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Deformation and acoustic emission of a penetrated granular bed

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In general, the rheological behavior of granular matter can mimic a certain side of the geophysical phenomena. In this experiment, the plunged granular matter is used to model the deformation and/or fracturing of the geophysical materials.

Penetration resistant force and acoustic emission (AE) from a plunged granular bed are experimentally investigated through their power-law distribution forms. The experimental apparatus used in this study is basically similar to that in our previous works [1,2]. In this experiment, AE measurement is used to approach the grain's-level microscopic behavior in a penetrated granular bed. An AE sensor (NF AE-9913) is buried in a glass beads bed. Then, the bed is slowly penetrated by a solid sphere by using a universal testing machine (Shimadzu AG-100NX). The average diameter of glass beads is varied from 0.4 to 2 mm, and the penetrating sphere's diameter ranges from 10 to 40 mm. During the penetration, the resistant force applied to the sphere and the AE signal are simultaneously measured [3]. The penetration speed (in the order of 1 mm/s) is kept slow enough to focus on the quasi-static regime. In this slow-penetration regime, the resistant force is independent of the penetration speed. Moreover, the resistant force shows power-law relation to the penetration depth. The obtained power-law exponent seems to depend on the size of granular column, i.e., the container's size. By comparing the resistant forces obtained by this experiment and other experiments, we confirm the relation between the resistant force and container's size. The smaller the container is, the larger the power-law exponent of resistant force becomes. This might mean that the slow penetration drag is affected by side wall of the container through force chains.

For AE signal, we observe a lot of (more than 1,000) burst-like AE events in each penetration experiment. We define the size of each AE event by its maximum amplitude. Then we find that the size distribution of AE events obeys power-law that is similar to Gutenberg Richter's law of the earthquakes statistics. However, the measured power-law exponent is not universal in this experiment. It rather depends on experimental condition. Particularly, the size of beads composing the penetrated granular bed affects the result significantly. The small glass beads bed shows larger power-law exponent. This tendency of power-law exponent indicates that the deformation of small-grains-bed is rather plastic, and the deformation of large-grains-bed shows brittle-like behavior. Namely, the emitted acoustic signal relates to the mode of deformation or fracturing. Since the grains network constructed in a small grains bed is dissipative, it also influences the statistics of AE events. The large AE events could be dissipated and screened by a lot of contact points in the small grains bed. This effect is also consistent with the current experimental result. In this study, only the AE events are measured and analyzed based on its power-law distribution. Actually, to characterize the mode of fracturing more precisely, electromagnetic emission (EME) should be also measured. Simultaneous measurement of AE and EME would reveal the details of the mechanics of slowly penetrated granular bed. Although this result is still preliminary to directly compare the power-law exponent with actual geophysical phenomena, the systematic behaviors of the power-law exponents are qualitatively informative to understand the deformation of the granular matter which relates to various geophysical phenomena and is quite different from usual continuum.

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