International Journal of Mining Science and Technology 25 (2015) 459–464

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Study on mixing and segregation behaviors in particulate fluidized bed system for mineral processing

Sahu S.N. *, Sahu A.K., Biswal S.K.

Mineral Processing Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar 751013, India

ARTICLE INFO

Article history:
Received 22 September 2014
Received in revised form 20 November 2014
Accepted 28 December 2014
Available online 18 April 2015

Keywords:
Liquid–solid fluidization
Mixing
Segregation
Locus point
Mineral processing

ABSTRACT

In order to identify the mixing and segregation behaviors in a mineral processing operation, present study aimed on the hydrodynamics of solid–liquid fluidization. The study was carried out in a fluidization column with tapings at different height of the bed to collect the sample. The binary particles considered in this study are hematite (4800 kg/m^3) and quartz (2600 kg/m^3) at different size fractions in the range of average size 87 $\times$ 10^{-6} m to 400 $\times$ 10^{-6} m. It is observed that for various binary mixtures, both quartz and hematite particles share the equal composition by mass (50%) at a particular height of fluidized bed, referred as "locus point" of mixing. Study indicates that the mixing zone volume will increase for a continuous fluidized bed plant operation. It is observed that the number of locus points varies from 1 to 3 signifying their dependency on the size ratios of binary mixture. Whenever, the difference in terminal velocity between quartz and hematite particles approaches to zero, mixing is enhanced. Further, the present study is extended to find the segregation index for the different size ratios of quartz and hematite particles. It is evident that depending on the size ratios, various regions such as complete segregation, partial mixing and complete mixing can be observed.

1. Introduction

In mineral processing, particulate fluidization technique is widely employed in gravity separation process to segregate heavy and light particles using either liquid or gas as fluidizing medium. In mineral processing, mineral particles of mixed size and density are recovered and separated through the segregation mechanism in a fluidized bed separator. Therefore the separation efficiency on the segregation of the particles depends on their physical properties such as size, shape and density of feed materials [1,2]. A binary mixture can contain different variety of combinations of particles such as: heavy and coarse, heavy and fine, light and coarse, and light and fine. In case the mixture consists of heavy and fine, light and coarse particles, an 'inversion' phenomenon may take place in the fluidized bed [3]. Separation of mixture by fluidization technique with sufficiently different physical properties also shows inversion phenomena. It has been reported by many investigators to predict the solid layer inversion velocity or critical velocity in solid–liquid fluidized bed. Appropriate fluidization condition can be chosen by knowing the physical properties of the mineral particles [4]. The inversion velocity represents an equilibrium condition for binary mixture in which particles will not segregate spontaneously due to lack of driving force for segregation. At superficial velocity of liquid is higher than the inversion velocity, there is a possibility of complete segregation between fine heavy and coarse light particles. Under this condition, heavy and fine particles occupy the top layer, whereas light and coarse particles are at the bottom of layer in fluidized bed system. Moritomi et al. studied different aspects of liquid fluidization of binary mixtures. They reported the various flow regimes in binary liquid fluidized bed [1]. Rasul et al. studied the separation of mineral particles using fluidization technique. They carried out various experiments for the validation of the mechanistic model for separation process [4]. It was observed that appropriate particle size and density played an important role in layer inversion phenomenon and validated the experimental data with the model proposed by Gibilaro et al. for prediction of stable mixtures in fluidized beds [3]. Further, they concluded that if chose right operating conditions, it is possible to separation any type of mixture.

Much experimental data exist in the literature concerning segregation of fluidized bed based on key process parameters such as

* Corresponding author. Tel.: +91 6742379525.
E-mail address: sacheye@gmail.com (S.N. Sahu).

http://dx.doi.org/10.1016/j.ijmst.2015.03.021
2095-2686/© 2015 Published by Elsevier B.V. on behalf of China University of Mining & Technology.

particle size and density, size ratio, solid loading, fluid velocity and geometry of the fluidized bed [5–7]. Al-Dibouni and Garside investigated the extent of segregation and intermixing for the size distributions having maximum size ratios between 2 and 6.7. They observed that at size ratio of 2, intermixing was occurred throughout the bed and particularly intense in the regions having a voidage of about 0.7. They further found that complete segregation occurred when values greater than 2.2 [8]. Epstein et al. used a simple serial model to predict the expansion characteristics of multiparticle systems, which assumes that the mixed bed behaves as though it was the sum total of any number of independently expanding mono-component beds [9]. Juma and Richardson considered the segregation velocity as a linear function of the axial position of the column and applied their analysis to a mixed zone sandwiched between the upper and the lower mono-component zones. It was observed that, during the fluidizing, a mixture of particles with close density or size may be mixed particle zone in the bed [10]. Epstein and LeClair studied intermixing and segregation of binary mixture of various size and density. They calculated the critical velocity (superficial liquid velocity at which complete intermixing occurs) by equating the bulk density difference is zero [11]. Felice et al. studied particle intermixing and segregation in solid–liquid fluidized bed consisting of particles differing in size or density or both [12]. Asif generalized the well-known correlation for the prediction of the expansion behavior and layer inversion of the binary solids. The results obtained from the proposed generalization are demonstrated by comparing its prediction with the literature experimental data [13]. Barghi et al. carried out an experimental work and reported that density differences between components play an important role in the segregating fluidization process of two-solid beds. Also on the basis of the obtained results, particle density exerted a greater effect on segregation than size and shape. They also observed that circulation of bed particles was a dominant factor in the mixing of flotsam particles [14]. Joseph et al. studied the segregation behavior of binary and Geldart B mixture. Three system types were explored: size segregation, density segregation and size/density segregation (with the smaller species denser and lighter) [15]. Nienow et al. studied the fluidization characteristics of powders of different densities. Here they illustrated the relationship between particle size, density, minimum fluidisztion velocity and sphericity [16]. Fluidization technique is also used to beneficiate fuel mineral like coal. Coal can be beneficiated by dry fluidization process depending upon the bed pressure drop and particle size. Formation of secondary gas-distribution layer plays an important role in improving the fluidization efficiency [17]. Vibratory fluidized bed is also used in beneficiation of coal in dry process. Here the operational parameters, such as superficial air velocity, vibration frequency and amplitude, initial bed height and separating time have significant effect on stratification of coal particles [18]. Air dense medium fluidized bed separator is also used for dry beneficiation of coal. A stable and uniform fluidized bed can be formed by using magnetic powder or a mixture of magnetic powder with fine coal as medium solids [19].

Even though many studies are available in the literature for general research, but considering the mineral processing, there is not still much detailed work done. The reason is that the physical properties of particles with respect to size and density are complex. Thus, an insight can be obtained through the knowledge of experimental observations and theoretical analyses of mixing and segregation behavior of binary mixtures in fluidized bed system. In this study, an attempt is made to explore the fluidization characteristics in terms of solid mass fraction along the height of column, segregation index to analyze the mixing and segregation behaviors of particles in solid–liquid fluidization through experimental investigation.

2. Experimental

The binary mixture considered for this study is hematite and quartz particles. The density of hematite sample is 4800 kg/m^3 and their size fractions considered are −300 + 210, −210 + 150, −150 + 100 and −100 + 75 μm. The density of quartz sample is 2600 kg/m^3 and their size fractions are −500 + 300, −300 + 210, −210 + 150 and −150 + 100 μm. The binary mixture of 4 kg was prepared by mixing of different size fractions of equal weight of hematite and quartz particles. The detailed parameters are available in Tables 1 and 2.

The experimental set-up consists of a glass cylindrical column of 1.5 m height and 0.1 m diameter. Fig. 1 is the actual fluidized bed experimental set-up used in this study. A plenum chamber is fitted at the bottom of the fluidization column and filled with glass beads in order to maintain the flow uniform across the cross section of the fluidized bed. Water was pumped through a rotameter

Table 1
Process parameters used in this study.

Details	Quartz	Hematite
Particle density (kg/m^3)	2600	4800
Solid loading (kg)	2.000	2.0
Liquid superficial velocity (10^{-2} m/s)	1.982	

Table 2
Size fractions for different mixture of quartz and hematite particles.

Sample No.	Size of quartz particle (10^{-6} m)	Mean particle size of quartz (10^{-6} m)	Size of hematite particle (10^{-6} m)	Mean particle size of hematite (10^{-6} m)
1	−210 + 150	180	−150 + 100	125
2	−150 + 100	125	−150 + 100	125
3	−210 + 150	180	−210 + 150	180
4	−500 + 300	400	−210 + 150	180
5	−300 + 210	255	−210 + 150	180
6	−300 + 210	255	−300 + 210	255
7	−300 + 210	255	−150 + 100	125
8	−500 + 300	400	−150 + 100	125
9	−500 + 300	400	−300 + 210	255
10	−500 + 300	400	−100 + 75	87.5

Fig. 1. Laboratory scale particulate fluidized bed set-up.