Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PPS21-P08 Room:Convention Hall Time:May 20 18:15-19:30

Impact experiments on a granular layer: an implication for crater scaling laws and the artificial Hayabusa 2 SCI crater

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Introduction : Regolith formation and surface evolution on asteroid are caused by high velocity impacts of small bodies. The ejecta velocity distribution is one of the most important physical properties related to the crater formation and it is necessary to reconstruct the planetary accretion process among planetesimals. The surface of small bodies in the solar system has a various property on the porosity, strength and density. Therefore, the impact experiment on the target with the various properties is necessary to clarify the crater formation process applicable to the small bodies in the solar system. These results obtained from the target with the wide range of condition could help us to speculate the physical properties of the asteroid surface from the artificial impact crater made by Hayabusa 2-SCI. We would try to determine the surface strength and the porosity by means of the observation of the ejecta shape and the velocity distribution.

Experimental method: The cratering experiment was made by using a vertical type one-stage light gas gun (V-LGG) set at Kobe Univ. We newly developed a special sabot-stopper system to exclude the disturbance of accelerating gas from the growing ejecta curtain. We used 4 types of targets: that is, they are the 100micron-glass beads target (porosity 37.6%), the 500 micron-glass beads target (porosity 37.6%), the 1~3mm granular pearlite (porosity 96.7%) and the crushed pearlite with the size of a few 100 microns (porosity 84.9-88.4%). There granular materials were put into the stainless steel container with the diameter of 30cm and the depth of 11cm. The target container was set in a large chamber with the air pressure less than 10^3 Pa or 10^5Pa. The material of the projectile that we used was an iron, a zirconia, an alumina, a glass, and a nylon, and it had a diameter of 3mm (2r0) and was launched at the impact velocity (vi) of 25 to 217m/s.

We made an impact experiment using an alumina sphere projectile on the 500-micron granular target and observed each glass bead by using a high speed digital video camera (nac memrecam HX-3) taken at 10^4 FPS. Then, we measured the ejection velocity and the initial position of each bead. We successfully obtained the relationship between the initial ejection velocity and the initial position for the bead ejecta. We also made the impact experiments on the 100-micorn glass beads target and the pearlite target using various type of the projectile at a constant velocity of 100 and 200 m/s, and observed the crater size and the shape of ejecta curtain, especially for the ejecta angle.

Result: We found that the ejecting velocity of the glass bead for the 500-micron target decreased with increasing the distance from the impact point. The obtained empirical equation between the ejection velocity and the initial position is as follows, ve/vi=0.66(x0/r0)$^{-1.6}$, where ve is an ejection velocity of glass beads, x0 is the initial position of ejecting beads. The ejection angle of the beads is found to be almost a constant of 40 degree irrespective of the initial position. The crater size for the 100-micorn target increased with the projectile density at the constant impact velocity and it was analyzed by using a crater scaling law to derive an empirical parameter characterizing the granular target. The relationship between the normalized crater size and the impact condition was written by [R*(rho$_t$/m)^(1/3)]/[(rho$_t$/rho$_p$)$^{0.03}$]=1.9*[gr/(vi^2)]$^{-0.17}$, where R is the radius of a final crater, rho$_t$ is the density of the target, rho$_p$ is the density of the projectile, m is the projectile mass, and g is the acceleration of gravity. From this obtained equation for the crater scaling law, we determined two key parameters of the coupling parameter (C=r vi^{mu} rho^{nu}): they are mu=0.40,nu=0.36. In the case of the crushed pearlite target, we found that the crater type changed from an incompressive type to a compressive type at the porosity from 83 to 88%.