A Simulation-Based Investigation of the Smooth-Wall, Radial Gravity Problem of Granular Flow through a Wedge-Shaped Hopper

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Abstract : Granular materials consist of particulate particles found in nature and various industries that, due to gravity flow, behave macroscopically like liquids. A fundamental industrial unit operation is a hopper with inclined walls or a converging channel in which material flows downward under gravity and exits the storage bin through the bottom outlet. The simplest form of the flow corresponds to a wedge-shaped, quasi-two-dimensional geometry with smooth walls and radially directed gravitational force toward the apex of the wedge. These flows were examined using the Mohr-Coulomb criterion in the classic work of Savage (1965), while Ravi Prakash and Rao used the critical state theory (1988). The smooth-wall radial gravity (SWRG) wedge-shaped hopper is simulated using the discrete element method (DEM) to test existing theories. DEM simulations involve the solution of Newton's equations, taking particle-particle interactions into account to compute stress and velocity fields for the flow in the SWRG system. Our computational results are consistent with the predictions of Savage (1965) and Ravi Prakash and Rao (1988), except for the region near the exit, where both viscous and frictional effects are present. To further comprehend this behaviour, a parametric analysis is carried out to analyze the rheology of wedge-shaped hoppers by varying the orifice diameter, wedge angle, friction coefficient, and stiffness. The conclusion is that velocity increases as the flow rate increases but decreases as the wedge angle and friction coefficient increase. We observed no substantial changes in velocity due to varying stiffness. It is anticipated that stresses at the exit result from the transfer of momentum during particle collisions; for this reason, relationships between viscosity and shear rate are shown, and all data are collapsed into a single curve. In addition, it is demonstrated that viscosity and volume fraction exhibit power law correlations with the inertial number and that all the data collapse into a single curve. A continuum model for determining granular flows is presented using empirical correlations.

Keywords : discrete element method, gravity flow, smooth-wall, wedge-shaped hoppers
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