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Collision dynamics of colliding wet solids: Rebound and rotation analysis

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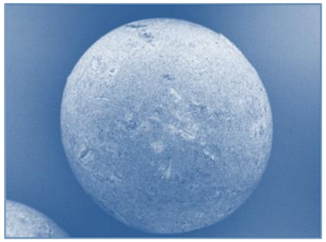



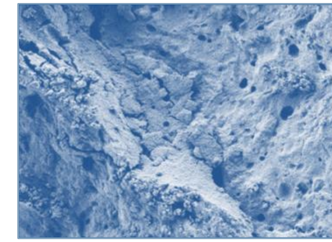

Collision dynamics of colliding wet solids:
rebound and rotation analysis

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Macro process

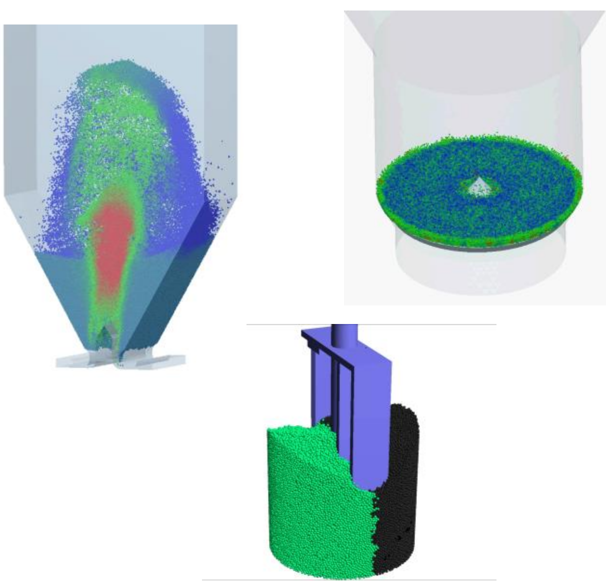
Granulation
Agglomeration
Spray drying
etc.

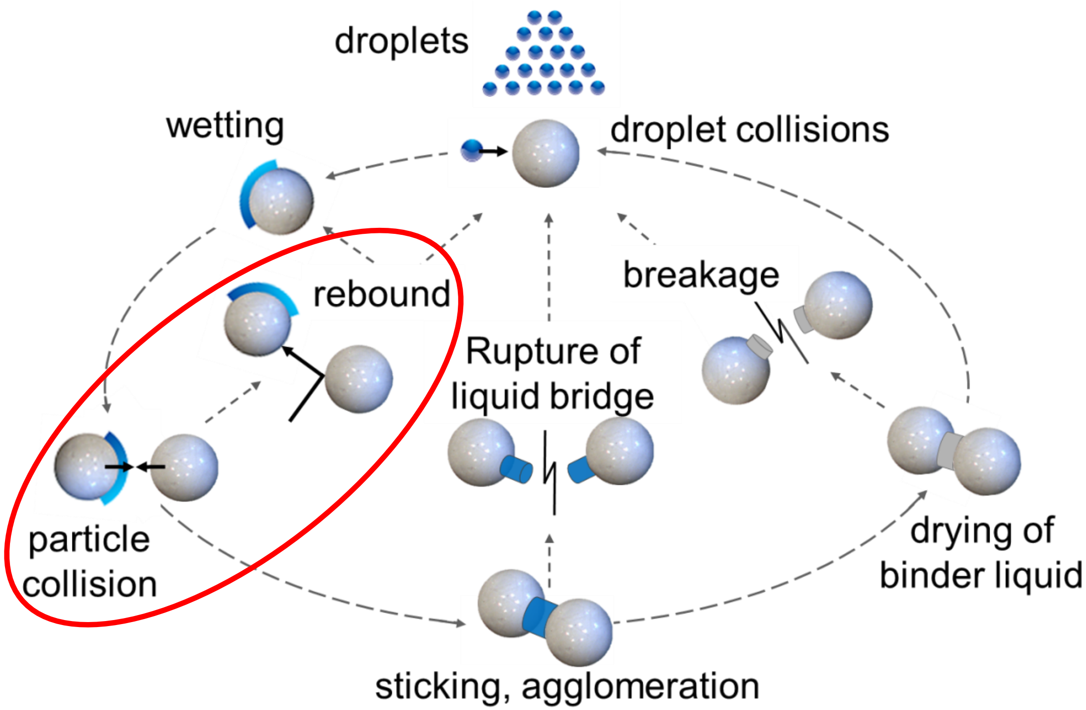
Consist of →

← Describe

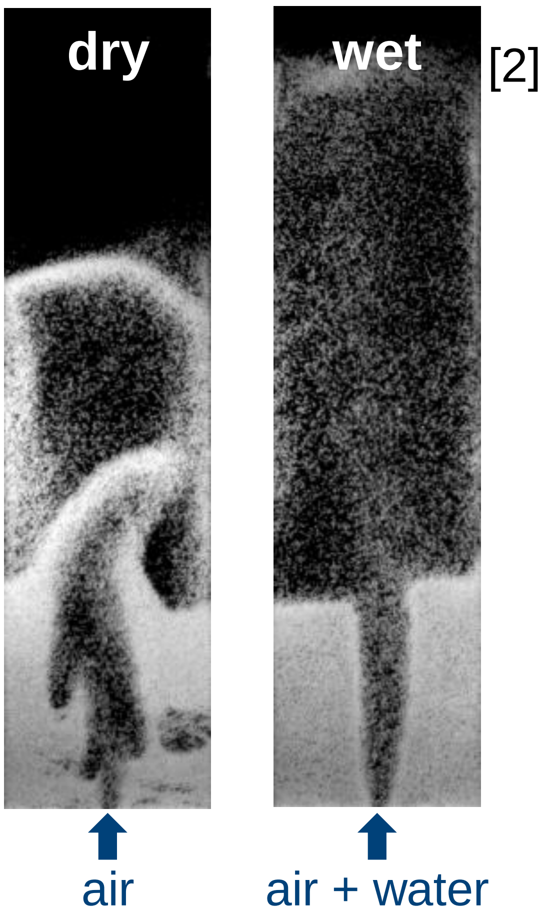
Micro processes

Wetting
Particle collision
Liquid transfer
Drying, etc.





- ~ 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**:

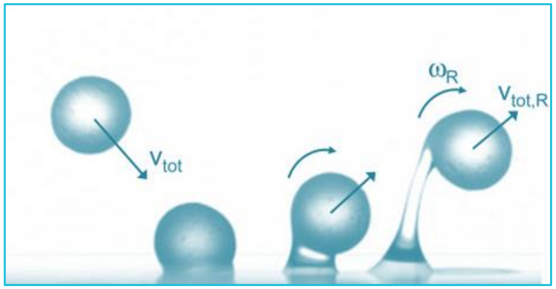
$$e = \frac{v_R}{v} = \sqrt{\frac{E_{kin,R}}{E_{kin}}} = \sqrt{1 - \frac{E_{diss}}{E_{kin}}}$$

Goal:

- $e_{wet} = f(e_{dry}, v_{rel}, \alpha, \delta_l, \eta_l, \sigma, \rho_l, d_P, \rho_P)$
- Application of correlation in DEM simulations

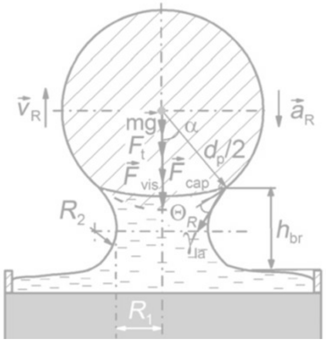
[1] Sutkar, Deen, Mohan, Salikov, Antonyuk, Heinrich, Kuipers; Chemical Engineering Science 104 (2013), 790-807
[2] Antonyuk, Heinrich, Deen, Kuipers; Particuology 7 (2009), 245-259

Experiments



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

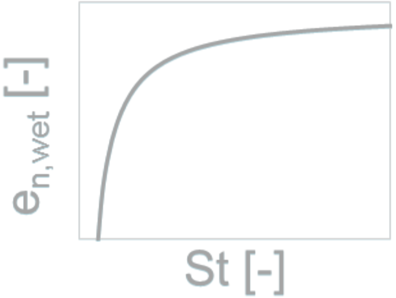
Modelling via force balance



$$m_P \frac{d^2 \vec{x}}{dt^2} = \sum F_i$$

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

Dimensional analysis

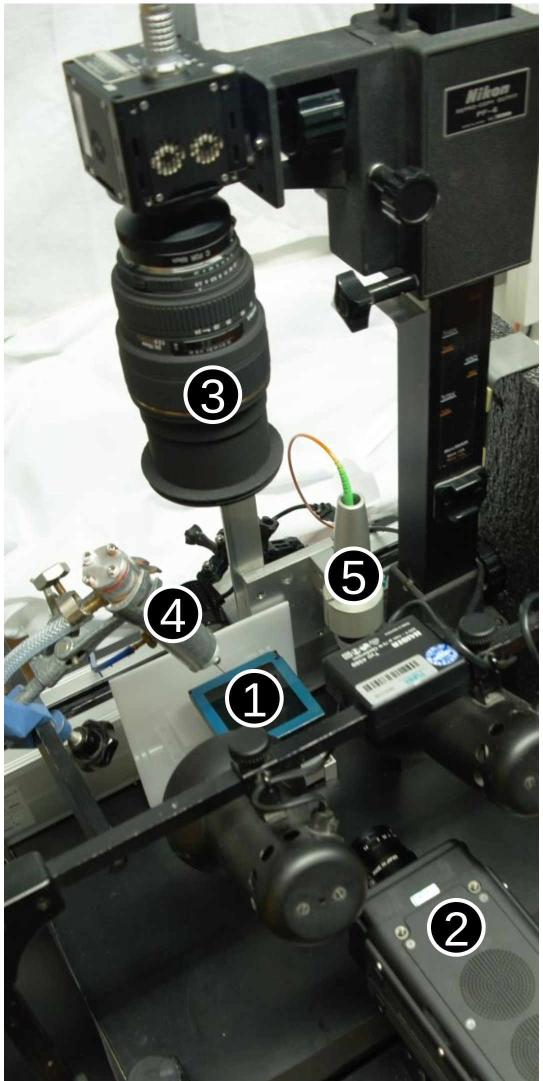


Crüger et al., Particuology 25 (2016), 1-9

VOF/IB simulation

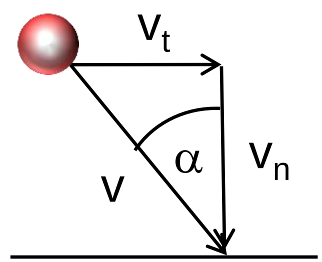
Presentation of Yali Tang:
Tuesday 18:00, room 1
Direct numerical simulations of collision dynamics of wet particles

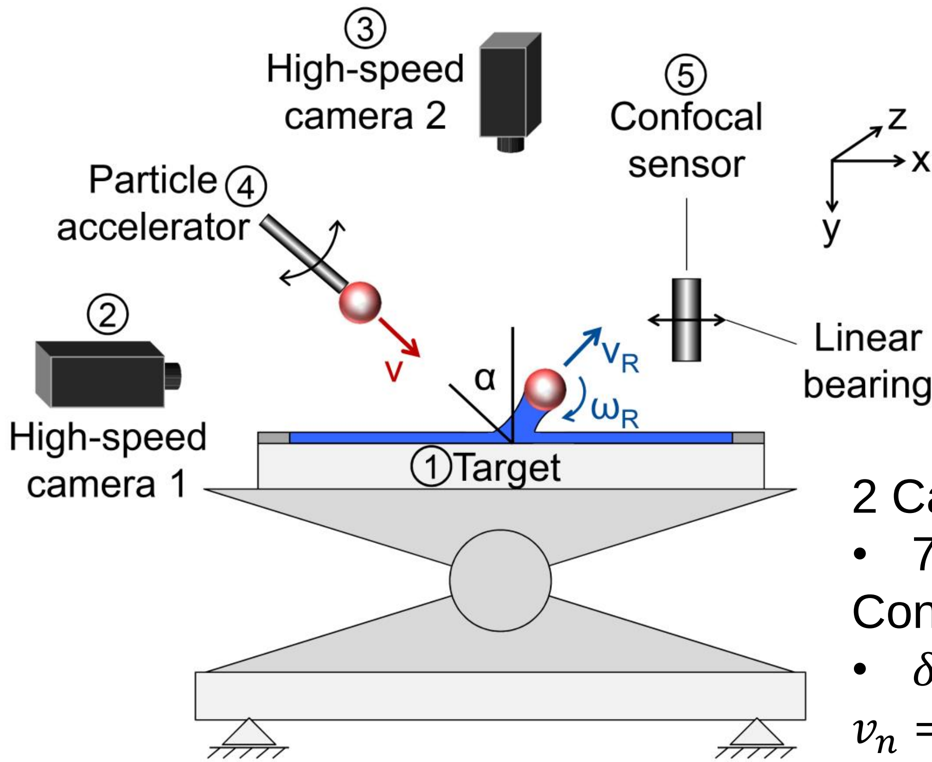
Jain, Deen, Kuipers, Antonyuk, Heinrich; Chemical Engineering Science 69 (2012), 530-540



Distinction between normal, tangential and rotational components:

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



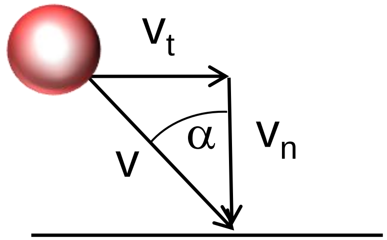


2 Cameras:
- 7000 fps

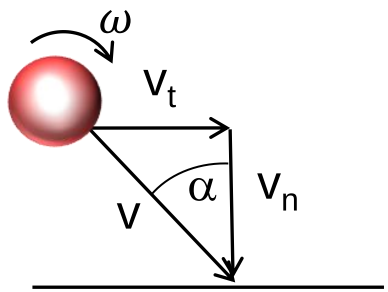
Confocal sensor:
- $\delta_l \pm 1$ µm

$v_n = 1$ m/s

Without initial rotation



With initial rotation



Particles:

γ-Al_2O_3

- d_{50} = 1.74 mm
- sphericity = 0.98
- porosity ≈ 70%
- rough surface (µm-range)

Target plate:

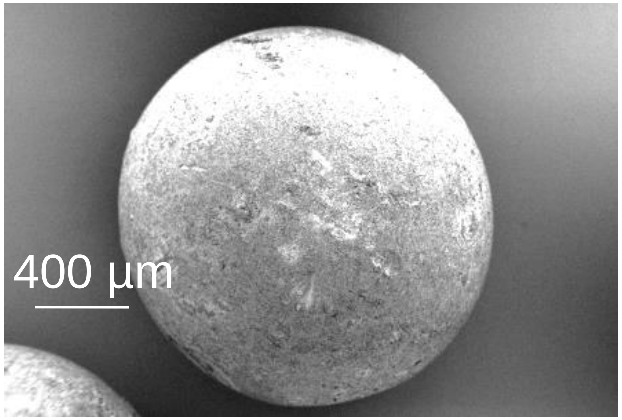
Glass

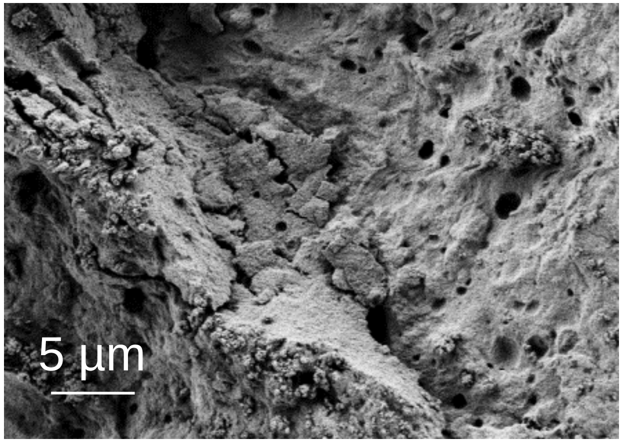
- smooth surface

Liquids: (23 °C, 1 atm)

Tween 20 – water solution

- 60 mg/L
- σ = 37.3 mN/m
- η = 0.82 mPa s



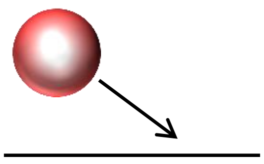


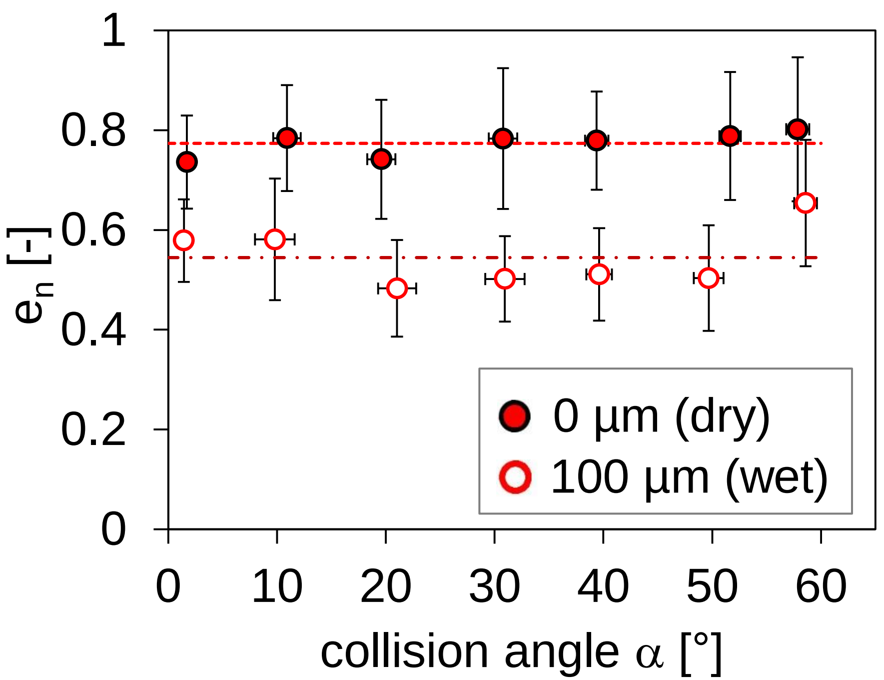
SEM images of particles

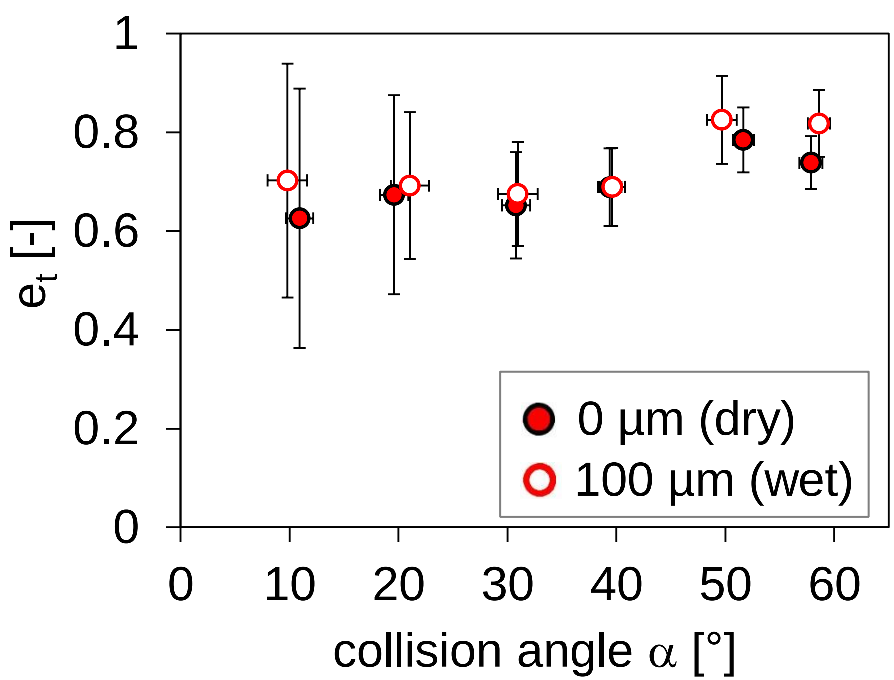
Results
Without initial rotation

$v_n = 1\ \mathrm{m/s}$

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





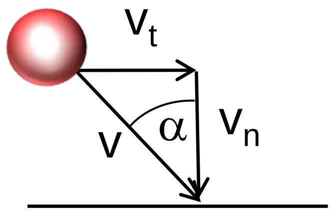


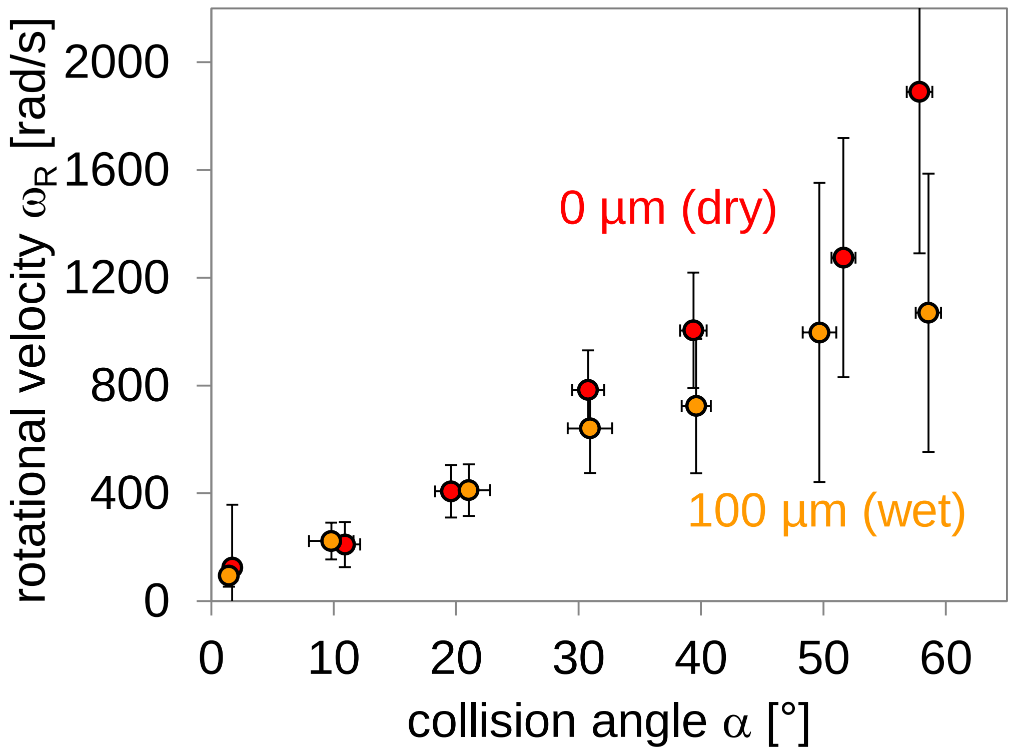
Results
Without initial rotation

Rotational velocity

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

Without initial rotation

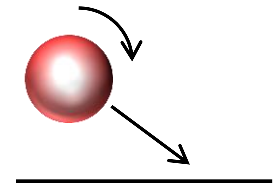


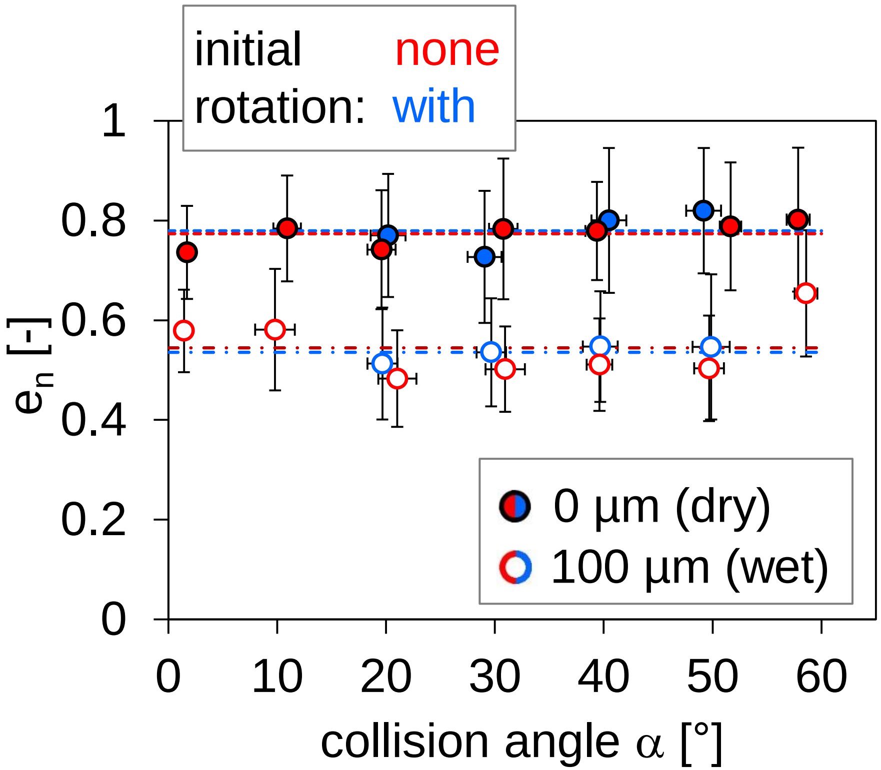


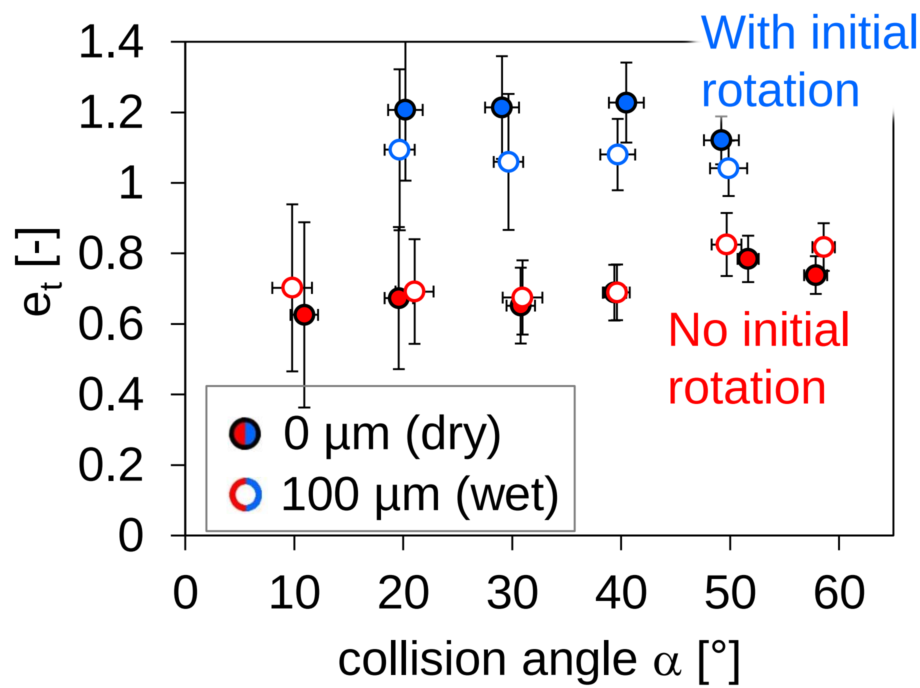
- e_n independent of initial rotation
- $e_t < 1$ if no initial rotation
- $e_t > 1$ if with initial rotation

⇒ conversion of energy between tangential movement and rotation?

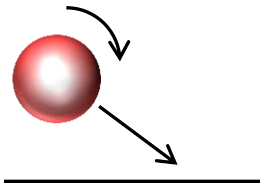
$v_n = 1\ \mathrm{m/s}$



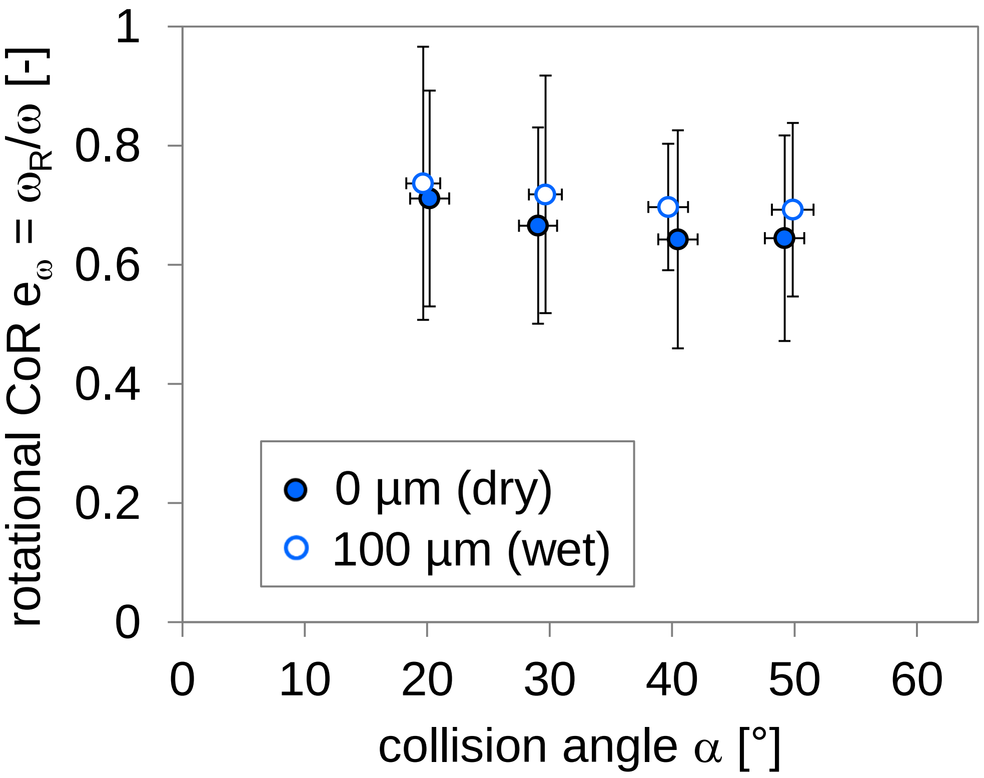


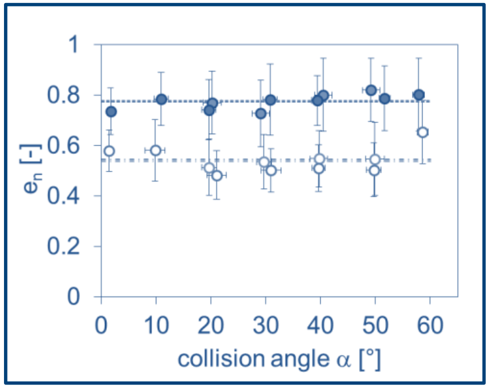


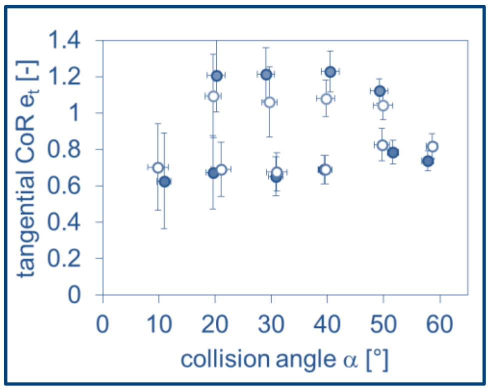
With initial rotation

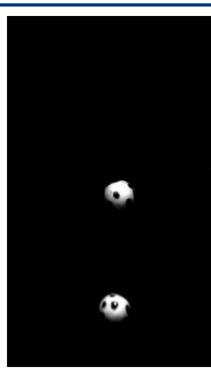


- ~ 30% of rotation is converted to translational movement









Normal coefficient or restitution

- e_n independent of α & initial rotation
- Depending on δ_l

Tangential coefficient of restitution

- Depending on α & 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

We thank for financial support: DFG Deutsche Forschungsgemeinschaft STW Enabling new technology

(HE 4526/9-1 & HE 4526/9-2)