Advanced Powder Technology 25 (2014) 1031–1037

Contents lists available at ScienceDirect

Advanced Powder Technology

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

Original Research Paper

Magnetite particle surface attrition model in dense phase gas–solid fluidized bed for dry coal beneficiation

Bo Zhang [a], Yuemin Zhao [a,*], Chenlong Duan [a], Ligang Tang [b], Liang Dong [a], Jinzhou Qu [a]

[a] School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China
[b] Coal Mining and Designing Department, Tiandi Science & Technology Co. Ltd., Beijing 100013, China

ARTICLE INFO

Article history:
Received 22 October 2013
Received in revised form 17 January 2014
Accepted 7 February 2014
Available online 22 February 2014

Keywords:
Gas–solid fluidized bed
Rate of particle attrition
Magnetite particles
Proportionality coefficient
Rittinger's surface theory

ABSTRACT

Dense-phase high-density fluidized bed has received considerable attention worldwide due to the urgent need for an efficient dry separation technology. This study on magnetite particle attrition model and size distribution change rule in a dense-phase gas–solid fluidized bed for dry beneficiation analyzes the complex process of magnetite particle attrition and fine particle generation. A model of magnetite particle attrition rate is established, with the particle attrition rate leveling off gradually with the attrition time in the dense-phase gas–solid fluidized bed. Magnetite particle attrition in the dense-phase gas–solid fluidized bed is consistent with Rittinger's surface theory, where the change in surface area of magnetite particles is proportional to the total excess kinetic energy consumed and the total attrition time. An attrition experiment of magnetite particles is conducted in a laboratory-scale dense-phase gas–solid fluidized bed for dry beneficiation.

1. Introduction

Coal plays a predominant role in China's energy consumption structure. In 2011, China's raw coal production is 3.52 billion tons, accounting for 77.35% of the primary energy production [1], and coal consumption accounts for 70.48% of the primary energy consumption [2]. As the main energy source, coal will make great contributions to the national economic development of China for a long time, thus it is of great significance to use the coal resources efficient and clean. Coal preparation technology is simple and effective method to improve the quality of coal, being used and developed worldwide. More than two-thirds of coal resources in China are distributed in arid areas. As the coal mining is transferred to arid areas, wet coal preparation is under restrictions [3], the efficient dry separation technology is urgent need. Existing mature dry separation technology mainly contain air jig [4–6], the compound dry separation [7–9] and the dense phase high density fluidized bed dry beneficiation [9–16]. Especially in recent years, the dense phase high density fluidized bed dry separation technology is received a widespread concern of home and abroad, because of its high sorting accuracy and the stable sorting effect. However, the attrition of magnetite particles in dense phase fluidized bed dry separation would change their size distribution, and influence the normal operation of dense phase fluidized bed dry beneficiation. Thus it is worthy to study the attrition of magnetite particles in fluidized beds.

Generally, it is believed that particle attrition takes place through surface abrasion in fluidized beds, As a matter of fact; many studies [17–19] on the attrition of particles in fluidized beds have been published. In addition, in order to verify the validity of the developed model, an attrition experiment of magnetite particles has been carried out in a lab-scale dense phase gas–solids fluidized bed for dry beneficiation [20–22].

2. Material and methods

2.1. Material

The isomorphism of Fe^{3+} of Magnetite particles of the dense phase gas–solids fluidized bed for dry beneficiation is the presence of substituting metal ions Al^{3+}, Ti^{4+}, Cr^{3+}, V^{3+}; the metal ions Fe^{2+} have been replace Mg^{2+}, Mn^{2+}, Zn^{2+}, Ni^{2+}, Co^{2+}, Cu^{2+}, Ge^{2+} and so on. Magnetite ore specific susceptibility $\chi > 4.0 \times 10^{-5}$ cm^3/g, which belongs to the strong magnetic minerals. Magnetization of magnetite is stronger, but the coercive force is small, is advantageous to the magnetic separation and demagnetization. Magnetite is one of the best magnetic materials as a heavy medium. Table 1 is

* Corresponding author. Tel./fax: +86 0516 83590092.
E-mail address: ymzhao_paper@126.com (Y. Zhao).

http://dx.doi.org/10.1016/j.apt.2014.02.002
0921-8831/

Table 1
Magnetite particle composition and bulk density.

Particle size (mm)	Magnetite particle	
	Magnetic material content (%)	Bulk density (g/cm^3)
−0.3 + 0.15	99.85	2.55
−0.15 + 0.074	99.86	2.41
−0.074 + 0.045	99.94	2.22

test the magnetite ore powder 0.3 + 0.15 mm, 0.15 + 0.074 mm and 0.074 + 0.074 mm three grain size of the magnetic material content and bulk density.

2.2. Experimental methods

In order to verify the validity of the model, the experiment of magnetite particles have been develop dense phase gas–solid separation for lab-scale fluidized bed. The lab-scale fluidized bed used in this study is shown in Fig. 1. The experimental apparatus consists of the fluidized bed main part. The fluidized bed column is cylindrical, the diameter of fluidized bed is 300 mm, and the height of fluidized bed is 550 mm. For air supply system is mainly composed of roots blower, air bag, flow control valve, pressure gauge and flow meter. Pressure gauge, the rotor flow meter and snort valve adjust the air pressure and air volume, storage surge tanks have the effect of voltage regulation. Dust is produced by fluidized bed injects into the atmosphere by dust removal device. In the long run, magnetite collision between particles and particle happens in the dense phase gas–solid fluidized bed, Magnetite particle is attrited, small particles quality content increase, as shown in Fig. 2. The granularity of the test used the laser particle size analyzer, and the process of test uses the fluidized bed test laboratory equipment. However, the attrition of magnetite particles in dense phase high density fluidized bed dry separation would change their size distribution (Fig. 3), and then influence the normal operation of dense phase fluidized bed dry beneficiation.

3. Description of attrition model

The attrition of magnetite particles in dense-phase high-density fluidized bed dry separation changes their size distribution and influences the normal operation of dense-phase fluidized bed dry beneficiation. Thus, the attrition of magnetite particles in fluidized beds is an important research topic. Particle attrition of the fluidized bed is mainly composed of the interparticle friction [23]. The friction effect of the dense-phase mainly fluidized bed mainly originates from fine particles generated from original particles in the outer layer, which, in turn, generates a new particle surface. This paper establishes a mathematical model of dense-phase fluidized bed medium attrition, with the attrition rate constant k of magnetite particles in the fluidized bed.

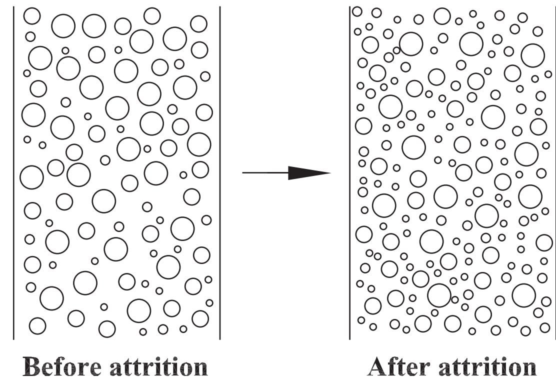

Fig. 2. Systematic image of dense phase separation fluidized bed before and after attrition run.

The mathematical model is established to make the following assumptions about wear rate:

(1) Magnetite particles are assumed spherical, with particle, friction being is the only reason that leads to smaller particles smaller. The fine particles are not subjected to further wear and tear, and the diameter of the fine particle is defined as the D_f.
(2) Broken magnetite particles are negligible; with friction power consumption producing a new surface, power attrition consumption is proportional to the process of generating a new surface area in material attrition [23].
(3) Quantitative analysis can be used to describe the continuous fluidized bed primitive magnetite average particle size D_0 (average diameter):

$$D_0 = \frac{\sum \omega_i}{\sum \frac{\omega_i}{D_i}} \tag{1}$$

D_a is the average particle size of the magnetite particle after attrition:

$$D_a = \frac{\sum \omega_{ia}}{\sum \frac{\omega_{ia}}{D_{ia}}} \tag{2}$$

where based on particle size distribution, ω_i, and ω_{ia} are the mass fractions of the narrow fraction attracted before and after sieve analysis; and D_i and D_{ia} are the average diameters attracted before and after sieve analysis (the arithmetic mean diameter between maximum and minimum diameters in the particle size).

(4) Supposing that all particles are spherical in each graded screening, the total number of particles is N_i for each sieve grain. Hence, the total mass of magnetite particles in the bed is written as follows:

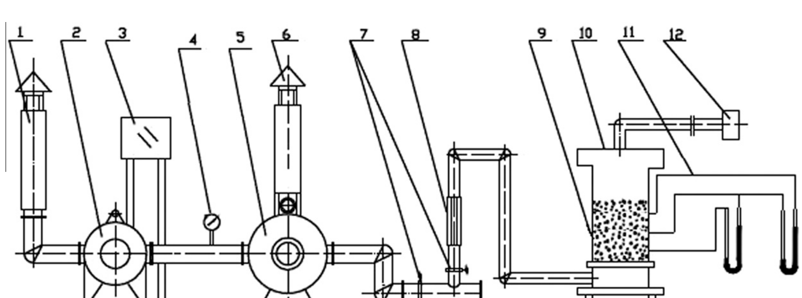

Fig. 1. Schematic diagram of experimental system. 1. Air filter, 2. Roots blower, 3. Power distribution cabinet. 4. Blower pressure gauge. 5. Storage surge tanks. 6. Air inlet silencer. 7. Flow control valve. 8. Flowmeter. 9. Fluidized bed. 10. Dust cover. 11. U tube differential pressure gauge. 12. Air extractor