The survey of physical properties of planetary subsurface using penetrator

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Physical properties of planetary surface such as porosity, grain size etc. are important features to control the thermal and mechanical properties of airless planetary surfaces, then the surfaces such as asteroids and the Moon have been observed by various remote sensing methods. However, the information obtained by the remote sensing is very limited on the mechanical properties of the subsurface layer. While the subsurface mechanical properties are important to elucidate the evolution of the surface geology induced by impacts and tectonics. Then, the exploration method has been studied for the subsurface investigation. A penetrometry is one of the candidates to investigate the subsurface mechanical properties in planetary explorations, and it has been already used for the Cassini-Huygens mission and was planned for Luna-A mission.

In this study, we studied the scientific aspect of the penetrometry, especially for the instrument called as a penetrator. The penetrator usually contains some instruments and can penetrate into planetary subsurface, then it can measure subsurface physical properties during the penetration. Particularly, we focused on the instrument of the accelerometer equipped on the penetrator, which can measure acceleration the resistance force induced from the subsurface materials.The resistance force acquired by the accelerometer on the penetrator would have information of the mechanical properties of the subsurface material. Then, in order to derive the information of the subsurface features from the resistance force, we should know the relationship between the resistance force and the physical properties of the granular layer simulating the subsurface regolith layer.

Therefore, we carried out penetration experiments on various regolith simulant in order to clarify the relationship between the resistance force and the physical properties of the regolith simulant. The resistance force was analyzed to construct the constitutive equation charactering the regolith simulant, and this equation could be useful to analyze the observation in the future mission and to study the evolution of the surface geology.

We used a cylindrical stainless penetrator with the diameter of 2.6cm and the height of 4.35cm. The accelerometer was mounted on the back side of the penetrator, and the penetrator was dropped at various heights to change the penetration velocity and free-fell on the target.We prepared the target by using spherical glass beads (0.5μm, 100μm, 200μm, 500μm, 1mm, 1cm), red clay (2-4mm), quartz sand (100μm, 500μm), and perlite (2-3mm). They were poured into an acrylic cubic case (15cm in each side).The penetrator was dropped through the acrylic cylinder with the inner diameter of 3 cm to control the position of the penetrator and to confirm the impact normal to the target surfaces.

In our experiment, the acquired wave forms showing the resistance forces were evaluated according to the following features: the maximum acceleration value, the acceleration value just before the penetration stop, the duration of the acquired wave. As a result, we found the relationship between the resistance force and the physical properties (porosity, granular size) and constructed the constitution equation for each regolith simulant, and then each equation could be used for the clue to identify the surface materials comparing with the observational data from the penetrator.

Keywords: penetrator, physical property, subsurface

