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Experimental study on the oblique collisional disruption on porous gypsum target

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Introduction

High-velocity impact among small bodies in the solar system could originate asteroidal bodies and EKBOs and so on through collisional disruptions. Then, the collisional disruption is one of the most important physical processes to clarify the formation and evolution of the small solar system bodies. The degree of collisional disruption is quantitatively defined by an impact strength, and it has been studied for various materials, then it is found that it depends on a porosity. Because the shock wave rapidly attenuates in a porous target, so the impact damage is well concentrated near the impact point (Arakawa et al.2009). Recently, many porous asteroids were found by the explorations, then it is important to understand the impact phenomenon for the porous asteroids. Okamoto and Arakawa (2009) conducted high-velocity impact experiments on porous gypsum targets, but they carried out them only for a head-on impact. However, oblique impacts would be dominant in the collisions among solar system bodies. Therefore, we conducted high-velocity oblique impacts for porous targets and examined the effect of impact angles on the collisional disruption.

Experimental method

The impact cratering experiments were conducted by using a two-stage light-gas gun at Kobe University. We used a polycarbonate sphere with the diameter of 4.75mm and the density of 1.2g/cm^3 for a projectile. A spherical gypsum target was prepared and it has the diameter of 70mm, the porosity of 61%, the tensile stress of 1.0MPa and the bulk sound speed of 1.19km/s. The impact velocity, V_i, was 4.0km/s and 7.0km/s. The impact angle, θ, was changed from 15 to 90-degree, where the head-on impact was defied as the impact angle 90-degree. The impact fragments during the disruption process were observed by a high-speed video camera to measure the ejection velocity of these fragments. In addition, we recovered impact fragments after the shot and measured the mass of each fragment to construct the mass distribution of these fragments.

Result

In order to study the degree of the collisional disruption quantitatively, we studied the relationship between the mass of the largest fragment normalized by the original target mass (m_l/M_t) and the energy density, $Q_t = 1/2V_i{}^2m_p/M_t$, where m_p, M_t are the mass of the projectile and target respectively. Our result for a head-on collision (θ=90) was almost consistent with a previous study for porous gypsum targets (Okamoto and Arakawa 2009). While, it was surprised that m_l/M_t did not change or was almost constant when the impact angle was changed from 90-degree of a head-on collision to 45-degree of a oblique collision. However, ml/Mt was significantly changed to be almost for θ of 15,30-degree at 4km/s and θ of 15-degree at 7km/s because an impact crater was formed instead of the catastrophic disruption.

In the case of oblique impacts, the kinetic energy effectively used for the impact disruption could be that originated from the normal velocity component of the projectile. Thus, we could calculate the effective energy density defined as $Q_c = 1/2V_i{}^2m_p\sin^2\theta/M_t$ and found that our result at the impact angle θ from 90 to 45-degree was not inconsistent with the previous study (Okamoto and Arakawa 2009). Therefore, the normal velocity component might be important for oblique impacts in these angles. However, Q_c did not work well at the impact angle smaller than 45-degree at 4km/s an 30-degree at 7km/s. This result indicates that not only normal component of the impact velocity but also the tangential component of the impact velocity might affect the impact disruption.

Keywords: collisional disruption, oblique impact, porosity