Stability of granular asteroids

Ishan Sharma

Mechanics Group, Department of Mechanical Engineering,

*Indian Institute of Technology Kanpur**

Recent observations [1] have suggested that several of the near-Earth asteroids may be granular aggregates held together by self-gravity alone. This poses new challenges when attempting to un- derstand their origins and/or developing threat-mitigation strategies. As in fluids [2], gravitating ellipsoidal granular aggregates are unable to support all manners of spins and shapes. This fact may help us relate asteroids observational data to their internal structure. Equilibrium shapes and dynamical evolution into these shapes of these objects were investigated in [3]. The granular aggregates were modeled as rigidperfectly-plastic materials obeying a Drucker-Prager yield crite- rion and following an appropriate flow rule. Here we further constrain the possible shapes of these objects by investigating the stability of the proposed equilibrium regions.

As opposed to fluids, the transition of granular materials from solid-like to fluid-like behavior is often modeled via non-smooth constitutive laws. Thus, the material moves in and out of equilibrium also in a non-smooth manner, as, for example, in the case of a dry Coulomb slider. This precludes application of standard spectral stability methods. Furthermore, the fact that asteroids are freely rotating bodies demands extra care during a stability analysis. This leads us to explore the energy criterion of stability that tests stability by bounding the excess kinetic energy. We extend the energy criterion to freely-rotating systems comprising of pressure-dependent non-smooth materials. The criterion so developed is then applied to test stability of granular asteroids. Finally, the results are illustrated in the context of several known near-Earth asteroids.

References

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*Electronic address: ishans@iitk.ac.in