tusail
Training in Upsacling
Particle Systems
Advancing Industry
Across Length-scales

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MARIE CURIE ACTIONS

Continuum modelling of non-uniform flows with application to detergent powder dosing

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Progression

Year 1 (UT)

✓ Fundamental work on continuum mechanics
✓ Developed **Material Point Method**
- Complex boundaries
- GPU CUDA / Python Interface
- Verified qualitatively validated
- Open-source

https://github.com/TUSAIL/PyroclastMPM

Year 2 (UT)

✓ Constitutive models for **solid regime**
✓ Constitutive models for **fluid regime**
✓ 2-Month secondments at SACMI
✓ Calibration workflow developed

Year 3 (P&G)

Modelling fluid-solid transition with application to detergent powder dosing

Multi-regime constitutive model and parameters

Solid-like model [1,2]

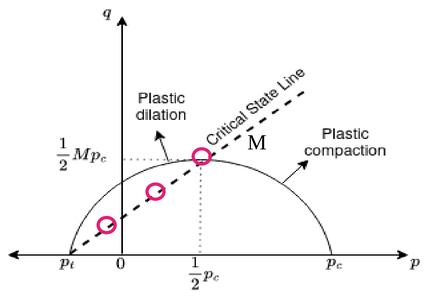
Modified Cam-Clay yield surface

$$f = [a(p_c) - p_t - p]^2 + (\frac{q}{M})^2 + a(p_c)$$

Isotropic Linear elasticity

$$\boldsymbol{\sigma} = 2G\boldsymbol{\varepsilon}_d^e - K\boldsymbol{\varepsilon}_v^e\boldsymbol{I}$$

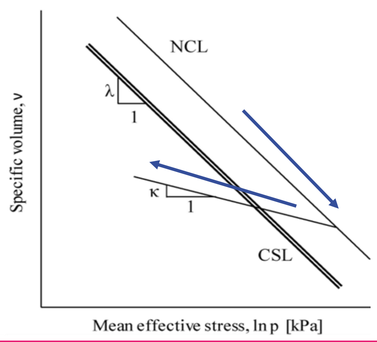
Shear stress over pressure



Hardening law

$$p_c = p_{c0}\exp(\frac{v}{\lambda - k}\Delta\varepsilon_v^p)$$

Specific volume over pressure



Fluid-like model [3]

Linearized μ(I) rheology

$$\mu = \mu_s + b\varphi$$

Inertial pressure

$$p = \left(\frac{2d|\dot{\gamma}|}{\varphi}\right)^2$$

Solid volume fraction

Jamming *transition*?

$$I' = \varphi = \frac{\phi_c - \phi}{a}$$

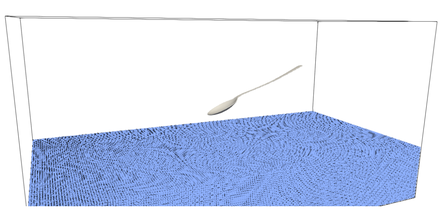
MPM geometry interaction

Friction between material points and geometry

$$\mu_{mpm} = \min\left[\mu_{pl}, \frac{\|\Delta v \times n_l\|}{\Delta v \cdot n_l}\right]$$

MPM simulation of powder flow

Modelling design choices



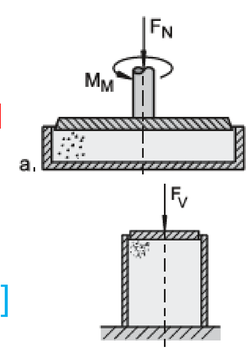
Vary powder properties (cohesion, density), e.g. powder A & B → Spoon-powder interaction (STL, motion frames)

Interaction/ habit (sweep, scoop, cut) → Measure (angle of repose, weight, discharge speed)

Experiments

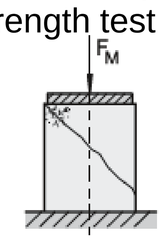
Ring/Torsional shear test [4]

Uniaxial compression [4]

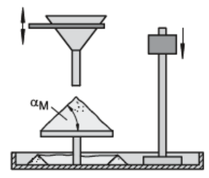


Characterization / calibration

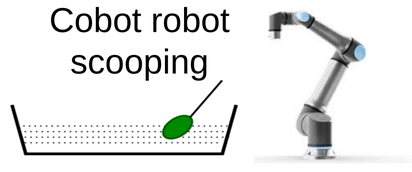
Unconfined yield strength test [4]



Angle of repose test [4]



Cobot robot scooping



2-stage validation

Conclusions

❑ **Material Point Method (MPM)** developed and validated (Year 1)
❑ **Solid-like** and **fluid-like** resolved and implemented. (Year 2)
❑ Modelling **Jamming transition** is still in progress

Outlook

❑ **Multi-regime constitutive model** will be applied to **dosing of detergent powders** with a spoon
❑ Experimental validation and calibration planned

Open questions

1. How do we calibrate parameters related to the jamming transition ϕ_c?
2. Recommendations on safe-material / or experiments to study dosing ?

References

[1] de Souza Neto, E. A., Peric, D., & Owen, D. R. (2011), John Wiley & Sons.
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[5] Vescovi, D. (2020), International Journal of Solids and Structures.

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