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Morphologies of impact craters formed on spherical gypsum

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1, Introduction

Impact cratering processes on small bodies are expected to be different from those on large planets because small bodies possess unique properties which affect impact cratering processes, such as high porosity (e.g., Britt et al., 2002), low gravity, small impact velocity (e.g., Bottke et al., 1994; Marchi et al., 2013), and irregular surface against crater size (Sullivan et al., 2002).

Many craters on irregular surfaces are observed on asteroids, such as Ida, Eros, and Itokawa, through the recent planetary exploration missions.

Fujiwara et al. (1993, 2014) produced distinctive-shaped impact craters on spheres and cylinders with a wide range of its radius in a laboratory, and presented the empirical relations between crater diameters/depths and the target curvature. In this study, we present the results of a series of impact experiments using spherical targets. The crater profiles on the spherical surfaces were measured with a higher accuracy than those obtained in the previous studies. Then, we propose a physical mechanism how the target curvature affects the crater volumes.

2, Experiments

Impact experiments were performed by using a two-stage light-gas gun at the facility of ISAS/JAXA. The two types of gypsum targets were used. One is a cube with ˜9 cm on a side, and the others are spheres with 7.8 cm, 10.9 cm, 17.0 cm, and 24.8 cm in diameter. The bulk density and tensile strength of the target was 1.05 g/cm^3 and 2.03 MPa, respectively. A projectile was a nylon sphere with 3.2 mm in diameter, and impacted into the target at ˜3.3 km/s. The targets were placed in a box made of styrofoam, and the box was placed in a vacuum chamber. After each shot, the target and their fragments were collected from the box. Then, the spherical surface including a resultant crater was scanned by a high resolution 3-D geometry measurements system (COMS MAP-3D). The volume of the crater was measured with the deviation from the spherical surface which determined by using the topographic data around the crater.

In addition, we used the iSALE shock physics code (Amsden et al., 1980; Ivanov et al., 1997; Wunnemann et al., 2006), to investigate the effects of target curvature on the pressure distribution in the target..

3, Results and discussion

The resultant craters consist of a centered pit and a spall zone which encompasses the pit. A larger target curvature led to a broader the spall zone. The volume and the diameter of the crater increase as the target curvature increases, although the depth of the crater is almost constant. The volume of the crater formed on the 7.8-cm spherical gypsum, which has the largest curvature, is 3.5 times larger than those formed on the cubed gypsum, while the pit volume of the crater on the 7.8-cm spherical gypsum is 1.8 times larger than those on the cubed gypsum. Crater profiles also show the spall zone becomes broader and deeper as the target curvature increases. The volume increase in the spall zone mainly contributes to the volume increase of the crater.

The distribution of the peak shock pressure in the targets is calculated by using the iSALE in a two-dimensional cylindrical coordinate. The attenuation behavior of an impact-generated shockwave should be controlled by the interaction between the shockwave and a rarefaction wave from the spherical surface. Since the geometry of free surface changes with the target curvature, the pressure distribution is likely to depend on the target curvature. Base on the results of such 2-D calculations, we found that a larger target curvature leads to a wider spallation zone produced by a pressure gradient from the deep interior to the spherical surface. This trend is qualitatively consistent with the experimental results.

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Keywords: impact craters, impact experiments, gypsum, curved surface, morphology, two-stage light-gas gun