315g Numerical Approach for Solving Dynamics of Dense Granular Flows

Rahul Agarwal, Ramanan Pitchumani, and Balakrishnan Pitchumani

Introduction

Granular materials are omnipresent in many fields ranging from civil engineering, food, mining and pharmaceutical industries. Often considered a fourth state of matter, they exhibit specific phenomena such as segregation, arching effects, pattern formation, etc. Due to its potential capability of realistically rendering these behaviors, the Discrete Element Modeling (DEM) is a very enticing simulation technique. DEM makes it possible to analyze and observe phenomena that are barely accessible experimentally. DEM works by tracking every particle in the system individually, maintaining for each a trajectory influenced by external factors such as gravitation or contacts with boundary objects and by the interactions with other grains. Flow of granules in silo is important in many industrial processes; most of the industrial processes require the silo to be mass flow. This property of flow depends upon many factors like friction between particle – particle and particle – wall, silo angle etc.

In the current article, for the physical problem of realistically rendering the collision in a numerical contact model suitable for computer simulation, we have used widely accepted theories such as the viscoelastic model of Cundall et al [1] which is mainly a variant of soft sphere model, but have also tested hard sphere model. The collision detection and contact models have been implemented in the DEM simulation code with advanced features in data structures storing the particle states at each time step. The simplest visco-elastic model is linear spring dashpot model. In this model it assumed that there are spring and damper attached to the particles under consideration in both normal and tangential direction. Spring forces accounts for the elastic collision and damper for the dissipation of energy. Simulations were performed for 3D geometry like silo discharge and angle of repose measurement. The simulation code has been developed in C++. Results Angle of Repose Measurement

To measure angle of repose through DEM first we need to stabilize the system containing the particles. In the simulation 1500 particles were taken of average size of 2.5 mm. By removing the side walls the extra particles are allowed to collapse and a heap is formed as shown in Fig.1. The angle of heap from the horizontal level i.e. angle of repose is measured using UTHSCSA ImageTool. Simulations were performed with different coefficient of friction to study its effect. The results are presented in Fig. 2 where the angle of repose increases with increase in friction coefficient.

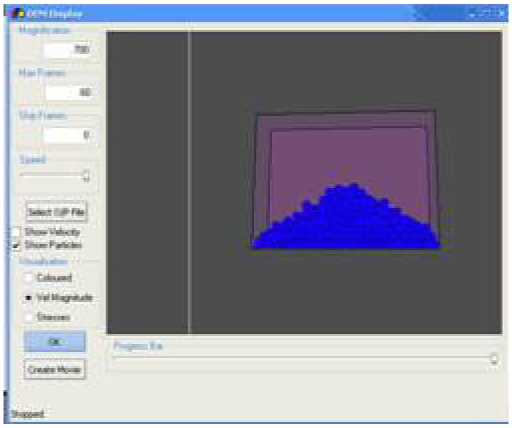


Fig 1: Display of angle of repose simulation with coefficient of friction = 0.9

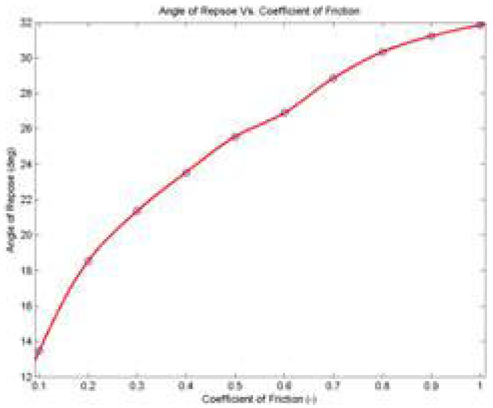
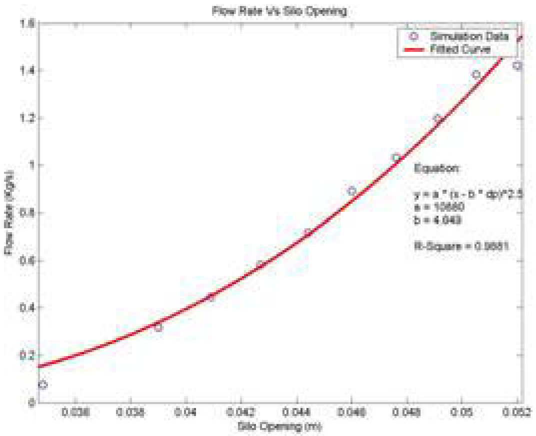


Fig 2: Effect of coefficient of friction on angle of repose

Silo Discharge

The simulation of discharge of planar mass flow silo was performed in a similar manner in 3D. The required geometry was fed in the program i.e. silo height, width, outlet angle. The number of particles taken in the simulation was 1500. Fig. 3 shows the dependence of silo flow rate with change in outlet opening. The flow rate varies to the power of 2.5 with the opening which is similar to that of the Beverloo [2]. Fig.4 shows the flow decreases exponentially with coefficient of friction.



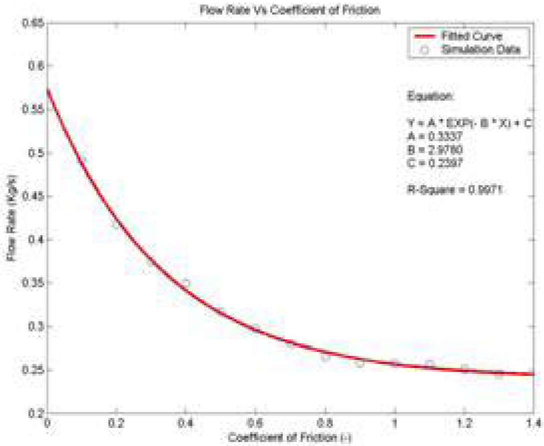


Fig.3: Variation of silo discharge rate with outlet width.

Fig.4: Variation of silo discharge flow with coefficient of friction

References

1. P.A. Cundall, O.D.L. Strack, Geotechnique, 29,1: 47-65 (1979).
2. W.A. Beverloo, H.A. Leninger, J. van der Velde, Chem. Eng. Sci. 15, 260 (1961).