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Full Length Article

Effect of bed characteristics on separation behavior of coal particles in a gas-solid fluidized bed

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ABSTRACT

Air dense medium fluidized bed can achieve effective separation of $-50+6$ mm coal. However, the bed characteristics significantly affect the separation behavior of coal particles. The results indicated that the bed critical expansion degree decreased with increase in static bed height, and the axial distribution coefficient of low-density particles increased from 0.798 at $H_s = 60$ mm to 0.950 at $H_s = 180$ mm with raising concentration of emulsified-phase particles, which revealed low bed height is advantageous for particles floatation, while bed density is not the main action factor in this process. As for bubble dimension calculation model, the Kato and Wen formula is favored for smaller relative error for 0.3–0.25 mm bed particles. In addition, separation was difficult when the density difference between the bed and the tracer spheres was more than 0.3 g/cm^3, and the λ value was almost constant with increase in fluidization number for each sphere whose density difference was less than 0.3 g/cm^3. With increasing $\Delta\rho$ from 0.07 g/cm^3 to 0.27 g/cm^3, the λ values for d = 38, 25, and 15 mm increased from 0.44, 0.69, and 1.54 to 0.64, 1.00, and 2.01, respectively.

1. Introduction

For gas-solid fluidized bed, particle characteristics is a key factor determining its fluidization quality, including particle size and distribution, surface roughness, density, shape, and hardness etc [1,2]. For dense medium coal preparation, whether wet or dry, magnetite powder is mainly used to achieve a certain density. Beginning with the early studies of Frazer and Yancey, many scholars have paid more attention to developing medium particles, including magnetite powder, iron powder, zirconium sand, beads, and quartz sand etc. Tang [3] adopted Geldart B magnetic powder as a dense medium solids, which was effectively applied in lump coal beneficiation owing to its wide adjustable range of bed density. In order to obtain an appropriate separation density, different kinds of materials can be mixed. Franks et al. [4] effectively separated copper ore by adjusting the weight ratios of three kinds of different mediums (iron powder, silica sand, and zirconium), and the fluidization numbers were controlled between 1.1 and 1.6.

For separation fluidized bed, gas velocity is the easiest way to adjust the bed apparent density. Under the premise of ensuring better separation accuracy, a higher gas velocity can improve the separation efficiency, certainly it also depends on material characteristics. Oshitani et al. [5] studied the flow behavior of medium particle under different gas velocities by measuring the force of a test sphere laying at different locations in a fluidized bed. He et al. [6] investigated the coal separation at different fluidization states, and found that low gas velocity had difficulty in providing sufficient external energy to overcome the resistance as particles movement, thus, density segregation phenomenon was blocked, whereas larger fluidization numbers ranging from 1.4 to 1.8, the material particles began to form an better ash gradient in the axial direction, this was due to appropriate gas velocity improving the bed activity and making it conducive to separate. However, low- and high-density coal particles become prone to occurring backmixing with further increase in fluidization number, which is bad to the separation process. As we all know a higher gas velocity destroys the bed stability, and large bubbles generate serious interferences to particle motion. The separation efficiency is usually determined by bed viscosity and the flow state of medium particle. In addition, feed particle properties also had an action on the bed fluidization characteristics and coal beneficiation, the fluidization conditions for coal samples with sizes of 6–13 and 13–25 mm showed a drastic change in surrounding zones, and feed mass fraction and rate that influenced the separation accuracy should be controlled into certain range [7]. With decrease in coal particle size, the specific surface area increased, while the sedimentation terminal velocity decreased. The increased drag force and gravity ratio resulted

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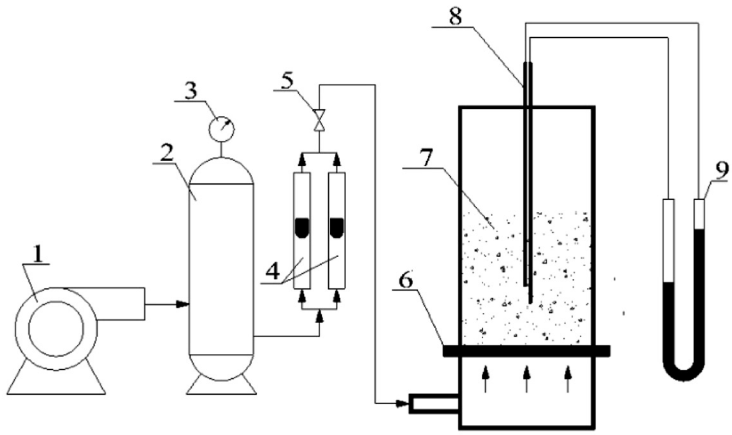
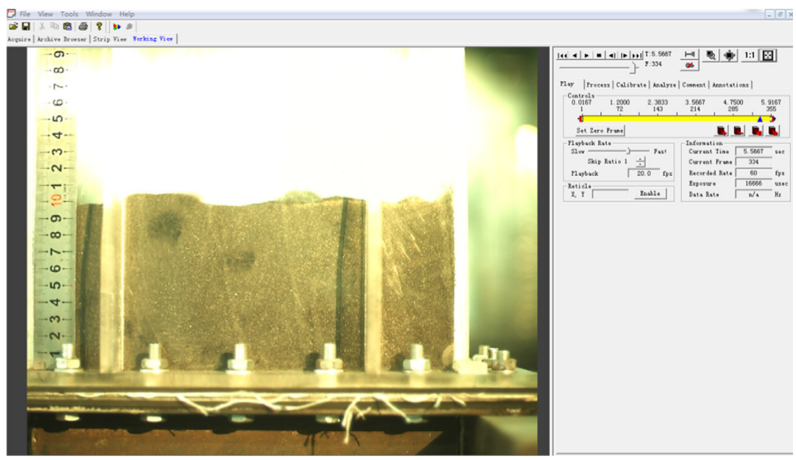


a: Flow chartof experimental system: (1) Fan blower; (2) Air buffer; (3) Pressure gauges; (4) Rotor flowmeter; (5) Blast gate; (6) Air distributor; (7) Fluidized bed; (8) copper pipe; (9) Manometer.



b: Actual image of gas-solid fluidized bed

Fig. 1. Experimental system of gas-solid fluidized bed.

Table 1
Bulk density of each size fraction dense medium.

Size fraction/mm	Bulk density/g/cm^3
0.3–0.25	2.455
0.25–0.18	2.527
0.18–0.125	2.565
0.125–0.074	2.642

Table 2
Average particle size of each size fraction dense medium.

Size fraction/mm	0.125–0.074	0.18–0.125	0.25–0.18	0.3–0.25
Average particle size/mm	0.093	0.147	0.208	0.266

in the enhancement of misplacement. So the optimal fluidization gas velocity should be selected according to the smallest particles in the feed [8]. Hence, a suitable fluidization gas velocity is a prerequisite for effective separation of material in a gas-solid separation fluidized bed.

In the last decade, fluidization separation technology has attracted more attention in the field of mineral processing. Gupta [9,10] and Xu [11,12] as well as other members had established a laboratory-scale air dense medium fluidized bed model machine. Apart from studying the fluidization characteristics, they carried out separation experiment using −5.66 + 0.42 mm coal and obtained the possible deviation E = 0.03–0.10 g/cm^3. At the same time, the migration of dense metal elements during the separation of −13.2 mm low-grade coal was also investigated. Sahu et al. [8,13–14] established a set of 600 kg/h continuous separation system in the laboratory, and by processing −25 + 6 mm Indian high-ash coal obtained the possible deviation, E = 0.12 g/cm^3. Oshitani et al. [5,15–18] found that the floatation or sinking of particle depended not only on the bed density, but also on the apparent fluidization velocity. Their findings revealed that iron ores with a minimum size of 17.6 mm could be effectively separated, while ores with sizes below 17.6 mm could not be stratified well obeying density. The ideal apparent density can be achieved by adjusting the gas velocity and selecting an appropriate dense medium. Moreover, the bed density adjustment range can be broadened by mixing two different medium particles.

Bubble dynamics behavior is the basic characteristic of a bubbling fluidized bed, which significantly affects pressure drop, bed height, expansion degree, and bed mixing degree. Although many scholars used theoretical and experimental methods and means to study the bubble movement behavior in chemical field extensively [19–22], but fewer studies referred to the air dense medium fluidized bed. Soria-Verdugo et al. [23] tracked object trajectories by using non-invasive tracing techniques and then performed digital image analysis. Rios et al. [24] found that the average vector velocity of a floating sphere rising from