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Effect of feed characteristics on the fluidization of separating fluidized bed for dry coal separation

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ABSTRACT

A separating fluidized bed (SFB) with magnetic powders as the heavy medium was used for dry coal separation. However, during the continuous separation process in the modularized dry coal separation system, the bed density under the coal inlets was found to fluctuate seriously. In this study, the effect of feed with different densities on the fluidization of the SFB was investigated using pressure time series and image analyses. The pressure measured at different bed heights severely fluctuated when particles run into the bed, and the bed surface sunk locally. After feeding, the SFB returned to the previous status, being a "separating fluidized bed". However, for large particles, the stability of the SFB was severely damaged, and the "separating fluidized bed" acted as a "bubbling fluidized bed", after feeding. Therefore, particles large enough to damage the stability of the SFB should not be fed into the bed.

1. Introduction

Harmful elements such as sulfur and nitrogen, which are the main cause of acid rain, and gangue can be removed by coal preparation before combustion. In recent years, dry coal separation is one of the hot topics in coal preparation field. With increasing shortage of water resources, dry coal separation has become increasingly important. A FGX dry separator [1] was investigated to separate −63.5 mm high-sulfur coal. An air table [2] was used for −6.3 mm coal separation. A novel rotary triboelectrostatic separator was used to separate fine coal acquired from power plants. A reflux classifier [3–5] was used for −8 + 0.5 mm coal separation. An air dense medium fluidized bed (ADMFB) [6–11] was proposed to separate coal with a size fraction of −50 + 6 mm by the China University of Mining and Technology, which was defined as a separating fluidized bed [12] (SFB). Since then, the ADMFB has been extensively investigated. A. K. Sahu [13–15] established a dry coal separation system based on the ADMFB in laboratory scale, with a throughput capacity of 600 kg/h. Z. Xu [16–18] and R. Gupta [19,20] designed an ADMFB separator in a laboratory. Furthermore, the effect of operating conditions on dry coal beneficiation was investigated, and the characteristics of the beneficiated low-rank coal were analyzed. J. Oshitani [21,22] used the ADMFB for separating iron ore. Z. F. Luo [23] and Y. M. Zhao [24–27] used a vibrating fluidized bed for fine coal separation.

A modularized dry coal separation system [28] based on the ADMFB, KZX40, was established in Northwest China, with throughput capacity of 40–60 t/h. Using KZX40, −80 + 6 mm coal could be separated efficiently, and the probable error E value was 0.055 when the separation density is 1.42 g/cm^3. During the continuous separation process, raw coal was fed into the bed using a feeder machine. However, in the industrial separation system, the bed density under the coal inlets was found to fluctuate seriously [29] and the stability of bed density can be affected by the process of feeding. Coal particles, gangue and other metals from mines can damage the stability of the SFB when run into the bed. In this study, the effect of feeds on the fluidization of the SFB was investigated using a laboratory-scale SFB, by analyzing the pressure time series, corresponding to the bubble dynamics and behaviors in gas–solid fluidized bed [30–34].

2. Experimental

The schematic experimental system is shown in Fig. 1. The bed was made using Perspex to observe objects in the bed, and the air chamber was made using stainless steel (SUS304). The statics bed height of the SFB is 100 mm. The pressure fluctuations were measured at 0.09, 0.07, 0.05, and 0.03 m above the bottom of the bed through four 4 mm I.D. copper probes with a fine mesh net at the side facing the fluidized bed, and four differential pressure transfers were used. The four test points were indexed as positions 1–4#. A high-speed video camera (Olympus, *i*-Speed 3) was used to collect the images. A data logger (National Instruments, USB 6361) was used to couple the high-speed camera and the differential pressure transfers. The MiDAS DA Software and *i*-Speed Control Software were used to record the pressure data and images synchronously. In the experiments, the sampling frequency of

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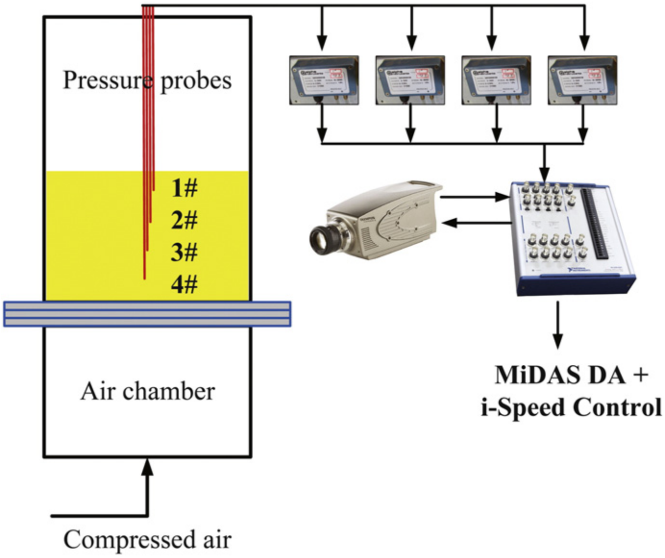

Fig. 1. Schematic of the experimental system.

pressure data was 1000 Hz, and the sampling frequency of image was 250 Hz.

Vanadium titano-magnetic powders, which can be recovered by a magnetic separator and recycled in the separating system, were used as the heavy medium in the SFB, because of their suitable bulk density. The properties of magnetic powders analyzed using magnetic tube, powder tester and vibration magnetometer are listed in Table 1. The size distributions were analyzed using a laser particle size analyzer and are shown in Fig. 2. The average particle size was 232 μm, and the dominant size fraction was −300 + 100 μm. Microfine magnetic powders (−74 μm) in the heavy medium are unsuitable for obtaining a better fluidization for separation, due to the large specific area and adhesive force among particles. Furthermore, the high content of coarse magnetic powders (+300 μm) is not suitable for fine coal separation according to the previous research [35]. The minimum fluidizing air velocity for the heavy medium in the SFB is 0.06 m/s tested in experiments, and the operational fluidizing air velocity is 0.072 m/s for obtaining a stable separating fluidized bed.

To collect the high-quality images, tracer particles, as shown in Fig. 3, were used to simulate materials with different densities in raw coal. A steel ball was used to simulate the metal products, and a large glass ball was used to simulate the large particles in raw coal. The properties of tracer particles are listed in Table 2.

3. Theory

The process of a particle falling into the SFB from a height is shown in Fig. 4a. The pressure waves generated from the collision between the particle and bed surface transfer downward by the compression of interstitial gas. Because of the particle dampers, the energy of the pressure waves decreases with the propagation distance. When the pressure waves reach the gas distributor at the bottom of the SFB, they are reflected. The collision between the particles and bed surface can be regarded as similar to the process of a ball colliding with an elastic body, as shown in Fig. 4b and c. For the low-density particles, the direction of the final velocity of collision may be reversed. However, for the high-density particles, the ball will move downward after the collision.

During the oscillation of particle and bed surface, part of the energy of the particle was transferred to the pressure waves and magnetic powders. According to the theory of momentum and momentum

Table 1
Properties of magnetic powder.

True density (kg/m^3)	Bulk density (kg/m^3)	Content of magnetic material (%)	Coercive force (kA/m)	Coefficient of magnetization (mm^3/g)	Moh's hardness
4600	2650	>90%	10.98	10–34.5	6

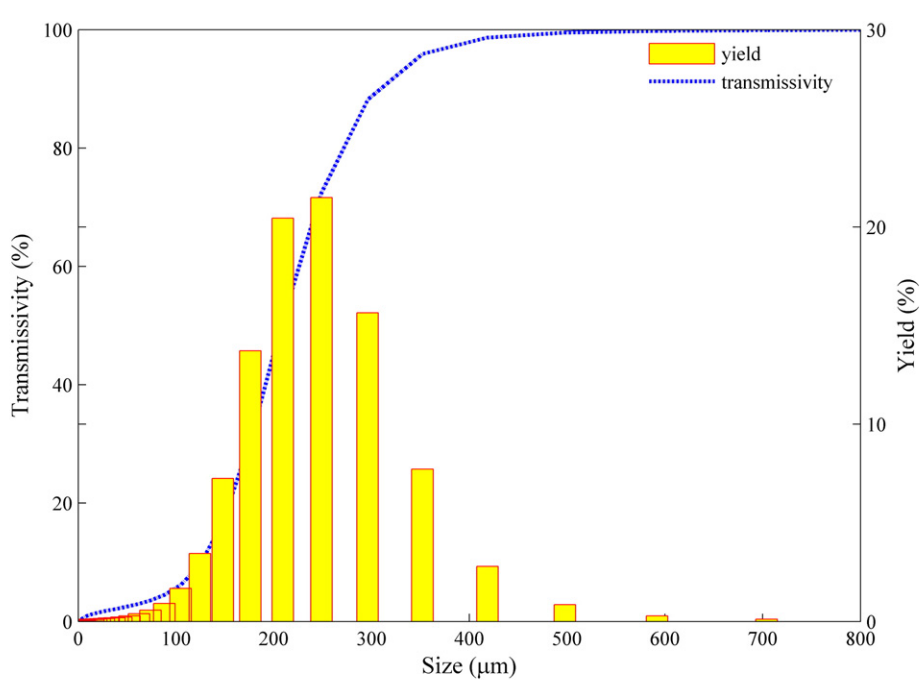

Fig. 2. Size distributions of the heavy medium.