Friedrich-Alexander-Universität Erlangen-Nürnberg

ENGINEERING OF ADVANCED MATERIALS

Institute for Multiscale Simulation

Granular Dynamics in a Shaken Container under Microgravity Conditions

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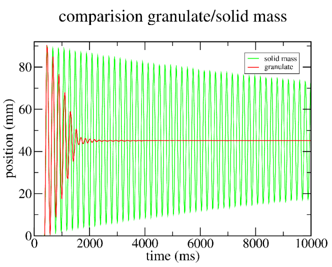
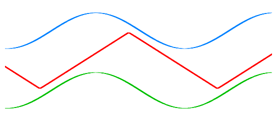
Granular Dampening

Granular dampers exploit inelastic collisions between particles to dissipate energy. These devices are easy to construct and require no maintenance.



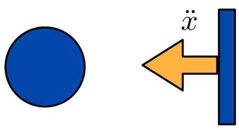
Amplitude of a relaxing spring with an attached granular damper (red) or solid mass (green).

Single Particle Model



Particle & wall collide when:

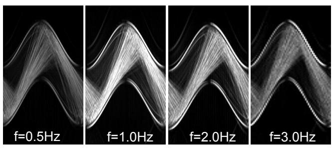
$$A\omega t_c = A\sin(\omega t_c) + L_g$$



If, at the time of collision, the wall <u>accelerates</u> inwards the particle will be collected, if the wall accelerates outwards the particle will be reflected/released. Both behaviors are separated by a threshold phase:

$$\omega t_c = \pi$$

Independence of Frequency

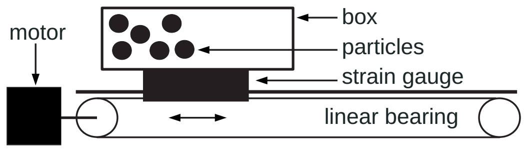


space-time-plot of particle trajectories. Due to the lack of a gravitational timescale the system's behavior is independent of the driving frequency.

Steady Driving

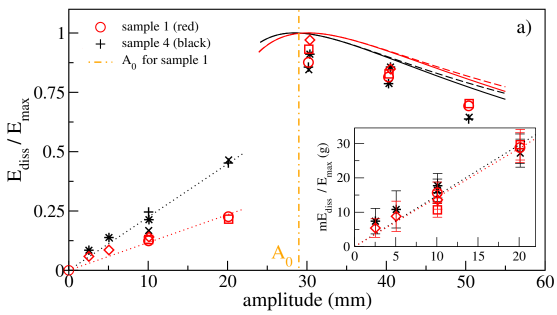
Phys. Rev. Lett. 111, 018001 (2013)

A box partially filled by steel spheres is driven along a sinusoidal trajectory while recording the power that is dissipated by the granulate as a function of amplitude and frequency of driving.



We identify two different modes of granular dynamics, depending on the amplitude of driving. For intense forcing the material is found in the collect-and-collide regime, while for weak forcing, the granular material exhibits gas-like behavior.

Energy Dissipation



Both regimes correspond to different dissipation mechanisms:

- ➡ For the collect-and-collide regime, we explain the dependence on frequency and amplitude of the excitation by means of an effective one-particle model:

$$E_{\text{diss}}^{\text{cc}} = \frac{1}{4}[1-\cos(\omega t_c)]^2 E_{\max}$$

- ➡ In the gas regime the dissipation is proportional to the volume swept by the side walls:

$$E_{\text{diss}}^{g} \propto m\frac{A^3\omega^2}{L} = \frac{A}{4L}E_{\max}$$

With the transition between the two regimes given by the threshold amplitude:

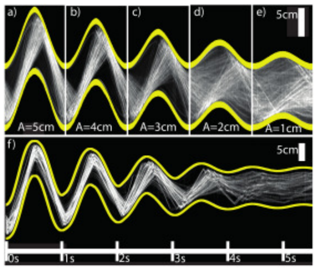
$$A_0 = \frac{L_g}{\pi}$$

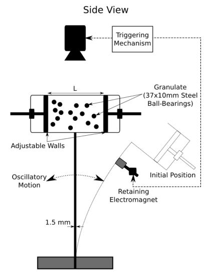
where L_g is the free length (gap size) in the container.

Granular Damper on a Relaxing Spring

Phys. Rev. E 84, 011301 (2011)
New Journal of Physics, submitted (2013)

When the oscillation of a spring is attenuated by means of a granular damper, in difference to viscous dampers, the amplitude decays nearly linearly in time up to a finite value, from there on it decays much slower.

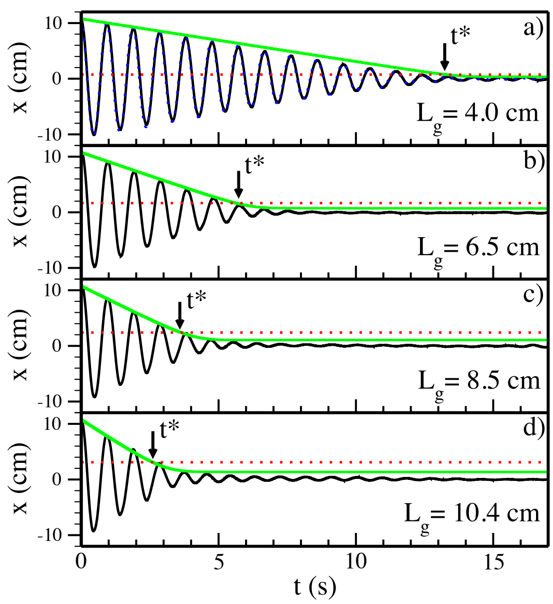




Space-time-plots a)-e): each sub-figure shows the granulate moving in a box sinusoidally driven at constant amplitude. f) The granulate moves in a box attached to an oscillating spring. Right: setup for the spring experiment.

We consider the relaxation process as a sequence of steady states and apply the energy dissipation model developed for the system driven at invariant amplitude. This leads us to an equation for the attenuation of the amplitude as a function of time:

$$\gamma\frac{dA}{dt} = -A(t)\frac{\omega m_{\text{eff}}}{2\pi k}\left[\omega\cos(\omega\tau_c) - \sqrt{\frac{k}{M}}\right]^2$$



Experimentally measured amplitude of the decaying oscillation for various gap sizes L_g (black), threshold amplitude A_0 (red) and envelope predicted by our model (green)

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