Abrasion experiments of mineral and meteorite grains: Dependence of particle size and vibration rate on abrasion rate and its application to Itokawa and lunar regolith particles.

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Rounded edges were found in some regolith particles collected from asteroid Itokawa [1] and Moon [2]. These particles should be formed by mechanical abrasion [1]. Seismic-induced grain motion by micrometeoroid impacts [1] and YORP effect [3] were proposed for the abrasion process on Itokawa. However, it is not clear how these processes actually work on the surfaces of the airless celestial bodies.

In order to understand detailed process of the abrasion, our research group have carried out abrasion experiments using mineral, rock and meteorite grains (grain size: 1-2 mm) [4]. Samples used were quartz, olivine, corundum, marble, L5 chondrite meteorite (Sayh al Uhaymir 001) and CM chondrite meteorite (Murchison). These particles were put into a vessel of 10 mL with the filling ratio of ~50 % and the sample was vibrated with the rate from 1000 to 3000 rpm using a multi-beads-shocker (YASUIKIKAI Co.). The proportion of powder (<250 μm) produced by vibration at first 1 min., ΔP_1, was adopted as the measure of abrasion and its dependence of the vibration rate and the sample strength was examined. However, the particle size used in the experiments (1-2 mm) is larger than Itokawa particles (< a few hundred μm). In addition, the vibration rates used in the experiments are larger than those estimated for Itokawa(~100 rpm) and Moon (~700 rpm) by considering the maximum seismic acceleration due to micrometeoroidimpacts onto their surface [5]. In the present study, therefore, we conducted new experiments with different parameters such as particle size and vibration rate using the same experimental procedure as [4]. In the present experiments, we used quartz grains for examining the effect of packing ratio in the vessel (Exp-1), particle size (Exp-2), mixing ratio of large and small particles (Exp-3). The effect of lower vibration rate (100 - 1000 rpm) was examined using olivine and basalt as well as quartz (Exp-4). Experiments using basalt at higher vibration rates were also made.

We obtained following results. Exp-1: $\Delta P_1$was constant in a wide range of the filling rate except for the filling rate of 2/3, where ΔP_1showed a peak value. Exp-2: $\Delta P_1$is proportional to the particle size. Exp-3: When the proportion of large particles is larger than 25%, $\Delta P_1$is almost constant and the same as $\Delta P_1$for the large particles. Exp-4: In the previous experiments, ΔP_1increases with the vibration rate with the power of 1.1-2.9 for large vibration rates (>~1000 rpm) [4] while the power becomes smaller (0.67-0.77) for smaller vibration rates (<~1000 rpm). This result shows that the abrasion mode changed at ~1000 rpm. In order to understand abrasion modes, SEM observation of powder particles produced in the abrasion experiments were also made. It was found that chipping of particle edges occurred at low vibration rate (~100 rpm) and the proportion of gradual wearing on the whole particle surface gradually increased as the vibration rate increased.

We estimated the amount of abrasion of Itokawa and lunar regolith particles in a regolith layer by impact based on the present experiments. ΔP_1values of basalt at 100 and 700 rpm, which corresponding to Itokawa and Moon [4], are ~0.1 %and ~1 %, respectively (Exp-4). If we consider the size of Itokawa and Moon particle (~100 μm), ΔP_1on Itokawa and Moon should be ~0.01%and ~0.1%, respectively(Exp-2). These values are larger than those estimated from the previous experiments [4] by the order of about 1.

The present results suggest that abrasion is possible on the Moon and may occur on Itokawa as well.

[1] Tsuchiyama et al. 2011. Science, 333, 1125-1128.

[2] Sakurama et al. 2016. JpGU, Abstract, PPS03-13.

[3] Connolly et al. 2015. Earth Planet and Space, 67: 12.

[4] Tsuchiyama et al. 2018. LPSC, Abstract 1844.

[5] Yasui et al. 2015. Icarus, 260: 320-331.