Rheology of dense particle suspensions

Srdjan Sasic and Henrik Ström
• Discharge of powders in many industries (pharmaceutical, mineral, chemical and food) - significant handling problems

• A simple geometry but a fascinating range of phenomena: jamming, arching (bridging), intermittent flow, ...
• We need a quantitative description of powder flow
• Large scale units – continuum description needed
• Rheology model needed: particles as a \textit{viscoplastic fluid}
• Governing equations have the same structure as the Navier-Stokes equations.
• Viscosity as \textit{a function of pressure and strain-rate}
\[ \tau = \mu(I)P \] Effective friction as a connection between tangential and normal stresses

\[ \mu(I) = \mu_s + \frac{\mu_2 - \mu_s}{I_0 \frac{I}{I} + 1} \]

\[ I = \frac{dD_2}{\sqrt{p/\rho}} \] Inertial number

\[ D_2 = \sqrt{D_{ij}D_{ij}} \] 2\textsuperscript{nd} invariant of the strain rate tensor

- Low inertial numbers: particles as a solid body
- High inertial numbers: particles as a granular gas
• We work with microcrystalline cellulose spheres (500 microns)
Results of the discharge process
What happens when we work with different resolutions?

![Graph showing different resolutions](attachment:graph.png)

- **coarse Δx**
- **refined coarse Δx**
- **original Δx**
- **refined Δx/2**
- **refined Δx/4**
Using very fine resolution leads to “revolutionary” effects

- The framework is catastrophically ill-posed
- Regularization needed
- Changed behavior for very high and very low inertial numbers
- Far from trivial
Work in progress - Regularization of $\mu (l)$ curve

Regularized model: solid line

Standard model: dotted line

$\mu_s \quad \mu_2$