Three-dimensional tracking of various sized glass beads ejected from crater formed by high-velocity impact

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Impact cratering has been recognized to be a general phenomenon occurring during the formation and evolution of solar system bodies. During crater formation, impact ejecta deposits on the surface around the crater, so it is important to consider the resurfacing process of solid bodies. Many researchers studied the velocity distribution of impact ejecta and the velocity distribution is well described by the π-scaling theory [1]. We can apply this scaling law for homogeneous targets, but recent asteroid explorations revealed that the boulders on the asteroid surface had a wide size frequency distribution [2][3], so this size frequency distribution might affect the scaling laws. Previous cratering experiments using a uniform-sized granular targets showed that an axisymmetric cone-like ejecta curtains were observed. On the other hand, Kadono et al. [4] observed non-axisymmetric and non-uniform ejecta curtain for targets with non-uniform particle sizes. They proposed that the formation mechanism of a non-uniform ejecta curtain might be related to the ejecta velocity distribution depending on the particle size. In this study, we carried out impact cratering experiments using granular targets with a particle size distribution, and established a three-dimensional particle tracking method for various sized ejected particles in order to examine the effects of the particle size on the ejecta velocity distribution.

Impact experiments were conducted by using a one-stage vertical gas gun at Kobe Univ., and a two-stage vertical gas gun at ISAS. Targets were glass beads with the size of 0.1, 1, 3, and 10 mm; they mixed evenly with an equal mass. We used 3-mm-sized spherical projectiles made of nylon, glass, alumina, titanium, zirconia, and iron at Kobe. The impact velocity ranged from 129 to 208 m/s. At ISAS, we used 1-mm-sized spherical projectiles made of aluminum, titanium, iron, and copper. The impact velocity ranged from 1.2 to 4.4 km/s. We used two synchronized high-speed cameras with a framing rate of 2000 to 10000 fps in order to obtain the three-dimensional trajectory of ejected beads.

The observational procedure is described as follows. First, we recorded a rectangular parallelepiped reference (30 cm ×30 cm ×40 cm) by two cameras to determine the spatial coordinate of the bead in the chamber. Next, we conducted impact experiment without a reference and recorded the ejecta curtain by synchronized two cameras. In order to identify each bead on their images, 6-8 colored glass beads (3, 5, 10, 18mm in the diameter) were set on the target surface near an impact point before the shot. Finally, we tracked the colored beads on each image, then obtained each bead position in the three-dimensional coordinate system based on the reference.

In this study, non-axisymmetric and non-uniform ejecta curtain was observed for all shots. And we succeeded to obtain three-dimensional trajectories of ejected beads by using the above method. The analyzed beads moved at a constant velocity in the horizontal direction, while they were accelerated in a vertical direction by the earth’s gravity (~10 m/s^2), showing a parabola trajectory. Our data was scattered slightly, but they could be approximate by the π-scaling theory. The ejection velocity distributions were divided into two trends which the one was twice larger than the other at same initial position. We should clarify this cause in the future. Besides, we did not observe the effects of bead size on the velocity distribution. Most beads were ejected radially from the impact point regardless of bead size while a part of them were ejected in different directions. This large angle deviation might be caused by the collision with larger beads before or after being ejected from the target surface.

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