International Journal of Mining Science and Technology 25 (2015) 421–427

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

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

Prediction of the position of coal particles in an air dense medium fluidized bed system

Prusti Pallishree *, Sahu Ashok K., Biswal Surendra K.

Council of Scientific & Industrial Research-Institute of Minerals and Materials Technology, Bhubaneswar 751013, India

ARTICLE INFO

Article history:
Received 5 September 2014
Received in revised form 1 November 2014
Accepted 5 December 2014
Available online 20 April 2015

Keywords:
Coal beneficiation
Pseudo-fluid medium
Dead zone area
Effective density

ABSTRACT

An air dense medium fluidized bed separator (ADMFBS) is used for dry beneficiation of coal using ultra-fine magnetite particles as a pseudo-fluid medium. In this process, the coal particle gains additional weight due to coating on its surface and deposition at dead zone area by fine magnetite particles. Hence, the effective density of coal particle increases and the position of coal particle changes accordingly. In this work, an attempt was made to predict the position of coal particle in non-bubbling condition dense medium fluidized bed system. Coal particles of different shape such as cubical, rectangular prism, spherical and triangular prism with different projected area and density were used. The results show that the position of coal particle in air dense medium fluidized bed follows descending order with respect to the increase of density, projected area of coal particle and different shapes (i.e., triangular prism, cubical, rectangular prism and spherical). Empirical mathematical correlations were developed to predict the position of coal particle.

1. Introduction

An air dense medium fluidized bed separator (ADMFBS) is one of the more efficient dry coal beneficiation process utilizing fluidization. The pseudo-fluid medium is made by suspending fine magnetite powder in air. This pseudo-fluid medium segregates the coal particles according to their densities. The feed materials segregate due to bed density but are also influenced by drag forces due to back-mixing of medium solids are discussed [1–3]. This back mixing of medium solids in ADMFBS affects the efficiency of segregation. In conventional dense medium separators, coal particles segregate into float and sink products according to their densities obeying an ideal solution condition. However, the lighter coal particles which have density less than bed density do not all float on the surface of the pseudo-fluid medium. Similarly the heavier coal particles which have density more than the bed density does not all sink to the bottom of the bed. This is due to the dynamic behavior of coal particle in the pseudo-fluid medium. The position of a particle in pseudo-fluid medium fluidized beds varies with particle shape, size and density as well as the physical characteristics of the medium. The performance/segregation efficiency (E_p) of ADMFBS mainly depends on the uniformity and dynamic stability of the fluidized bed [4–7]. In many instances, the E_p value is relatively poor, which is the motive for detailed investigation in order to enhance the efficiency of ADMFBS. Mohanta et al. have studied the effect of feed size on the separation performance and tried to quantify the optimum size range for the satisfactory operation of the air dense medium fluidized bed separator [8]. Chikerema and Moys have investigated the effect of the particle size, shape, and density on the performance of air fluidized bed in the application of dry coal beneficiation [9].

In air-dense medium fluidized bed systems, ultra-fine magnetite particles are often used as the medium [10–11]. Coal particles may gain additional weight in the pseudo-fluid medium of a fluidized bed system due to being coat by magnetite particles on their surface, depending on the adhesive characteristics of the medium. During fluidization, eddy formation takes place around coal particles, which creates a dead zone over the top surface of each particle. Magnetite media particles deposit on this dead zone area of the coal particle, which increases the weight of the particle. Thus, the actual density of the particle increases and this influences the position of coal particle in the air dense medium fluidized bed system.

The present study focuses on predicting of the position of coal particles in air dense medium fluidized bed systems, which having an average bed density of 1.7×10^3 kg/m^3. Coal particles of different shapes such as cubical, rectangular prism, spherical and triangular prism having different size and densities are used. Using the experimental data, empirical correlations are developed to predict the position of a coal particle in the air dense medium fluidized bed.

* Corresponding author. Tel.: +91 674 2379526.
E-mail address: pprusti@immt.res.in (P. Prusti).

http://dx.doi.org/10.1016/j.ijmst.2015.03.015
2095-2686/

2. Materials and methods

2.1. Sample preparation

2.1.1. Coal sample

The coal sample was collected from one of the mines in the Talcher area, Mahanadi Coal Field Ltd., Odisha, India. It is high ash non-coking coal and comes under the category of "F" grade. The coal was crushed to different sizes. Different densities of Coal particles ranging from 1.3×10^3 to 1.8×10^3 kg/m^3 were segregated using heavy media liquid prepared by mixing analytical grade acetone and bromoform. Different shapes of coal particles, including cubical, spherical, rectangular and triangular prism, were prepared for this study. Coal particles of increasing size were named "A", "B" and "C" with projected areas 6.25×10^{-4}, 9.0×10^{-4} and 12.25×10^{-4} m^2, respectively. Each set contains four different shapes with varying density. The dimensions of the coal particles are given in Table 1. The total number of coal particles used in this study was 72 (6 densities × 3 projected areas × 4 shapes).

2.1.2. Magnetite sample

Magnetite powder was used as the fluidizing medium. The magnetite sample was collected from M/s. Uranium Corporation of India Limited, Jaduguda Mines, Jharkhand, India. The sample was crushed and ground to below 45 μm size and processed through low intensity magnetic separator (1800 Gauss) to upgrade the Fe value to 69.51%. The particle size distribution of this magnetite sample was measured by a CILAS Model No. 1064 particle size analyzer. The physical and chemical characteristics of magnetite sample were measured. The bulk density of the magnetite sample was measured. The XRD analysis of magnetite particles was carried out by X'Pert PRO PANalytical. The shape of the magnetite particles was identified by scanning electron microscope, SEM (JEOL, Model No. JSM-6510).

2.2. Experimental set-up

The laboratory scale experimental set-up consists of a cylindrical column of 0.1 m diameter and 1 m height made of Perspex. The air distributor was made up of a filter cloth (fabric type) PL 2511 sandwiched between two wire meshes. This was used to facilitate a stable non-bubbling fluidized bed expansion. The fluidized bed column has a plenum chamber at its base to which the air inlet pipe was connected. Dry compressed air was supplied to the plenum chamber from the air compressor via a refrigerated air dryer. The flow rate of dry air was measured by the rotameter. Pressure tappings were provided at different heights starting from the plenum chamber up to the top of the fluidization system in 0.1 m intervals. A nozzle bank was connected to respective pressure tapping points in the fluidized bed. The nozzle bank is a combination of small ball valves and pipes that facilitates pressure drop measurement. The output nozzles were connected to the mercury U tube manometer. The schematic diagram of the experimental setup is shown in Fig. 1.

Table 1
Dimension of coal particles.

Type	Projected area ($\times 10^{-4}$ m^2)	Cubical shape (cm)	Rectangular prism shape (cm)	Spherical shape (cm)	Triangular prism shape (cm)
A	6.25	C-A 2.5 × 2.5	R-A 3.5 × 1.8	S-A 2.0	T-A 2 (2.1 × 1.5)
B	9.00	C-B 3.0 × 3.0	R-A 3.5 × 2.6	S-B 2.4	T-B 2 (2.7 × 1.7)
C	12.25	C-C 3.5 × 3.5	R-A 4.0 × 3.1	S-C 2.8	T-C 2 (3.1 × 2.0)

The magnetite powder of 6 kg was dried and fed into the fluidizing column. The media particles were fully fluidized by dry compressed air to avoid agglomeration, and then allowed to settle down in the column for de-aeration. Then, the bed stability characteristics were studied by varying the flow rate of dry compressed air in order to achieve non-bubbling fluidization.

The pressure drop was recorded for each air flow rate. Minimum fluidizing velocity was determined using the pressure drop method. Air flow rate was controlled to maintain a required expanded bed height of 0.45 m with desired average bed density of 1.7×10^3 kg/m^3. A coal particle was then fed to the top of the stable fluidized bed and allowed to reach equilibrium position. The supply of dry compressed air was suddenly shut-off after a certain period of time. The magnetite media particles were then gently removed using suction pump until the coal was located. The position of each coal particle was recorded. The original position of the coal particle in the fluidized condition was then calculated by multiplying the factor of ratio of expanded bed height to static bed height. This procedure was repeated for all 72 coal particles having different size, shape and density.

3. Results and discussion

3.1. Magnetite particles characteristics

The particle size distribution of magnetite sample measured by CILAS Model No. 1064 particle size analyzer is given in Table 2. The harmonic mean diameter of the magnetite powder sample is 5.98 μm. The physical and chemical characteristics of magnetite sample are given in Table 3. This sample contains 69.51% Fe, 1.4% SiO_2 and 0.76% Al_2O_3. The XRD study on the magnetite powder was carried out, which is shown in Fig. 2. It is observed that minor quantity of phillipsite clay and quartz is present in magnetite powder. The presence of clay provides more particle–particle cohesive force resulting in less channeling and gives uniform expansion in the fluidized bed. The shape of the magnetite particles studied using scanning electron microscope, SEM (JEOL, Model No. JSM-6510) is shown in Fig. 3. It is shown that the particles are of irregular shape.

3.2. Stability characteristics

Stability characteristics of fluidized bed were studied in order to get non-bubbling expansion of magnetite media. Fig. 4 represents bed expansion of magnetite particles in fluidized bed system for different static bed heights at various superficial air velocities. It

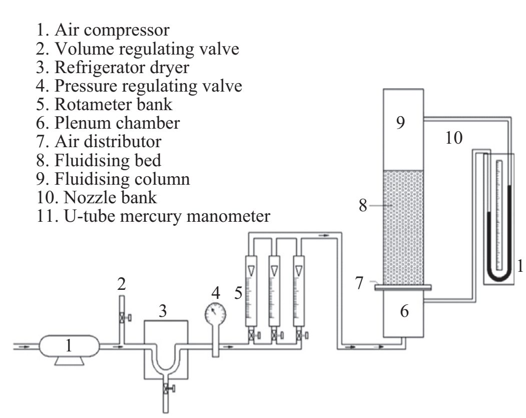

Fig. 1. Schematic diagram of laboratory scale air dense medium fluidized bed setup.