Normal coefficient or restitution
- $e_n$ independent of $\alpha$ & initial rotation
- Depending on $\delta_l$

Tangential coefficient of restitution
- Depending on $\alpha$ & initial rotation
- $e_t > 1$ possible for initial rotation

Rotation
- Depending on $v_t$
- $e_\omega < 1$ for initial particle rotation

Outlook
- Energy balance (poster)
- Extension on collision of wet particle & dry plate
- Extension on particle – particle collisions (dry – dry, dry – wet, wet – wet)
Looking forward to your questions and comments

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