Simulating and modelling segregating rods and spheres

Richard M. Lueptow*, Yongzhi Zhao†, Ryan P. Jones*, Hongyi Xiao,* and Paul B. Umbanhowar*

* Department of Mechanical Engineering
Northwestern University
Evanston, IL 60201 USA
e-mail: r-lueptow@northwestern.edu

† Department of Chemical and Biological Engineering
Zheijang University
Hangzhou 310027 China
e-mail: yzzhou@zju.edu.cn

ABSTRACT

Most studies of segregation of flowing granular materials focus on spherical particles, even though particles in practical situations often are non-spherical. Here we focus on mixtures of rod-like (cylindrical) particles of the same diameter but different lengths and mixtures of rod-like and spherical particles. The rod-like particles are described mathematically as super-ellipsoids, which require somewhat more complicated collision detection algorithms in DEM simulations. Parallelizing the simulation code for GPU processing requires further special considerations. Comparison of super-ellipsoid DEM simulations with previous "true geometry" models of cylindrical particles validates the approach.

We use super-ellipsoid rod-like particles to study particle size and shape segregation in bounded heap flow for a variety of mixtures of rod-like particle diameters and lengths as well as for mixtures of rod-like particles and spherical particles, comparing results with matching experiments. In the flowing layer of a bidisperse rod mixture in a bounded heap flow, shorter rods percolate toward the lower portion of the flowing layer, while longer rods rise toward the upper portion of the flowing layer. The rods tend to deposit on the underlying bed of particles in the heap such that they are aligned with the flow with the smaller rods deposited upstream of the larger rods due to segregation. Likewise, for a bidisperse mixture of spherical particles and rod-like particles having the same diameter, the spherical particles segregate lower in the flowing layer to deposit on the upstream portion of the heap while rods rise to the upper portion of the flowing layer, depositing on the heap further downstream. This segregation occurs even when the diameter and length of the rod-like particles equals the diameter of the spherical particles.

The percolation velocities associated with the segregation depend on the local shear rate and the concentration of the other particle species, just as is the case for size [1, 2] or density [3] bidisperse spherical particles. Using this percolation velocity and an appropriate value for collisional diffusion, the advection-diffusion-segregation continuum model for segregation [1] accurately predicts the segregation of rod-like particles of different lengths as well as rod-like and spherical particles.

Partially funded by The Dow Chemical Company.

REFERENCES

[1] Y. Fan, C.P. Schlick, P.B. Umbanhowar, J.M. Ottino, and R.M. Lueptow, “Modelling size segregation of granular materials: the roles of segregation, advection, and diffusion”, *J. Fluid Mech.*, **741**, 252-279 (2014).

[2] C.P. Schlick, Y. Fan, A.B. Isner, P.B. Umbanhowar, J.M. Ottino, and R.M. Lueptow, “Modeling segregation of bidisperse granular materials using physical control parameters in the quasi-2-D bounded heap”, *AIChE J.*, **61**, 1524-1534 (2015).

[3] H. Xiao, P.B. Umbanhowar, J.M. Ottino, and R.M. Lueptow, “Modeling density segregation in flowing bidisperse granular materials”, *Proc. Royal. Soc. A*, **472**, 20150856 (2015).