Elastogranular Relaxation

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Abstract

Slender rod-like structures often interact with granular-like matter in nature---a proboscis navigates cells, a root grows through grains of dirt, or a biological membrane interacts with nearby tissues. These interactions are well-documented but little-understood phenomenon, particularly near jamming, where grains act as a solid rather than a fluid. This experiment aims to gain insight on the mechanics of an elastica in a granular medium to make links between macroscopic experiments and microscopic behavior in polymers or biological systems. The experiment involves using a stage filled with grains to determine the distance between the beam ends and the curvature of the beam. The packing fraction of grains and the thickness of the beam were varied, producing different and sometimes surprising results. At small thicknesses, the motion of the beam is controlled by the grains regardless of packing fraction. At higher thicknesses and fluid packing fractions, the bending energy consistently decays exponentially. However, near jamming, even with reasonable thickness, the elastica can be trapped in certain configurations; the grains do not allow easy relaxation of the beam. These findings suggest there are thresholds of elastic energy and packing fraction that control the relaxation of a membrane and open opportunities to better understand what affects this behavior.

Methods

We used a function generator and amplifier to shake a 25x25cm stage at 5Hz and 1.2G. We varied the amount of grains and the thickness of the beam in the stage to provide different results. A Matlab code analyzed images taken of the stage, finding the distance between the beam ends and measuring local curvature along the elastica.

The relaxation of an elastica in a granular medium is influenced both by the motion of the surrounding grains and the bending energy of the beam. In the first case, the elastica has enough bending energy to influence the grains, allowing it to relax reliably. Over multiple trials, the same beam releases over a significant portion without interruption in its smooth exponential decay.

Results

Figure 4B: Relaxation near jamming. As the packing fraction decreases below 52%, the beam (2.5mm thick, shown) often stays bent.

Regardless of bending energy, at high packing fractions a beam cannot influence the motion of a high volume of packed grains. Grains jammed locally, forcing the beam into curved configurations with little chance of relaxing further. The beam is surrounded.

Conclusions

• Within certain bounds of packing fraction and thickness, an elastica relaxes reliably. Bending energy is significant and able to smoothly decrease exponentially, while packing fraction increases relaxation time and thickness decreases it slightly.

• Low thicknesses and high packing fractions increase the influence of the granular medium. Bending energy infrequently decays smoothly, demonstrating the influence of the motion of the granular medium over the inclination of the elastica to relax.

Discussion

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References

References


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