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Direct observation of impact cratering for granular targets

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A scaling relation on impact cratering in gravity regime has been studied for many years, based on explosion and impact experiments for granular targets. However, even for the gravity regime, the crater formation processes may be affected by target material properties. Thus we need to take into account the effects of target material properties on the scaling relation. However, little is known as to how the scaling relation is related to target material properties. In order to investigate this issue, direct observation of transient crater growth is necessary. We thus have developed the laser method to directly observe transient crater growth. In this method, a vertical laser-sheet is used to illuminate a target at the impact site. Under this condition, polycarbonate projectiles, which are accelerated by a single-stage light-gas gun, are impacted vertically into a target. The temporal change of a laser line on the target surface during the transient crater growth can be observed by a high-speed video camera set above the target. Analyzing images taken by the camera, we can obtain the data on the temporal change in diameter and depth of the crater cavity.

In this study, using the laser method, we observed transient crater growth for impacts into glass sphere targets. We first showed that the transient crater collapses owing to gravity, resulting in increase in diameter and decrease in depth. In addition, we found that the increase rate in diameter of the crater cavity during the formation process of transient craters does not follow a simple power-law relation; the data at early times appears to follow a power-law relation, but the data at later times (but before the end of transient crater formation) deviates from the power-law relation. This departure from a power-law relation is different from the previous result observed by the quarter-space technique, in which the increase rate in diameter was shown to follow a simple power-law relation (this is because the previous study focused only on earlier times of the formation process of transient craters). This result indicates that a more rigorous approach to interpreting transient crater growth is required. This approach should not be based on a power-law. We thus propose to modify Maxwell's Z-Model, assuming that the velocity magnitude of the excavation flow decreases exponentially with time. We demonstrated that our new model can represent the diameter growth during the formation process of transient craters. This model can also represent well the diameter growth for various targets (e.g., dry sand target), whose material properties such as porosity and internal friction are different. Based on these results, we discuss the effects of target material properties on the scaling relation.