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Impact cratering experiments on granular slopes

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Impact cratering is an important process for the evolution of planetary surfaces. Many experiments of impact cratering into granular media have been conducted to understand its basic physics (e.g., Walsh et al., 2003, de Vet and Bruyn, 2007). These studies have shown that as impact energy becomes larger, simple craters transform into complex craters. In addition when gravity is more important than the target strength, the crater diameter increases in proportion to the 1/4 power of the impact energy. Peculiar craters on asteroids have been discovered in recent planetary missions. Some craters on asteroids are likely to be in the transitional regime between the gravity and strength dominated regimes. In order to better understand how such craters may have formed, we have recently conducted experiments around the transitional regime (Takita and Sumita, 2013). In addition, because asteroids have large topography relative to its size, some craters seem to have formed by impact on slopes (Jaumann et al., 2012). However, since most previous experiments were performed on horizontal targets, impact cratering on slopes is still poorly understood. In this study, we report the results of experiments to understand the effects of slope angle on crater formation.

The experiments in this study were performed by dropping spherical projectiles into an inclined granular target. Projectiles are made of stainless steel (density: 7.70g/cm^3) and their diameters are 11.0mm and 22.2mm. We use sand (mean diameter of 0.204mm, density of 2.66g/cm^3, angle of repose of 37.2○, volumetric packing fraction of 0.56) for the granular target. The slope angle ϑ was 0○,11○,16○,22○,34○. Impact energy E was 0.055 , 0.073 and 0.58 J. Crater formation process was recorded by a high speed camera. The 3-D topographies of the granular target before and after the impact were measured by a laser displacement meter which we move by a stepping motor. Resolution of the laser displacement meter is about 0.024mm for vertical direction, and about 0.1mm for horizontal direction. The stepping motor moves at 0.2mm intervals. We obtained the vertical displacement of the granular target caused by the impact by subtracting the topography of the target before and after the impact. We defined the maximum vertical displacement as the crater depth, the length of the crater in the dip direction projected to the horizontal plane as the crater length, and the width in the strike direction as crater width.

We find that the part of the crater rim disappears when ϑ is larger than about 20○. From studying the images recorded by high speed camera, we find that when ϑ becomes large, the slope above the impact point collapses and this causes the partial disappearance of the rim.

Comparing with the Vestan craters (Jaumann et al., 2012), we find that both laboratory and Vestan craters have common asymmetric shape with ejecta spreading down slope and the location of the maximum depth also shifted towards downslope. We find that the crater depth decreases with ϑ . On the other hand, crater length and crater width remains unchanged from 0○to 22○and increased when ϑ was larger than 22○. As a result, the depth / length ratio decreased from 0.25 to 0.05 with the increase of ϑ.

We also analyzed the impact energy dependence of the crater scales and fit them by a power law relation AE $\wedge$ α. We find that with the increase of ϑ, both the prefactor A, and the exponent α changes. This shows that the scaling law obtained for the horizontal granular target cannot be directly applied to impacts on slopes.

References:

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