Mixing analysis of binary system of particles in an agitated bed by Discrete Element Method

Ajit Mujumdar[a], Masayuki Horio[b], Toshio Maetani[c], and Naomichi Nakamura[c]

[a] New Jersey Center for Engineered Particulates, New Jersey Institute of Technology, Newark, NJ 07102, USA
[b] Tokyo University of Agriculture & Technology, Nakamachi, Tokyo, 184-8588, Japan
[c] JFE Steel Corporation, Steel Research laboratory, Chuo-ku, Chiba, 260-0835, Japan

Abstract

A three dimensional numerical code based on the discrete element method (DEM) is applied to simulate the mixing characteristics of binary system of particles in an industrial agitator. The device consists of blades rotating in the range of 60 -140rpm enabling the rigorous mixing of particles. In order to overcome the computational limitations on using the number of particles, simulation scale is magnified in the range of 10 to 40. Effect on the quality of mixing of particles for various magnification factors is compared. Concentration of particles is analyzed by taking a sectional cut in the agitated bed in 3D planes. Quantitatively, it is found that the magnification factor has a little effect on the estimated concentration of particles. Effect of withdrawal of the blades on the mixing of particles is also analyzed. Experimental comparison with the numerically simulated results is found to be in good agreement.

Introduction and simulation methodology

Application of discrete element method for modeling of powders in industries has been a focus of research for the past several decades. Apart from analyzing the applicability of various contact models and computational algorithms, the discrete element modeling faces stiff challenges in simulating the real life systems, which typically consists of millions of particles. In order to quantify the mixing of binary or ternary system of particles, simulations are performed for the smaller systems and appropriate scalable techniques are used for the interpretation of such results for the bigger systems. However, even a small size system consists of millions of particles therefore a realistic simulation can be performed only by making certain assumptions by which a small size system can be modeled. In this work, simulations of an industrial agitator are performed using discrete element model for the smaller size system consisting of binary system of particles agitated by the blades mounted on a rotating shaft. A magnification factor is estimated, which represents the real size system and the results are compared with the experimentally observed characteristics of the particles in the mixed bed.

Mixing vessel is a conical frustum of 4.5 cm diameter and a vertical height of 7.0 cm. Numerical simulations are performed for the magnification factors in the range of 10 to 40. Agitation is provided to the vessel by rotating the blades at speeds of 60, 120 and 140 rpm. Densities of particles are 7.8 g/cc and 8.9 g/cc, respectively. A well-known Cundall-Stack model is applied for the calculation of normal and tangential forces. Initially, lighter particles are allowed to settle by gravity and the heavier particles are places on the top of lighter particles. Rotation is applied and the blades are withdrawn from the mixture at the end of simulation period. Figure 1 illustrates the initial settled position of particles in the vessel.

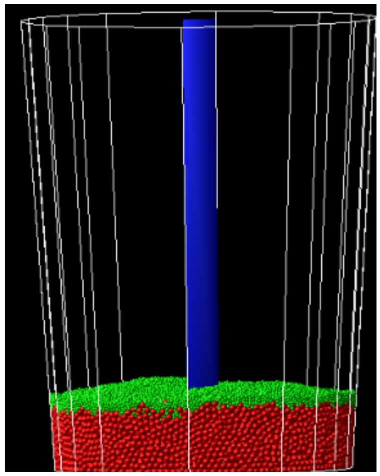

Figure 1. Initial position of settled particles in the mixing vessel

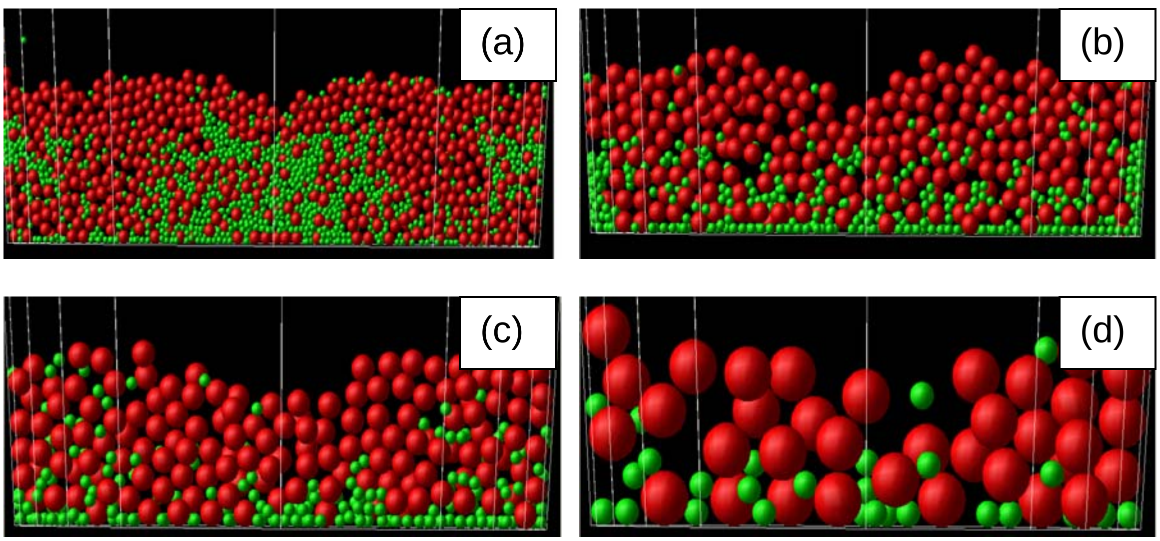

Figure 2. XY-Cut, 2.5 revolutions, 60 rpm, (a) M10, (b) M15, (c)M20 and (d)M40,

Snapshots from the simulations for 2.5 revolutions of the blades rotating at 60 rpm for the various magnification factors are shown in Figure 2. As seen from sectional cut in X-Y plane of the snapshots, heavier particles appeared to be reaching the bottom of the vessel. With an increase in the magnification factor, the capability of discrete element model results clearly shows the inability to qualitatively analyze the flow pattern of the particulate systems; however, quantitative analysis of such results does not seem to differ significantly. Average concentration of bigger size (lighter) particles is found to be in close agreement for all the magnification factors.

Comparison of the simulation case of magnification factor 10 found to be in good qualitative agreement with the experimental results (performed at JFE facilities) as shown in Figure 3. Also, for the ideal concentration of 0.3623 in a binary mixture, the estimated concentration values are found to be different for the different sectional cuts taken for the analysis (c.f. Figure 4).

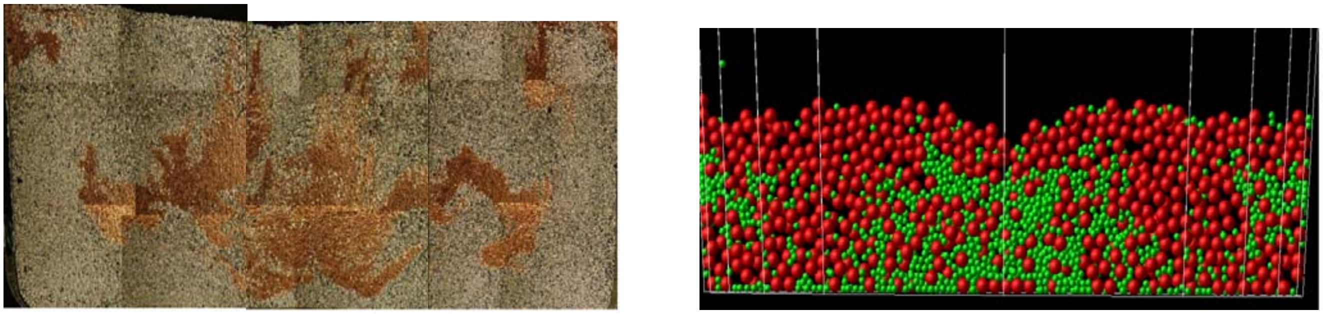

Figure 3. Experimental and simulation comparison of binary system of particles after 2.5 revolutions of the blades.

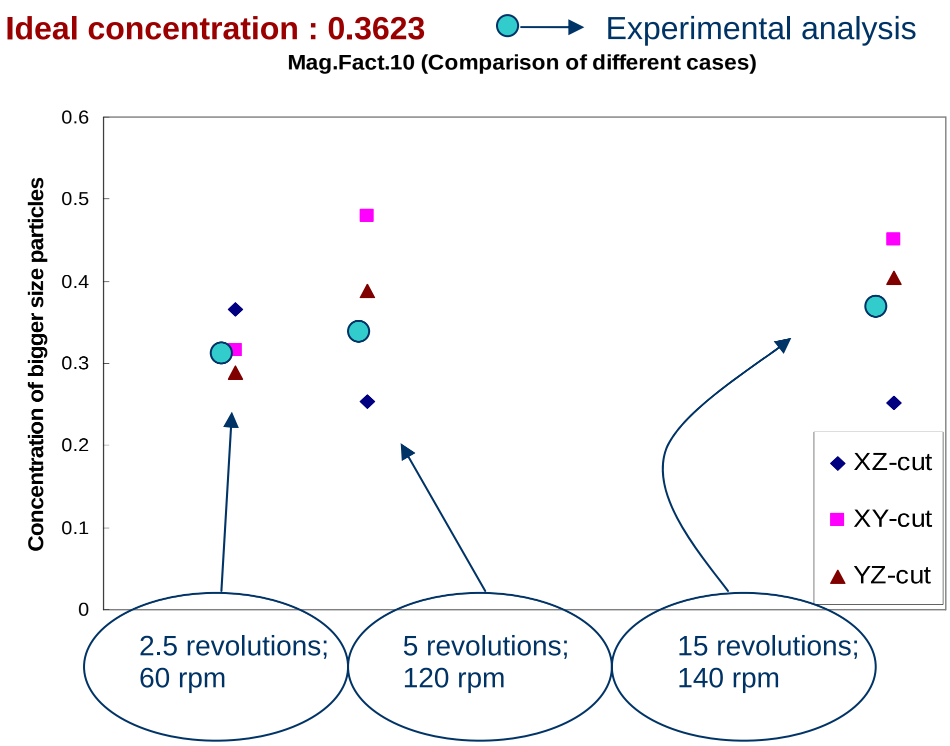

Figure 4. Concentration of bigger size particles for different rotational speeds (Magnification factor: 10)

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