Orientational ordering and stress transmission in packings of straight or curved spherocylinders with different surface roughness

G. Lu, ETH Zürich, Switzerland; J.R. Third, ETH Zürich, Switzerland; C.R. Müller, ETH Zürich, Switzerland.

An improved understanding of the packing of non-spherical materials is of high relevance for industry and academia [1]. Nonetheless, particle systems are opaque, making the acquisition of experimental measurements a formidable challenge [2]. On the other hand, numerical modelling such as the discrete element method (DEM) provides an alternative route to inspect the internal properties of granular systems [3]. However, so far most DEM studies have only considered systems composed of spherical particles [4], irrespective of the fact that granular materials are commonly non-spherical [5]. Recently, particle shape has been recognized as a very significant parameter influencing both the geometric structures and the stress propagations within granular packings [6]. For example, Hidalgo et al. [7, 8] reported that in packings comprised of elongated rectangles the vertical force in the system did not saturate with depth (due to the preferred horizontal alignment of particles).

In this study, non-spherical particles of different aspect ratios (3, 5 and 7) and surface roughness were modelled in a discrete element method (DEM) framework. The surface roughness of the non-spherical particles was adjusted by the number of spheres used to construct the non-spherical particle. In total 9000 straight or curved particles were simulated in a two-dimensional rectangular container (width of 20 times the particle aspect ratio). We found that the surface roughness of the particles crucially influenced both the orientational ordering of the particles and the force transmission within the bed of grains. Taking rods of aspect ratio 3 as an example, it can be seen from Figure 1 that a coarser particle surface favored the direct transmission of the bed weight to the bottom of the container compared to a smoother particle surface. On the other hand, the stresses measured at the bottom of the container filled with curved particles of the same aspect ratio were higher than for the case that the container was filled with straight particles.

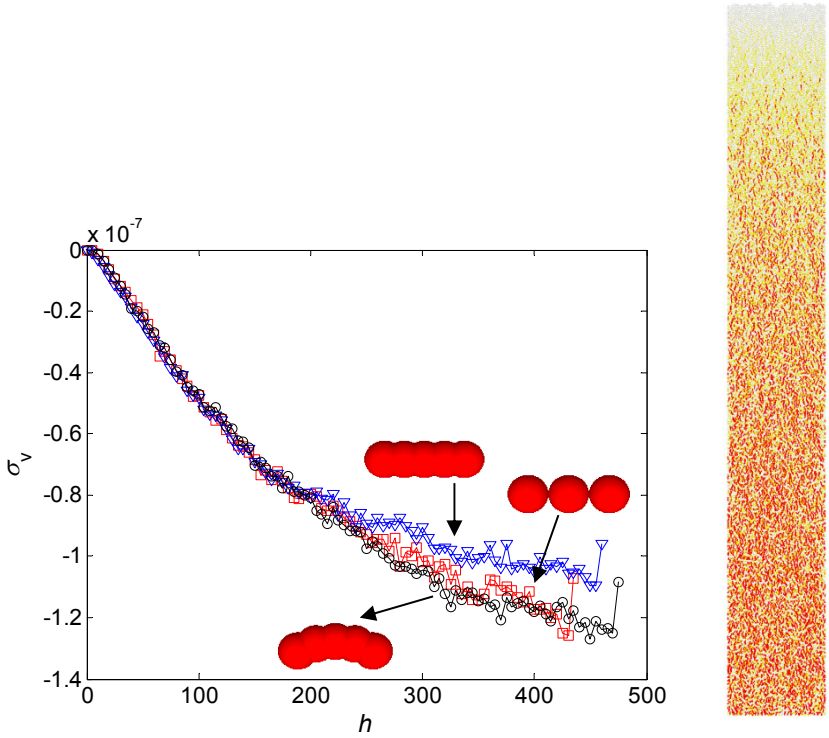


Figure 1 Comparison of vertical stress transmission in a two-dimensional packing composed of 9000 elongated straight and curved spherocylinders (aspect ratio 3). Coarser or curved particles

favour the force propagation to the bottom of the container. The right diagram shows the force chains formed within the system containing curved particles. The colour represents the magnitude of the contact force in the vertical direction.

Reference

[1] S. Torquato and F. H. Stillinger, Rev. Mod. Phys. 82, 2633 (2010).
[2] C. R. Müller, J. F. Davidson, J. S. Dennis, P. S. Fennell, L. F. Gladden, A. N. Hayhurst, M. D. Mantle, A. C. Rees and A. J. Sederman, Phys. Rev. Lett. 96, 154504 (2006).
[3] H. P. Zhu, Z. Y. Zhou, R. Y. Yang and A. B. Yu, Chem. Eng. Sci. 62, 3378 (2007).
[4] H. P. Zhu, Z. Y. Zhou, R. Y. Yang and A. B. Yu, Chem. Eng. Sci. 63, 5728 (2008).
[5] T. B örzsönyi and R. Stannarius, Soft Matter 9, 7401 (2013).
[6] A. G. Athanassiadis, M. Z. Miskin, P. Kaplan, N. Rodenberg, S. H. Lee, J. Merritt, E. Brown, J. Amend, H. Lipson and H. M. Jaeger, Soft Matter 10, 48 (2014).
[7] R. C. Hidalgo, I. Zuriguel, D. Maza and I. Pagonabarraga, Phys. Rev. Lett. 103, 118001 (2009).
[8] R. C. Hidalgo, I. Zuriguel, D. Maza and I. Pagonabarraga, J. Stat. Mech.-Theory E. 06, P06025 (2010).