REGOLITH MECHANICS ON ASTEROID SURFACES

J. Biele[1] and S. Ulamec[1]
[1]German Aerospace Center - DLR, MUSC, Linder Höhe, 51147 Cologne, Germany

Introduction: It is very likely that most asteroids surfaces are covered by a regolith layer. We are focussing on the mechanical properties of such regolith, i.e., a granular material under micro-gravity (µ-g) conditions.
Any operations on asteroids that are not remote, need to interact mechanically with the surface material, and for resource utilization possibly with also subsurface layers. For controlled landing of any spacecraft the surface mechanical properties are crucial; for sampling or extraction of a boulder, the strength properties are relevant as is for successful anchoring of any machinery or astronauts. Debris clouds (ejecta or shattered material) may be lofted for long times in a micro-g environment, thus impeding robotic and human operations including utilization of asteroid resources. Regolith mechanical properties also influence the thermal inertia which can be remotely observed.

Space missions: We recall the strength values derived from the Rosetta mission and the bounces of Philae (Nov. 2014) [1-3] and report on laboratory experiments and simulations conducted to constrain the possible bouncing of MASCOT, the small lander [4] onboard of the Hayabusa-2 mission (arrival June 2018). A similar analysis - but even more crucial for mission success - has to be done for the deployment and relocation motion of MASCOT-2, a slightly bigger version of MASCOT, foreseen to be contributed to the ESA/AIM mission [5,6] an asteroid impact mitigation demonstration to the Didymos binary asteroid system.

Concepts: We briefly describe the key concepts, burrowed from continuum mechanics on the one side, from granular mechanics on the other side. It turns out that most concepts of engineering soil mechanics have limited application, since the g-dependent terms vanish and only effects of cohesion remain. Friction and cohesion become the two dominant effects

What is known? A lot of in-situ properties are known for lunar regolith, but very little for comets (67P being the only data point) and asteroids (one complicated data point for Itokawa). Of course, for asteroids there are meteoritic analogs, thus the compressive/tensile strengths and elastic properties of the bulk material for them can be estimated with some confidence.
We then discuss “What can be observed?” and “What has/can been simulated?”.

Conclusions:
Large uncertainties in the mechanical properties remain, especially in the µ-g regime, on surfaces of metallic asteroids, on electrostatic charging, on forces. Much more experimental and simulation work will be necessary to predict the mechanical interaction with asteroid surfaces with some confidence.

References: [1] Biele J. *et al.* (2015) *Science 349*, aaa9816. [2] Ulamec S. *et al.* (2015) *Acta Astron., 107,* 79-86. [3] Ulamec S. *et al.* (2016) *Acta Astron*., *125*, 80-91. [4] Ho T.-M. *et al.* (2016) *Space Sci. Rev*., DOI 10.1007/s11214-016-0251-6. [5] Michel, P., *et al.* (2016). Adv. in Space Res. (57): 2529-2547. [6] Cheng A. *et al.* (2015) *Acta Astron., 115*, 262-269.

Topics: Granular media, Future space missions, asteroid resources, thermal modeling, Rosetta

Submit the .doc or .odt file, AS WELL as a .pdf file.