On the origin of Two-Body interactions in shaken granular media

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Recent experiments from *Lozano et al.*, [2], showed an emergent interaction between pairs of bronze spheres in a horizontally shaken granular layer in the dense phase. Mixtures of such spheres and grains seggregate in the form of lanes of spheres perpendicular to the shaking direction [1]. The interaction described in [2] is attractive at contact and scales with the density of grains ϕ shown by the probability distributions of pair distance and the long-time tails in trapping times.

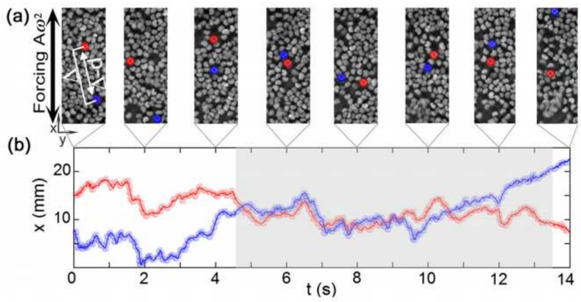

Figure 1: System of granular particles (grey) with two inclusions (red and blue) from [2]. Once the spheres go close they stay close for a long time; this indicates an effective attractive interaction.

We present a computational framework to extract these forces. We model of horizonatally shaken vibrated granular disks, with a polydispersivity of 10% and packing fraction ϕ. The shaking is introduced by an oscillating force acting on the disks and an additional random force to account for the shaking in a 3rd dimension. We introduce the spheres by means of disks that do not follow the shaking; to model the effects of a 3d rotation of spheres on the plate.

$$f_r = \frac{1}{2}\left(\mathbf{F}_2 - \mathbf{F}_1\right)\cdot\hat{\mathbf{r}}; \quad f_t = \frac{1}{2}\left(\mathbf{F}_2 - \mathbf{F}_1\right)\cdot\hat{\mathbf{t}} \qquad (1)$$

By pinning the inclusions at different positions we are able to explore a wide range of the relative position vector $\mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1$; we define the transverse direction $\mathbf{r}\times\mathbf{t} = 0$. Including only repulsive forces to model volume exclusion we compute the total force on each inclusive particle $\mathbf{F}_1$ and $\mathbf{F}_2$. In a first exploration we report an anisotropic interaction; the radial force deppends on the relative angle of the doublet respect to the shaking direction, α, as seen in Figure 2.

Measures of the tangential forces show an emmergent torque that aligns the doublet in the direction of the shaking. In contrast to many body experiments, when spheres

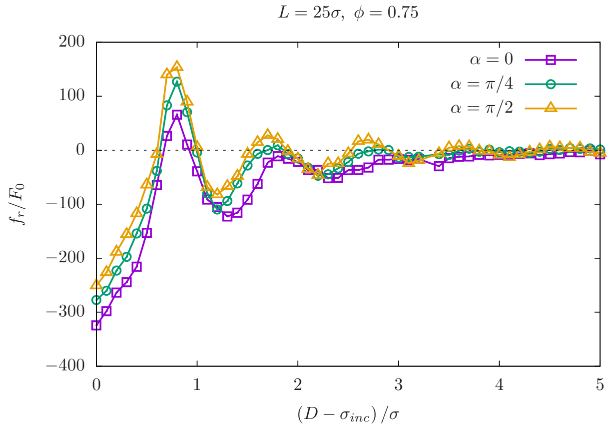

Figure 2: Radial component of the radial force for a system of packing fraction $\phi = 0.75$. The interaction is attracrive for $f_r < 0$. We are able to see a sctructure and a long range tail.

assemble in lanes (2-3 sphere width) perpendicular to the shaking direction.

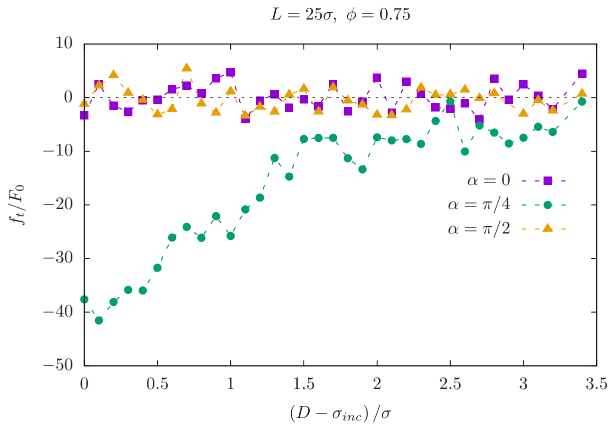

Figure 3: Transverse relative force at $\phi = 0.75$. For $f_t < 0$ torque aligns particles in the shaking direction.

After chacterising the force between inclusion the next question to ask is on the origin of the force. At first there are two candidates: (1) a phoretic mechanism; (2) a Casimir-like mechanism. To answer to this question we have to look for gradients in the local density field ϕ and the stress tensor $\sigma_{\alpha\beta}$, specially the pressure $p = \frac{1}{2}Tr\left(\sigma_{\alpha\beta}\right)$

[1] Aranson, I. S., and Tsimring, L. S., Rev. Mod. Phys. **78**, 641 (2006).

[2] Lozano, C., Zuriguel, I., Garcimartín, A., and Mullin, T., Phys. Rev. Lett. **114**, 178002