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Investigation of the fluidization of LiF-barite binary mixtures

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ABSTRACT

This investigation focused on the effect of the operating parameters, barite content and particle size on the minimum fluidization velocity and particle agglomerate sizes of select LiF-barite binary mixtures. Experimental results showed that the relative fluidization in the bed of a binary mixture was better than the fluidization of a single component LiF bed. Results also identified two distinct regions in binary mixtures; namely the fragmentation and lubrication regions. In addition, it was found that the Zhou-Li model could be used to predict particle agglomerate sizes by explaining the forces present between agglomerate particles. The calculated results for the binary system agreed well with experimental data.

1. Introduction

$LiPF_6$ is a supporting salt in the electrolyte of lithium-ion batteries and prepared by direct reaction of gaseous PF_5 with solid LiF [1,2]. It is well known that a fluidized bed reactor provides better solid-gas contact than a conventional fixed bed reactor, which improves the efficiency and speed of solid gas reactions. However, commercially-available LiF has an average particle size of 16 μm and repose angle of 40 degrees. These attributes cause this material to form cohesive particles, which means that slugs and channels [3,4] are produced during its fluidization [5–7].

To improve the fluidization quality of these cohesive particles, several methods have been applied including mechanical vibration, acoustic vibration, magnetic fields, addition of coarse particulates, and surface modification of the primary particles [8]. Addition of coarse particles has received considerable research attention, which has resulted in significant improvements in uniform fluidization.

Li et al. have found that addition of inert particles to viscous particles can be used as a way to control particulate cluster size [9]. Dutta et al. have reported that the fluidization quality of a two-component system can be significantly improved by a decrease in particle adhesion [10]. Wang et al. have found that nanoparticle aggregates of Group C materials could be homogeneously fluidized by adding typical Group A powders [11].

Tung et al. have proposed a mathematical model to illustrate the synergistic effects between particles in a two-component system [12]. Kono et al. have held that addition of select particles increases the plastic deformation coefficient and tensile strength of the original granule emulsification phase, which then induces uniform fluidization over a wide range of gas velocities [13]. These authors have reported that added particles induces a surface modification in host particles, which weakens adhesive forces of the original particles and improves the fluidization of more viscous original particles.

Chaouki et al. have estimated particulate agglomerate sizes using the assumption that the difference between an agglomerate's gravitational force and its buoyant force was equal to the van der Waals forces acting between the primary particles [14]. Morooka et al. have estimated the agglonerate sizes of Si3N4 powders according to the principle of energy balance [15]. Horio and Iwadate have assumed that agglomerate collision energies were equal to cohesive energies between agglomerates [16]. Moseley and O'Brien have developed a two particle collision model for the case of elastic particles that have surface adhesion [17]. Iwadate and Horio have developed a mathematical model to predict an equilibrium agglomerate size in a bubbling fluidized bed of cohesive powders that was based on the balance of bed expansion forces caused by bubbles and agglomerate-to-agglomerate cohesive rupture forces [18]. Zhou and Li have proposed a mathematical equation that describes how the joint action of the drag and collision forces is balanced by gravitational and cohesive forces [19].

In this study, the addition of a certain mass ratio of particles of selected size to a bed of parent LiF fine particles was investigated

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regarding it effects on fluid behavior and LiF agglomeration size. The causes of fine LiF particle agglomeration were discussed theoretically and the mechanism for improving the quality of fluidization of LiF granules analyzed.

2. Experimental

2.1. Binary mixture in a gas-solid fluidized bed

The proposed binary mixture system that was studied in the experimental gas-solid bubble fluidized bed consisted of barite and LiF. The barite($BaSO_4$) used in this study was used as an additional particulate to improve slugs and channels during the LiF fluidization process. The pressure drop curves for these materials are shown in Figs. 1 and 2 and physical properties of the binary mixture system provided in Table 1.

It was observed that, as gas velocity increased, the pressure drop across the bed first increased and then rapidly decreased (Fig. 1). This result was the classic cohesive particle pressure drop curve for a fluidized bed, which showed that the gas initially flowed through particulate slugs, and then the bed suddenly collapsed producing the channel stage. The slugs and channels stages and LiF particle clusters are shown in Figs. 3 and 4.

The fluidization pressure curve of barite in a bed 12 cm in height showed that, in comparison, the quality of barite fluidization was much better than that of LiF (Fig. 2). A steady fluidization was achieved with increased gas velocity.

2.2. Experimental apparatus

A schematic flow diagram of the experimental pilot fluidized bed used in this study is shown in Fig. 5 and the specifications of the fluidized bed and operating variable ranges listed in Table 2. The fluidized bed was fabricated from a cylindrical glass tube such that the fluidization behavior of the particulate bed was easily observed.

After being dried in an oven at 120 °C for 2 h, the mixed particles were loaded into the fluidized bed and air fed into the bottom of the column by an air compressor. Flow meters were used to control the gas flow rate and pressure sensors used to assess the fluidization parameters. The particle bed height was fixed at 12 cm before experiments began.

Homogenized binary agglomerate mixtures with different particle mass ratios were carefully sampled from different axial and radial locations in the bed after the bed was completely fluidized (after 30 min of mixing). This was accomplished using an in-house designed sample ladle that avoided disruption of their size, structure, and shape. Typical LiF agglomerate structures that were extracted from the bed after fluidization showed that the agglomerates were nearly spherical in shape as a result of the gas flow and the equivalent diameter of the particles obtained from the average of five measurements (Fig. 4). For measurement of agglomerated particle sizes, two principles were employed in the sampling process. First, samples were taken from moving particles and, second, samples were taken from the whole material flow several times at short intervals. Therefore, when the system was initially fluidized and held stable for five min, a long-handled spoon was used for sampling from a constant height on the side of the fluidized bed

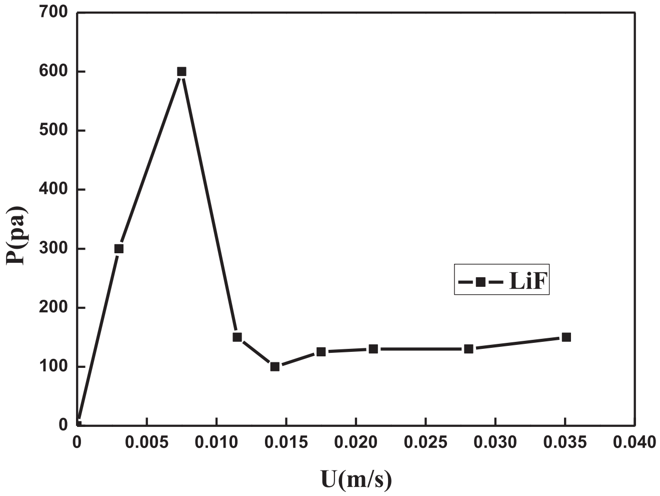

Fig. 1. Fluidized pressure drop curve of LiF (H = 12 cm).

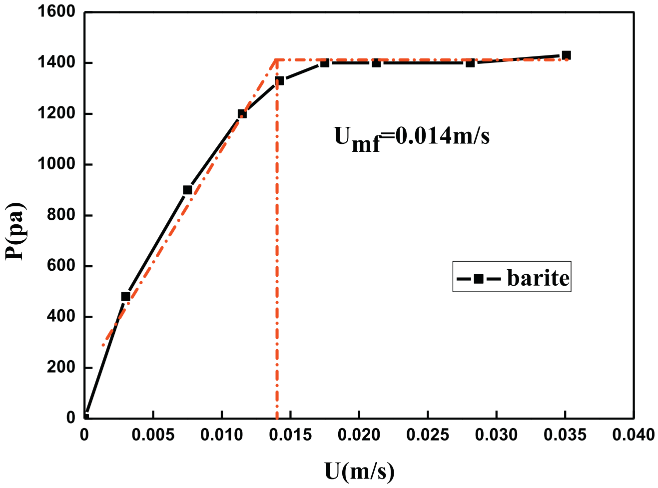

Fig. 2. Fluidized pressure drop curve of barite (H = 12 cm).

Table 1
Physical property of barite and LiF.

Particle species	Particle size (μm)	Bulk density (g/cm^3)	Compaction density(g/cm^3)
Barite	150–180	2.19	2.49
	180–250	2.29	2.45
	250–380	2.25	2.44
LiF	10–30	0.76	1.16

Fig. 3. Slugs and channels at the LiF fluidization process.