Crater scaling laws of ejecta velocity distribution and crater size constructed for very low strength target

Ryo Sugimura[1], *Masahiko Arakawa[1], Minami Yasui[1], Hiroki Senshu[2], Sunao Hasegawa[3]

1. Graduate School of Science, Kobe University, 2. Planetary Exploration Research Center, Chiba Institute of Technology, 3. Japan Aerospace Exploration Agency

Impact craters are very common geological feature on solid bodies, and the size-frequency distribution of these craters are used to determine the surface age of various solid bodies such as asteroids and satellites according to the crater chronology. The crater size scaling law, which can allow us to predict the crater size from the impact condition such as an impact velocity, an impactor size and density, a target density etc., is necessary to apply the crater chronology for each solid body. The crater size scaling law depends on the crater formation mechanisms; they are controlled by a surface gravity or a surface strength. Then, we need to use an appropriate crater size scaling law suitable for each solid body.
In general, the surface gravity of small bodies is too small to control the crater size so that the surface strength is a dominant mechanism to control the crater size. Although the surface strength of small rubble-pile bodies is estimated to be kPa order, the kPa order strength is enough large to control the crater size on small bodies. However, there are no systematic cratering experiments in low strength material to construct the crater scaling law applicable for small rubble-pile bodies. Thus, we made impact cratering experiments on very low strength targets changing from 400 Pa to 800 kPa to construct the crater scaling laws for the size and the ejecta velocity distribution.
Impact experiments were conducted by using a two-stage light gas-gun set at Kobe University and JAXA. A spherical Al-projectile with the diameter of 2mm was launched at 2, 4, 6 km/s. The targets were made of the mixture of quartz sand and porous gypsum changing the contents from 1 to 23 vol.%, and the target shape was cylinder with the dimeter of 25 cm and the height of 10 cm. The crater formation process was observed by a high-speed camera with the frame rate of 10^5FPS, and the slit with the width of 1 cm covered the target surface to observe the ejecta curtain in 2-dimension.
The crater spall radius, *R*, was found to increase with the decrease of the target tensile strength, *Y*, and the results are well described by the π-scaling theory in the strength regime as follows: $\pi_R=0.82\ \pi_Y^{-0.18}$.
The ejecta curtain was observed to be a Y-shape at the initial stage of the ejecta curtain growth, then the curtain shape changed to the pillar-like shape at the later stage. The ejecta particles composed of the Y-shape curtain were measured in the high-speed images to determine each trajectory, and then each initial position and velocity was calculated to construct the eject velocity scaling law. The relationship between the initial position (x) and the ejection velocity was well scaled by the specific velocity (v^*) derived from the target density and strength, $v^*=(Y/\rho)^{1/2}$, and the crater spall radius as follow, $v^*/v=0.64(x/R)^{-4.0}$. We found that the ejection angle of impact fragments became higher with approaching the crater wall, and this ejection angle change with the distance from the impact point could originate the Y-shape ejecta curtain observed only in the strength regime. This characteristic feature of the Y-shape curtain cannot be explained by Maxwell Z-model applicable for sand-like incompressible material. Then, we proposed a modified Z-model considering a rigid boundary with the crater shape, and this model can reconstruct the Y-shape curtain.

Keywords: Impact crater, Crater scaling law, Ejecta curtain

