Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

“Buoyancy” in granular medium: how deep can an object sink in sand?

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ABSTRACT

The behavior of granular matter is different from either fluids or solids. One may not be able to answer even a naive question such as how deep an object can sink in sand. Answers to the depth of footprints on sand beach and its dependence on grain size have never been seriously studied before and may deserve a closer look and better understanding. Laying a ball of fixed size onto granules, we have measured the sinking depth (SD) of the ball into granules of different sizes and studied the dependence of SD on the sizes of the ball and granules. We find that the SD is very sensitive to the size of granules and the variation of SD on granule size is not monotonic. The maximum SD occurs at $r \approx 1/20\ R$, where r and R are the radii of granules and the ball, respectively. This ratio does not depend on the density of the ball and the volume fraction of granules. An empirical formula of SD on densities and sizes of the ball and granules are obtained based on the experimental results.