Experimental study on momentum transfer in high-velocity impact on asteroid

Kazuhiro Horikawa[1], *Masahiko Arakawa[1], Minami Yasui[1], Kei Shirai[1], Sunao Hasegawa[2]

1. Graduate School of Science, Kobe Univ., 2. ISAS, JAXA

Asteroid Impact and Deflection Assessment (AIDA) mission is scheduled by NASA and ESA. This mission is constituted by two separate missions which are DART (Double Asteroid Redirection Test) by NSAS and Hera by ESA. The impactor with the mass of 500 kg will be impacted on the moon of the asteroid Didymos named Dimorphos with the size of 160 m in DART mission, then the deflection of the trajectory of Dimorphos caused by the impact will be detected by astronomical observations to study the effiects of the kinetic impactor on the small asteroid. Especially, the momentum transfer efficiency of the impactor onto the asteroid is the most important parameter to control the asteroid deflection and defined as β-1= P/mv, where m and v are the impactor mass and the velocity, respectively; P is the momentum of ejecta accompanied by the crater formation. The β-1 is strongly dependent on the subsurface mechanical properties [1], so the theoretical and numerical studies have been conducted to obtain β-1 for various subsurface properties of asteroids [1, 2, 3]. These studies give us a chance to elucidate the subsurface properties of Dimorphos by AIDA mission. However, the experimental study is still limited to confirm and improve these theories and the numerical models, then we conducted the high-velocity impact experiments to study β-1 by using the targets with various impact strength simulating small porous asteroids.

The impact experiments were conducted by using a horizontal type two-stage light gas gun at the impact velocity (v) from 0.6 to 3.6 km/s. The projectile was a spherical polycarbonate with the size from 2 to 7 mm. The target was a spherical porous sand-gypsum mixture with the porosity of 40 % and the static tensile strength (Y) from 800 kPa to 100 kPa; the size was from 30 to 90 mm. The target was set in a recovery box and hung from the ceiling by a string. A small crater was formed on the target by the head-on collision and the target was accelerated toward the impact direction, then it swung like a pendulum. The target movement after the impact was observed by a highspeed camera with the framing rate of 10^5 FPS, and the velocity of the center of the mass for the target was measured on these recorded images. The β-1 was found to increase with the impact velocity and it almost proportional to the velocity for 100 and 300 kPa targets; it is proportional to $v^{1.6}$ for 800 kPa targets. The β-1also increased with the decrease of the strength, so the target with the strength of 100 kPa had the largest β-1 value for all targets in this velocity range. According to the previous study [1, 3], the β-1 is scaled by the characteristic velocity (v*) written by $(Y/\rho)^{0.5}$, where ρ is the target density. We then applied this v^* to our results and found that the β-1 for 100 and 300 kPa targets were well merged by using v/v^*, but the β-1 for 800 kPa was slightly higher than that for others. This difference might be caused by the difference of the ejection angle of fragments excavated from the crater. The ejection angle for 800 kPa targets measured from the impact surface was observed to be higher than that of others. Since the velocity component parallel to the impact direction was larger for the ejected material with a high ejection angle, the β-1 for 800 kPa might be larger than others.

[1]Holsapple and Housen, Icarus 221,875–887, 2012. [2]Raducan et al., Icarus 329, 282–295, 2019. [3]Jutzi and Michel, Icarus 229, 247–253, 2014.

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