High-velocity impact cratering experiments on snow simulating porous icy bodies: Effect of impact melting on crater size scaling law

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On porous icy satellites and cometary nuclei, large impact craters with the diameter comparable to 1/3 of the body are observed. Large impact craters are formed by the impact compression in porous materials. The bodies in the outer solar system collide with each other at the impact velocity larger than 1 km/s [Zahnle et al., 2003]. In such a high-velocity collision, the impact point and the surrounding areas can be effectively compressed and heated, and the impact melting layer can be formed on the bottom of the impact crater. The degree of impact melting is very sensitive to the impact velocity, and it also depends on the material property of impactor and target, and the porosity and the sintering duration of target. The existence of impact melting layer might affect the crater size scaling law, so it' s important for the crater chronology on porous icy bodies to study the impact melting layer. In this study, we carried out high-velocity impact cratering experiments on snow and examined the effect of impact melting on the crater size scaling law.

The snow targets were prepared by compaction of ice particles smaller than several tens of mm. Ice particles were poured into the container and compressed to control the porosity. The porosity was 50 or 60%. The sintering duration changed from 2 to 6 days. Two types of projectile, an aluminum sphere with the diameter of 2 mm and a polycarbonate sphere with the diameter of 4.7 mm, were launched from two-stage light gas gun installed in Kobe University. The impact velocity was 0.9 km/s for polycarbonate projectile, and it changed from 2 to 4 km/s for aluminum projectile. The target was set in the vacuum chamber at -15 ºC evacuated below about 150 Pa. The collisional disruption was observed using a high-speed digital video camera with the frame rate of 10^5 fps and the shutter speed of 380 ns. After the shot, the target was cut using the band-saw to measure the crater diameter and depth and to observe the impact melting layer.

Just after the impact, the snow particles were ejected from the impact point to make the cone-shaped envelope. As the time passed, the shape of the neck of ejecta envelope changed from cone to pillar. The pillar-shaped ejecta envelope has not been observed on snow so far [e.g., Arakawa & Yasui, 2011]. After the pillar-shaped ejecta envelope was observed, some large spall fragments were ejected. The number of spall fragments for 50%-porosity target was larger.

Next, we observed the shape of impact crater. On the target surface, the shallow spalling area was observed. This spalling area had the irregular shape such as circle, ellipse, and rectangle. The circular pit entrance was observed at the center of the bottom of spalling area. From the cross section of impact crater, it was found that the width of the pit entrance was narrow and the pit bulged from the entrance. On the bottom of pit, the long and narrow hole formed by the projectile penetration was observed. The intact polycarbonate projectile was recovered from the bottom of penetration hole while the aluminum projectile was destructed and a part of the projectile was recovered. The impact melting layer was observed on the wall of pit and around the projectile at the impact energy larger than 40 J. Furthermore, in the case of 50%-porosity target, the compaction layer with the thickness of 1-2 mm was observed outside the impact melting layer.

Finally, we examined the relationship between the impact energy and the maximum spalling diameter, *D*s, or the pit diameter, *D*p. The *D*s for 50%-porosity target was larger than that for 60%-porosity target: the *D*s for 50% was 48 mm, 1.4 times larger than that for 60% at 100 J. On the other hand, the *D*p for 60% was larger than that for 50%: the *D*p for 60% was 20 mm, 1.6 times larger than that for 50% at 100 J.

[References] Zahnle et al. (2003), Icarus 163, 263; Arakawa & Yasui (2011), Icarus 216, 1.

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