Simulations of granular flows close to the angle of repose

GDR, Transnat
16-17 mai 2011

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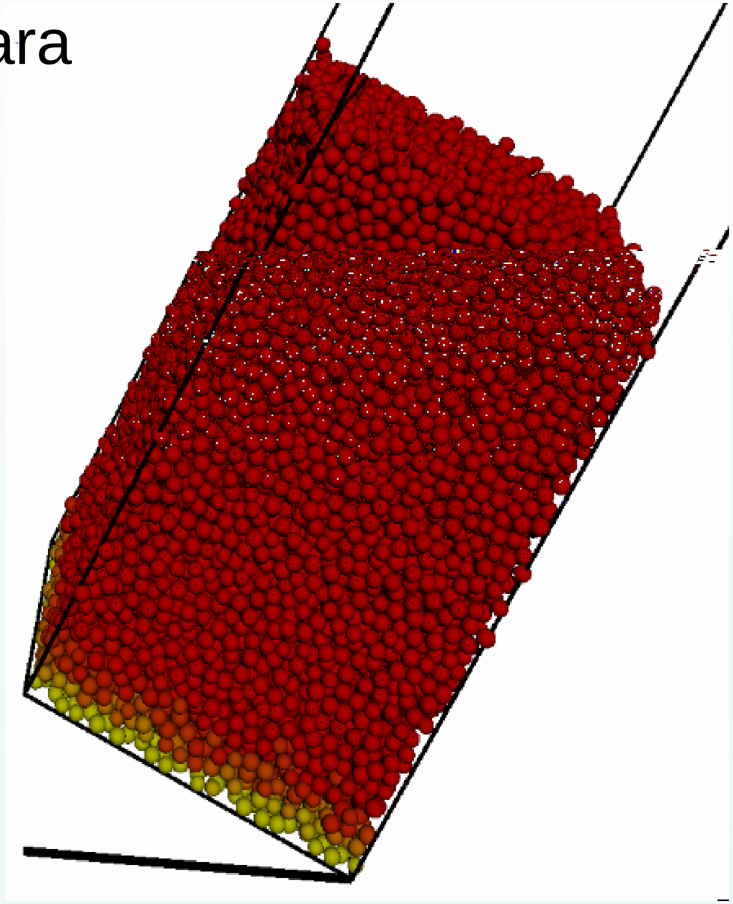

Granular flows on a bumpy bottom

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PHYSICS OF FLUIDS VOLUME 11, NUMBER 3 MARCH 1999

Scaling laws in granular flows down rough inclined planes

O. Pouliquen[a)]

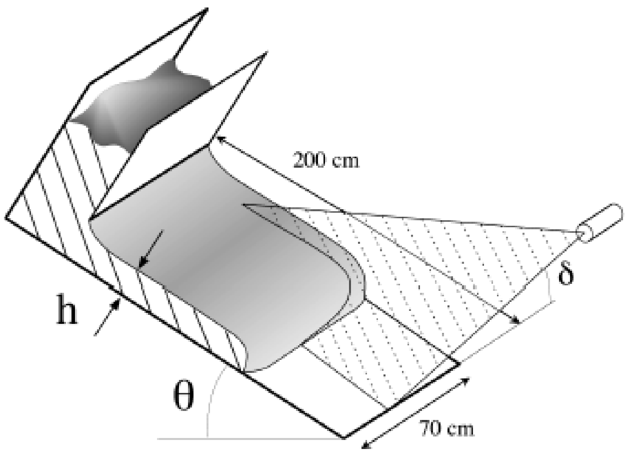
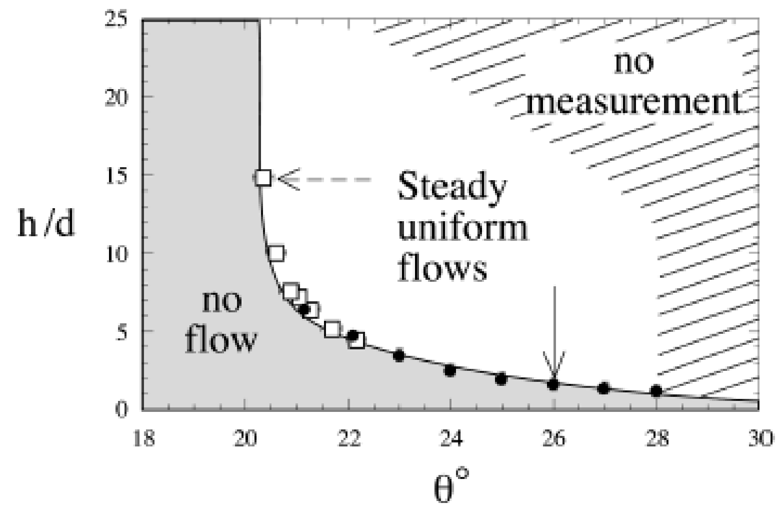


FIG. 1. Experimental setup.



No Coulomb-like friction

Simulations

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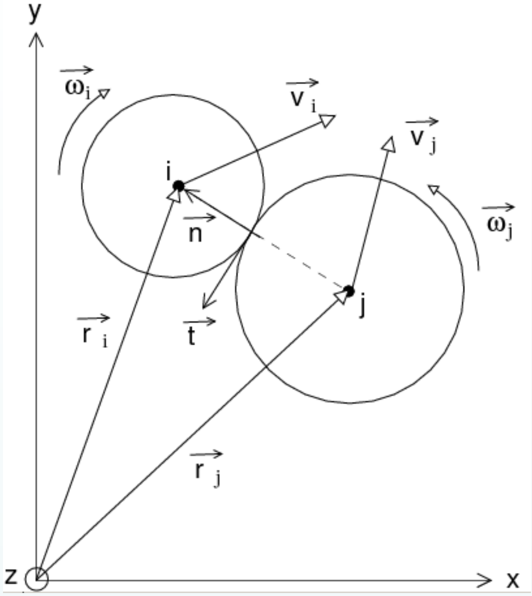
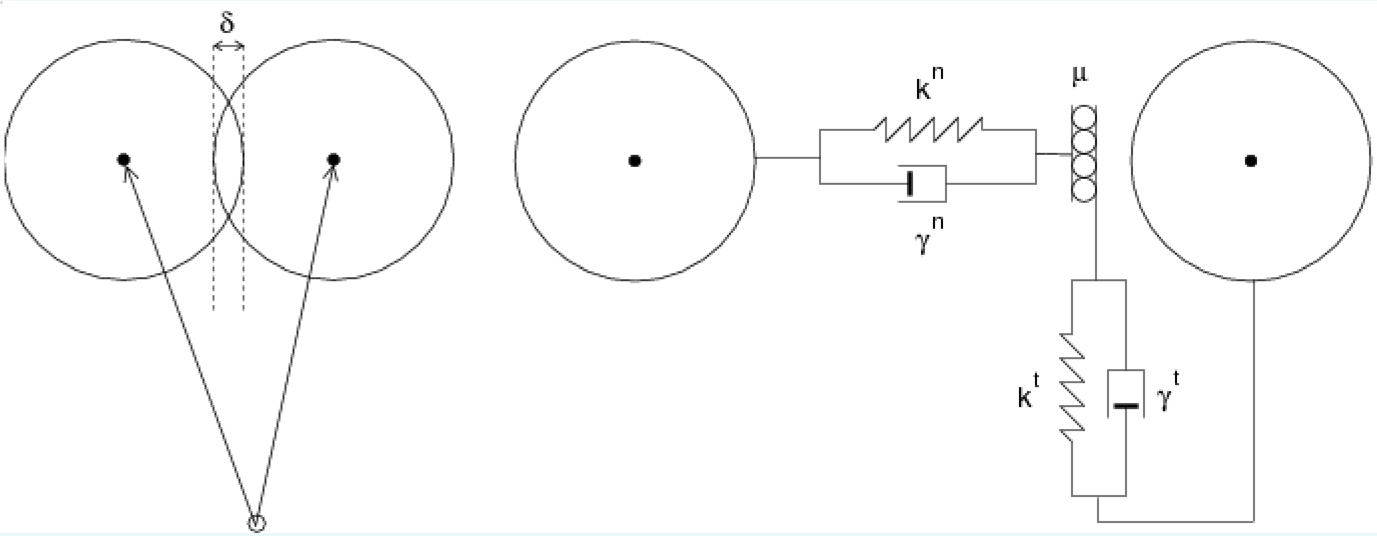


Solve equations of motion for N spheres flowing down a bumpy incline $\Rightarrow$ forces?

Linear spring - dashpot

- $F_n = k_n\,\delta + \gamma_n\,d\delta/dt$
- $F_t = \mathrm{MIN}(\mu F_n,\ k_t\,u + \gamma_t\,du/dt)$

$k_n d/mg \approx 10^5$ (to save time…)

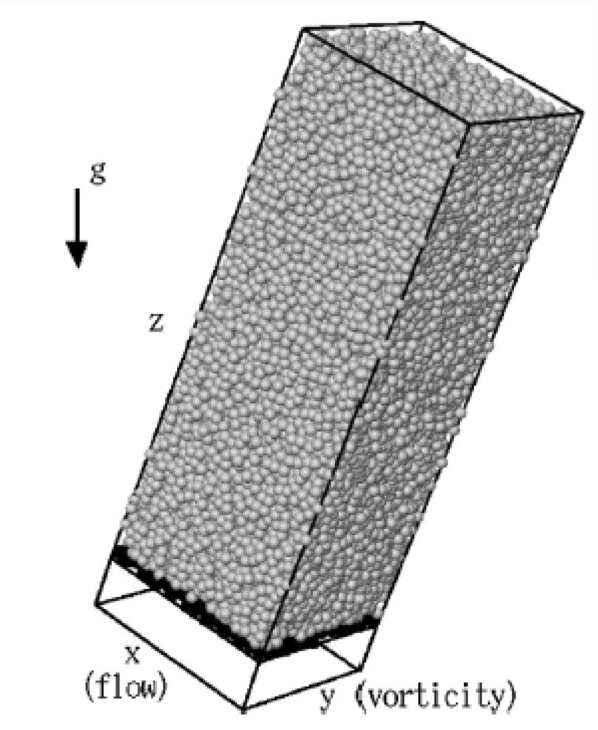


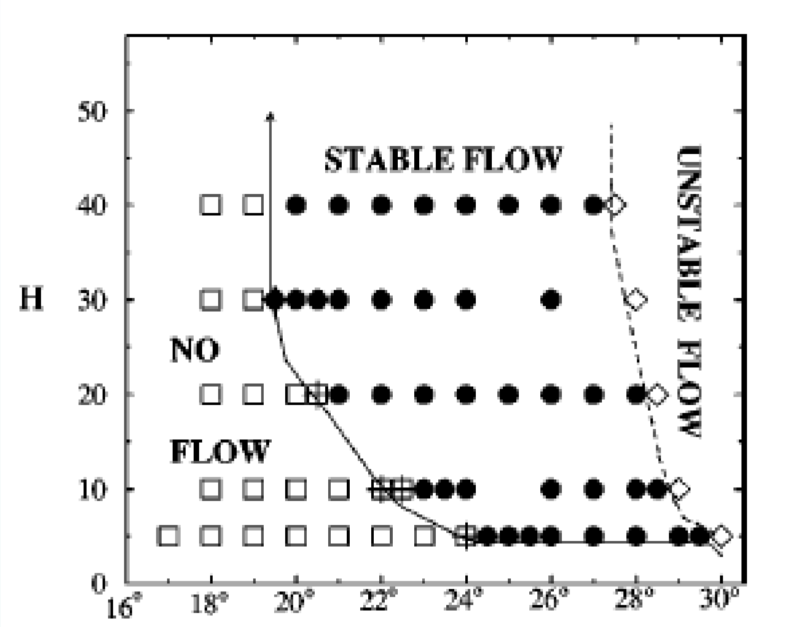
Simulations

PHYSICAL REVIEW E, VOLUME 64, 051302

Granular flow down an inclined plane: Bagnold scaling and rheology

Leonardo E. Silbert,[1] Deniz Ertaş,[2] Gary S. Grest,[1] Thomas C. Halsey,[2] Dov Levine,[3] and Steven J. Plimpton[1]





(b)

Oscillations close to the angle of repose?

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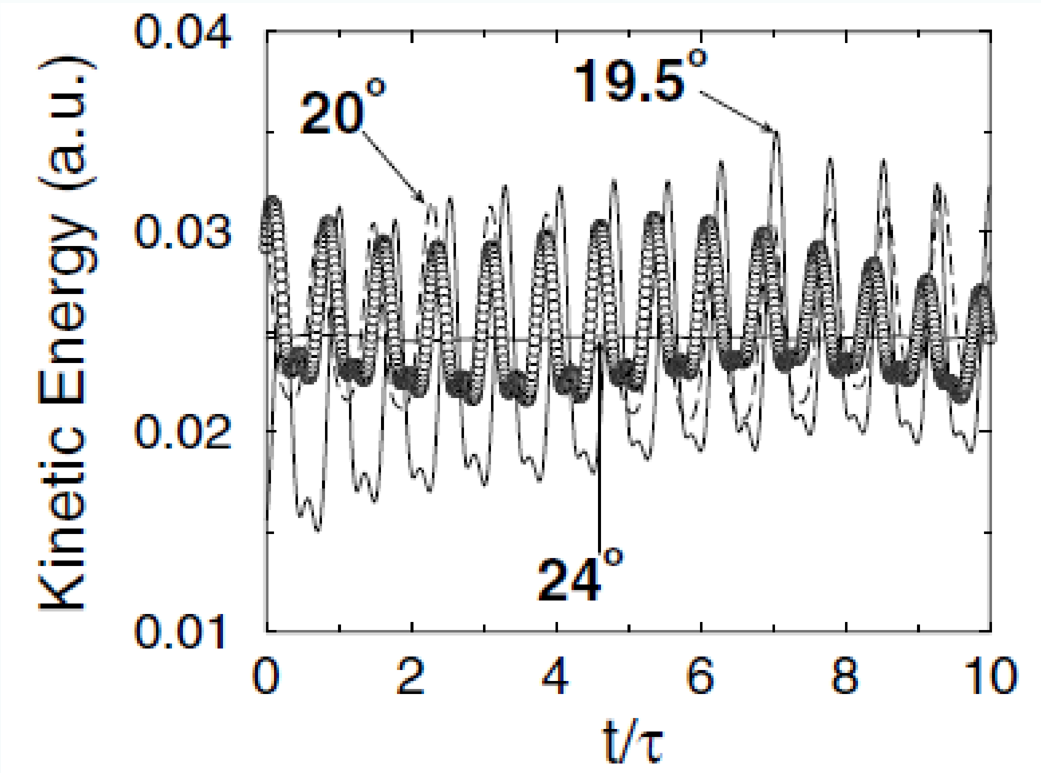
PRL 94, 098002 (2005) PHYSICAL REVIEW LETTERS week ending 11 MARCH 2005

Temporally Heterogeneous Dynamics in Granular Flows

Leonardo E. Silbert*



- Learn something about jamming?
- Explain « booming » sand?

Oscillations
close to the angle of repose?

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Temporally Heterogeneous Dynamics in Granular Flows

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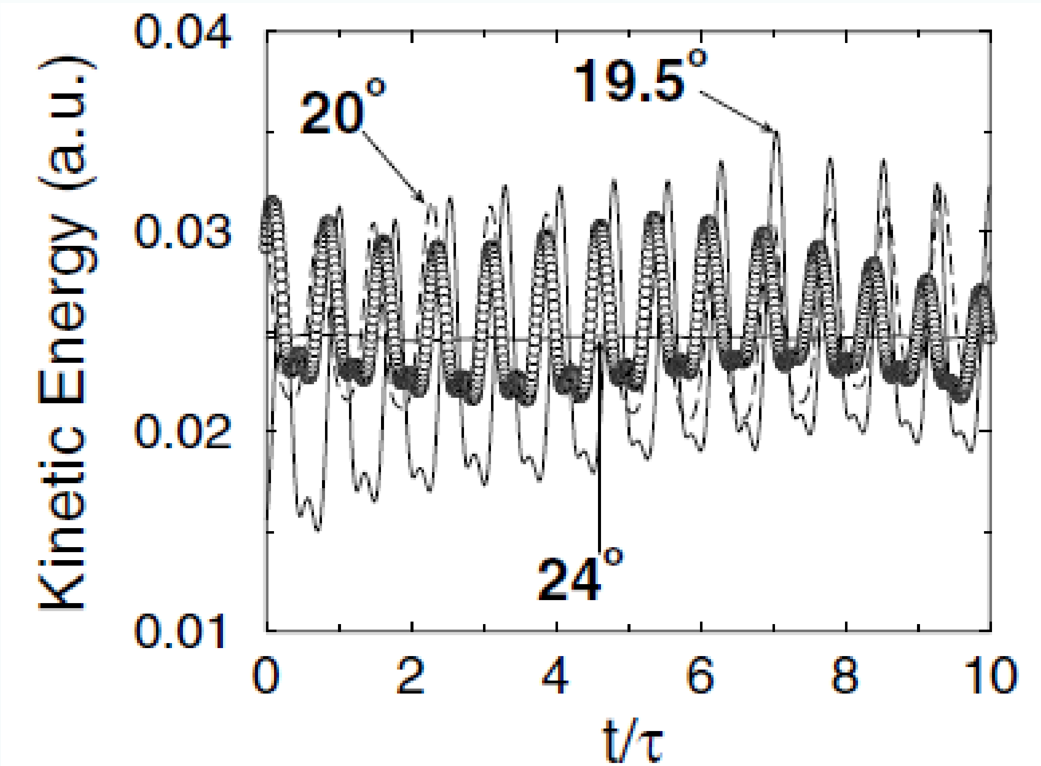
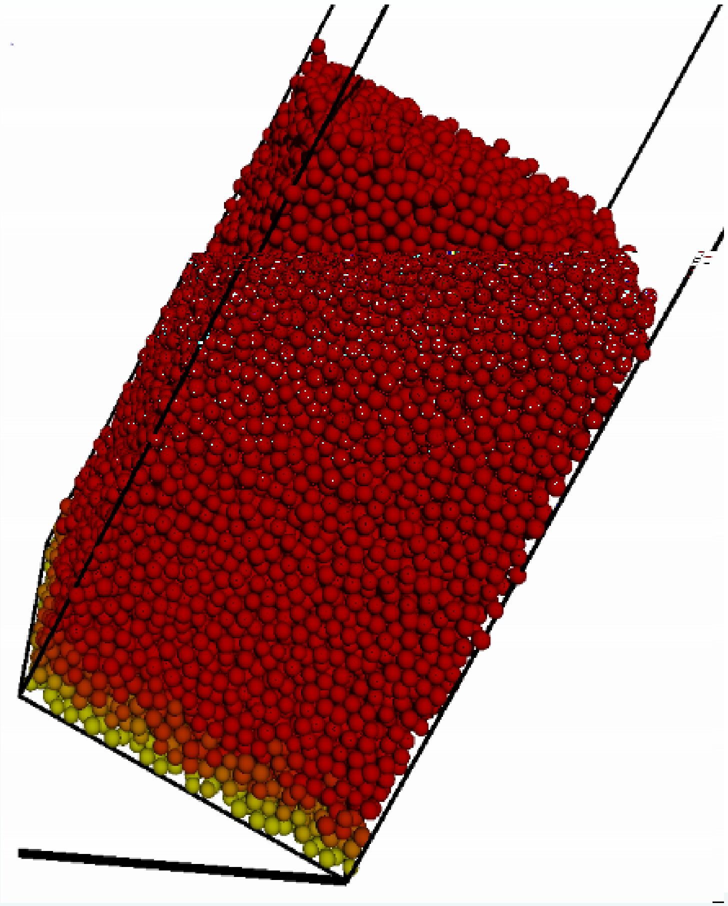
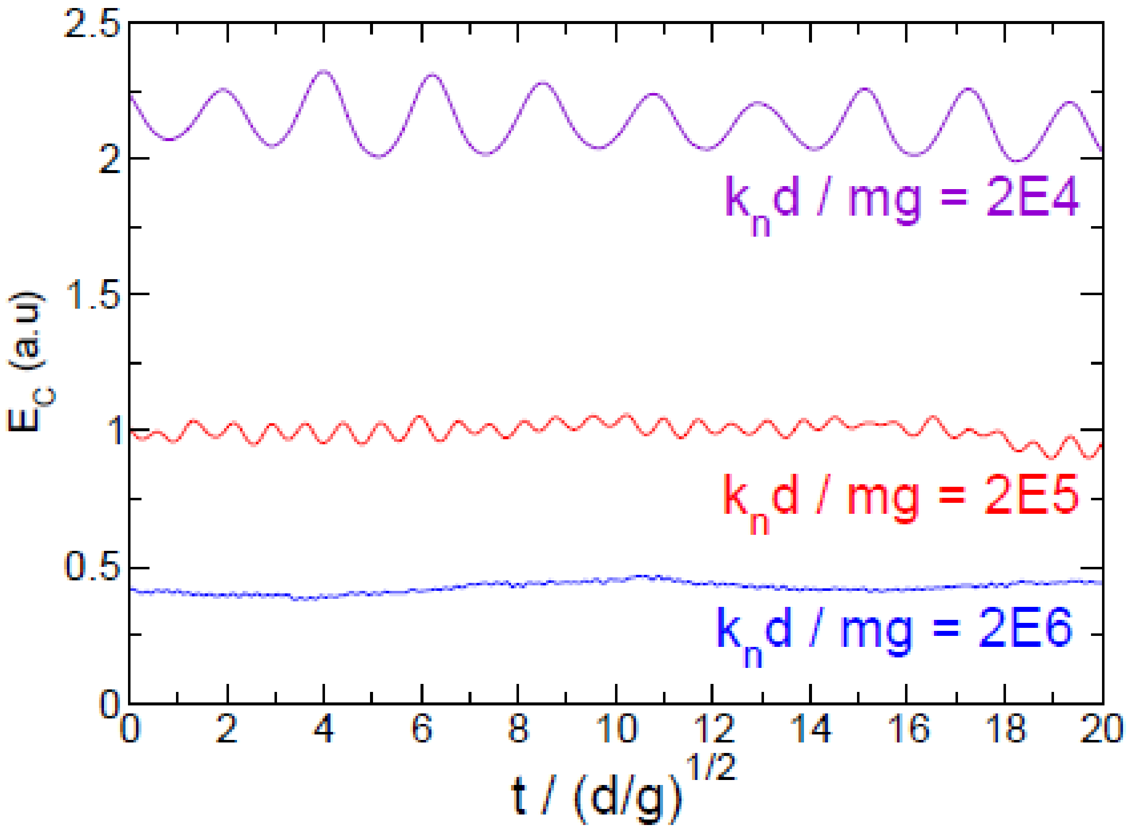


- Learn something about jamming?
- Explain « booming » sand?

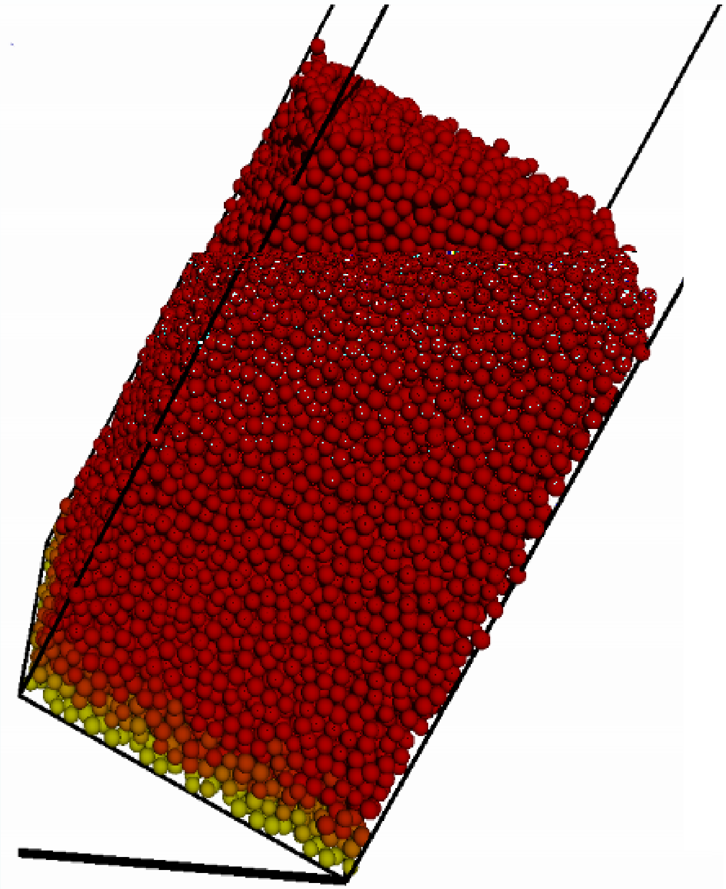
Artifact of the force model ?

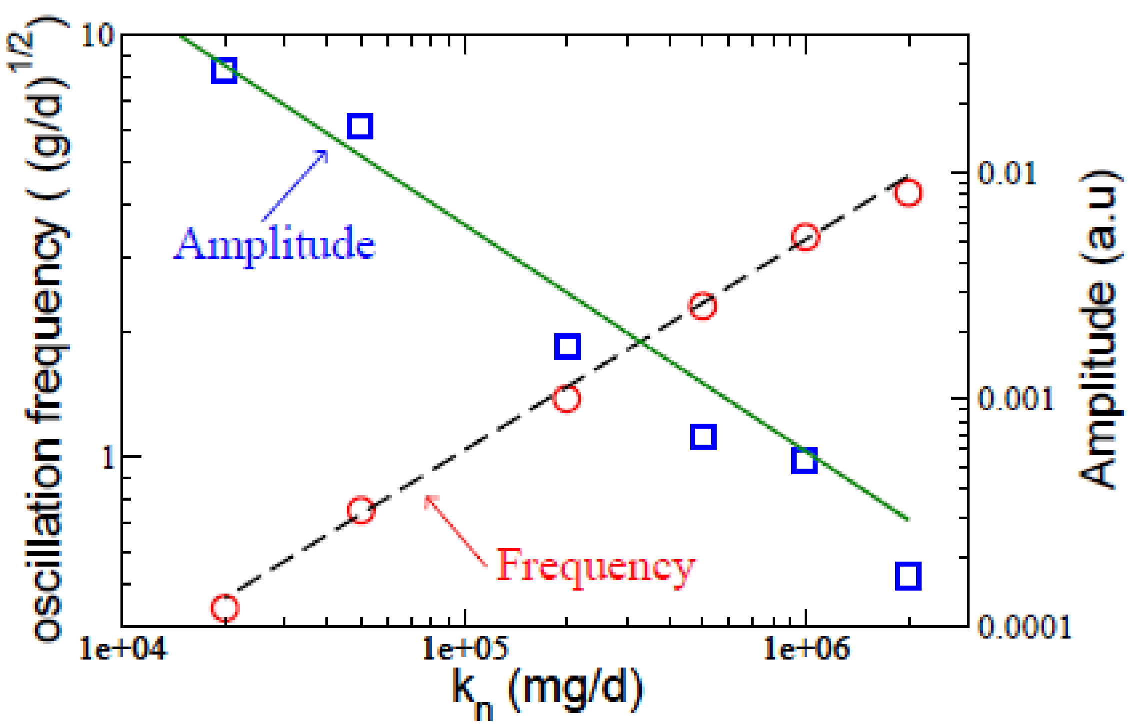
Effect of k_n ?





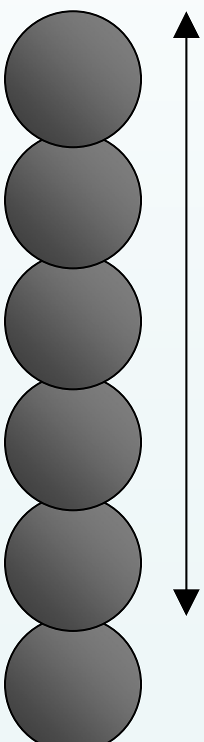
Effect of k_n ?




oscillation frequency ((g/d)^1/2)
10
1
Amplitude
Frequency
0.01
0.001
0.0001
Amplitude (a.u)
1e+04
1e+05
1e+06
k_n (mg/d)

And for real grains…?

$$F_n = \frac{2E\sqrt{R}}{3(1-\nu^2)}\delta^{3/2} \longrightarrow k_n = \frac{dF_n}{d\delta} = \frac{E\sqrt{R}}{(1-\nu^2)}\delta^{1/2}$$



n grains

$$F_n = \frac{2}{3}k_n\delta$$

$$F_n = nmg$$

$$\left.\begin{matrix} \\ \\ \end{matrix}\right\} \quad \left(\frac{d}{\delta}\right)^{3/2} = \frac{4E}{\pi(1-\nu^2)\sqrt{2}n\rho dg}.$$

$$\frac{k_n d}{mg} = \frac{3}{2}n\frac{d}{\delta} = \frac{3}{2}\left[\frac{2\sqrt{2n}E}{\pi(1-\nu^2)\rho dg}\right]^{2/3}$$

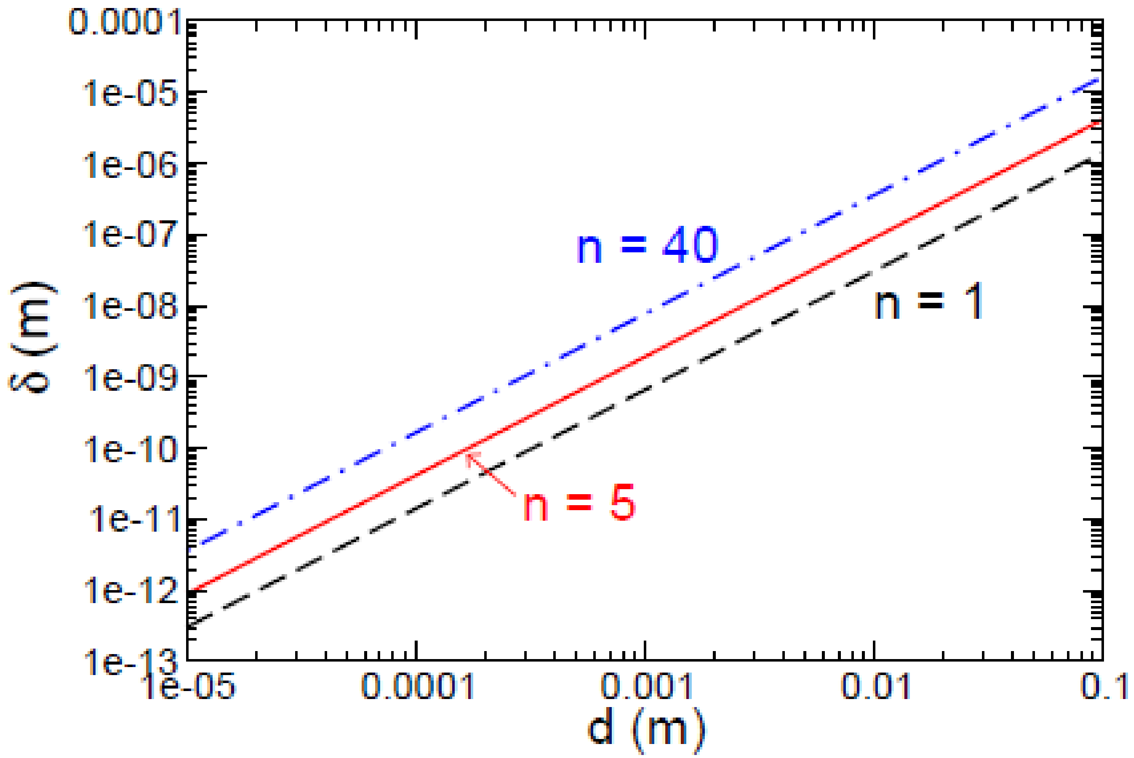
Stiffness

$$\frac{k_n d}{mg} = \frac{3}{2} n \frac{d}{\delta} = \frac{3}{2} \left[\frac{2\sqrt{2n}E}{\pi(1-\nu^2)\rho d g} \right]^{2/3}$$

Overlap

$$\delta = \frac{3d^{5/3}n^{2/3}}{2K}$$

$$K = \frac{3}{2}\left[\frac{2\sqrt{2}E}{\pi(1-\nu^2)\rho g}\right]^{2/3}$$



Glass Spheres d ≈ 1mm ⇒ d ≈ 1nm (size of the roughness a the bead)

Thus… we are doing nanophysics!

Conclusion

- Simulations should be used with care especially for time $\approx$ collision time
- This work casts doubt on the Hertz for inter-grain forces which reposes on the assumption that the grains are beautiful, smooth spheres that are pushed together.
- At the nanometer scale, the grains are certainly not smooth. The force law will be governed by their asperities, of which we know almost nothing.