INDUSTRIAL APPLICATION OF CONTINUOUS POWDER FLOW MODELING

Testing for industrial usage

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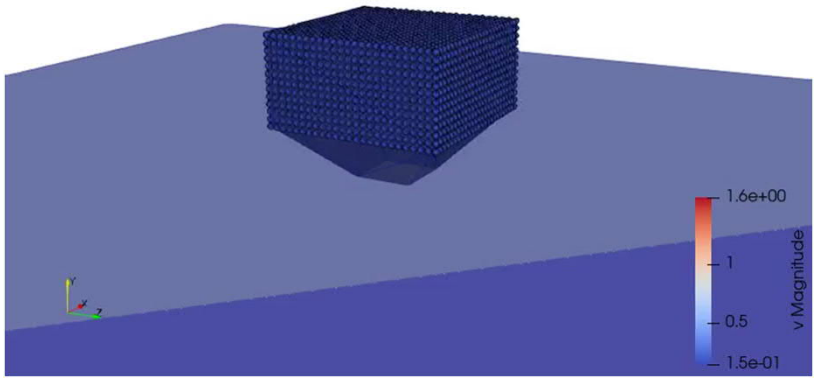
June 17th, 2024

GOAL

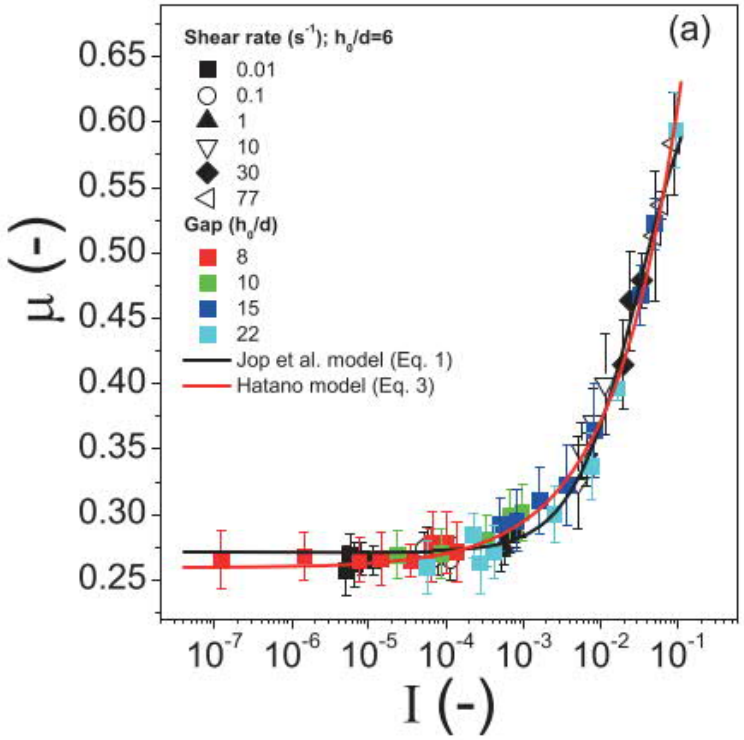
1 - Make state-of-the-art continuous powder flow models available to industry.

2 - demonstrate to IFPRI members how these models can help solve large-scale industrial powder flow problems in reasonable time.



APPROACH

- Adjustable "$\mu - f(I)$" rheology
  - *Verified for large range of shear rates*
  - *Flexible and extendible*
- Open-source LAMMPS package (Sandia)
  - *Implement MPM (a so-called grid-less method)*
  - *Proven track record, well maintained*
  - *Large user community*
- Apply to large-scale solids flows from industry
  - *Make it (relatively) easy to use*
  - *Tune parameters (via DEM or direct)*
  - *Define the right measuring methods (see results Kit*
  - *Demonstrate via real-life examples*
  - *Outline the way forward*



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Installation steps

1 - See poster!

2 - Suggestion: Make a photo or copy from the IFPRI website

3 - Do not hesitate to ask if you get stuck

Running LAMMPS-Rheo

Adapt input file in.rheo.sd_silo

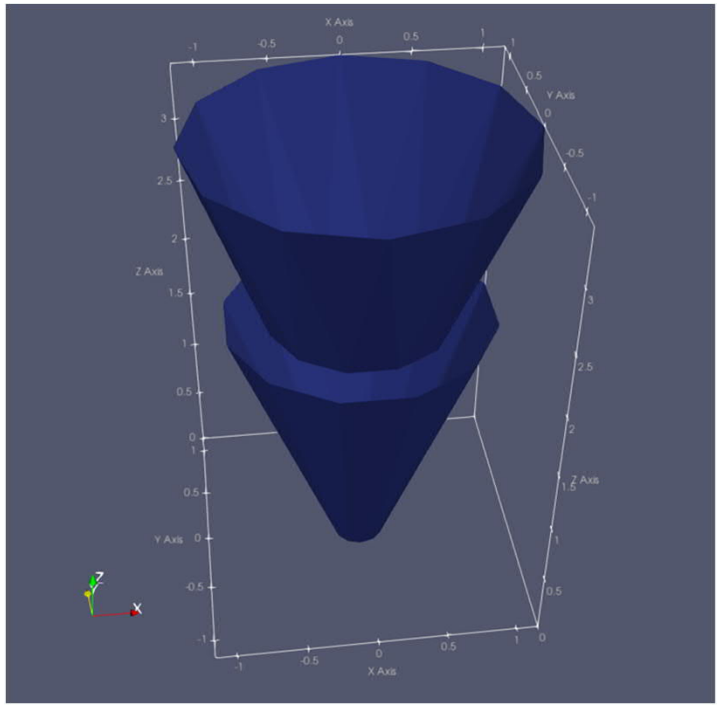
1) Parameters mu(I)-rheology

$$\mu(I) = \frac{\mu_s I_0 + \mu_2 I}{I_0 + I}$$

2) Wall of silo

3) Run simulation

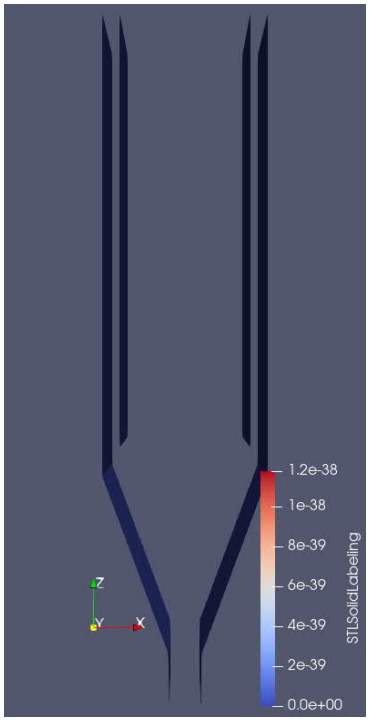
4) Process results



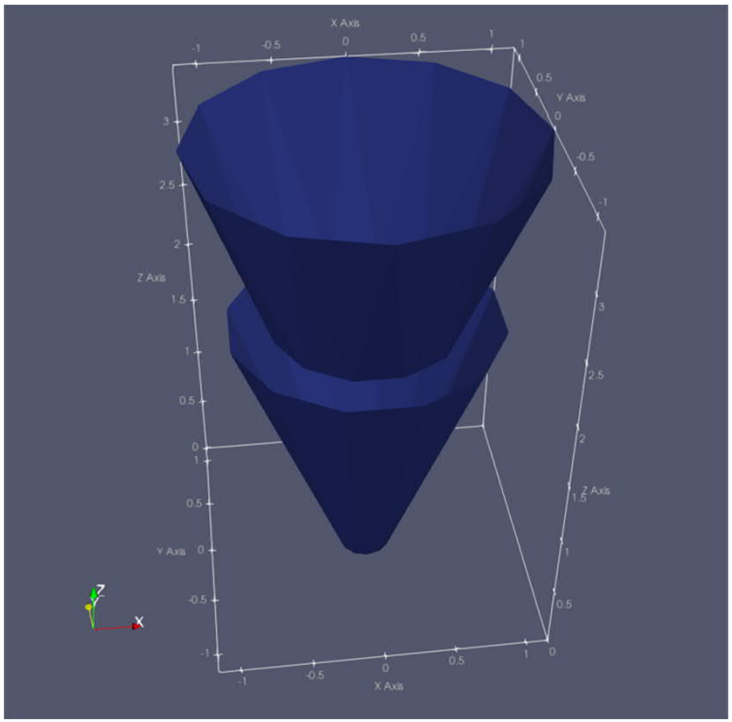
RESULTS

Gels Example powder flow workshop 2023

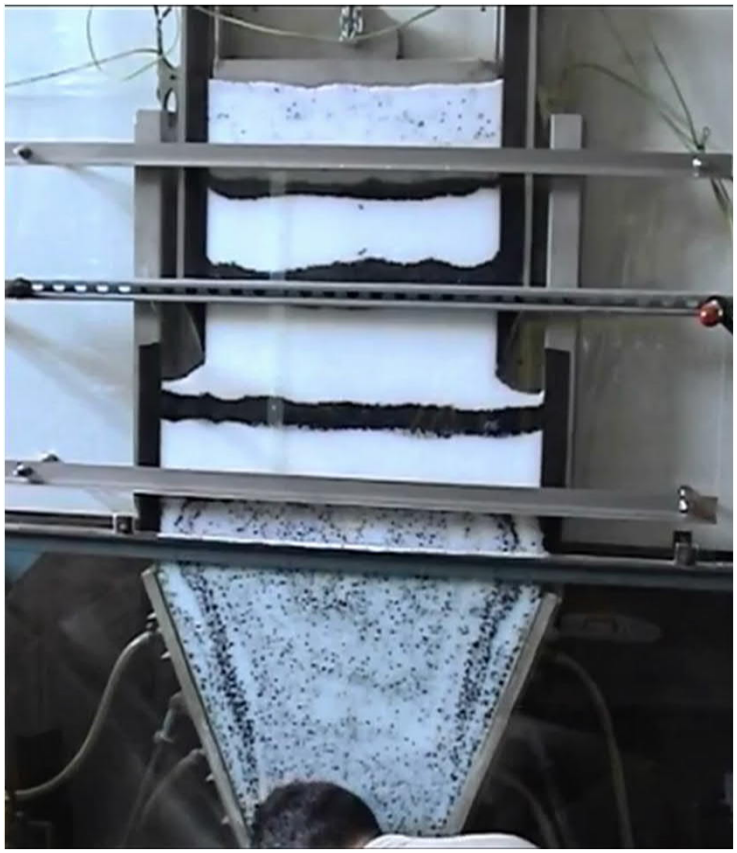
Original 2D-case



3D-case



Cold-flow experiments PA6 granules in 2D silo, 10 cm deep



DEM FLOW SIMULATIONS
PREDICTING STAGNANT ZONES

LIGGGHTS simulation package

Simple DEM interaction model

- **Restitution coefficient**
  - Less important for dense flow
- **Particle-particle friction coefficient**
- **Rolling friction coefficient**
- **Soft particles (reduction required time steps)**

Calibration of DEM parameters

- **Experimental characterization tests as input**

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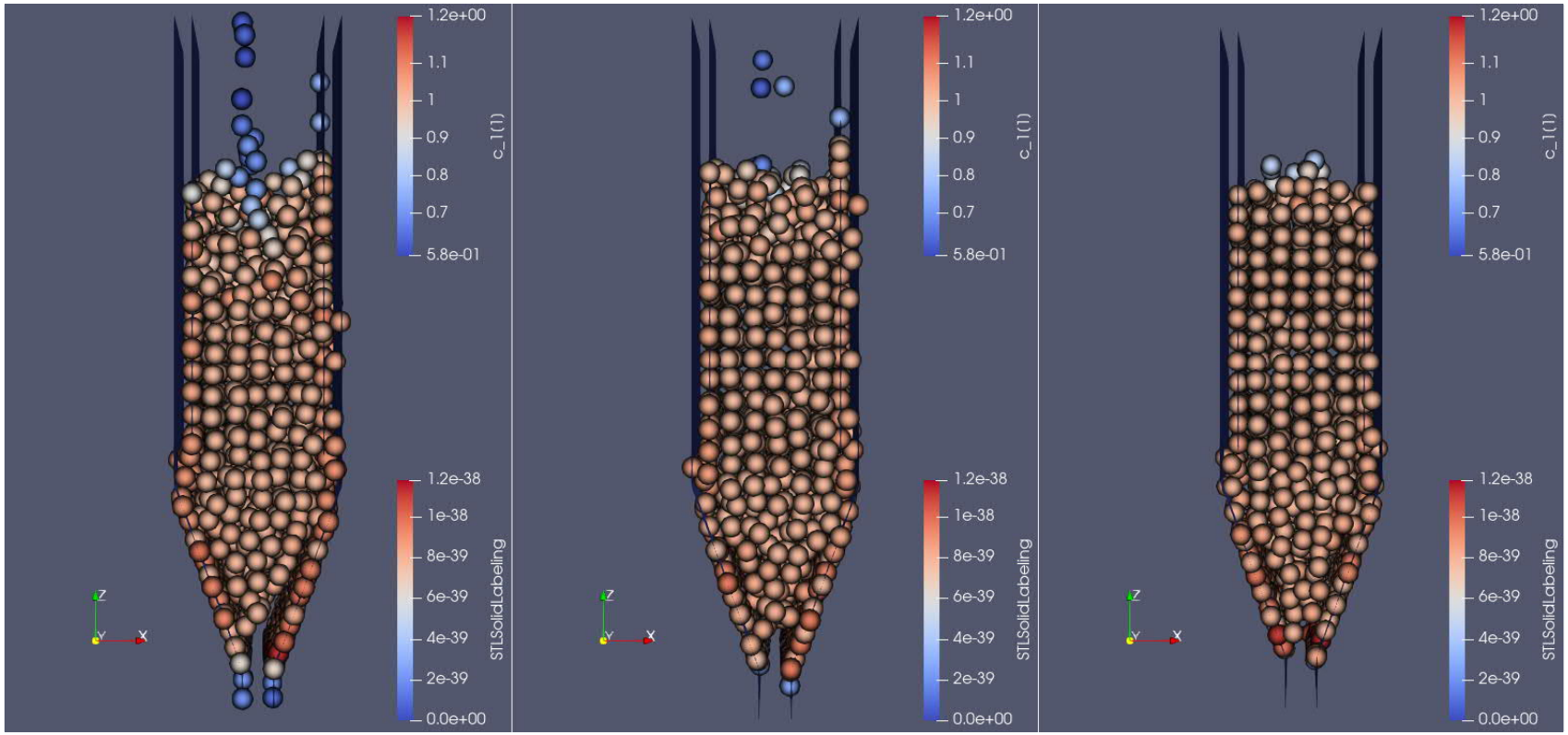
LAMMPS-Rheo “2D”-simulation

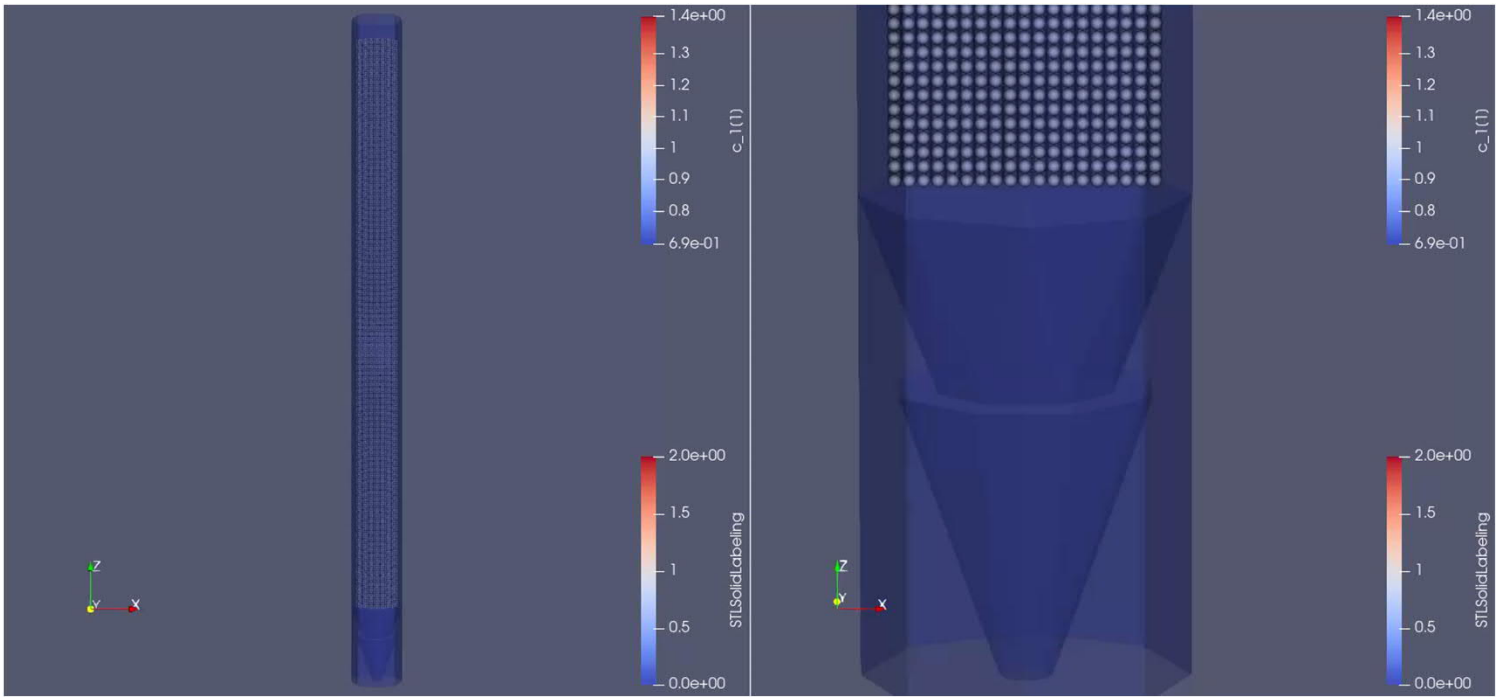
Testing different friction coefficients



Industrial application LAMMPS-Rheo

Flow profile in process equipment

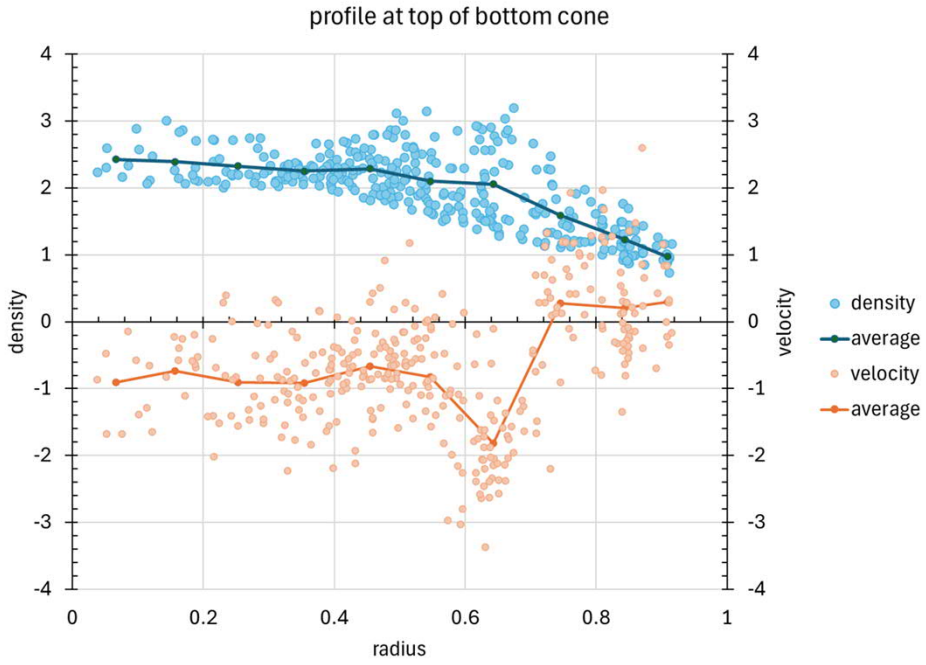
1) Maldistribution in residence time (Workshop example)



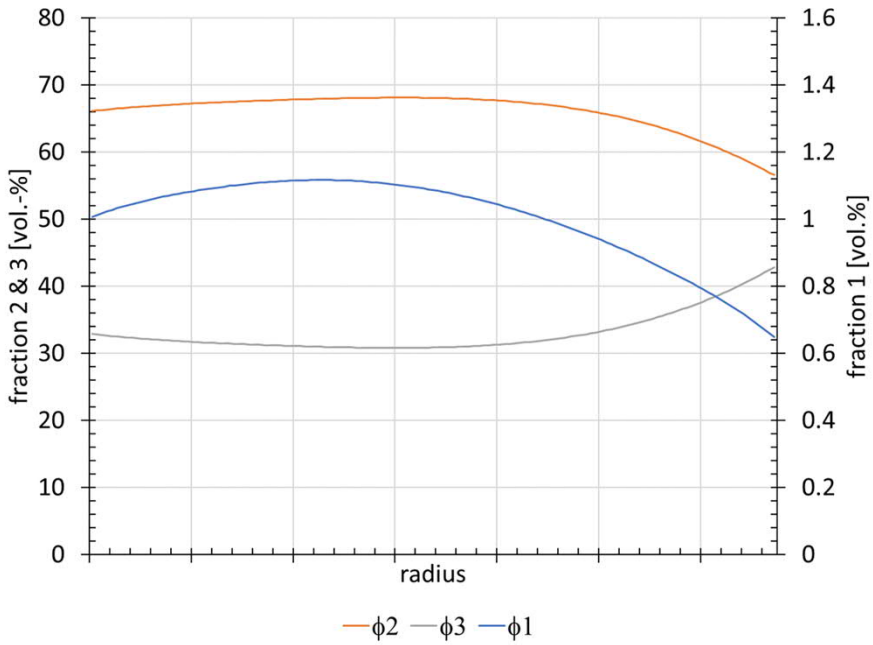
Can we see interesting things?

Processing of data

Density at top of bottom cone



Effect segregation in column



BENEFITS

- Results similar to DEM, but now on full-scale 3D systems and without DEM's course-graining! (Never before available to industry)
- Allows detailed analysis and solving of flow problems as they occur in large-scale systems
- Significant in-kind contribution from Sandia and MIT (will be UC Berkeley)
- Will allow trouble shooting without building large-scale (pilot) equipment
- Will allow better design of new to build equipment
- Better understanding of interaction of (varying) powder flow properties with process equipment, identifying and mitigating critical flaws

STATUS AND WAY FORWARD

LAMMPS-rheo

- μ(I)-rheology implemented
- LAMMPS-rheo use tested in industry
  - Model easy to implement & run
  - Positive on phenomena observed
  - Minor repairable flaws identified
  - Detailed testing and analysis needed for quantitative conclusions

Request for continued IFPRI support

- Extensive testing of model
- Extension of rheology description
  - Dilatancy
  - Cohesion
- Extension of “wall” functionality
  - Velocity & movement of wall (e.g. stirrers)
- Tuning method for rheology parameters
- Critical evaluation of powder rheology
  - Envalior with academia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