

## Three-dimensional tracking of ejecta particle: Effects of boulder size on ejecta velocity distribution

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The ejection process during the crater formation is important to consider the resurfacing process on solid bodies, so there are many studies related to the ejection process. Many of them were based on the experimental results for the targets composed of homogeneous sized regolith particles and they did not include the effect of the target particle size. However, recent asteroid explorations revealed that the boulders on the asteroid surface had a size frequency distribution in a wide range of the boulder size. The impact cratering experiment by Hayabusa2 spacecraft, which actually observed the crater formation process on the asteroid surface by DCAM3, resulted in the formation of the asymmetric and heterogeneous ejecta curtain. In this study, we carried out impact cratering experiments on granular particles with various sizes to investigate the ejecta velocity distribution, and we then discussed the effect of the ejecta particle size on the  $\pi$ -scaling law for ejecta velocity distribution. Moreover, we estimated the maximum size of the boulder which could be ejected out of the final crater.

Impact experiments were conducted by using a one-stage vertical gas gun at Kobe Univ., and a two-stage vertical gas gun at ISAS. We used glass beads with the median grain diameter of about 100  $\mu\text{m}$ , as a target. In order to obtain the three-dimensional trajectory of the ejected beads, we recorded the ejection process by two synchronized high-speed cameras with a framing rate of 2000 to 10000 fps. We set the tracer beads with the size of 3–30 mm on the target surface before the shot and tracked them each image. Their traces in the three-dimensional coordinate system were determined based on the calibration.

We found the difference of the ejection process depending on the size and the buried volume of the tracer bead. First, we studied the ejecta velocity distribution which is defined as the relationship between the ejection velocity and the initial position of ejecta particle, which is the distance between the impact point and the center of the tracer bead, and found that the ejection velocity of the larger tracer bead was slower than that of the smaller one. We then rescaled it by using another initial position which is the distance between the impact point and the outside edge of the tracer bead. As a result, the size dependence of the tracer bead was almost disappeared, so that the redefined initial position enabled us to refine the ejecta velocity scaling law for large tracer beads.

The refined scaling law was theoretically analyzed by using the Z-model. Since the ejection velocity varied with the initial position according to the Z-model, the large tracer bead on the target surface could be pushed by target beads with the velocity depending on the initial position: A tracer bead was pushed at the inner edge by higher velocity than that at the outer edge. Thus, we assume that the ejection velocity of a large tracer bead could be roughly calculated as the average velocity of the target beads excavated from the area of a large tracer bead. More detail analysis showed us that the twice of the diameter of the tracer bead centered at the outer edge could be most suitable area for calculating the average ejection velocity applicable to large tracer beads.

Next, we investigated the effect of the buried volume of the large tracer bead on the ejection process. We found that the buried volume was larger as the ejection velocity was higher while the volume buried was larger as the moved distance was smaller. Finally, we applied our refined scaling law for the ejecta velocity distribution and calculated the maximum size of the boulder which can be ejected outside the final crater. As a result, we found that the boulders with the radius larger than 0.3 times the crater radius could not be ejected outside the final crater.

キーワード：クレーター形成過程、エジェクタ速度分布、クレータースケール則、小惑星、岩塊、サイズ頻度分布

Keywords: cratering, ejecta velocity distribution, crater scaling law, asteroids, boulders, size frequency distribution