ACOUSTIC PROBING OF A SINKING BALL IN SHAKEN GRANULAR SEDIMENTS

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A convenient method to determine the viscosity of a fluid is to drop a high density ball in it. As the ball is dropped into the fluid, it accelerates as a result of the gravitational field until it reaches a terminal velocity. In the laminar flow regime, the terminal velocity of the ball is inversely related to the viscosity of the fluid via Stokes' law. Instead, in a yield stress fluid such as foams, emulsions and granular suspensions, the ball will stop sinking at a certain depth due to solid-like friction between the particles, which depends on the sinking velocity of the ball and the normal pressure. The jamming phase diagram provides a general framework to explain such a transition from a liquid-like flowing state to a solid-like jammed state as a function of the density of randomly packed particles and the applied shear.

Understanding an intruder sinking in quicksand remains a conceptual and practical challenge: there are very few direct experimental investigations inside realistic 3D opaque dense granular suspensions. Here, we use acoustic probing to investigate the sinking dynamics of a ball in a vibrated granular sediment saturated by water (Figure 1a). In the absence of vibrations, the ball placed on the surface of the granular sediment will remain still, i.e. the undriven granular suspension exhibits a yield stress. But when the sediment is vibrated its behavior changes dramatically and a ball placed on the surface will immediately begin to slowly sink (Figure 1b).

We investigate the difference between horizontal and vertical vibrations on the preparation of the sediment and on the sinking dynamics of the ball (as an effective temperature). We observe that the two types of vibrations yield suspensions with different packing densities which in turn results in very distinct sinking dynamics. Additionally, we investigate the influence of the intensities of the vibrations on the flow of the sediment and the motion of the ball. Our experimental results are consistent with the frictional rheology revealed in dense granular media [1]. Moreover, we find that the vibrations primarily affect the yield stress (i.e., static friction coefficient) and consequently control the depth of sinking (Figure 1c). This acoustic monitoring should allow a better understanding of the mechanical properties of dense granular suspensions and ocean sediments as well as landsliding.

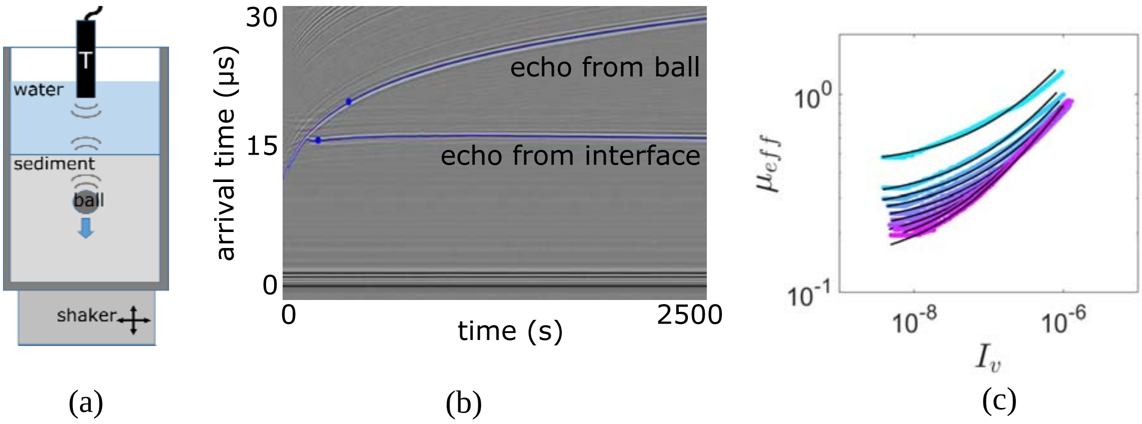

Figure 1. (a) Schematic of ultrasonic monitoring of a sinking ball in dense granular suspension, using a piezoelectric transducer (T). (b) Stack of waveforms showing the reflection of the sinking ball and of the interface. (c) Effective friction coefficient as a function of a viscous number I_v [2] for different vibrational intensities. The black lines represent a fit of the frictional rheology model.

References

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[2] Fall et al, *Rheology of sedimenting particle pastes*, J. Rheol. **57**, 1237 (2013)