Studying Alumina Flow Using DEM Numerical Simulation

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Abstract

A Discrete Element Method (DEM) model was developed by CAETE Engenharia in order to help understand and predict alumina flow. The DEM model is the adequate approach in order to simulate granular flows such as alumina. The simulation technique consists in a transient simulation which tracks the trajectory of the particles inside the studied system. It needs an intensive computational power to be performed. The numerical model was tested and validated by simulating the ISO902 angle of repose experiment of alumina.

Alumina flow DEM simulation can be quite useful to improve a variety of processes in the aluminium smelters. Some application examples are alumina silo’s feeding, silo’s discharge, cell alumina feeding and point feeding design improvement studies. In the alumina refinery, many other applications can also be found related to bauxite and alumina flows.

In this work, the DEM modelling was used to help the design improvement of a Søderberg point feeding system. CBA is in the process of installing point feeders in their Søderberg cells. For this purpose, a feeding chute was designed to receive the alumina from the hopper and to direct it to the anode gas skirt, close to the pneumatic crust breaker. In the initial design, the identified issue was the feeding hole being closed by the alumina. It was discovered that the feed chute was not feeding the alumina into the hole opened by the breaker, dropping the alumina in a wrong place instead. Then, an optimized feed chute was proposed. The new design was built and tested with success.

Keywords: Alumina flow simulation, Alumina angle of repose, Aluminium reduction cell point feeder, Granular flow, Discrete Element Method (DEM) simulation.

1. Introduction

Granular material is a set of a large number of discrete solid particles interacting with each other. It simultaneously presents characteristics of both solid and fluid materials. It can flow similar to a fluid, and also it can withstand a certain level of shear stresses, forming piles or stacks. Granular flows are quite common in mining activities and smelting industry. Alumina and bauxite flows are examples of such flows, as presented in Figure 1.

Figure 1. Examples of granular materials. Left: iron ore. Right: bauxite.

The dynamic behaviour of granular material is very complex, including particle-particle and particle-wall interactions.

2. Discrete Element Method

The Discrete Element Method (DEM) is a type of numerical model suitable for analysing granular flows. The method is essentially transient, and the state is calculated at the end of each small time step. It aims to track the movement of all particles of the system, requiring highly intensive computational effort. The basis of DEM can be found in literature [1]. Recently, granular flow simulation research has rapidly evolved worldwide, accompanying the increase in computational power [2].

Contrary to the traditional CFD models that consider the flow as a continuum discretized in mesh points/volumes, the DEM model simulates the motion of each individual particle. Motion equations are solved for each of these particles in the domain. Collisions of particles are also evaluated in DEM as well as the capillary forces.

A particle present in a granular flow can have two types of motion: translational and rotational. At every time step, a force balance according to Newton's second law of motion is carried out for each particle, considering its interaction with the contacting particles and a fluid in the case of a particle-fluid coupled model. In fine particle systems, non-contact forces such as the van der Waals and electrostatic forces are relevant, and they should also be included. DEM simulations can provide a variety of dynamic information results, such as the trajectories, forces acting on individual particles, and final configuration of particle packs in repose.

The forces present in DEM simulations are showed in Figure 2, where i, j, and k are particles. $\mathbf{F}^c$ is the contact force, $\mathbf{F}^{nc}$ is the non-contact force (van der Waals/electrostatic), f^n is the normal component of the contact force, $\mathbf{f}^t$ is the tangential component of the contact force, $\mathbf{m}^r$ is torque from rolling friction, $\mathbf{m}^t$ is torque from tangential forces, $\mathbf{v}$ is translational velocity, ω is angular velocity, m is the mass of the particle, $\mathbf{g}$ is the gravitational acceleration and h is the distance between spheres.

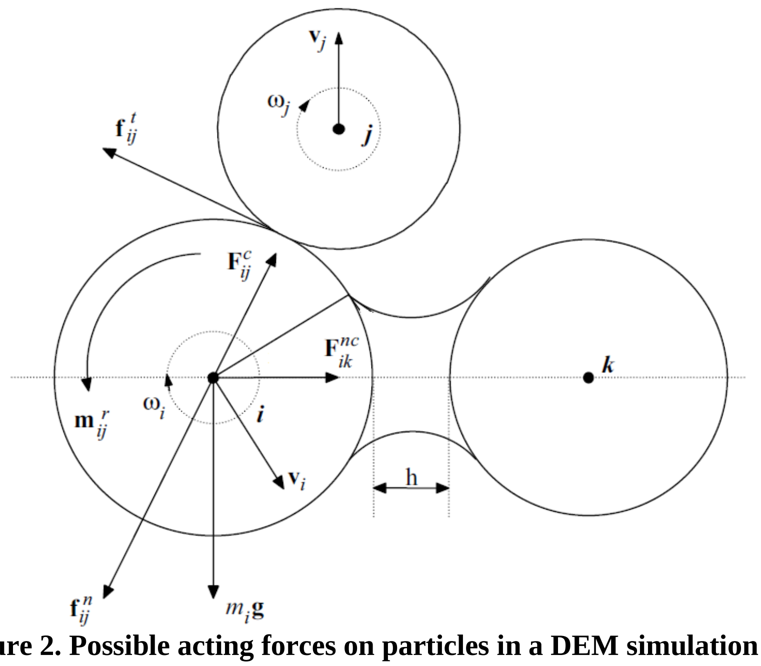

Figure 2. Possible acting forces on particles in a DEM simulation [3].

cause the alumina to destabilize the repose angle. The position of the bottom valves is not relevant for the stack behaviour, neither the number of valves, according to the results of the DEM simulations.

The Green Søderberg point feeding system was improved with the help of DEM simulations. Initially, in the first prototypes, the alumina was accumulating on the crust top. This occurred because the alumina was falling outside the radius of the hole provided by the crust breaker. A revised project was proposed where the position of the tube in the chute was improved and the majority of the alumina now falls inside the crust hole directly on the bath. According to the recent reports, the new feeding system has been operating quite successfully [5].

The segregation of different-diameter particles can be studied in DEM simulations as shown in simulation results. Another possibility is to combine CFD models with DEM simulations, for example, in the case of particles in suspension. In such numerical simulations, the fluid flow drag forces are recalculated and applied to the particles at each time step. CFD/DEM coupling is being studied in CFDEM project, which aims to combine open-source software OPENFOAM with LIGGGHTS [4].

7. References

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