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Hypervelocity cratering experiments on ice-silicate mixture targets

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Introduction: It is well known that ice-rock mixtures could be a main component of icy satellites, and the crust of asteroid Ceres. Especially, Dawn space craft of NASA will arrive at Ceres in March 2015 and several types of remote sensing will be carried out. Ceres is a member of main asteroid family, so the icy crust could be impacted by various asteroids with different components and physical properties. Therefore, we should obtain various information from the investigation of the observed crater morphologies such as material properties of impacted asteroids and the internal structures of the icy crust and more. To do these investigation, the laboratory experiments would be necessary. Impact experiments on ice-rock mixtures have been conducted systematically by changing the impact velocity from 0.1 to 7km/s and by using the projectile with different densities. However, the cratering experiments on ice-rock mixtures were quite limited at the rock contents below 50wt.%. When we apply our results to the crater on Ceres, the results are not enough to discuss the crater morphology right now. Therefore, we made cratering experiments on ice-rock mixtures with the rock content higher than 80wt.%, and the several types of the projectile were used to compare the results with the previous works.

Experimental method: Impact experiments were conducted by using a two-stage light gas gun at Kobe University. We prepared the targets of ice-rock mixtures simulating the Ceres icy crust. The target consisted of water ice and quartz sand having a particle size of about 100 and 500μm, and the water content was from 20 (porosity=0%) to 2.5wt%(porosity=42%). The ice-sand mixture was made in a cylindrical metal container with the height of 5 to 10cm and the diameter of 15cm. The water-sand mixture was frozen in a freezer with the temperature from -23 ℃ to -15 ℃. Spherical projectiles were used and their diameter were 2mm (aluminium, zirconium, titanium, copper, stainless steel), 1mm (alminium, titanium, stainless steel). We launched a projectile at 1.5 ~7.0km/s with a nylon sabot, and the sabot was separated from the projectile before the impact. A target was set in a vacuum chamber just before the impact, and to prevent the target from melting, the chamber was evacuated for thermal insulation. The air pressure in the chamber during the experiments was kept in the range of 150 ~230Pa. A crater formation process was observed by high-speed video cameras. The crater shape formed on the recovered target was measured by a caliper and a laser displacement meter.

Results: In the case of a non-porous target with 20wt.% water content, we found a conical hole called as ‘Pit’ at the collision point and a shallow trace called as ‘Spall’ around the pit. Hiraoka et al. 2004 investigated how the spall diameter depended on the rock content of targets, and reported the results below 50wt.% of the rock content: the spall diameter decreased with the increase of the rock content. However, our result for the rock content of 80wt.% (water content 20wt.%) showed that the spall diameter was almost the same as that obtained for the rock content of 50wt.%. Then, we found the spall diameter could be constant between 50wt.% and 80wt%. The pit diameter linearly increased with the decrease of the water content between 20wt.% (porosity=0%) and 2.5wt.% (porosity=42%). This might be caused by the target strength decreasing with the increase of the target porosity. The ratio of the pit depth, H, to the pit diameter, d, (H/d) was found to decrease with the decrease of the water content from 20wt.% (porosity=0%) to 2.5wt.% (porosity=42%), and this ratio was clearly small compared with the previous results for pure ice by Burchell and for non-porous ice-rock mixtures by Hiraoka. Then, we might speculate that H/d decreased simply with the decrease of the water content, but we should consider the effect of target porosity in the future.

Keywords: icy body, impacts, experiment, water content, strength regime, cratering