Experimental study of high-velocity impacts into granular material in reduced gravity

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The surfaces of small bodies are in a microgravity environment. Therefore, it is important to understand how gravity affects crater size to estimate physical properties of the surface. Several studies have investigated the effect of gravity on crater size for low-velocity to high-velocity (1 m s^{-1} to 6.6 km s^{-1}) impacts: the gravitational dependence of crater size was obtained in the low- and high-gravity range (Gault & Wedekind, 1977; Schmidt & Housen, 1987; Cintala et al., 1989; Takagi et al., 2007; Kiuchi et al., 2019). It was shown that the crater diameter was proportional to -0.165 ~ -0.19 power of the gravitational acceleration except for the one conducted using drop tower and showed that the crater diameter formed under microgravity was not different from the one formed under 1 G (Takagi et al., 2007) . The difference in the results of previous studies is not understood because the number of available laboratory data is limited. On the other hand, collisions between planetary bodies generally occur at high-velocities ranging from several kilometers per second to several tens of kilometers per second. However, there are few experimental examples in high-velocity regions over several kilometers per second in reduced gravities. A drop tower or a parabolic flight are generally used for microgravity experiments, however, it is difficult to conduct impact experiments at a velocity of several kilometers per second in these experimental facility.
In this study, we developed a drop system to conduct high-velocity impact experiments in reduced gravity. By assembling a simple drop tower in the vacuum chamber of a two-stage light-gas gun at the Japan Aerospace Exploration Agency (JAXA), low gravity experiments at the impact velocity of several kilometers per second can be realized. The drop system is consists of ball bearings and two rails for dropping a target container smoothly. The top of the container was fixed near the ceiling of a chamber with a height of 2 m by electromagnets, and the container is dropped by turning off electromagnets. The acceleration values are measured by an accelerometer placed at the bottom of the container. When the container filled with 12 kg of sand was dropped under vacuum condition, simulated gravity on the container was obtained in the range of 0.06 - 0.07 G. The falling time of the container was about 0.4 s in these condition.
In addition, we conducted high-velocity impact experiments. The ambient pressure was 100 Pa. While the container was falling, a projectile was fired by the two-stage light-gas gun. The crater formation process was observed with a high-speed video camera installed outside the vacuum chamber. We used quarts sand of representative diameter 425 μm as the target material, and used a polycarbonate sphere of diameter 4.76 mm as the projectile. A polycarbonate sphere is 1.2 g cm^{-3} in density. The target material was loosely filled in a stainless steel container with a diameter of 30 cm and a height of 10 cm. A projectile was impacted at a velocity of 1.2 km s^{-1}. As a result, the diameters of craters formed at 0.06$\pm$0.03 G was about 1.8 times larger than the one formed at 1 G. Gravitational dependence of the crater diameter was clearly observed. We organized the results using pi-scaling (e.g., Holsapple, 1994) and found that our results in reduced gravity agreed well with the crater size scaling law for the sand targets (Housen and Holsapple, 2011). Note that diameters of craters formed in reduced gravity shows the lower limit of the final crater diameter because the crater formation may not have been completed before the container dropped. In the presentation, we will discuss the crater formation time and introduce the additional impact experimental results.

Keywords: Impact ctater, High-velocity impact experiments, Low gravity

