

Anomalous low friction coefficient in shear thickening suspensions

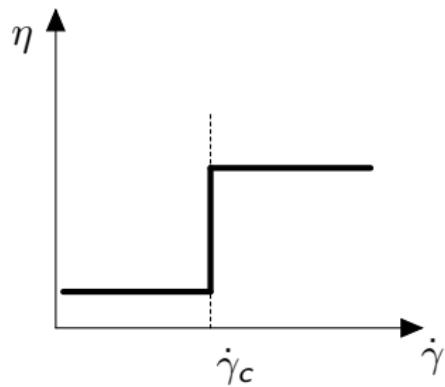
Cécile Clavaud, Antoine Bérut, Bloen Metzger, Yoël Forterre

IUSTI CNRS Marseille, France



What is shear-thickening?

Shear-thickening: brutal increase in viscosity at a critical shear rate.

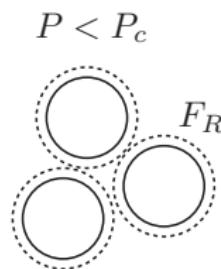


People running on a pool filled with a corn-starch suspension.

A promising scenario: frictional transition

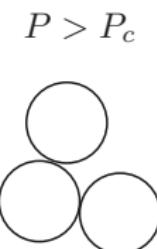
Idea: frictional grains with short-range repulsion

Seto et al. PRL 2013, Wyart and Cates PRL 2014.



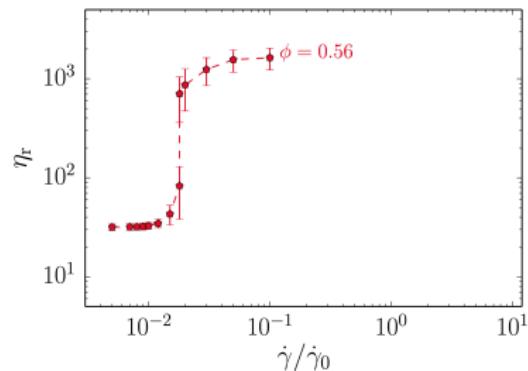
$P < P_c$

$$\mu_p = 0$$



$P > P_c$

$$\mu_p \neq 0$$



adapted from Mari et al. J. Rheol. 2014.

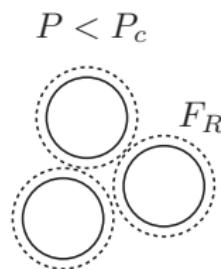
Recent experimental support:

Lin et al. PRL 2015, Guy et al. PRL 2016, Royer et al. PRL 2016.

A promising scenario: frictional transition

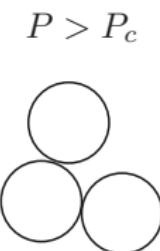
Idea: frictional grains with short-range repulsion

Seto et al. PRL 2013, Wyart and Cates PRL 2014.



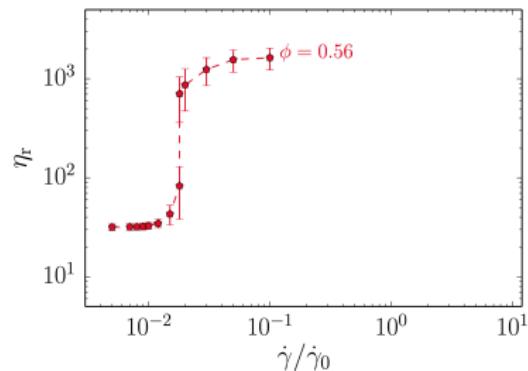
$P < P_c$

$$\mu_p = 0$$



$P > P_c$

$$\mu_p \neq 0$$



adapted from Mari et al. J. Rheol. 2014.

Recent experimental support:

Lin et al. PRL 2015, Guy et al. PRL 2016, Royer et al. PRL 2016.

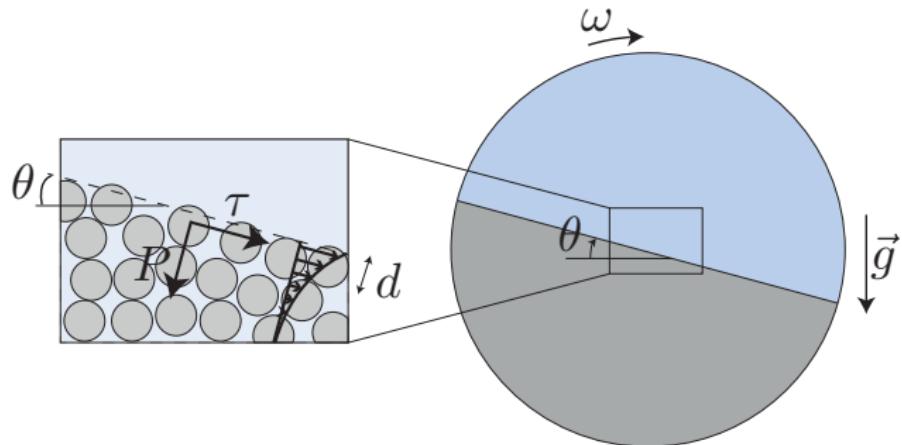
No direct evidence of a frictional transition: need to access μ_p .

Probing μ : pressure imposed rotating drum experiments

- Non buoyant suspensions.
- No inertia: $St \rightarrow 0$.

Steady avalanche in
quasi-static regime: $\omega \rightarrow 0$.

$$\mu = \frac{\tau}{P} = \tan \theta$$

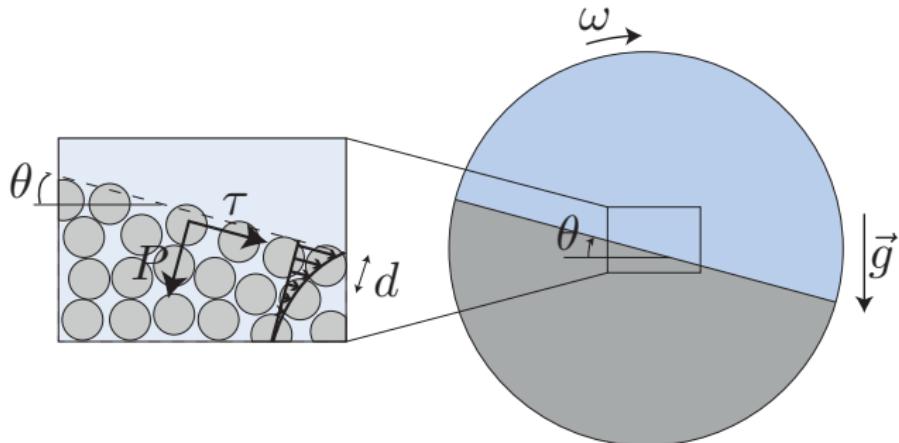


Probing μ : pressure imposed rotating drum experiments

- Non buoyant suspensions.
- No inertia: $St \rightarrow 0$.

Steady avalanche in
quasi-static regime: $\omega \rightarrow 0$.

$$\mu = \frac{\tau}{P} = \tan \theta$$

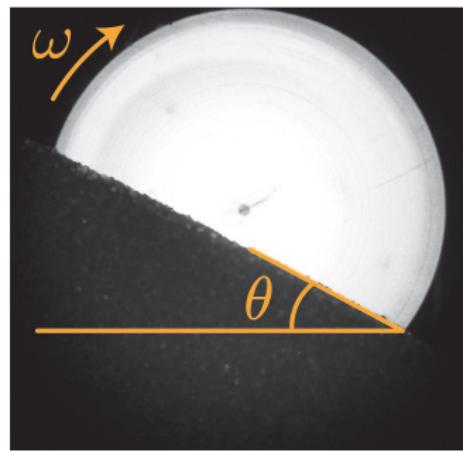


Pile angle θ gives access to μ .

Surface flow: measure of μ at low confining pressure.

Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.

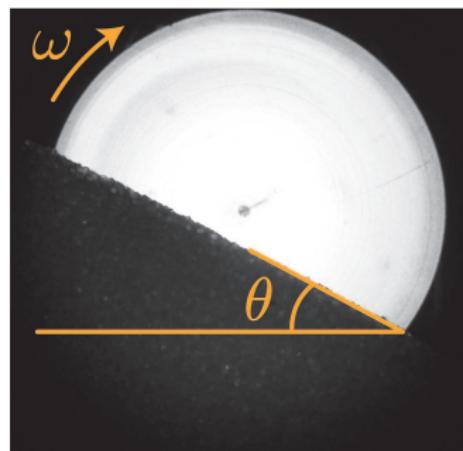


$$\theta \simeq 25^\circ, \mu \simeq 0.47$$

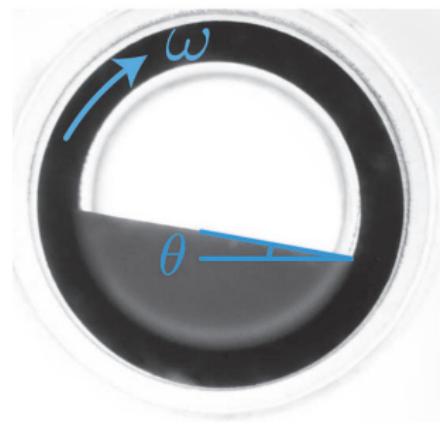
Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.

Shear thickening suspension:
potato starch 35 μm in water.



$$\theta \simeq 25^\circ, \mu \simeq 0.47$$

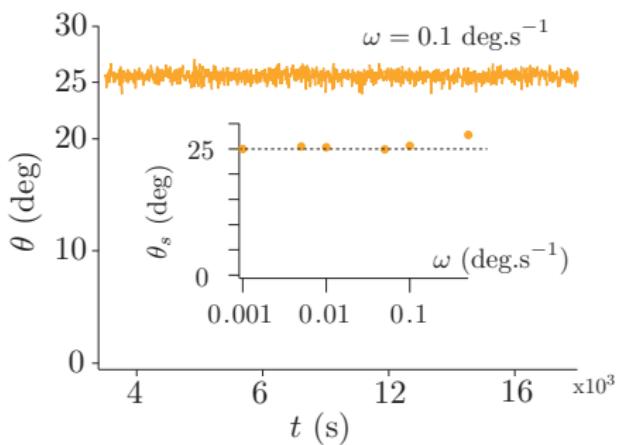


$$\theta \simeq 8.5^\circ, \mu \simeq 0.15$$

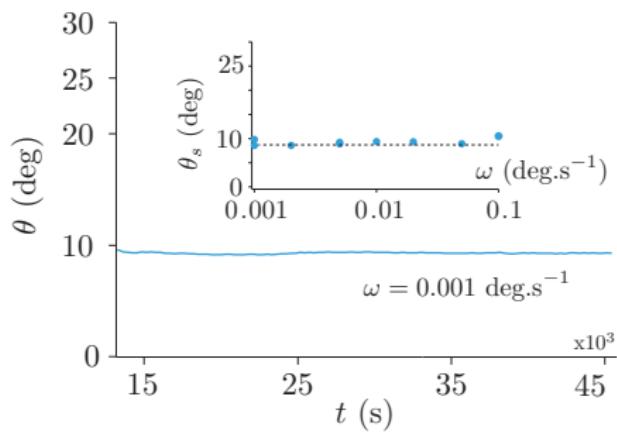
suggests that $\mu_p \rightarrow 0$.

Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.

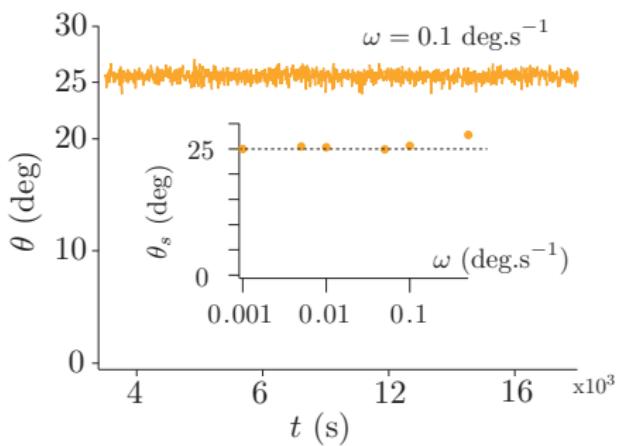


Shear thickening suspension:
potato starch 35 μm in water.

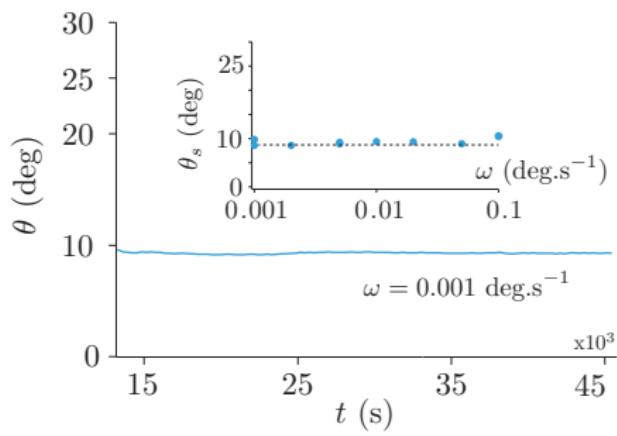


Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.

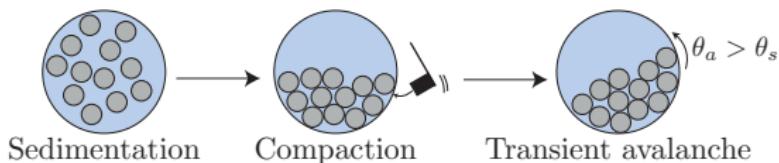


Shear thickening suspension:
potato starch 35 μm in water.

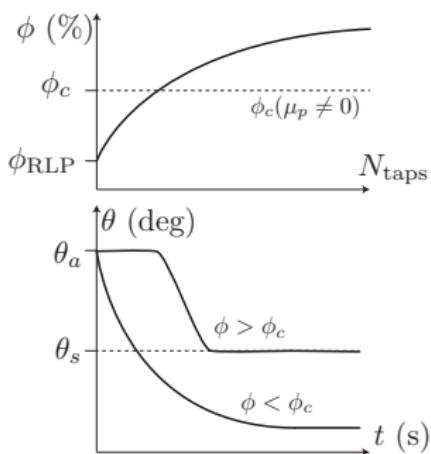


Shear thickening suspensions: $\mu_p \rightarrow 0$ at low P .

Another way to probe μ : compaction and dilatancy

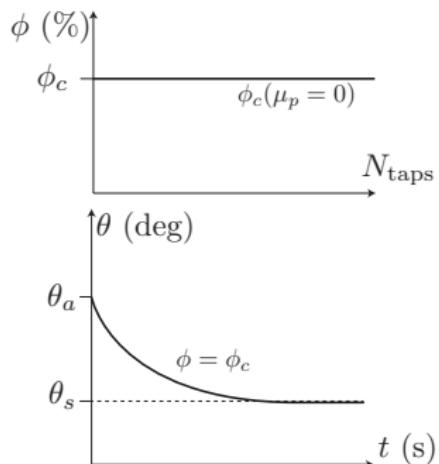


Frictional grains:



Pailha et al. Phys. Fluids 2008.

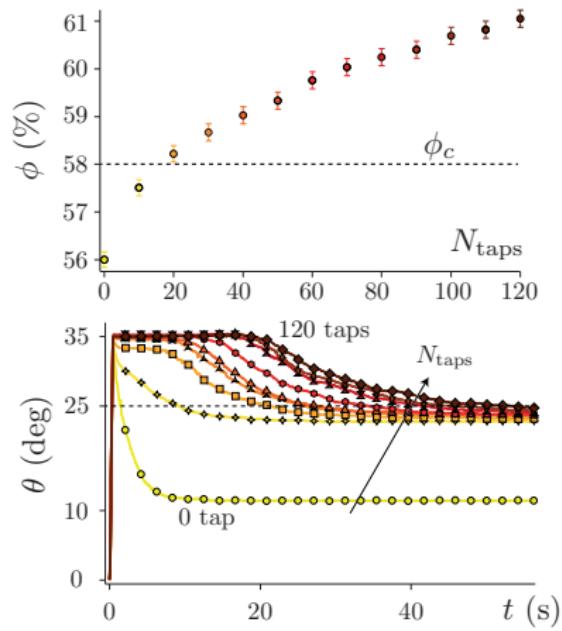
Non frictional grains:



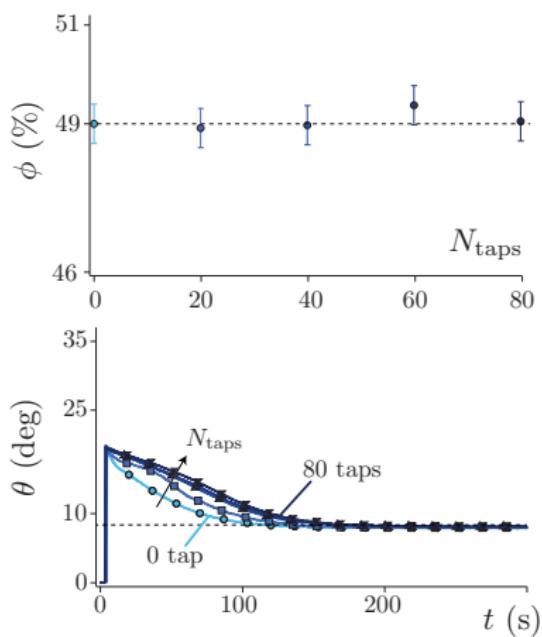
Peyneau and Roux. PRE 2008.

Compaction and transient avalanches

Classical suspension:
glass beads 500 μm in oil.

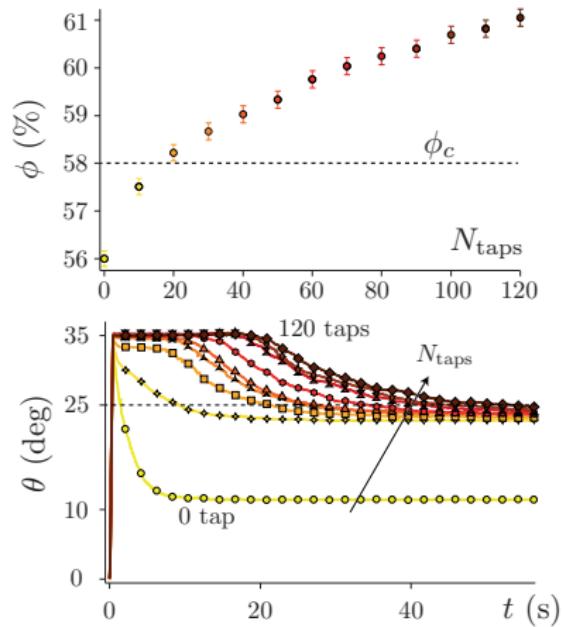


Shear thickening suspension:
potato starch 35 μm in water.

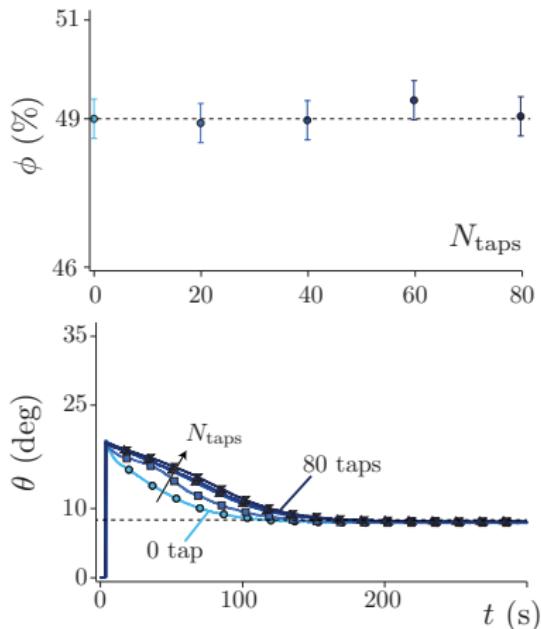


Compaction and transient avalanches

Classical suspension:
glass beads 500 μm in oil.

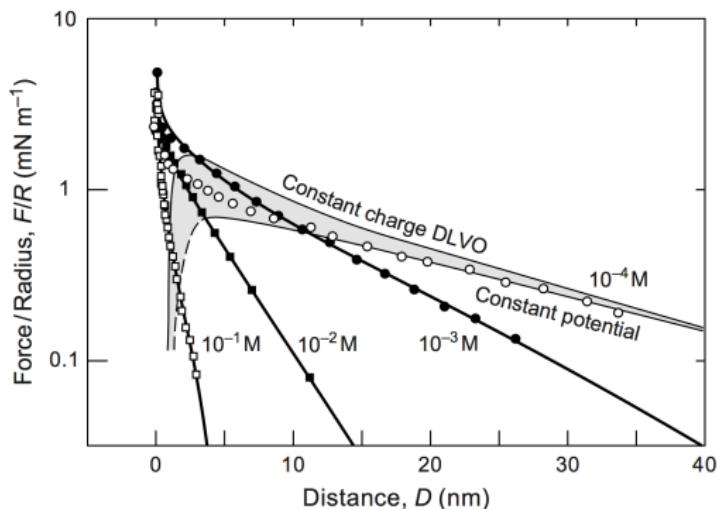


Shear thickening suspension:
potato starch 35 μm in water.



Shear thickening suspensions: no compaction, no dilatancy, thus $\mu_p \rightarrow 0$

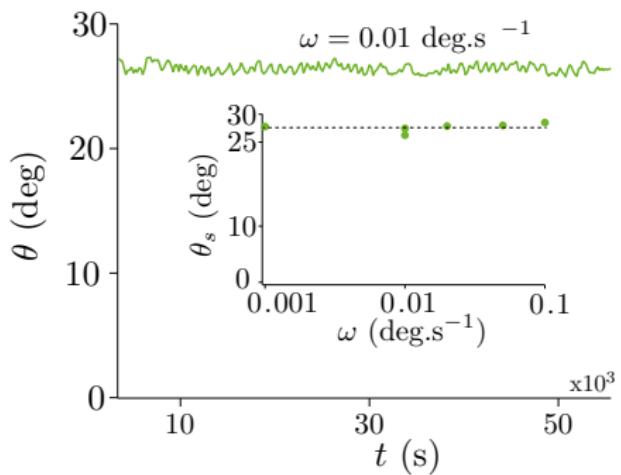
From frictional to frictionless by tuning the repulsive force



Israelachvili, Intermolecular and surface forces

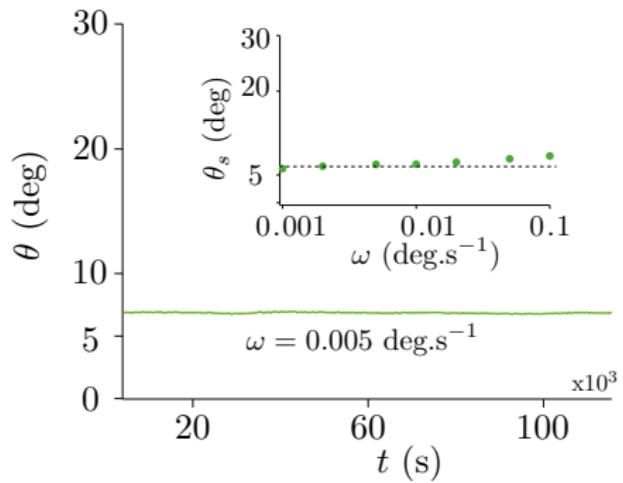
From frictional to frictionless by tuning the repulsive force

NaCl aqueous solution:



$$\theta_s \simeq 27.5^\circ, \mu \simeq 0.52$$

Deionized water:

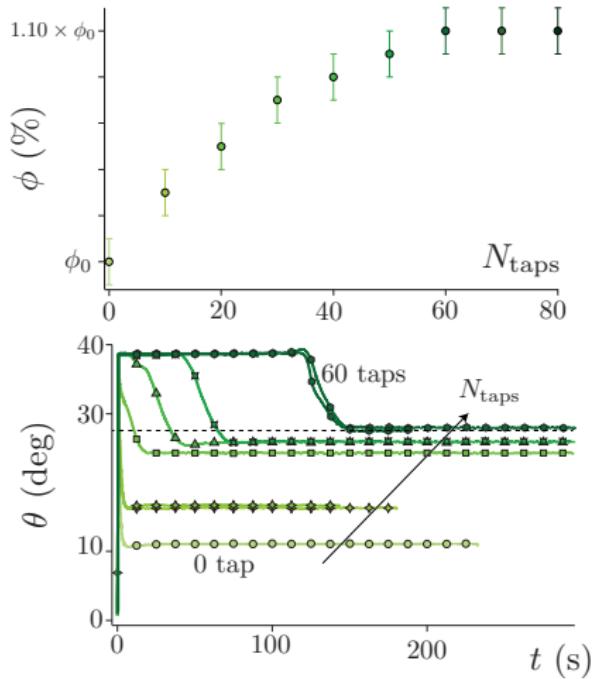


$$\theta_s \simeq 6^\circ, \mu \simeq 0.11$$

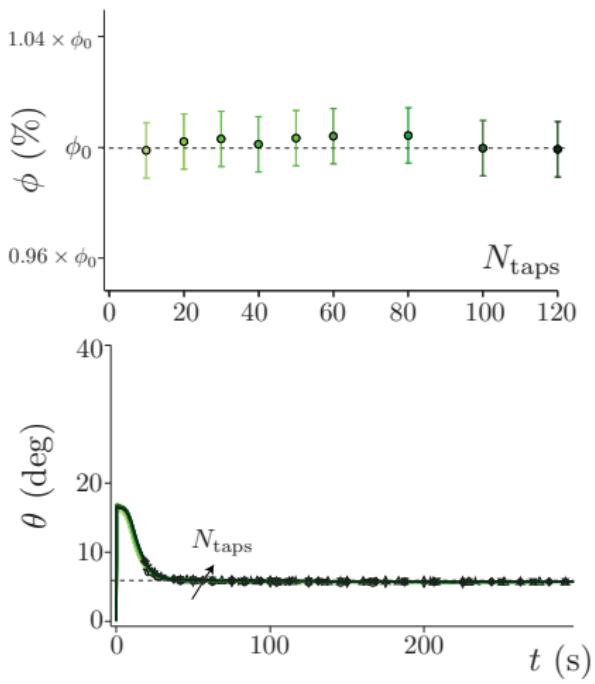
$\mu_p \simeq 0$ (Peyneau and Roux. PRE 2008).

From frictional to frictionless by tuning the repulsive force

NaCl aqueous solution:



Deionized water:



Conclusions

Shear thickening suspensions:

- low pile slope angle,
 - no compaction, → frictionless behavior at low P .
 - no dilatancy,

Conclusions

Shear thickening suspensions:

- low pile slope angle,
 - no compaction, → frictionless behavior at low P .
 - no dilatancy,

Controlling the repulsive force allows us to switch the friction on and off.

Conclusions

Shear thickening suspensions:

- low pile slope angle,
 - no compaction, \rightarrow frictionless behavior at low P .
 - no dilatancy,

Controlling the repulsive force allows us to switch the friction on and off.

First direct evidence supporting the frictional transition scenario.

Conclusions

Shear thickening suspensions:

- low pile slope angle,
 - no compaction, → frictionless behavior at low P .
 - no dilatancy,

Controlling the repulsive force allows us to switch the friction on and off.

First direct evidence supporting the frictional transition scenario.

Future work: measure the friction coefficient as a function of P .