Simulations of regolith response to a low-speed impact of a lander in a low-gravity environment: application to the lander MASCOT on Hayabusa2

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Hayabusa2, the JAXA asteroid sample return mission, was launched on December 3rd, 2014, towards the carbonaceous asteroid (162173) Ryugu. The main spacecraft carries the European (DLR/CNES) lander MASCOT, a 10kg cuboid, whose release on the asteroid surface is expected to provide valuable information about the asteroid and regolith properties (Ho et al. 2016). We developed numerical simulations of MASCOT impact on Ryugu in support of the Hayabusa 2 mission. More generally, these simulations also allow us to better understand the response of asteroid surface regolith with given grain properties (friction, size distribution) to a low-velocity impact in a low-g environment.

To simulate the regolith response to MASCOT impact, we used the N-body gravity tree code pkdgrav and performed numerical simulations of lander bouncing on a granular surface in the low-gravity environment of Ryugu (2.5 ×10−4 m/s2). Contact dynamics between regolith particles are modeled by the Soft-Sphere Discrete Element Method (SSDEM). Two kinds of regolith friction properties (moderate or gravel-like) were considered in the simulations. The influence of cohesion is left for a future study. Most of the simulations we ran so far considered a Gaussian grain size distribution with a 1-cm mean radius, a 33% standard deviation and no particles beyond the standard deviation. Three regolith depths were considered: 15 cm, 30 cm and 40 cm. We then ran a large set of simulations and analyzed the influence of the different regolith properties, impact angles, MASCOT orientation and coefficients of restitution, on the response of the regolith and on MASCOT after its low-speed collision (19 cm/s).

To analyze the results, we computed characteristics related to the impact itself, such as the collision duration and the linear coefficient of restitution (outgoing to ingoing speed ratio of MASCOT’s center of gravity), as well as the properties of the crater resulting from the impact and MASCOT’s following evolution. We find that the linear coefficients of restitution and outgoing angles have a strong influence on the distance that MASCOT will travel after the first bounce, if it bounces. We also find that those distances are slightly longer with a gravel-like regolith. Most of the simulations tend to show that the distance increases with the impact angle from the vertical, as does the linear coefficient of restitution (see figure). Maximum distances are obtained in our simulations with MASCOT landing on one of its corner, with an angle of approach of 60°, and are around 40-45m for a bed depth of 15cm, and around 23m for a 40cm-depth bed. The crater left by the impact and the displacement of regolith grains can serve as a measure of the response of the regolith to the lander impact. We typically find that, as expected, the crater is deeper and larger with moderate-friction grains than with gravel-like ones. Other on-going analyses (e.g. ejecta blanket etc) will be presented at the conference.

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