Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PPS21-P03 Room:Convention Hall Time:May 25 18:15-19:30

Porosity of Granular Surface of Small Bodies - Relationship between Pressure and Porosity

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The Moon and many asteroids have regolith on the surface. Regolith can have various porosities and if we compress powder bed that has porosity, porosity is expected to decrease. Revealing the relationship between pressure and change in porosity makes it possible to estimate penetration depth of interplanetary dust particles or meteorites, and lander on asteroids. Porosity of planetesimals formed of dust aggregates is theoretically expected to 90 % (Kataoka et al., 2013). On the other hand, laboratory experiments show that surface of target constructed by such fluffy dust aggregates is compressed when impacted by sieved dust aggregates (Meisner et al., 2012). It is possible that porosity of planetesimals can be changed by impacts between planetesimals. Revealing their relationship is useful to estimate aggregate's porosity during the evolutional process toward planets.

First, it is necessary to determine porosity before compression. In this work, we focus on regolith on asteroids, i.e. granular bed accumulated under microgravity conditions. Porosity is determined by configuration of particles. Factors affecting regolith porosity are particle diameter, particle shape, interparticle force, and gravity. An empirical formula that include force ratio between interparticle force and gravity is presented (Yu et al., 2003; Kiuchi and Nakamura, 2014). However, this empirical formula is obtained by measurements under 1 G, so it is necessary to check if this formula can work under microgravity. Additionally, particle size distribution is not included in this formula. Regolith particle is not monodisperse because regolith is made up of impact fragments. So it is necessary to take effect of particle size distribution into account. Size distribution of impact fragments is usually represented as power-law. A geometric model has been proposed to estimate the porosity of granular bed that has close packing state (e.g. made by tapping) constructed by particles having power-law size distribution (Suzuki et al., 2001). However, porosity of loose packing state doesn't agree with the value predicted by the model. More studies for relationship between porosity of loose packing state and particle size distribution are needed to estimate initial porosity of regolith after deposition.

Second, we consider cases of impact or landing, i.e., when pressure is applied to regolith.

In this study, we conduct compression experiment of silica sand 1-3, of similar shape and different size distributions (median diameter is 13 μm, 24 μm, and 73 μm, respectively) fly ash (4.5 μm), fused alumina particles (5.3 μm), and basalt fragments smaller than 210 μm prepared by an impact experiment (29 μm) (hereafter called "basalt") using a centrifuge and compression testing machine.

We sieved them into a cylindrical container of diameter 5.8 cm and depth 3.3 cm (for basalt, diameter 2.7 cm and depth 1.4 cm) and the top part of the bed over the height of the container was leveled off. Silica sand 2 and basalt samples are resemble in median diameter, but porosities before compression are different, 58 % and 52 %, respectively. That means basalt has lower porosity. Power indices of cumulative volume fraction versus particle size are 0.53 and 0.78, respectively, so we obtained similar result with Suzuki et al. (2001): in the cases of loose packing state, porosity decreases with increase of the power index. We applied 1-18 G by the centrifuge or up to 106 Pa by the compression testing machine on the sample and determined porosity after compression from the sample volume obtained by bed height or displacement by compression.

In this presentation, we make a comparison between our result and existing powder compaction equations. In addition, we discuss about change in porosity by pressure and change in compressive strength by porosity in relation with particle size distribution.

Keywords: planetesimals, asteroids, porosity, powder and granular material