Estimation of abrasion rates of regolith particles on Itokawa and the Moon based on abration experiments.

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External 3D shapes and surface morphologies of Itokawa and lunar regolith particles examined by X-ray nanotomography and SEM showed that some particles have rounded edges, which should be formed by mechanical abrasion [1-3]. Seismic shaking by micrometeoroid impacts on the Itokawa surface was proposed for the abrasion [1]. In order to understand abrasion processes and evolution of regolith particles on the airless bodies, abrasion experiments have been made [4,5]. In this study, we have performed additional abrasion experiments together with SEM observation of abraded grains in order to examine abrasion process and obtaine a general equation for the abrasion rate and the results were applied to abrasion of Itokawa and lunar particles.
The samples used were quartz, olivine ($Fo_{\sim 90}$) and basalt. They were crushed and grains 1~2 mm in size were selected except for some to examine grain size effect (0.5~1 mm and 2~4 mm). These grains (~6.5g) were put into a vessel (10 mL) of agate, dunnite or basalt with ~50% fraction. Then the vessel was shaken with vertically-vibrational motion in a mill (Multi-beads-shocker: YASUIKIKAI Co.). Powder with the size less than 1/6 of the grain size (e.g., <250 mm for 1~2 mm grains) produced by abrasion was removed by sieving. The amount of abrasion, P, was defined as the difference between the grain masses before and after the abrasion, which was normalized by the initial grain mass.
For quartz grains, P increases with abrasion duration, t, (20 sec to 360 min) with the power of ~0.25 irrespective of vibration rate, Ω(100 to 2500 rpm). The amount of abrasion in the first 1 min, P_1, increases with Ω(100 to 3000 rpm) for quartz, olivine and basalt. The powers of P_1 - Ωrelation, m_i, at $\Omega <$ ~700 rpm (m = 0.1~0.4) are smaller than those at $\Omega >$ ~700 rpm (m_i = 1.2~2). P_1 increases with the grain size, d, at Ω = 2000 rpm for quartz and the power value is temporally ~1.6. If we assume that the power relation between P and t is applicable to different sample materials and that between P_1 and d to different sample materials and Ω, we can obtain the following equation; $P = A_i \times \Omega^{mi} \times d^{1.6} \times t^{0.25}$ (Eq.1), where A_i is the proportionality and the suffix i denote the sample materials. SEM observation together with the $P-t$ relation showed that the abrasion advances by chipping grain corners (chipping) for $P <$ ~1% while grain corners and edges become rounded (wearing) for $P >$ ~1%.
The maximum accelerations by impact on Itokawa and the Moon can be estimated to be ~1 and ~100 m/s^2 based on the impact experiments [6], which correspond to $\Omega$of ~100 and ~700 rpm, respectively. This gives A_i' s in Eq.1 with d = 1.5 mm and t = 1 min are ~0.2 % (olivine) on Itokawa and ~0.5 % (basalt) on the Moon. If typical grain convection time by impact of ~180 s on Itokawa [7] is adopted as the maximum value of t, P is estimated to be ~0.003 and ~0.1 % for d = 100 μm and 1 mm, respectively. As the Itokawa grains have rounded edges (wearing), >~4×10^9 and >~3000 times of impact are required, respectively, for $P >$ 1 %. If the impact frequency on Itokawa [7] is considered, these numbers of impact required for wearing are too large, suggesting that grain abrasion on Itokawa is not expected and impact on the larger parent body (>~20 km) [8] should be necessary. In contrast, on the Moon, A_i ~ 0.5% suggests possible abrasion because of longer residence time in a regolith layer than Itokawa.
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Keywords: Abrasion, Hayabusa mission, Impact

