Revealing the frictional transition in shear-thickening suspensions

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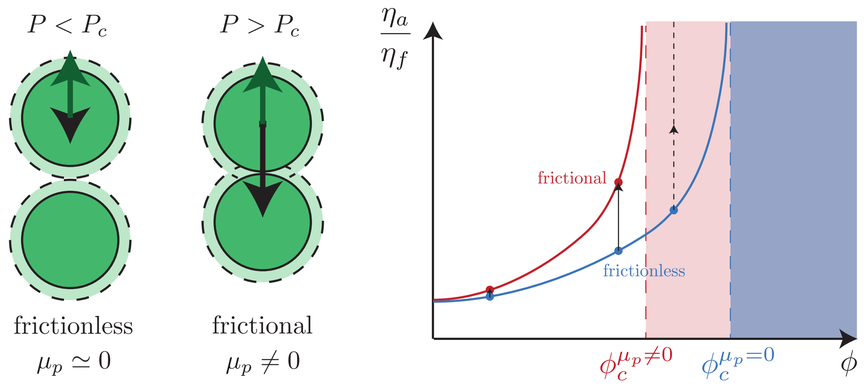
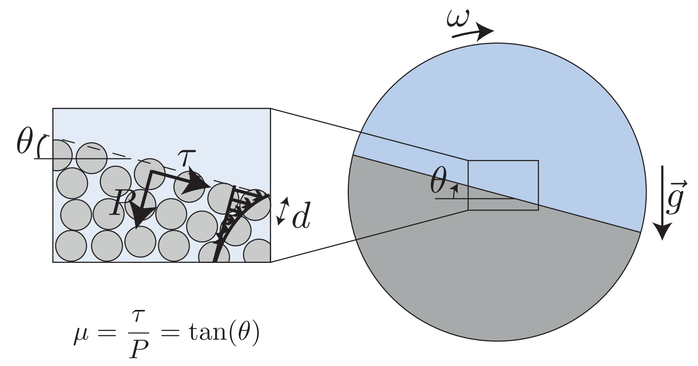
Shear thickening: brutal increase in viscosity at a critical shear rate.

(http://www.tuxboard.com/seriez-vous-capable-de-marcher-sur-leau, advertisement for Mach by Hong Leong Bank).

Recent model: frictional transition induced by the presence of short range repulsion.

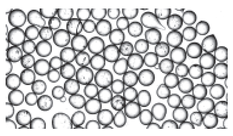


Our approach: probe the macroscopic friction coefficient μ using pressure imposed experiments.

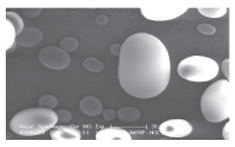


Newtonian vs. shear-thickening suspensions

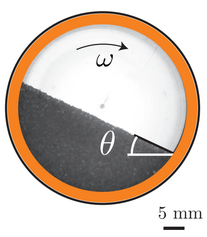
Newtonian
large glass beads in viscous fluid



Shear-thickening
potato starch in water

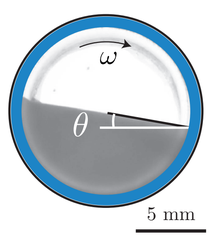


Stationary avalanches: quasi-static regime



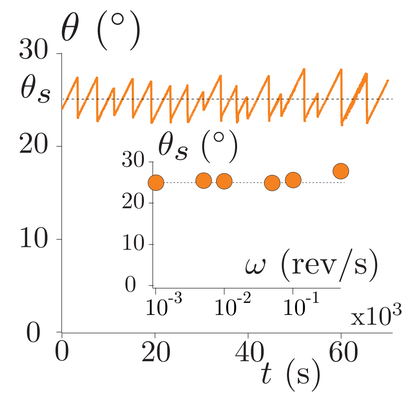
$\theta \simeq 25°$
thus
$\mu \simeq 0.47$

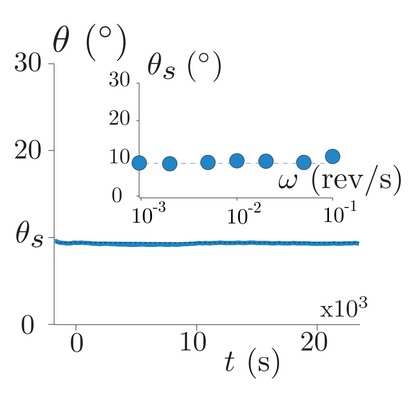
frictional system



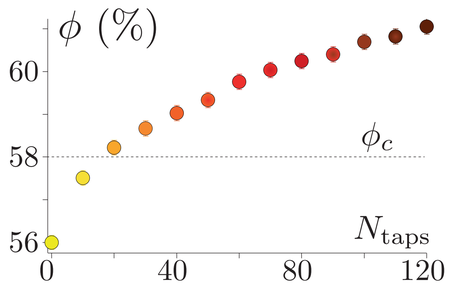
$\theta \simeq 8.5°$
thus
$\mu \simeq 0.15$
(suggests $\mu_p \simeq 0$)

frictionless system

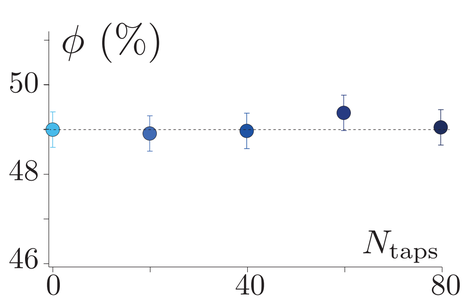




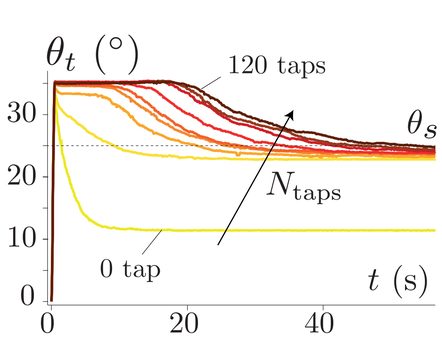
Compaction and dilatancy: dynamic study



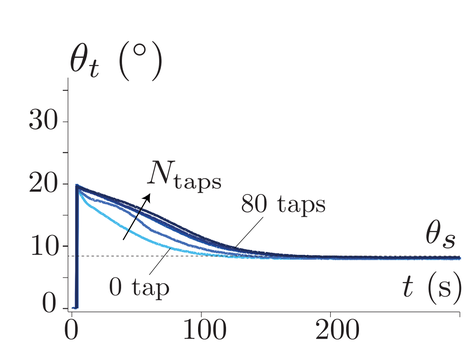
Compaction: frictional system



No compaction: frictionless system



Dilatancy: frictional system



No dilatancy: frictionless system

Conclusion

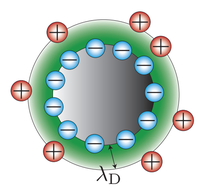
Standard Newtonian suspension (large glass beads)
- high steady avalanche angle
- compaction
- dilatancy

→ **frictional suspension**

Shear-thickening suspension (potato starch)
- low steady avalanche angle
- no compaction
- no dilatancy

→ **frictionless suspension** at low P

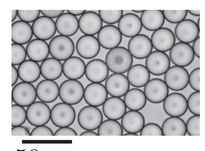
Frictional transition by tuning the repulsion



Model system: silica beads in aqueous solutions.

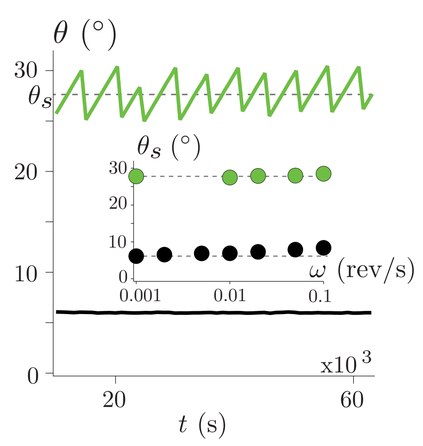
Negative surface charge induces repulsion which can be screened by adding ions.

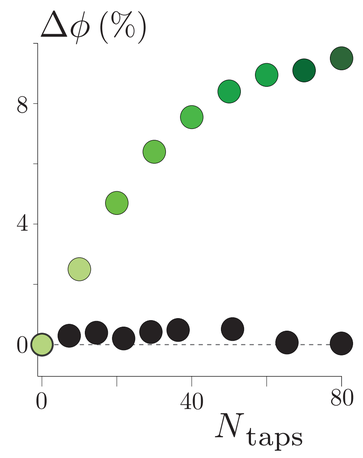
$\lambda_D \propto \frac{1}{[\text{NaCl}]}$ is the Debye length.

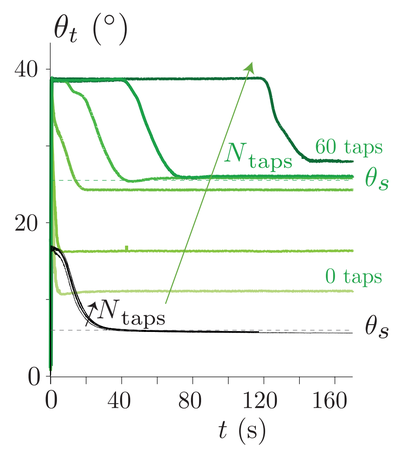


Stationary avalanches, compaction and dilatancy

Green: $[\text{NaCl}] = 10^{-1}\text{mol.L}^{-1}$ Black: pure water







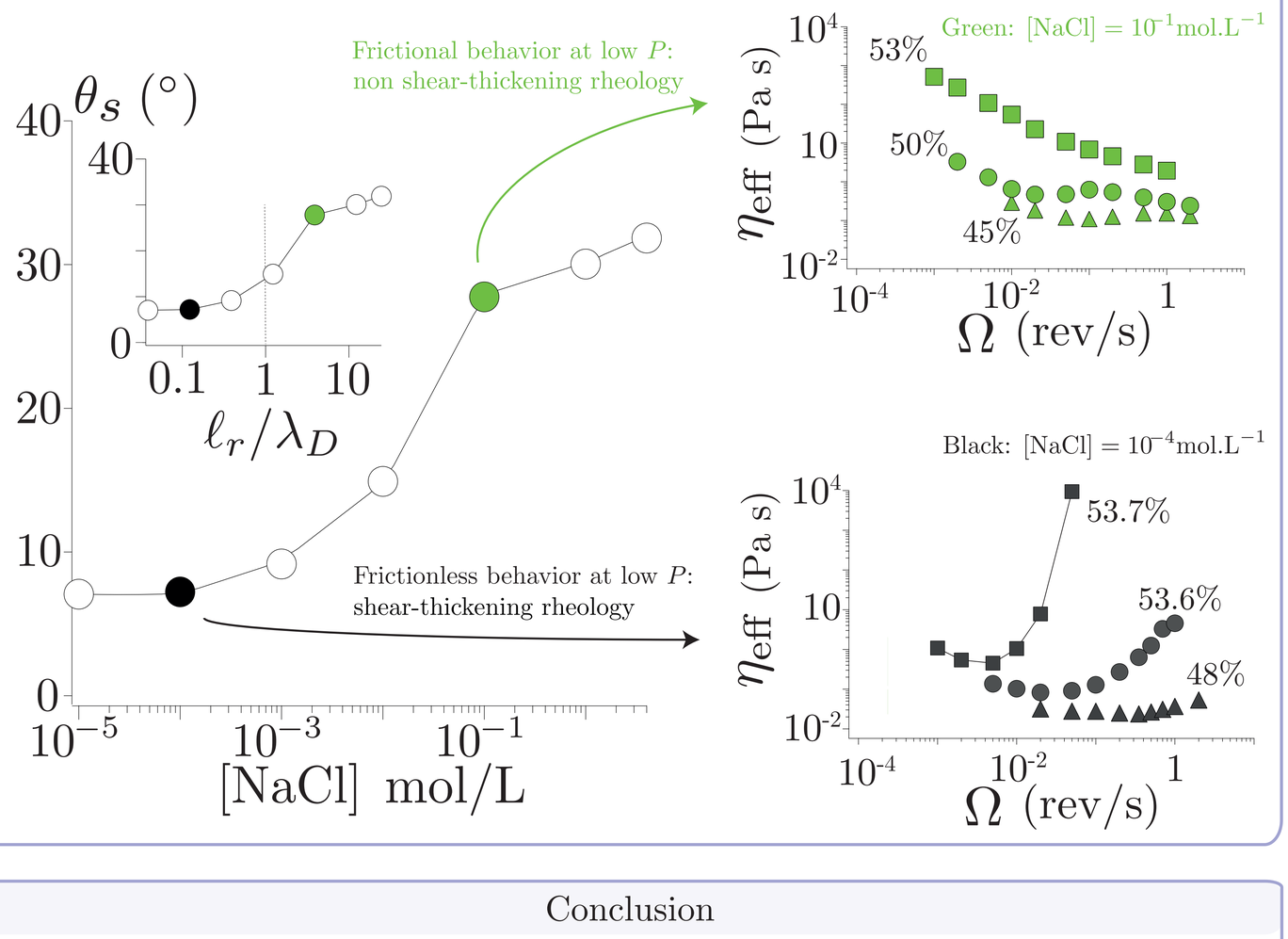
$[\text{NaCl}] = 10^{-1}\text{mol.L}^{-1}$
- high avalanche angle
- compaction
- dilatancy

→ frictional suspension

Pure water
- low steady avalanche angle
- no compaction
- no dilatancy

→ frictionless suspension at low P

Link with the macroscopic rheology



Conclusion

$\frac{l_r}{\lambda_D} \ll 1$: **existence of a frictionless state** at low P → **shear-thickening rheology**

tuning the range of the repulsive force by controlling [NaCl]

$\frac{l_r}{\lambda_D} \gg 1$: **frictional state only** → **non shear-thickening rheology**

Perspective

Change the confining pressure P at constant P_c (constant [NaCl]) and measure the macroscopic friction μ

Article: Clavaud et al. (2017) Revealing the frictional transition in shear-thickening suspensions. Proc. Natl. Acad. Sci. USA, doi:10.1073/pnas.1703926114

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