PPS21-P12 Room:Poster Time:April 29 18:15-19:30

Study on fundamental characteristics of penetration dynamics into icy target

NAMBA, Kazuya[1*] ; SUZUKI, Kojiro[2]

[1]Grad. Sch. Eng., The University of Tokyo, [2]GSFS, The University of Tokyo

A penetrator, which penetrates the surface of a planet, a satellite and so on to investigate the interior by high-speed hard landing, is expected to play an important role in the solar system exploration of the future. Comparing to soft lander, penetrator has advantages of consuming less fuels, enabling us to launch multiple probes at a time because of its low mass, and so on. However, probe must survive hard impact in collision, thus no penetrator missions have been successfully achieved so far. The icy object, such as 24 Themis and Europa, is expected to contain organics which serve as the precursor of life in their subsurface. Therefore, the cryo-penetrator, which penetrates the icy object and investigate specimens of subsurface which have not been contaminated by cosmic rays, should have a high importance. For a penetrator into regolith, a fully-developed flyable penetrator has been successfully developed for the Lunar-A mission, though the mission itself has been cancelled. For icy target, however, the number of studies from the engineering viewpoint is quite limited, for example, the conceptual study on CRAF mission to a comet nucleus (Adams et al., NASA CR-177393, 1986). In this study, we investigated the fundamental properties of the penetration dynamics of the cryo-penetrator, by conducting penetration experiments into the target made from H_2O ice.

Penetration experiments were conducted by using a ballistic range in our laboratory. The projectile is accelerated by the compressed air, launched horizontally and crashed into a target body. Impact speed is set from 100 m/s to 300 m/s. Two types of projectile, a needle-like one (iron, size: ϕ2.45x15mm, mass: 1.71g) and a blunt cone-like one (brass, ϕ8.4x15mm, 2.33g) are used. Three types of target, pure H_2O ice (size: 270x175x130mm, mass: 5.5kg, density: 0.90g/cm^3, porosity: 3%), low purity H_2O ice (150x120x100mm, 1.5kg, 0.75g/cm^3, 19%) and an oil clay (155x120x70mm, 2.2kg, 1.7g/cm^3) are used. A high-speed camera (frame rate: 2200-8800fps, exposure time: 15μs) is used to observe a sequence of events: the free-flight of the projectile, impact, crater formation, penetration, and so on.

We found that the penetration into H_2O ice produces ejecta of icy fragments, which erupt conically immediately after collision, and then produces the jet-like ejecta in the almost perpendicular direction to the surface that continues more than 100 msec. On the other hand, the penetration into clay target produces ejecta outward-conically for duration of a few msec. Moreover, we found that the penetrator tends to be pushed back from the target by the ejecta, since the ice around the projectile has been almost broken into pieces erupting as the ejecta and the penetrator cannot be fixed inside the target without receiving the gripping force from the ice. We also found that eruption was continued even after the projectile has completely bounced from the target. This phenomena is frequently observed when the projectile with a less slender body. In the case of a slender penetrator, however, it is hardly subject to bounce-back. Consequently, a slender shape seems more suitable to the penetrator for icy target. The shape of crater consists of the pit region on the center, the spall region which is a shallow depression on the periphery of the pit, and cracks spread a wide range of target. It is qualitatively consistent with previous researches using bullet shape (e.g. Kato et al., Icarus 113(2) 423-441, 1995., Arakawa, Low Temperature Science 66 113-121, 2008). The pressure at a point of impact is estimated by using the one-dimensional planar impact approximation (Wada, JSIAM 16(4) 19-31, 2006): the result shows that it is beyond the Hugoniot elastic limit (HEL), thus the H_2O ice is expected to behave like fluid in the vicinity of the impact point.

This work is supported by Grant-in-Aid for Scientific Research (B) No. 25289301 of Japan Society for the Promotion of Science.

Keywords: icy object, penetrator, crater, ballistic range