High-velocity impact experiments in reduced gravity: The effect of cohesive strength of particle layers

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The surfaces of small bodies are in a microgravity environment, and it is important to understand how gravity affects crater size to estimate the 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). In most of the studies, the crater diameter was shown to be proportional to −0.165 ~ −0.19 power of the gravitational acceleration. However, in a microgravity environment such as the surface of small bodies, the effect of the cohesive strength of the regolith layer on crater formation may be more dominant than the effect of the gravity. The transition condition between the gravity regime and the strength regime is not well understood because the available laboratory data is limited.

We assembled a simple drop tower in the vacuum chamber of a two stage light gas gun at the Japan Aerospace Exploration Agency (JAXA) to conduct high velocity impact experiments in reduced gravity. We used quartz sand (particle size is ~425 μm) as the target material, and used a glass sphere of diameter 1 mm as the projectile. 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 0.05 G was about 1.8 times larger than the one formed at 1 G and gravitational dependence of the crater diameter was clearly observed(Kiuchi et al., 2020, JpGU–AGU). We compiled the results using pi-scaling (e.g., Holsapple, 1994) and showed that our results in reduced gravity agreed well with the crater size scaling law for non–cohesive sand targets (Housen and Holsapple, 2011).

In addition, we used targets of fine glass beads (particle size is ~40 μm) and fused alumina particles (particle size is ~40 μm). As a result, the crater diameter formed at 0.05 G was not much different from the one formed at 1 G for both targets. We infer that the gravitational dependence of the crater diameter was reduced due to the effect of the cohesive strength of these targets. We constrained the transition condition between the gravity regime and the strength regime by estimating the tensile strength of the particle layers based on the measured cohesive force of the particles (Nagaashi et al., in press). From our experimental results, it was found that the effect of the target strength becomes dominant when the tensile strength of the particle layer is larger than $10\rho gD$, where ρ is the density of the particle layer, g is the gravitational acceleration, and D is the crater diameter. We will discuss the effect of the cohesive strength on the size frequency distribution of small craters on particle layers.

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