ABSTRACT

Ketterhagen, William Roy Ph.D., Purdue University, December, 2006. Modeling Granular Segregation during Hopper Discharge. Major Professors: Jennifer S. Curtis and Carl R. Wassgren.

Granular materials may readily segregate due to differences in particle properties such as size, shape, and density. This segregation may occur in many industrial processes involving granular materials and will occur even after a material has been uniformly blended. Segregation is typically problematic in that the quality of products is usually contingent upon maintaining some measure of blend homogeneity.

The present work aims to investigate the causes and extent of segregation of granular materials during flow from a hopper. Segregation data are obtained from discharge of quasi-three-dimensional wedge-shaped hoppers and fully three-dimensional cylindrical hoppers. The granular material is modeled as bidisperse, inelastic, frictional spheres via the discrete element method (DEM) employing a soft-particle contact model. Complementary experimentation in small hoppers with bidisperse, glass beads provides data for validation purposes. These small-scale experiments allow for direct comparison with the computational data on a one-to-one basis.

Results show the extent of segregation increases with particle diameter ratio while it decreases with increasing fines mass fraction and the ratio of hopper outlet size to particle size. Additionally, parameters such as the hopper aspect ratio and wall angle affect the shape of the segregation profile over the course of discharge. Further, the extent of segregation is observed to increase with both the particle-particle and particle-wall friction coefficients. A brief study of three different hopper fill methods

shows that the initial state homogeneity has a pronounced effect on the discharge profile.

The DEM data also permit visualization of the internal granular flow and microstructure. Colors are assigned to each particle based on a measured quantity such as the particle velocity, residence time, or the local mass fraction — a new color scheme developed in this work. Thus, the development of spatial concentration gradients during flow is observed, which provides novel insight as to how the fundamental segregation mechanisms manifest themselves in hopper geometries to yield the given discharge segregation results. Using the segregation results and flow visualizations, recommendations for reducing the extent of segregation during hopper flow from a product and process development standpoint are made.