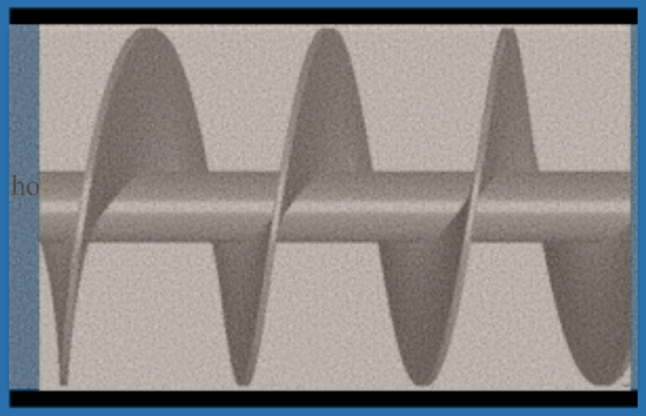
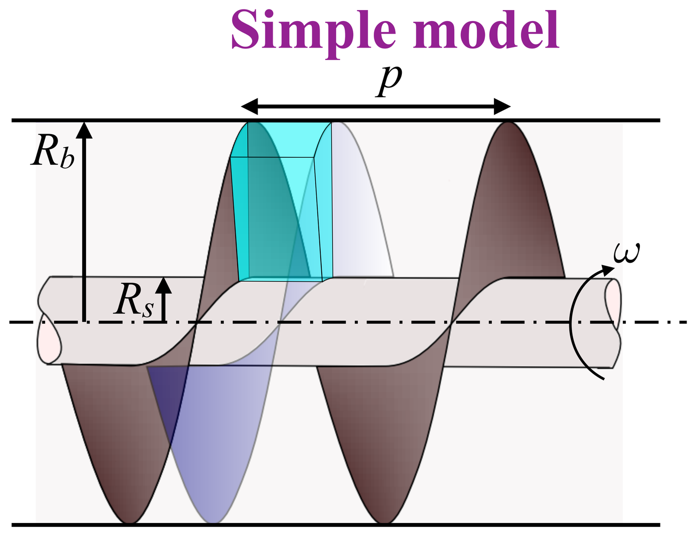


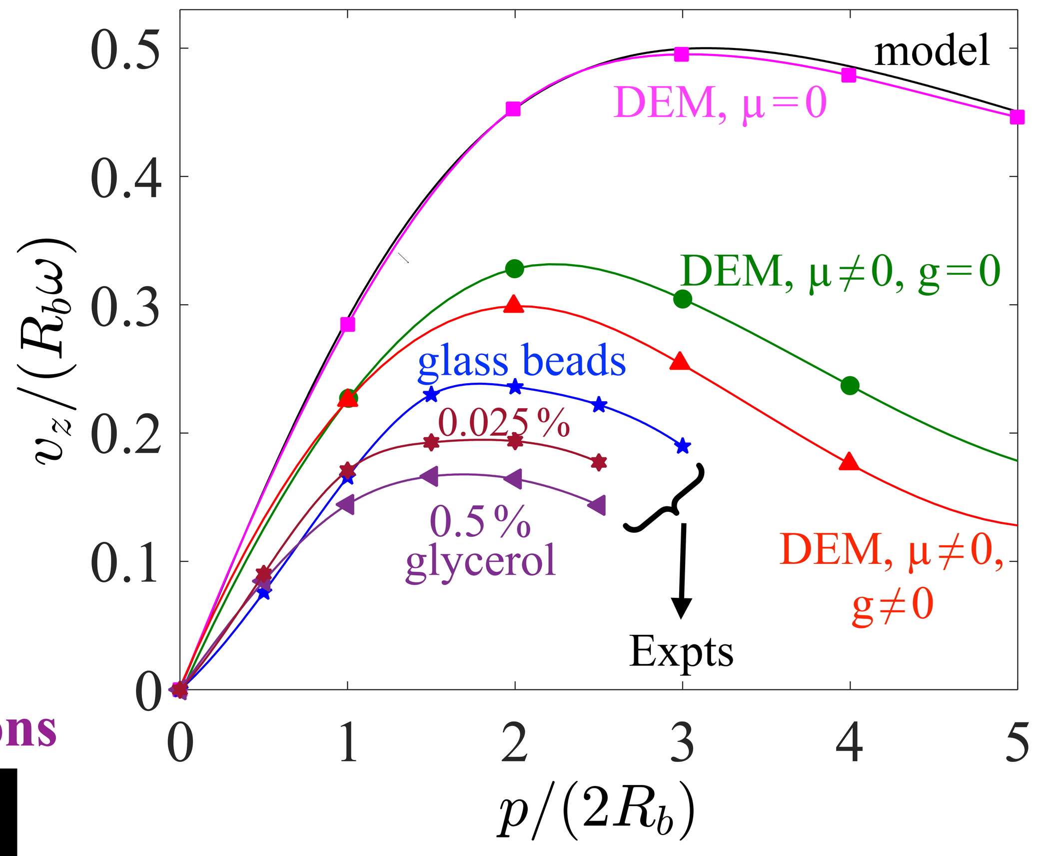
Precision powder feeding

Prabhu Nott
Gautam Vatsa, Sanyogita
Indian Institute of Science, Bangalore

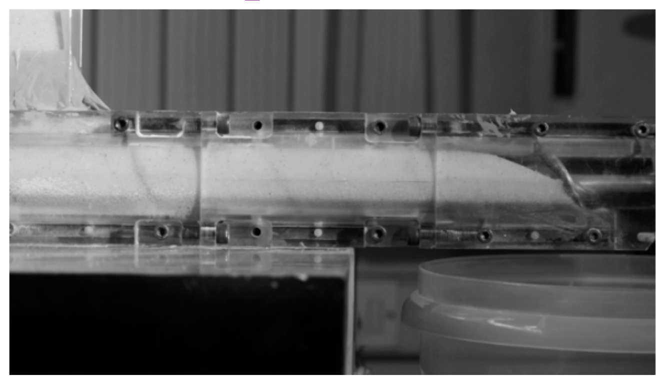
Summary of work in previous years

Simple model

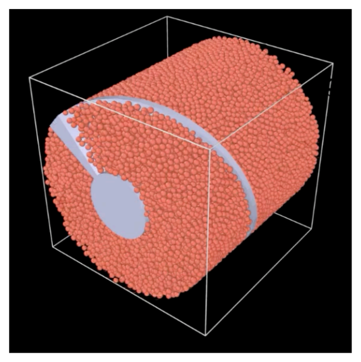




Experiments

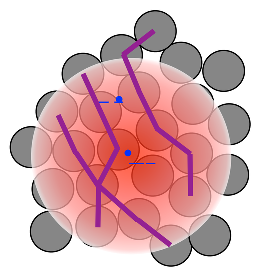


DEM simulations



Model, simulations and experiments show feed rate maximum at a particular $p/(2R_b)$

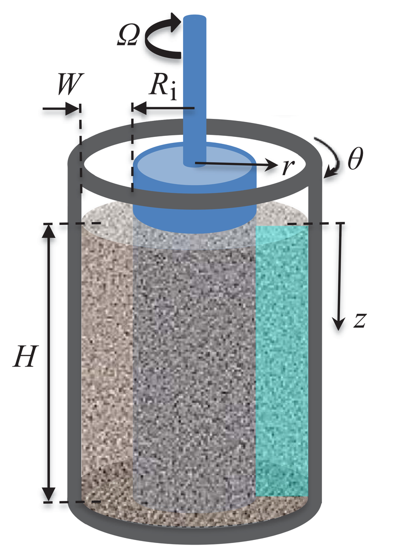
Non-local model

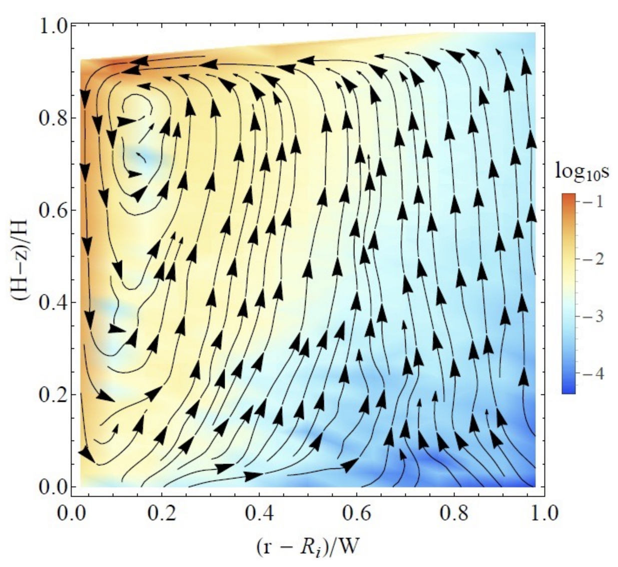


$$\boldsymbol{\sigma} = -p\,\boldsymbol{\delta} + \frac{2\mu}{\dot\gamma}\left(p_c\,\boldsymbol{D}' - \underline{\ell^2\,\Pi\,\nabla^2\boldsymbol{D}'}\right), \qquad p = p_c\left(1 - \frac{\mu_b}{\dot\gamma}\nabla\cdot\boldsymbol{u}\right) - \underline{\ell^2\,\Pi\,\frac{\mu_b}{\dot\gamma}\nabla^2\nabla\cdot\boldsymbol{u}}$$

$$p_c = \Pi - \underline{\ell^2\,\frac{d\Pi}{d\phi}\,\nabla^2\phi},$$

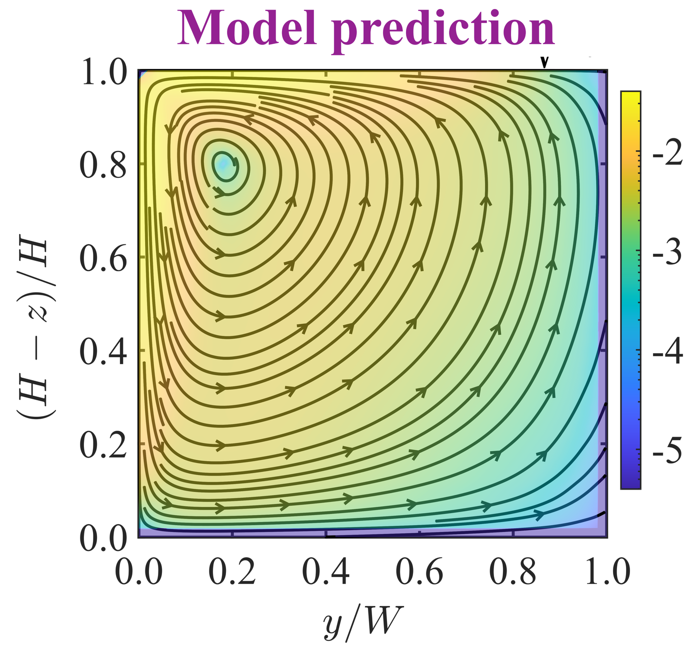
Validation: secondary flow in a cylindrical Couette cell





Krishnaraj & Nott (2016)

Model prediction



Vatsa & Nott (2025)

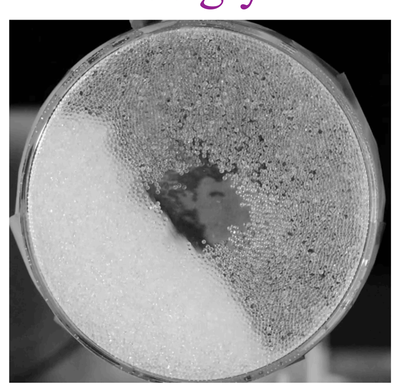
The model captures the strong coupling between packing fraction and velocity fields

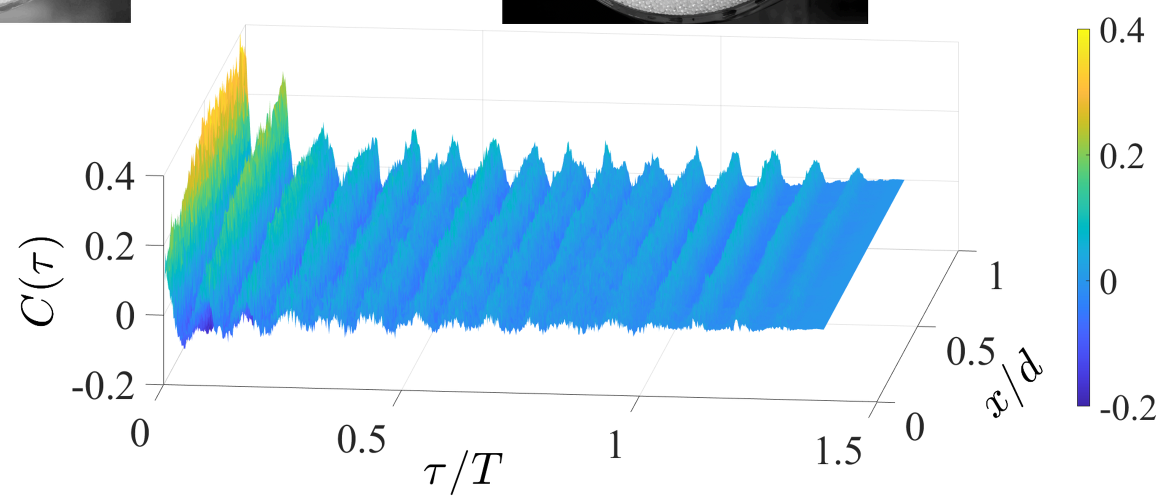
Flow fluctuations in model cohesive powders

0% glycerol

0.025% glycerol

0.2% glycerol





Space-time correlation

$$C(\tau,\delta) = \langle v(t,x)\, v(t+\tau, x+\delta)\rangle$$

Measurements in steady, non-inertial flows needed.

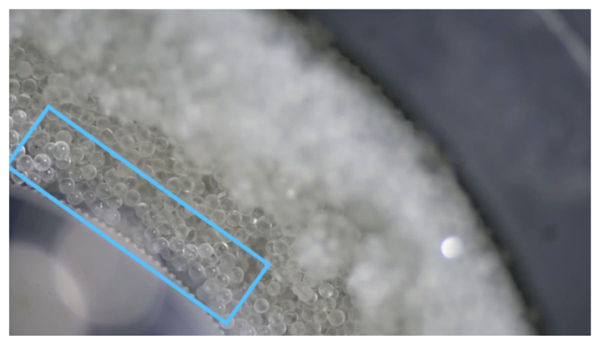
Influence of cohesion on stress and kinematics

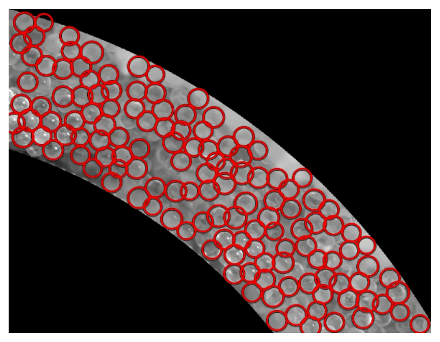
Classical treatment: Cohesion only alters yield condition $F(\boldsymbol{\sigma}) = F_{\text{non-coh}}(\boldsymbol{\sigma}) - \tau_{\text{coh}}$

But experiments show that cohesion also affects the post-yield kinematics. Must alter the flow rule:

$$D_{ij} = \dot\lambda \frac{\partial F}{\partial \sigma_{ij}}$$

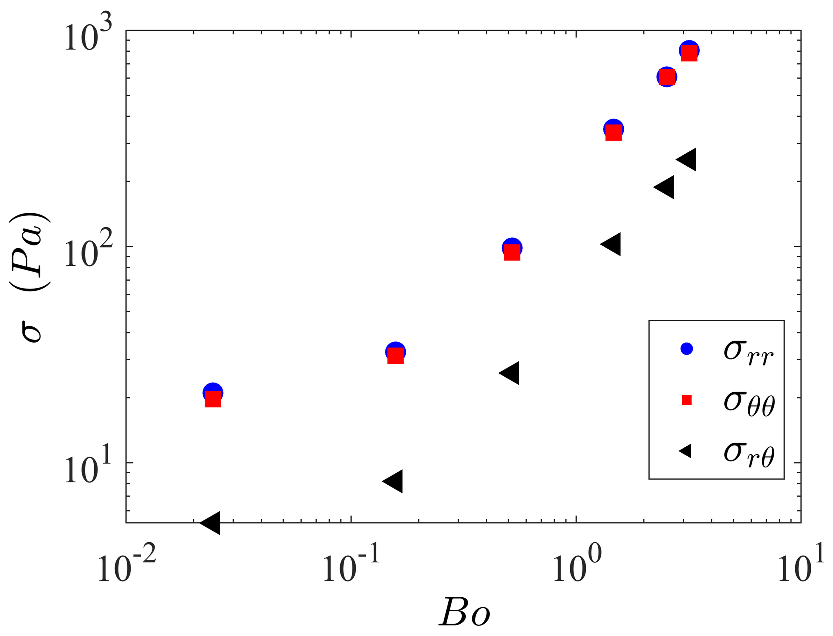
Flow imaging experiments shows cohesive powder forming clusters

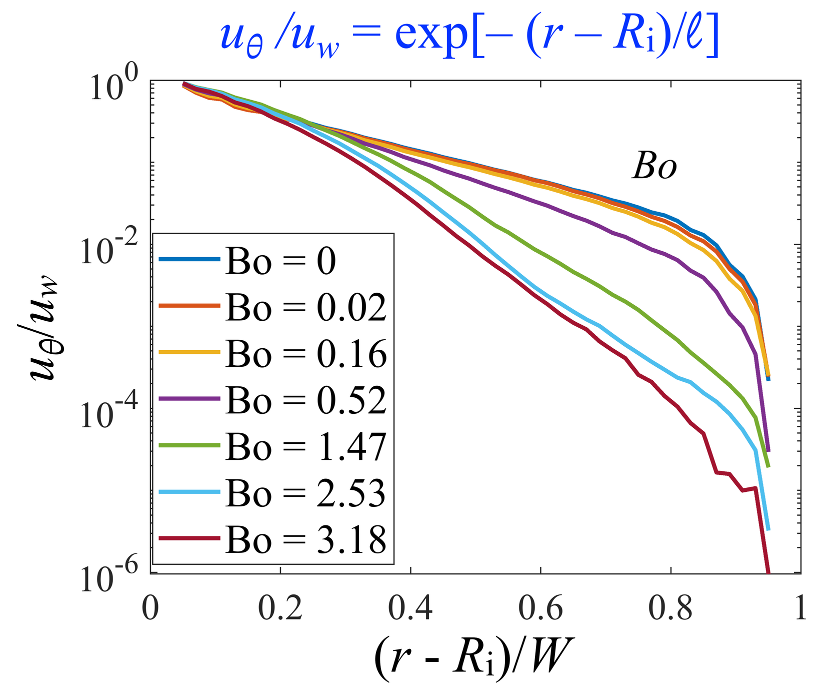


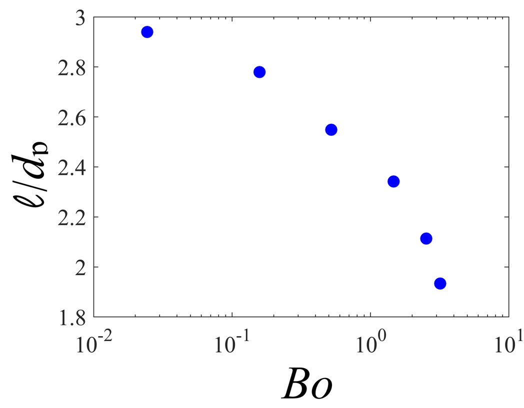


Experiments unable to clearly identifyclusters

DEM simulations of cylindrical Couette flow





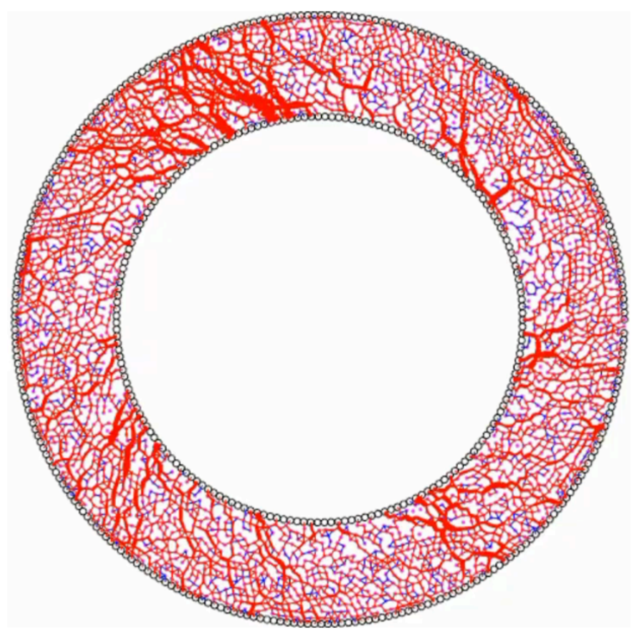


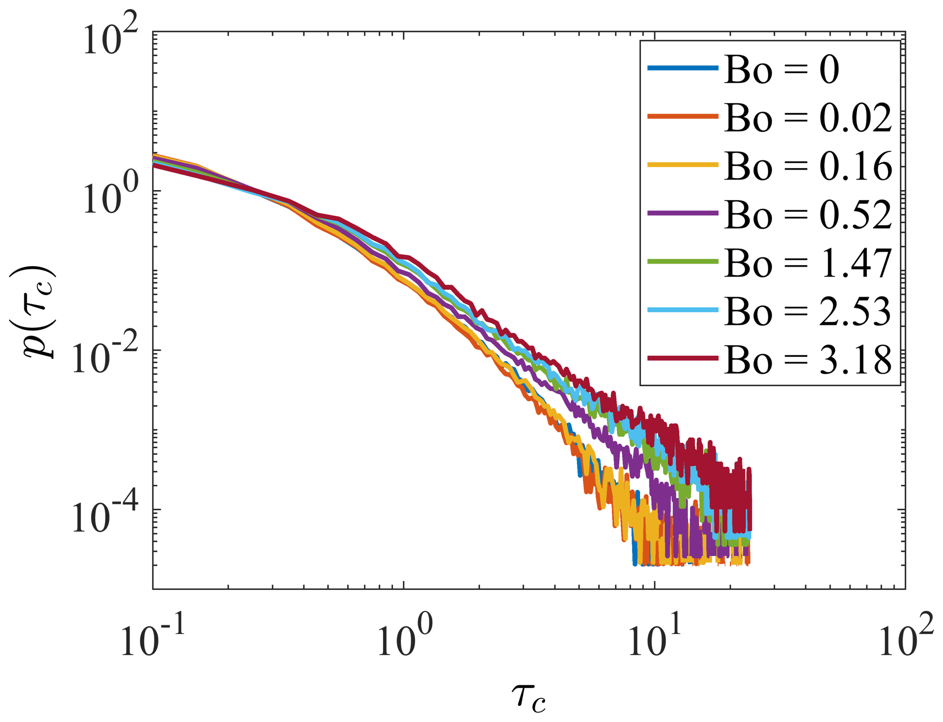
Substantial dependance of the stress and kinematics on cohesion.

Micromechanical understanding needed.

Effect of cohesion on the statistics of contacts

Bo = 3.18





Cohesion increases number and and duration of contacts.

Must use data on micromechanics to build a continuum model.

Conclusions

- Experiments on model cohesive powders show formation of particle clusters, but optical imaging does not clearly identify clusters.
- DEM simulations of cylindrical Couette flow used to study the influence of cohesion. Cohesion strongly affetcs the stress and velocity fields.
- Tensile contacts bearing cohesive forces stabilize compressive force chains. Mean contact duration increases substantially with increasing cohesive force.
- The challenge now is to make use of the micromechanics of particle interactions to build a continuum model for cohesive powders.