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"Lock in accelerometry" to follow sink dynamics in shaken granular matter

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Understanding the penetration dynamics of intruders in granular beds is relevant not only for fundamental Physics, but also for geophysical processes and construction on granular soils in earthquake areas. Indeed a phenomenon named soil liquefaction can cause buildings to sink or tilt in areas separated of 1000 km from the epicentre in the worst cases. The damages on the constructions, the pipes and the roads may be huge. There is a conventional understanding of liquefaction from which scientists made theoretical and empirical laws for geotechnical use and building construction, but the dynamical penetration of buildings into the soil is still not well understood.

While the penetration of intruders in 2D laboratory granular beds can be followed using video recording, it is useless in 3D beds of non-transparent materials such as common sand. Wireless accelerometry constitutes a natural alternative that has been used in very few occasions, however, it has never been used to quantify the penetration into horizontally shaken granular beds. Here we propose a method to quantify the sink dynamics of an intruder into laterally shaken, fluidized granular bed. We developped an embarked accelerometer small enough to fit into a modelized building. This sensor allows us to follow the intruder in realistic conditions namely buried in a 3D box of sand.

Our method is based on the temporal correlations between the signals from a reference accelerometer fixed to the shaken granular bed, and the accelerometer deployed inside the intruder. We demonstrate that our method is able to determine the time interval of sinking of an intruder into shaken granular beds for both quasi-2D and 3D systems [1]. Due to its analogy with the working principle of a lock in amplifier, we call this technique Lock in accelerometry (LIA).

In the experiments the intruder stops at a depth that we assume to be the beginning of the "jammed" granular phase. We are now developing numerical simulations based on a molecular dynamic algorithm to confirm or not this assumption. We modelized a granular bed with particles of the same size than the one used in the experiments. Because we have access to the velocity of every particles we can quantify the dynamic of each layers of the granular medium and find its "jammed" boundary.

Reference

[1] G Sánchez-Colina, L Alonso-Llanes, E Martínez, AJ Batista-Leyva, C Clement, C Fliedner, R Toussaint, and E Altshuler. Note :"lock-in accelerometry" to follow sink dynamics in shaken granular matter. Review of Scientific Instruments, 85(12) :126101, 2014.