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Experimental study on penetration and sticking of snow projectiles on sintered snowball

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[Introduction] Icy planetesimals could be formed by collisional growth of ice dust aggregates, thus they would have an initial porosity larger than 90% [e.g., 1,2]. Since icy planetesimals are supposed to be the size of ˜10km, so they would have small self-gravity to cause the difficulty for re-accumulation of the fragments ejected by collisional disruption among planetesimals. Highly porous bodies such as a planetesimal would dissipate impact energy through the compression of the pores and this process allows them to stick each other. When the two bodies collide each other in sufficient different size, they could stick easily as the smaller body could penetrate into the larger body [3]. Therefore, it is expected that the initial growth of icy planetesimals is expected to be driven by direct sticking among them. In this study, we examined the impact conditions for the collisional sticking and the impact disruption of porous icy bodies; the dependencies on the porosity and the mass ratio of the projectile to the target were studied.

[Method] All impact experiments were carried out in a cold room at the temperature of -15^{o}C in Institute of Low Temperature Science, Hokkaido University. Snow targets were made of ice particles with the average size of several 10s um, which were prepared by spraying tiny water droplets into liquid nitrogen reservoir. These ice particles were put into a spherical mold with a constant volume, and it was gently compressed with the maximum pressure of 1 MPa. After the compression, the target was removed from the mold and it was kept in a plastic bag in order to sinter them at - 15^{o}C. All the targets had diameters of 60 mm and a porosity of 40 to 70 % (mass of 62.4 - 31.1 g), and they were sintered from 1 hour to 1 month. The projectiles were cylindrical snow with the diameter of 10 mm and the porosity of 30 % (mass of 0.35 g) sintered in 1 day at -15^{o}C. We used three methods in order to accelerate a projectile; free fall (impact velocity of 2 - 3 m/s), spring gun (10 - 20 m/s) and He gas gun (30 - 200 m/s). The projectile was launched onto the center of the target (head on collision). The impact phenomenon was recorded by using a high-speed digital video camera with the recording rate from 1,000 - 5,000 flames per seconds and the shutter speed of 20 us. After the impact, the mass distribution of recovered fragments was measured and the velocity distribution of the fragments was also measured. Additionally, the crater profile of the target was measured by using a laser displacement when we observed the sticking.

[Result] We classified the collisional types into 5 types according to the largest fragment mass normalized by the original target mass (ml/Mt) and the antipodal fragment velocity (Va); they are rebound of the projectile (ml/Mt ˜ 1), sticking of projectile (ml/Mt $>$ 1), cratering (1 $<$ ml/Mt $<$ 0.5), catastrophic disruption (ml/Mt $<$ 0.5), catastrophic disruption with penetration of the projectile (ml/Mt $<$ 0.5 and Va $>>$ Vg). As a result, it was found that sticking of projectile occurs at the target porosity larger than 60% and at the sticking velocity from 40 to 90 m/s for the porosity of 60% and from 15 to 70 m/s for the porosity of 70%. The depth of a crater hole formed by sticking of projectile was measured to find that the penetration depth was nearly proportional to the impact velocity and that the depth formed on the target with the porosity of 70% was 5 times deeper than that of 60% target at the same velocity. The penetration depth derived at the impact condition of Q$*$ was 1/6 of the target length for 60% and 1/2 of the target length for 70%.

[1] Wurm and Blum (1998), Icarus 132, 125-136. [2] Wada et al. (2009) APJ 702, 1490-1501. [3] Wada et al. (2010) Clarification of collision physics of planetary bodies (VI)

Keywords: impact experiment, icy planetesimal, porosity, sticking, penetration