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Pressure drop characteristics of adjustable slotted distributor in fluidized bed

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Abstract

In this paper, a fluidized bed with a adjustable slotted gas distributor was used to study fluidization in a 230 mm×200 mm rectangular fluidized bed by adjusting the spacing between the two slotted gas distributors. The pressure drop of the distributor at different inlet gas velocities was obtained and the change law between pressure drop and distance between distributors was summarized. This study provides a theoretical basis for the application of adjustable slotted gas distributor fluidized bed.

Keywords: *Geldart D; Adjustable slotted gas distributor; Pressure drop*

1. Introduction

Fluidized bed was used in various chemical units, which was common in the production processes of agricultural products, food, pharmacy, biochemistry and so on. It can strengthen the contact and transfer between the fluid and the particles [1-3], which was characterized by good gas-solid mixing, high mass transfer and heat transfer rate, uniform bed layer and strong controllability.

Among them, the most widely used gas-solid fluidized bed was mainly composed of bed, gas distribution device and gas-solid separation device (mostly a cyclone separator). In these parts, the most important part of the whole fluidization operation was the gas distribution device, that is, the gas distributor. The study found that there were many differences between the area near the distributor and the main body of the bed, and more and more attentions had been paid to the distributor [4]. The distributor should have a certain pressure drop so that the gas can be evenly distributed. Usually, the pressure drop of the distributor is greater than 1/10 to 3/10 of the total bed pressure drop. But in practical operation, the pressure drop of the distributor is as small as possible to reduce the energy consumption, and sometimes it is designed around 5% of the total bed pressure drop of [5]. A gas distributor that can perform well fluidization operation should be able to achieve uniform distribution of gas, low energy consumption, no leakage and clogging, convenient operation and long service life.

The distributor used in various applications were various. The original gas distributor was porous distributor, that is, the holes with the same diameter were distributed on the distributor. With the development of fluidization technology, more and more distributors were applied in the actual operation. Zhao et al. [6] used a tubular gas distributor to study the fluid dynamic behavior in an internal circulating fluidized bed. Chen et al. [7] used tilted gas distributor to investigate the depth of the distributor jets in a gas-solid fluidized bed. Hassan et al. [8] used porous gas distributor and tubular gas distributor to numerically study the solids circulation flux in an internal circulating fluidized bed.

At present, the distributor design was mainly composed of a single-layer distributor, and was often applied only to one type of material in the operation processes or the applicable materials had a narrow range of particle size distribution, it cannot be automatically adjusted according to operation requirements, without adequate consideration of the pressure drop of the distributor, the energy consumption was large.

The purpose of this study was to use a self-developed adjustable slotted gas distributor[9] for empty bed fluidization experiments. The pressure drop of the distributor at different inlet gas velocities were obtained, and the change law between pressure drop and distance between distributors was summarized. It provided a theoretical basis for the application of adjustable slotted gas distributor fluidized bed.

2. Experimental

2.1. Experimental process and equipment

The experimental process is shown in Fig. 1. The gas generated by the blower was regulated by the bypass valve. The flow rate was shown by the gas flowmeter (VA300 type, flow rate 2~600 m^3/h, German CS Instruments). After that, it entered a rectangular fluidized bed (homemade, 230 mm×200 mm) equipped with an adjustable slotted gas distributor (opening rate 6%). There were two pressure measuring points on the bed, all along the axial direction of the fluidized bed, respectively 30 mm below the distributor and 30 mm above the distributor. Differential pressure transmitter (TRD-150205A, measuring range 0~1500 Pa, Tianjin Run Da Zhong Ke Instrument Co., Ltd.) was connected to two pressure measuring points through the trachea to measure the pressure drop of the distributor. The data recorded by the paperless recorder (TRD-21R, Tianjin Run Da Zhong Ke Instrument Co., Ltd.).

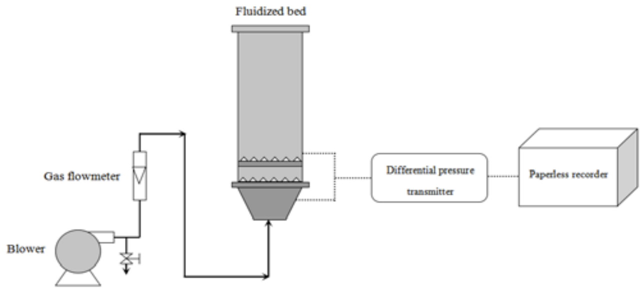

Fig. 1 Experimental flow chart.

A self-designed fluidized bed with a adjustable slotted gas distributor was used in the experiment. The distributor was made up of two slotted gas distributors. As shown in Fig. 2, the upper distributor size was 340 mm×220 mm, the slit area size was 220 mm×190 mm, the distributor opening rate was 6%, the number of the angle steel was 6, the side length of the angle steel was 23 mm, the distance between the angle steel was 2 mm and the height of the angle steel was 16 mm. As shown in Fig. 3, the lower distributor size was 220 mm×190 mm, the distributor opening rate was 6%, the number of the angle steel was 6, the side length of the angle steel was 23 mm, the distance between the angle steel was 2 mm and the height of the angle steel was 16 mm. Two distributors were connected by two guide components. The upper distributor was bolted to the bed. The lower distributor can move up and down under the guidance of the guide rail, so as to achieve the effect of adjusting the distance between distributors.

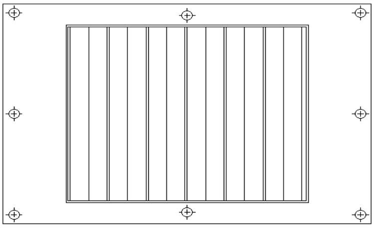

Fig. 2 Upper distributor.

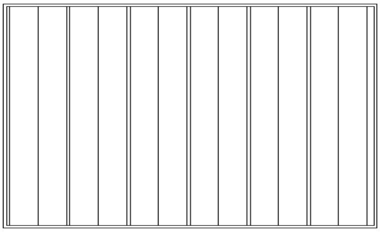

Fig. 3 Lower distributor.

2.2. Experimental method

The adjustable double-layer slotted gas distributor was connected to the fluidized bed with different distance between distributors (d) (0 mm, 10 mm, 20 mm, 30 mm and 40 mm). The pressure transmitter was connected to the bed through the trachea and the pressure transmitter was connected to the paperless recorder. Open the blower, open to maximum and gradually reduce the opening, control the gas flow from the maximum 310 m^3 / h to become smaller and keep the open interval of 10 m^3/h. The recording interval of the paperless recorder was 1s, each interval recorded for 60 s. The average value was the pressure drop (ΔP) of the empty bed under the corresponding gas velocities (v). Each group of experiments was repeated 3 times and the average value of the data was taken.

3. Result and discussion

3.1. Influence of distance between distributors on pressure drop

The pressure drop of the distributor was the pressure loss caused by the gas passing through the distributor. Fig. 5 showed the relationship between pressure drop and gas velocity of an adjustable slotted gas distributor under different distance between distributors. It can be seen from the figure that the pressure drop of the distributor increased with the increase of gas velocity, while the pressure drop of the distributor was different at different distance between distributors. When the spacing between the distributors was 0 mm, that was, when the two distributors were almost close, the pressure drop produced by gas passing through the distributor was large and the pressure drop value was close to the 20 mm spacing. It was considered that when the distance between distributors was too small, the flow area between the plates was too small, so the pressure drop was larger. When the distance between the distributors gradually increased from 10 mm to 40 mm, the pressure drop of the distributor increased with the increase of the distance between the distributors at different gas velocities. This was because when there was a certain space between two distributors. The gas needed to consume more energy when it flowed through the space area, so it produced a certain pressure drop.

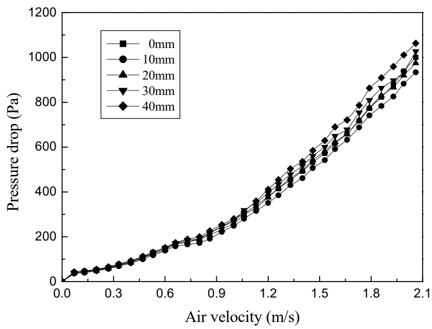

Fig. 4 Variations in pressure drop at different distance between distributors

3.2. Influence of gas velocity on pressure drop.

Fig. 5 showed the relationship between pressure drop and distance between distributors when the gas velocity was 1.59~2.06 m/s, that was, when the gas velocity was large. It can be seen from the figure that when the distance between distributors was the same, the difference between the pressure drops of the distributors corresponding to the adjacent gas velocity were not differ much as the gas velocity decreased, and the difference was approximately 50 Pa. Fig. 6 showed the relationship between pressure drop and distance between distributors when the gas velocity was 0.07 to 0.53 m/s, that was, when the gas velocity was small. It was clearly showed in the figure that when the distance between the distributors was the same, the difference between the pressure drop of the distributor corresponding to the adjacent gas velocity was also decreasing with the decrease of the gas velocity and the difference reduced from 20 Pa to 5 Pa. This was because when the gas velocity was small, the gas flow was relatively stable, so when the gas velocity changed, the pressure drop had a smaller change.

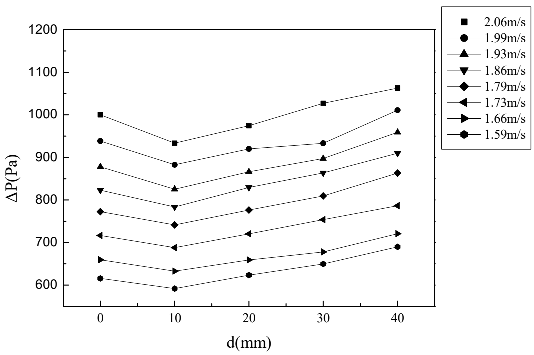

Fig. 5 Influence of pressure drop on distributor when gas velocity was 1.59~2.06 m/s

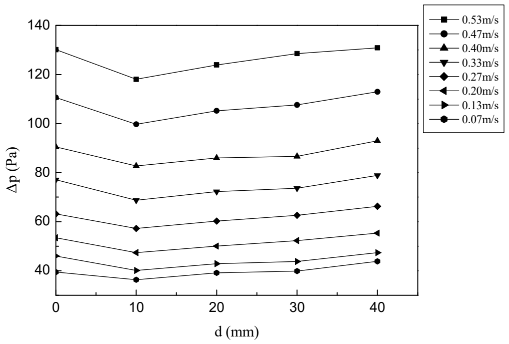

Fig. 6 Influence of pressure drop on distributor when gas velocity was 0.07~0.53 m/s

3.3 Experimental design analysis

It can be seen from Fig. 5 and Fig. 6 that except for the distance between distributors was 0 mm, at the same gas velocity, when the distance between the distributors increased from 10 mm to 40 mm, the change of the pressure drop of distributor showed a trend of linear function. Furthermore, under different gas velocities, the gradient of the pressure drop was approximately the same. This showed that the influence of the spacing between the distributors on the pressure drop was regular.In this paper, the results of orthogonal test were analyzed by Minitab software.

3.3.1. Intuitionistic analysis

Fig. 7 showed the mean main effects plot. It can be seen from the figure that the gas velocity had a significant effect on the pressure drop of distributor and the shape of the image was roughly a parabola. This showed that when the gas velocity was small, the gas velocity had little effect on the pressure drop, but as the gas velocity increased, the impact became greater. This further proved the previous conclusion.

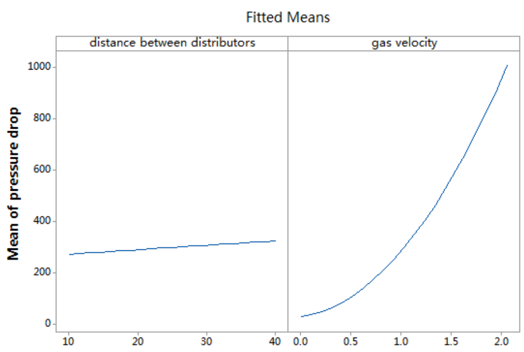

Fig. 7 Main effects plot.

3.3.2. Regression analysis

Table.1 Regression analysis

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	42.85	5.75	7.46	0.000	
v	-5.79	8.08	-0.72	0.475	20.16
d	-0.559	0.193	-2.90	0.004	3.82
v*v	206.25	3.29	62.71	0.000	15.16
d*v	2.230	0.161	13.85	0.000	8.82

Use Minitab statistical software to perform linear regression analysis on this orthogonal test. The results of the analysis were shown in Table. 1. By analyzing the above data, it can be seen that the self-interaction item of gas velocity had the most significant effect on the pressure drop, followed by the interaction term of the gas velocity and distance between distributors. In the regression analysis, the P value corresponding to the gas velocity was 0.475, which was significantly greater than 0.05. Therefore, the impact of gas velocity on the distributor was not significant. Through the regression analysis, the regression equation of the distributor pressure drop was also obtained:

$$\Delta p = 42.85 - 0.559d - 5.79v + 206.25v^2 + 2.230d \cdot v \qquad (1)$$

4. Conclusions

A self-designed adjustable slotted gas distributor was used to carry out fluidization experiment. The results showed that when the distance between distributors was 0 mm, pressure drop generated by the gas through the distributor was large. When gas velocity was 2.09 m/s, pressure drop can reach 1040 Pa and pressure drop value was similar to when the spacing was 20 mm. When distance between distributors gradually increased from 10 mm to 40 mm, pressure drop of the distributor increased with increase of spacing at different gas velocities. However, when gas velocity was low, the difference between pressure drop corresponding to the adjacent gas velocity decreased with the decrease of the gas velocity. Through the experimental design analysis, it was concluded that the self-interaction of gas velocity had the most significant effect on the pressure drop, and the fitting relationship between pressure drop, gas velocity and distance between distributors was obtained: $\Delta P = 42.85 - 0.559\ d - 5.79\ v + 206.25\ v^2 + 2.230\ d \cdot v$.

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