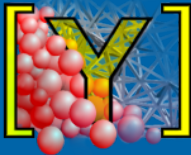


Users' committee meeting

“DEM simulation of weakly wetted granular material”



Short overview of the work done by FG-team

CONTENT

Implementation in Software

Capillary bridge models

Results of DEM-simulations of split-bottom shear-cell

CFD-simulations of the shear cell

Conclusions

Yade (Yet Another Dynamic Engine)

Pros

- Reliable, modern code
- OpenMP-parallelization

Cons

- Lower calculation speed
- No MPI-support

LIGGGHTS (LAMMPS improved for general granular and granular heat transfer simulations)

Pros

- MPI-support
- High calculation speed

Cons

- Some problems with capillary simulations (v2.x)
- Old-style code

Implemented CBMs:

1. Weigert et al.
2. Willett et al. (full and reduced)
3. Rabinovich et al.

Input constant parameters:

1. Contact angle θ
2. Liquid bridge volume V_b
3. Surface tension γ

Controlled parameter:

Separation particle distance s

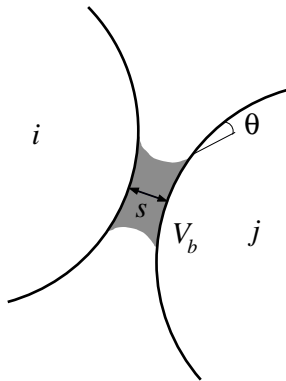


Fig. 1: Capillary bridge schema

Comparison with experiments of Willett et al.

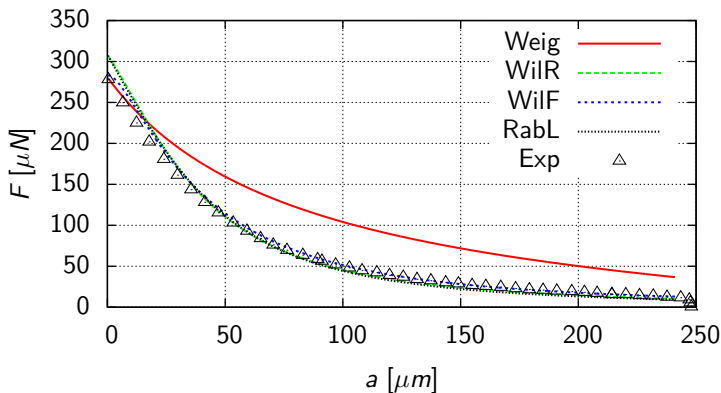


Fig. 2: Comparison of different kinds of capillary bridge models with experimental data from Willett. $R_p = 2.381\text{mm}$, $V_b = 13.6\text{nl}$, $\theta = 0^\circ$.

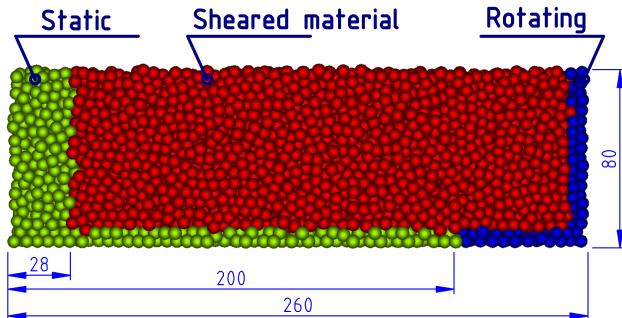


Fig. 3: Setup of split-bottom configuration

DEM parameters

- $R_p = 2.381\text{mm}$; $\rho = 150\text{kg}/\text{m}^3$; $t_c = 5.4 \cdot 10^{-6}\text{s}$; $e_n = e_t = 0.83$
- Particle number $\approx 2 \cdot 10^5$; Rotation period 100s;

AVERAGING TECHNIQUES

The software to analyze DEM-shear-cell results
<https://github.com/gladk/rheometeranalyze>

RheometerAnalyze

- Written in C++
- Import of text-data in different formats
- Export in text-form, VTK
- External libraries: boost, alglib, vtk, eigen3

Steady state analyze

$$\bar{\phi} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \phi dt$$

$$t_2 - t_1 \gg \Delta t$$

Snapshots analyze

$$\langle \phi \rangle = \frac{1}{\Delta t} \int_t^{t+\Delta t} \phi dt$$

Typical results from DEM-simulation:

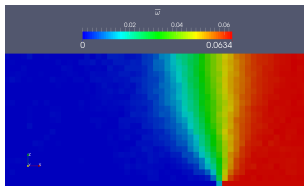


Fig. 4: $\bar{\sigma}$

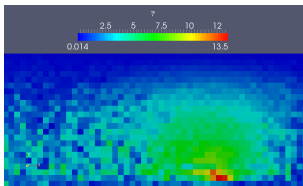


Fig. 5: $\bar{\tau}$

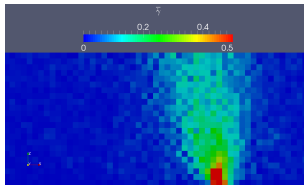


Fig. 6: $\bar{\dot{\gamma}}$

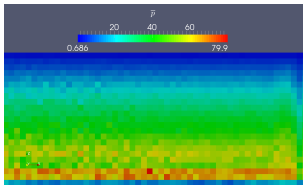


Fig. 7: \bar{p}

Local shear stress as a function of local pressure:

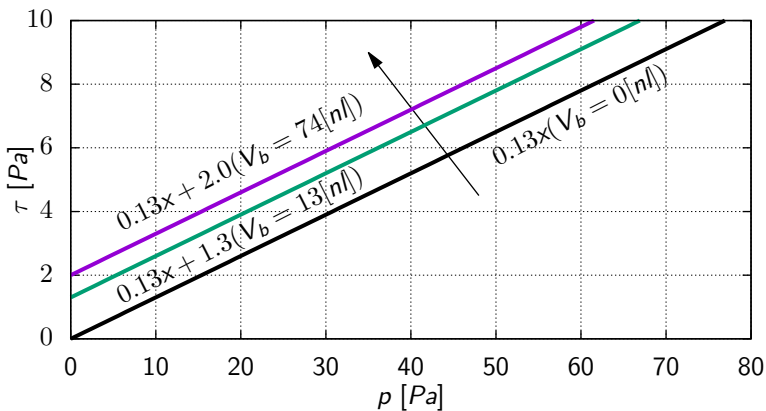


Fig. 8: $\tau(P)$.

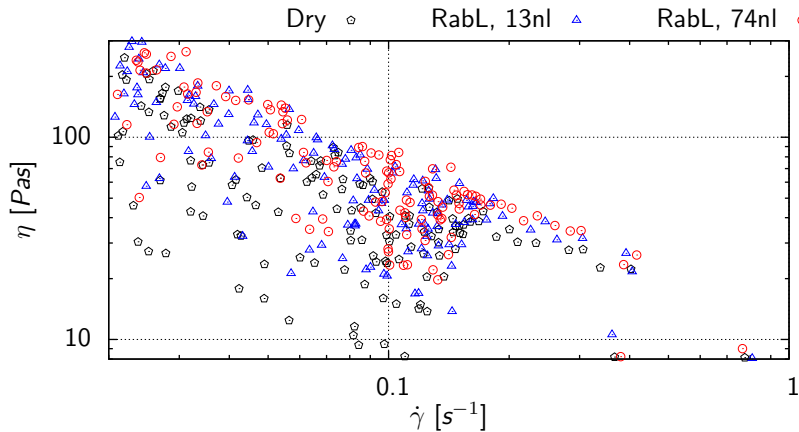


Fig. 9: Apparent shear viscosity $\eta(\dot{\gamma})$ for $\dot{\gamma} > 0.02s^{-1}$

Development of the local shear deformation γ :

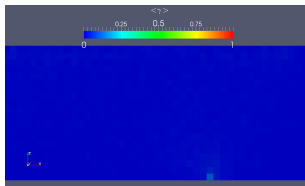


Fig. 10: $\langle \gamma \rangle$ ($t = 0.0225\text{s}$)

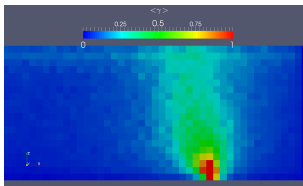


Fig. 11: $\langle \gamma \rangle$ ($t = 2.25\text{s}$)

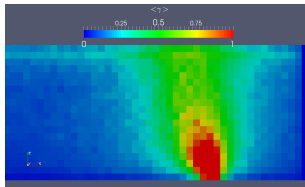


Fig. 12: $\langle \gamma \rangle$ ($t = 4.5\text{s}$)

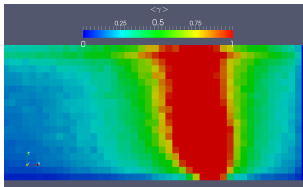


Fig. 13: $\langle \gamma \rangle$ ($t = 9.0\text{s}$)

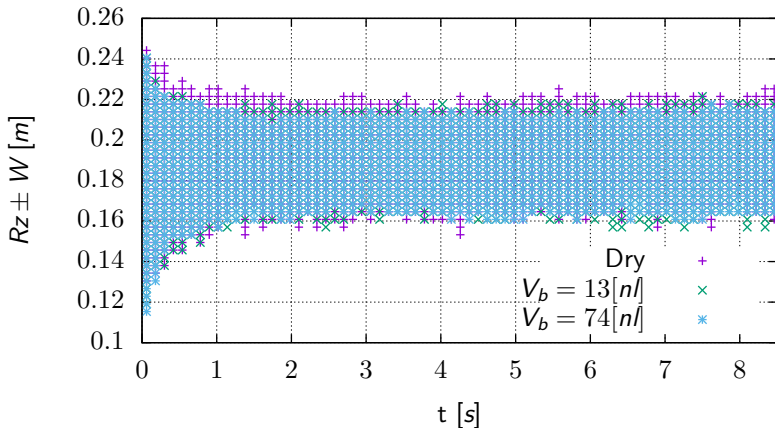


Fig. 14: Comparison of shear band position and width as a function of time for both weakly wet and dry state

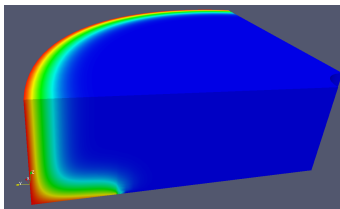


Fig. 15: $U(t = 0.01)$ s

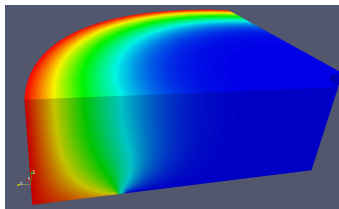


Fig. 16: $U(t = 0.10)$ s

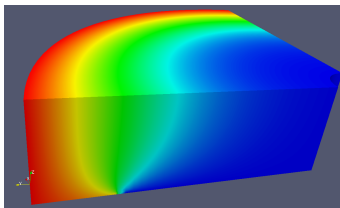


Fig. 17: $U(t = 0.30)$ s

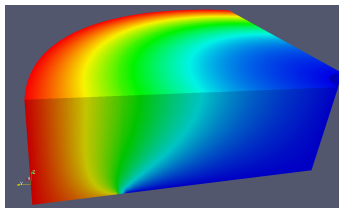


Fig. 18: $U(t = 1.00)$ s

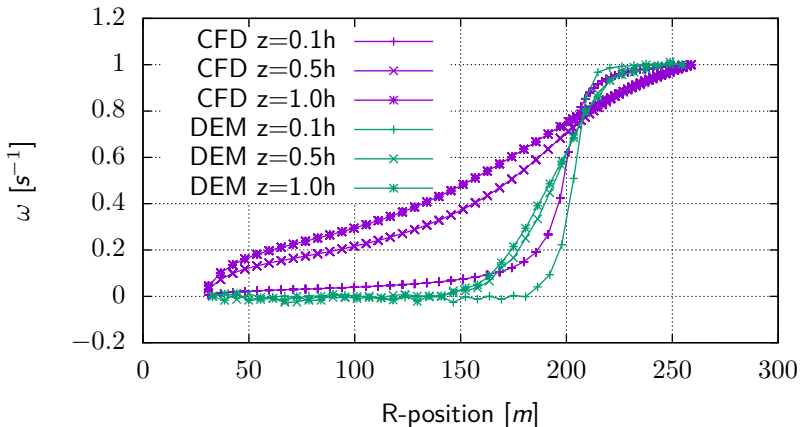


Fig. 19: Normalized velocity profiles from CFD and DEM simulations

1. Implement and compare of different capillary bridge models
2. DEM simulations of the shear cell
3. Micro-macro parameter transitions
4. CFD-simulations of the shear cell (first stage)

Thank you for your attention!