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Impact crater formation on the snow-ice layered structure

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Impact craters are found on every solid bodies in the solar system, and they are formed by high speed impacts of small bodies. The study on the crater scaling law has been conducted to estimate the formation condition of these craters, so the cratering experiments have been made for the various materials to refine the scaling law. The icy bodies which exist usually in the outer solar system have a wide variety of the size and the density, and the icy bodies with the middle and the large sizes could be covered with the snow regolith on the icy crust. In this two layer structure, the crater size and the formation condition of the crater on the icy crust could be affected by the regolith layer. However, there are no cratering experiments on two layer structure made of snow and ice although most of the experiments were made for the homogeneous rock and ice or the basalt block covered with rocky regolith. In this study, we tried to clarify the effect of the snow regolith layer on the crater formed on the ice layer. Moreover, the particle velocity of snow layer should be determined to estimate the crater size formed on the ice block. Then, the snow plate simulating the regolith layer was used to measure the particle velocity and it was used to refine the scaling law applicable to the layered structure on the icy bodies.

Impact experiments were made by using a vertical gas gun set in a cold room at -10 degree. The cylindrical projectile was launched at 300 and 450m/s and made of ice and polycarbonate. The mass of ice and polycarbonate is 1.60g and 1.68g, respectively. The ice target was a rectangular ice block with the mass of 8kg. The ice block was covered with a snow layer which was made of ice particles with the size less than 710 microns and the snow thickness was from 5 to 30mm. After the impact, the crater formed on the ice block was measured to describe the diameter, the volume and the depth. In the case of the measurements of particle velocity for snow plates, the snow plate thickness was changed from 10 to 40mm and they were impacted by an ice and a polycarbonate projectile. A high speed digital video camera was used to record the ejection of the snow particles with the frame rate of 2x10^4 to 5x10^3.

We found that the antipodal velocity of the snow plate decreased with the increase of the plate thickness at the constant impact velocity. Moreover, the decay rate of the particle velocity for ice projectile was found to be larger than that for polycarbonate projectile. The ice projectile was completely disrupted at the moment of impact but the polycarbonate projectile was observed to be intact through the snow plate, so that it was recovered without disruption. The relationship between the antipodal velocity of v_e and the plate thickness (t) was obtained to be v_e=a t/d^{-b}, where d is the thickness of the projectile 10mm.

In the case of the cratering experiments, we compared the crater size formed on the ice block for ice projectile with that for polycarbonate projectile and noticed that the crater formed by ice projectile was always smaller than that formed by the polycarbonate projectile at the constant impact velocity. The crater size decreases with the increase of the thickness of the snow plate for each projectile and each relationship was empirically determined. This relationship was theoretically related to the particle velocity of snow plate at the boundary between snow plate and ice block. This theory was proposed in Dohi et al. (2012), in which the crater scaling law was extended to the two layer target. We applied their modified scaling parameter Pi$*$ to our results and obtained the following relationship between the crater volume and the Pi$*_Y$, Pi$_v$=2.05x10^{-9}Pi$_Y*^{-2.6}$.

Dohi, K., Arakawa, M., Okamoto, C., Hasegawa, S. and Yasui, M. (2012) The effect of a thin weak layer covering a basalt block on the impact cratering process, Icarus, 218, 751-759.

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