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Characteristics of Geladart-B Particles in Fluidized Beds

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Abstract – Using quasi-two-dimensional bubbling fluidized bed system, Characteristics of Geladart-B[8] particles in fluidized beds, flow pattern, minimum fluidized velocity and gas bubble size is investigated experimentally. And the method of signal processing of image gray scale is adopted to get bubble sizes. The experimental result indicates that the height of particles in the bed grows with the gas flow rate increasing and the bed pressure drop increases if the static bed height increases. Moreover, bubble size grows bigger when the gas velocity at the inlet grows faster. As the air velocity is getting higher, the amplitude of fluctuation of the bubble size is increased sharply.

***Keywords*:** Flow pattern, Minimum fluidized velocity, Bubble size, Gas flow rate.

1. Introduction

Fluidized beds are widely used in many fields, such as medicine processing factories, power plants, chemical reactors and so on[1]. So promoting working efficiency and quality of fluidized beds continues to be profound, especially in the limitation of some extreme operating condition[2]. There exists many bubbles in fluidized beds, which start from gas distribution plate and grow bigger during their ascents. As an obvious feature, the characteristic of bubbles partly determines the transfer of mass and energy. So it is fundamental to get well known of the size distribution of bubbles and get distinct understanding of the behavior of them[3]. And during the process of formation, growth and eruption of bubbles, there exists a stable gas bubble diameter, which is considered to be a vital parameter for mass transfer[4].

Lare et al.[4] used a small capacitive double needle probe to measure the porosity variations. And they got the result that bubble frequency increase with the increase of superficial gas velocity. Muller et al.[5] studied the bubble bevavior in two-dimensional fluidized beds using the technology of particle image velocimety. Goshima et al.[6] compared the difference of fluidization characteristics between silica nanoparticles and hollow borosilicate glass microparticles and they analyzed the influence of bubbles' sizes from gas exchange rate. Through experiments, Dong et al.[7] found that if the decrease of the degree of electrification of granules results in the increase of gas bubble sizes.

In this article, Geldart-B[8] particles are adopted in the experiment and the maximum diameter of gas bubbles, pressure drop of the fluidized bed and minimum fluidization velocity are compared under different conditions, such as various superficial velocity and static bed height. After photographing the process of fluidization of large particles with a digital camera, the size of gas bubbles can be easily got through signal processing of image gray level without complex and expensive apparatus.

2. Experimental apparatus

The experiment is conducted on the condition in Table 1 and made on a two-dimensional fluidized bed as Figure 1, which is 0.79m high, 0.1m wide and 0.01m thick of the inner size. The wall of the bed is made of plexiglass, and the porous air distributor is on bottom. The gas comes from a fan and the flow rate is adjusted with controlling the glass rotameter ranged from 0-1.25m3/h. Then the gas gets to the bottom of the fluidized bed through the gas chamber. There laid a certain amount of glass beads in the fluidized bed, which can be fluidized as long as the superficial gas velocity exceed the minimum fluidized velocity, of which properties are shown in Table 1.

Table 1: Experimental conditions and particle properties.

static bed height	gas flow rate	material	mean diameter	average density
110, 140, 170mm	0-1.2m3/h	glass beads	0.1, 0.5mm	$2600kg/m^3$

The pressure signal sampling setup with a scale of 0-10kPa keeps recording the data of the bed pressure drop. On the bottom of the bed, there located a pressure tap while another tap is placed on the bed at the height of 0.54m.

The whole fluidized process is photographed by a digital camera. Because the thickness of the fluidized bed is thin enough, it is convenient to get a clear view to see the gas bubbles' movement. Then the pictures are processed with the method of signal processing of image gray level by MATLAB.

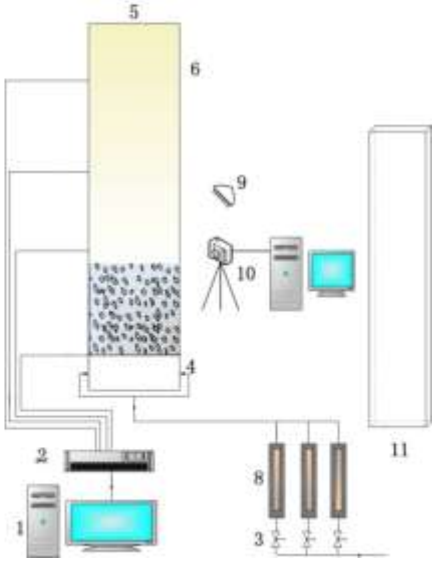

Fig. 1: The fluidized bed and the glass rotameter: (1) computer; (2) pressure signal sampling setup; (3) control valve; (4) air chamber; (5) outlet of the fluidized bed; (6) fluidized bed; (8) glass rotameter; (9) powerful light source; (10) digital camera; (11) fluidized bed.

3. Results and discussion

3.1. Flow pattern

The movement of glass beads(mean diameter=0.1mm) is depicted in Figure 2. The air stream comes from the bottom of the fluidized bed, which is covered with the porous air distributor. When the gas passes through the particles, there exists drag forces and buoyancy forces[9]. If the velocity of the air reaches the minimum fluidized velocity of solids, particles start to flow and few tiny bubbles appear (Q=0.325m3/h).

Further increase of the gas velocity, it is clear to observe bubble evolution, rising, growing and burst (Q=0.45m3/h). During the fluidization process, the collisions among neighbour bubbles result in the deformation and coalescence of bubbles[10]. So the shape and scale of bubbles continue changing at different time and different height (Q=0.65, 0.85m3/h). When the air stream velocity is high enough, granules move intensively and it is obvious to see big bubbles in the bed (Q=1.25m3/h).

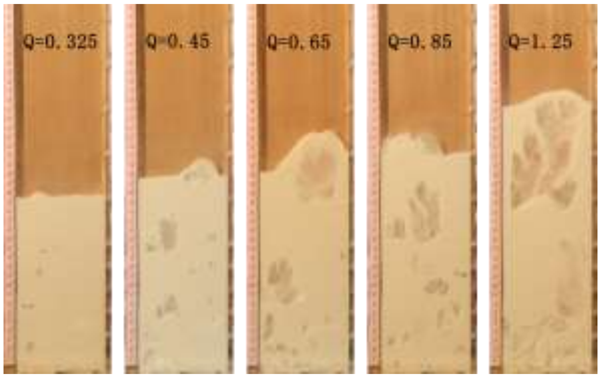

Fig. 2: Evolution of particle movement in the fluidized bed (Q: gas flow rate at inlet, m3/h).

3.2. Minimum fluidization velocity

In order to obtain the minimum fluidization velocity, it is necessary to get the effect of gas velocity on the bed pressure drop, as is shown in Figure 3[12]. According to Jin[11], it can bring hysterisis that the method of measuring pressure drop with the gas velocity increasing. So both method a and method d are adopted. However, it turns out that hysterisis phenomenon is not obvious for this kind of glass beads, of which mean diameters is 0.1mm.

Bed pressure drop arise dramatically until particles start to be fluidized. As long as the superficial gas velocity exceed the minimum fluidization velocity, bed pressure stop arising but fall slowly. And the gas velocity corresponding to this turning point is exactly the minimum fluidization velocity in Table 2[9].

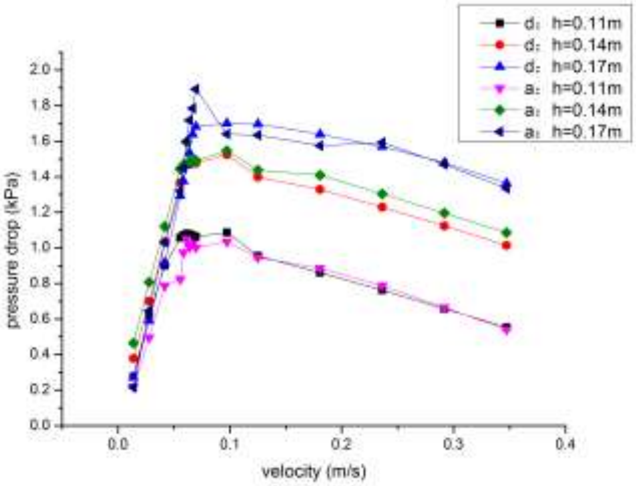

Fig. 3: Effect of gas velocity at inlet on bed pressure drop (a:measure pressure drop with the increase of gas velocity; d: measure pressure drop with the deduction of gas velocity; h: static bed height).

Table 2: Minimum fluidization velocity Vs static bed height.

static bed height(m)	0.11	0.14	0.17
minimum fluidization velocity(m/s)	0.071	0.073	0.072

3.3. Bubble size

In order to observe gas bubbles clearly, particles with mean diameter of 0.1mm are adopted. When gas comes through particles, a part of them provide the power to force particles flow and other parts turn into bubbles[9]. Darton et al.[13] proposed the equation below to describe bubble size.

$$A = 0.54\left(U - U_{mf}\right)^{0.4}\left(h + 4\sqrt{F_0}\right)^{0.8}/g^{0.2} \tag{1}$$

where A denotes the sphere's diameter, which has the same volume with the gas bubble; U is the superficial gas velocity, Umf the minimum fluidized velocity, h the height above the distributor plate; F0 is the area of bubbles at the distributor, g the gravity acceleration.

As Figure 4, it is apparent to see that the bubble size grows bigger and changes periodically while superficial gas velocity increase. The fluctuation of the size has a small range when the velocity is low (v=0.3611m/s). As the air velocity is getting higher, the amplitude of fluctuation is increased sharply (v=0.8333m/s). This phenomenon happens due to the intensive movement among particles and gas stream[13].

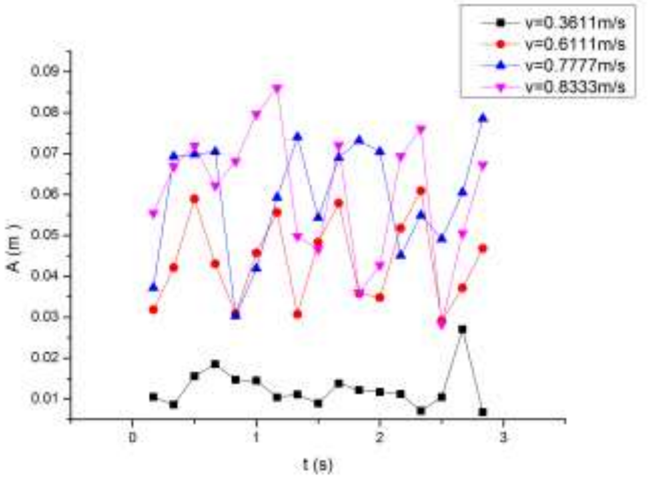

Fig. 4: Bubble size at different superficial velocity (A: bubble size, t: time, v: superficial velocity).

4. Conclusions

Characteristics, such as flow pattern, minimum fluidized velocity and gas bubble size is investigated in this experiment, and the main conclusion can be summarized as follows:

1. Gas bubbles grow bigger and deform badly with the increase of gas flow rate. Besides the bed height turns higher due to the bubbles becoming larger.

2. The bigger static bed height is, the greater is the pressure drop. However, the static bed height almost has no effect of minimum fluidized velocity.

3. The fluctuation amplitude of bubble size is directly proportional to the superficial gas velocity.

Acknowledgements

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