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Effect of agitation on the characteristics of air dense medium fluidization

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ABSTRACT

In order to study the effect of agitation on the characteristics of air dense medium fluidization, we designed and constructed an agitation device. Analyses were then conducted on the fluidization characteristics curves, the bed density stability and the average bubble rise velocity U_a under different agitation conditions. The results indicated that a lower bed pressure drop (without considering lower gas velocity in a fixed bed stage) and higher minimum fluidized velocity are achieved with increasing agitation speed. The height d (distance between the lower blades and air distribution plate) at which the agitation paddle was located had a considerable effect on the stability of the bed density at 9.36 cm/s < U < 10.70 cm/s. The higher the value of d, the better the stability, and the standard deviation of the bed density fluctuation σ dropped to 0.0364 g/cm^3 at the ideal condition of d = 40 mm. The agitation speed also had a significant influence on the fluidization performance, and σ was only 0.0286 g/cm^3 at an agitation speed of N = 75 r/min. The average bubble rise velocity decreased significantly with increasing agitation speed under the operating condition of 1.50 cm/s < U–U_{mf} < 3.50 cm/s. This shows that appropriate agitation contributes to a significant improvement in the fluidization quality in a fluidized bed, and enhances the separation performance of a fluidized bed.

1. Introduction

The use of a special agitation device in a bubbling fluidized bed, makes particles be suspended in the bed under the combined action of the drag force from the fluid and the agitation paddle acting force; this mechanism is knows as an agitated fluidized bed [1]. Domestic and foreign scholars have conducted researches on the kinetic characteristics of a fluidized bed by comparing the fluid dynamics characteristics of an agitated fluidized bed with those of a conventional fluidized bed. Yu et al. found that agitation had a greater influence on the bed during initial fluidization; however, under a complete fluidization, the influence was not clear [2]. As particles easily bond with each other, agitation could suppress aggregation and reduce or even prevent agglomeration between the particles and the sticking phenomenon on the wall surface of the bed [3]. Leva studied the effect that the manner in which the agitation blades were mounted and the direction of rotation had on the bed pressure drop and agitation power; it was concluded that agitation would cause a lower bed pressure drop if the agitation blades made particles move in the same manner as the particles in a conventional fluidized bed [4]. At the same time, Li et al. investigated the bed pressure drop by using two types of agitation paddles double-anchored and double-framed. They found that horizontal blades were more conducive to breakage of bubbles, but vertical blades promoted the generation and growth of bubbles; the result demonstrated that the double-anchored paddle always decreased the bed pressure drop [5]. Reed and Fenske conducted a study on the effect of agitation on bed pressure drop, with the conclusion that agitation would help improve fluidization quality [6]. The main reason was that agitation could suppress channeling and slugging of the bed, thereby, maintaining a good fluidization state [7]. An agitated fluidized bed is widely used in the chemical industry, and it is mostly used to fluidize fine particles. Few studies have been conducted on Geldart B particles [8]. Magnetite powder, belonging to Geldart B particles, is used as a heavy medium in the air dense medium fluidized bed, and its dominant size fraction is 0.074–0.3 mm. In this study, agitation energy is introduced into such a fluidized bed, and the fluidization characteristics and density stability that we studied are regarded as a basis for obtaining a uniform and stable fluidized bed and improving the force [9,10] and separation characteristics of coal particles.

2. Experimental

2.1. Experimental system and apparatus

The experimental system used in this study is shown in Fig. 1. It consisted of an air supply system, fluidized bed model, agitation

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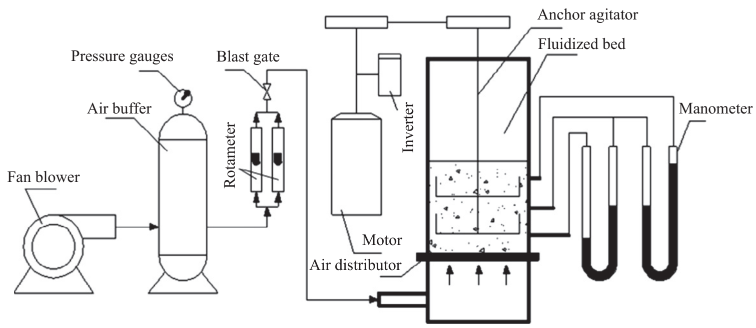

Fig. 1. Experimental system of gas–solid agitated fluidized bed.

system, differential pressure measuring installation, and dust pelletizing system. In the experiment, the fan blower was turned on and a fixed amount of magnetite powder was fed into the bed where it was fluidized by the flowing gas whose pressure was controlled at approximately 0.02 MPa. A motor drove the agitated body to rotate, and the agitation speed was controlled by adjusting the inverter. The fluctuations in pressure between two arbitrary points of the fluidized bed was monitored by the U-shape piezometric pipes attached to the sidewall, and the super-fine dust particles generated during fluidization were collected using a filter box device.

The fluidized bed consists of a bed body, air chamber, and air distributor. To facilitate simple testing and observation, the bed body was made of a transparent plexiglass column with an inner diameter of 230 mm and height of 400 mm; the static height of the medium bed was 180 mm. The gas distributor contains two perforated plexiglass plates and several pieces of fabric. In order to measure the change of bed height in time, the sidewall of the bed was marked with graduated scale.

The motor had a power of 700 W, and the agitation speed could be adjusted within a range of 0–250 r/min. The agitation paddle was double-anchored and all its horizontal and vertical blades, which were right-angled triangles, pointed in the direction of the blades movement with a small acute angle, in addition, the intersection angle between the upper and lower blades is 45°. The distance between the upper and lower blades was 50 mm in the test. We considered the height (distance between the lower blades and air distribution plate) where the agitation paddle is mounted to be 20 mm before determining the ideal condition.

2.2. Magnetic medium properties

Geldart B magnetic power, which is applied in coal separation as the medium solid particle with wide size fraction and high density was used in the test. The true density was 4200 kg/m^3, and bulk density was 2430 kg/m^3; its magnetic material content and saturation magnetization were 99.68% and 76.80 A m^2/kg, respectively. The size distributions of the medium solid are listed in Table 1.

Table 1
Particle size distribution of the medium solid.

Size fraction (mm)	Magnetite powder productivity (%)
+0.30	0.22
−0.30 + 0.15	57.84
−0.15 + 0.074	41.26
−0.074	0.68
Total	100.00

2.3. Method and evaluation indicator

The bed pressure drop per centimeter can be calculated by reading the difference in the liquid level of U-shaped piezometric pipes. Then, the fluidization characteristics curves can be drawn, and the variation characteristics of the bed pressure drop and minimum fluidization velocity are analyzed and compared at different agitation speeds. Further, the effects on the bed density stability are also explored under different agitation conditions; the bed density is calculated using

$$\Delta p = \rho g \Delta h \quad (1)$$

where Δp is the pressure differential between two measuring points; ρ the density between two measuring points; g the gravitational acceleration, and Δh the distance between two measuring points.

The standard deviation of the bed density fluctuation σ, which is the indicator to evaluate the fluidization performance ($N = 4$ in the test), is

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\rho_i - \overline{\rho})^2} \quad (2)$$

where σ is the standard deviation of the bed density fluctuation; N the sample numbers of pressure measuring points in the bed; ρ_i the density at each pressure measuring point; and $\overline{\rho}$ the arithmetic mean density of all measurements taken at each bed-pressure measuring point.

Furthermore, to investigate the influence of agitation on bubbles, the bed fluidization performance is studied in terms of the average bubble rise velocity.

3. Results and discussion

3.1. Effect of agitation on the bed pressure drop

The fluidization characteristics curves are shown in Fig. 2. We observe that agitation speed does not have a considerable effect on the bed pressure drop at a very low gas velocity in a fixed bed stage. However, the effect becomes prominent as the gas velocity increases; a higher agitation speed causes the pressure drop to decrease significantly. The pressure drop tends to be steady, almost not influenced by the agitation speed when the gas velocity is higher than the minimum fluidization velocity.

In a fixed bed stage, the fluidized bed is mainly affected by two factors. One is that agitation helps reduce the bridging phenomenon between particles and decreases the peak value in fluidization characteristics. At the same time, it allows the medium solids to accumulate more closely, therefore increasing the bed pressure drop across the bed. The other factor is that the agitation blades play a role in lifting the entire bed of medium solids, increasing the void fraction and decreasing the effective density