High velocity cratering experiments on sand-gypsum targets simulating asteroids

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A lot of impact craters are found on asteroids. To clarify the impact cratering processes on asteroids, many researchers conducted impact cratering experiments using various materials such as sand, ice, and basalt. Housen and Holsapple (2011) proposed crater scaling laws and it enable us to extrapolate experimental results to asteroid impact results on the surface. They referred rocky materials having the compressive strength larger than several MPa to constructed the crater scaling laws, but it is unclear whether these scaling laws can be applied to porous materials having low strength or not. Therefore, we conducted impact cratering experiments in order to study the cratering processes on porous rocky asteroids with low strength and the effects of the strength on the crater size and the ejecta velocity. Then, we propose the crater scaling laws applicable to low strength porous materials.

A low strength target was made by mixing quart sands with the diameter of 100 μm with porous gypsum. The mixing ratio of sand to gypsum was changed from 2:1 to 30:1 in the wt.%, and the measured tensile strength was found to change with this mixing ratio. Impact experiments were conducted by using a two-stage light gas gun, and an Al spherical projectile with the size of 2mm was launched at the velocity of 2, 4 and 6km/s. The impact-cratering process was observed by using a high-speed video camera at the framing speed of 10^5fps. Furthermore, we set a 1cm-slit on the target surface to observe 2-dimensional ejecta flow: the slit can exclude most of the ejecta covering through the line of sight of the high-speed camera. This 2-dimensional ejecta observation gave us an accurate relationship between the initial position and the velocity of ejecta fragments.

The tensile strength of the porous mixed sample was measured by a Brazilian test and we found that the tensile strength was changed in the three orders of magnitude from 1MPa to 1kPa with the increase of the sand volume content from 30 to 50%.

The morphology of the recovered crater was characterized by two regions: they are a spall region and a pit region. The spall region looks rough circle but actually it has a polygonal shape with a shallow depth, and it is formed by tensile wave reflected from the surface. The pit region exists at the center of the crater and it has a semi-spherical shape with the diameter rather smaller than the spall region. This spherical region could be formed by the compressive wave and the shear failure was expected in this region. The spall diameter was found to increase with the decrease of the target tensile strength, however the crater depth, which is defined as the depth from the initial surface to the pit floor, showed constant, irrespective of the tensile strength. Moreover, it is very difficult to recognize features characterizing a pit and a spall region in the crater interior for the low strength target as low as 1kPa.

We constructed a crater size scaling law on the strength regime by using our results and compared it to the previous studies obtained for a high strength material. Then, the obtained scaling law for a weak target was written by , where $\pi_R$is the scaled crater radius and $\pi_Y$is the scaled strength in the conventional scaling laws. We found that our $\pi_R$was smaller than the $\pi_R$of frozen sand but larger than the $\pi_R$of porous gypsum. We also constructed the crater scaling law for the crater depth, and it was written by , where π_d is the scaled crater depth, and then it is obvious that $\pi_d$was almost constant, irrespective of the tensile strength. The reason why our π_R is smaller than the result of frozen sand is considered to be due to the impact energy being consumed by collapsing tiny porous in the gypsum in the target.

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