

Fluidization Characteristics of Nanoparticles With High Packing Capacity

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Abstract: In this paper, the minimum fluidization velocity of nanoparticles was measured on the basis of high packing volume, the effects of fluidization velocity and initial bed height on fluidization characteristics of nanoparticles were studied from the perspectives of macroscopic phenomena and microscopic characteristics by comparing fluidization height, local pressure drop, agglomeration particle size, voidage and other parameters. The results show that the bottom material is not completely fluidized under high packing quantity, and the determination results of the minimum fluidization velocity are different from previous studies. Secondly, with the increase of fluidization wind speed and initial bed height, the drag force between gas and solid increases, the degree of fluidization turbulence increases, the fluidization height and local pressure drop both increase, and the growth process of agglomeration is accelerated, and the particle size of agglomeration increases.

1. Introduction

The particle size of nanoparticles is between 0.1 nm and 100nm, and they are in the transition field between macro and micro scales. As a bridge between macro materials, atoms and molecules, they have important scientific research value. Fluidization is a multiphase flow method to study and treat the mixing, mass transfer and heat transfer of solid particles, gas and liquid phase in the industrial process [1].

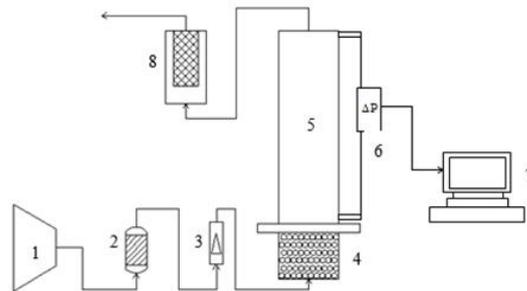
In terms of macroscopic properties, Chaouki et al. [2] first proposed the concept of fluidization and agglomeration of nanoscale particles. They found that Cu/Al₂O₃ nanoparticles formed stable clusters during fluidization and diffused in a uniform manner, which had the properties of high void and high specific surface area. Jesus gomez-hernandez et al. [3] used P25 nanoparticles with an initial bed height of about 4.7cm to study the changes of bubbles and particle concentration at different locations during fluidization of nanoparticles. In the study of microscopic characteristics, Morooka et al. [4] used a variety of materials, set the initial bed height at about 7.5cm, and estimated the size of ultrafine particle clusters through the energy balance model. Hakim et al. [5] used a high-resolution direct imaging system to study the fluidization and agglomeration behavior of nanoscale particles. Zhou Tao et al. [6] used a force balance model with an initial bed height of 4cm to predict the average agglomeration size model during fluidization of nanoparticles.

In previous research on nanometer particle fluidization, most of the initial packing height within 4 to 10 cm. It belongs in low height of packing. However, nanoparticles have smaller particle size, viscosity effect is larger, the initial high has a great influence on its at the bottom of the fluidized bed, which affect the fluidization characteristics of the whole scope, so we need further to study high packing the fluidization behavior and properties of the nanoparticles. Based on high packing quantity, we set the initial bed height within 4 ~ 20 cm, find the determination of the minimum fluidization velocity of nanometer materials, fluidized height, measure local pressure drop, mass of particle size, porosity, etc to study the fluidization air velocity. Finally, we find the influence of initial bed high impact on the fluidization characteristics of nanoparticles, through wavelet transform mathematical methods, such as the axial movement of nanoparticles to discuss specific analysis, get under a high amount of filler nanoparticles appear special circumstances and in view of the analysis.

2. Experiment Method and Apparatus

2.1. Experiment Apparatus

The experimental nanoparticles were NH-109, mainly composed of SiO₂(purity > 99%), hydrophobic powder. The packing density is 89kg/m³, the original particle density is 2560kg/m³, the specific surface area of is 210-240m²/g, the initial particle size is 25nm.



1: Compressed dry N₂ cylinder, 2: dryer, 3: rotameter, 4: gas distributor, 5: fluidization column, 6: differential pressure transmitter, 7: computer, 8: filter

Figure 1 Experimental flow chart

The experimental device is shown in figure 1. The high-pressure nitrogen cylinder is used as the gas source. After passing the pressure reducing valve and the color-changing silica gel dryer, the fluidized gas is guaranteed to have stable pressure and no water. After passing the air distribution board, the gas evenly distributes on the cross-section of the fluidized bed, and fluidizes the bed material placed in the lifting tube. The fluidized gas will carry a small amount of particles into the bag filter behind the fluidized bed and eventually flow into the atmosphere.

2.2. Measurement and Treatment of Experimental Parameters

In this experiment, the height of fluidization was determined by the transmittance identification method: a beam of strong light was shone on the riser, and the height of fluidization was defined as the lowest height that could see the other side of the pipe wall. In this experiment, a differential pressure transmitter was used to measure the pressure drop in the hoisting tube. The range of the differential pressure transmitter was 2000pa with an accuracy of 0.1%. The current signal 4-20mA was output. By controlling the opening and closing of the sampling tube, a small amount of agglomerations can be obtained in a relatively stable state. The agglomerations are distributed on the black background plate and recorded.

3. Results and Discussion

3.1. Determination of Minimum Fluidization Velocity

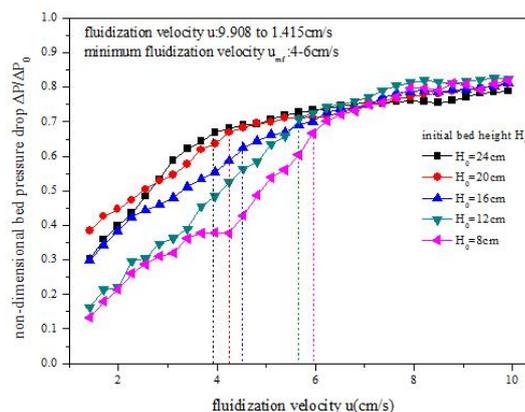


Figure 2 Measurement of minimum fluidization velocity

When the fluid passes through the particle bed, the particle changes from a stationary state to a moving state as the flow rate increases. When the drag force generated by the fluid upward is equal to the weight of the particle bed, the particle begins to fluidize, and the flow rate at this point is called the minimum fluidization velocity.

In this paper, the standard method [7] was used to measure the minimum fluidization velocity of nanomaterials, and the initial bed height H_0 was 8, 12, 16, 20 and 24cm, respectively. As shown in figure 2, the dimensionless bed pressure drop changes at different initial bed heights H_0 were measured as the fluidized wind speed gradually decreased. It can be seen from the figure that, as the fluidized wind speed gradually decreased, the bed pressure drop curve remained basically unchanged within a certain range and began to decline gradually at a certain point. In this experiment, the maximum point of the slope change of the pressure drop curve was used to determine the value of the minimum fluidization velocity. As the initial bed height increased, the horizontal range of the bed pressure drop curve gradually increased, and the measured value of the minimum fluidization velocity gradually decreased, with an average value of 4.8cm/s.

3.2. Influence of Fluidization Wind Speed and Initial Bed Height on Fluidization Height

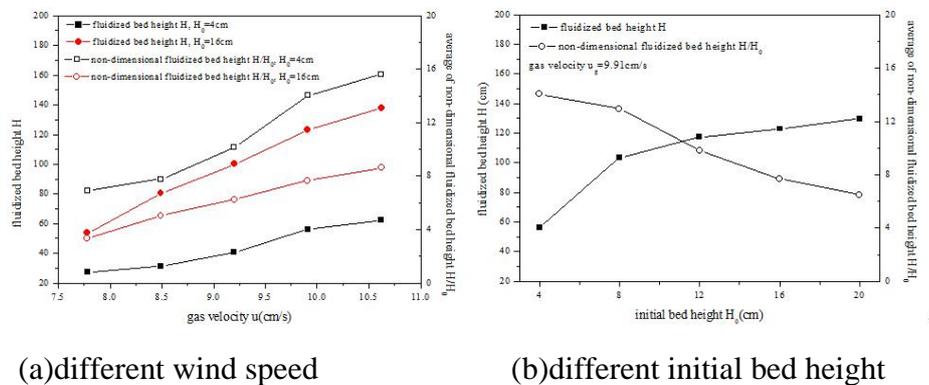


Figure 3 Variation of fluidization height of nanoparticles

Figure 3(a) shows the variation curve of the bed expansion ratio of experimental nanoparticles with fluidized wind speed. The expansion ratio of various particles is related to their own types, particle size, density, initial bed height and fluidized bed diameter. For the same kind of material, initial bed height is between 4cm to 16cm. It can be found that the fluidization wind speed change the fluidization process, due to the material quantity is less, in the process of fluidized material concentration is low, less interaction between solid particles, and the change of wind speed of working condition of high low bed expansion ratio change is more obvious.

Figure 3(b) shows the change curves of flow height and expansion ratio of different initial packing heights. When the initial bed height of the material increases from 4cm to 20cm, the average fluidization height increases from 56.1cm to 129.7cm, and as the initial bed height increases, the fluidization height increases at a slower rate. Different from the influence of fluidized wind speed, with the increase of the initial bed height, the amount of material in the lifting tube increases, the gas-solid contact becomes more frequent, and the drag force between the air and the solid increases, which promotes the material expansion and reaches a new equilibrium state. At the same time, the increase of the initial bed height promotes the growth process of the agglomeration, and the effect of the viscosity impedes the equal-ratio expansion of the material, so that the expansion ratio decreases with the increase of the initial bed height.

3.3. Influence of Fluidized Wind Speed and Initial Bed Height on Particle Size of Agglomerates

The influence of various experimental conditions on the agglomeration growth can be studied from the micro perspective through the variation of agglomeration particle size, so we make a systematic analysis combined with the macro phenomenon. As shown in figure 5, the agglomeration collected at the interface of fluidization height is distributed on the black background

plate, and the particle size distribution map is drawn after identification and processing by IPP software.

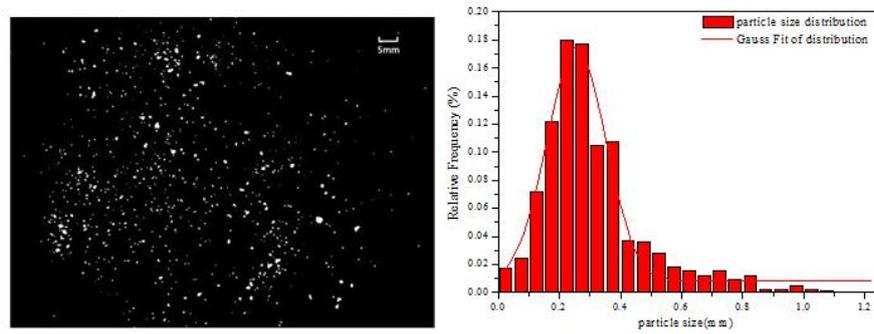


Figure 4 Treatment diagram of agglomeration particle size

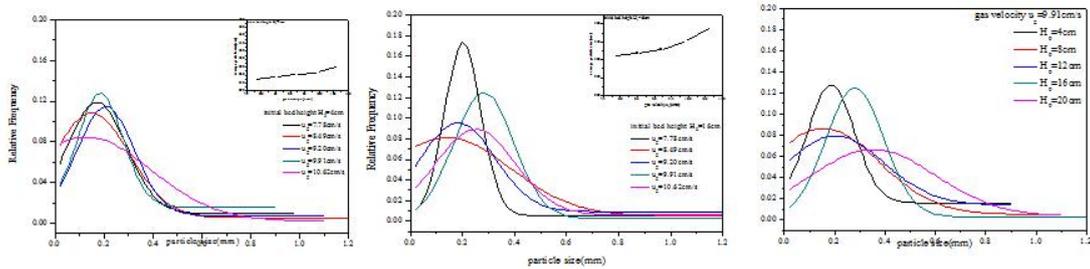
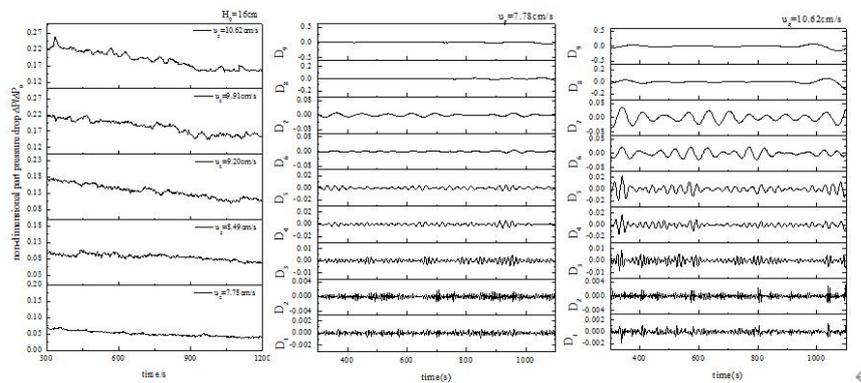


Figure 5 Distribution of particle size of different fluidized wind speeds and initial bed heights

As can be seen from the distribution curve of particle size in each working condition in FIG. 5, the distribution of particle size was fitted by the distribution curve. As the fluidized wind speed increased, the distribution curve of particle size of the cluster gradually shifted to the right. In addition, by comparing $H_0 = 4$ cm and $H_0 = 16$ cm condition can be found that under the condition of low initial bed high, the working condition of each peak differences are more obvious, including peak corresponding to peak particle size, percentage, low in bed against instability is stronger. But the particle size distribution with wind speed change law is consistent. At the same time, the low bed high percentage of each peak were higher bed working conditions, and the working condition of high bed material have higher proportion in big size scope, instructions from the particle size distribution in the working condition of high bed material, large size poly group as a whole, the more the average particle size increases.

3.4. Effects of Fluidized Wind Speed and Initial Bed Height on Local Pressure Drop



(a) Local pressure drop diagram (b) $u_g=7.78\text{cm/s}$ (c) $u_g=10.62\text{cm/s}$

Figure 6 Local pressure drop and wavelet transform at different fluidized wind speeds

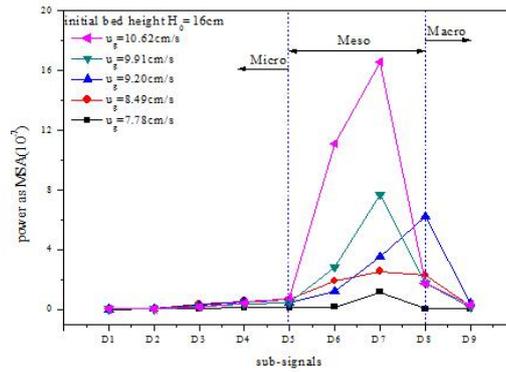


Figure 7 Energy distribution of each scale wavelet at different flow rates

The pressure drop fluctuation was analyzed by wavelet transform, and the energy of each wavelet was analyzed at the same time. The main fluctuation of fluidization of nanoparticles is concentrated in the low-frequency region, and the movement frequency of nanoparticles along the axial direction caused by gas-solid interaction is low, while the reason for the fluctuation in the high-frequency region is mainly caused by the small fluctuation of the gas source itself and other secondary factors in the flow process. Secondly, with the increase of wind speed, under the premise of keeping the wavelet transform scale consistent, the difference in the high frequency region is small. The increase of fluidized wind speed promotes the turbulence degree of the movement of nanomaterials, the gas-solid movement is more intense, and the exchange scale along the axial direction increases, which occupies the main position in the local pressure drop fluctuation.

In figure 7, it can be seen that the change of Micro and Macro areas is small, indicating gas source itself, noise and air bubbles of nanoparticles fluidization effect is small. Meso area is the main energy change area, relatively obvious, the influence of fluidization velocity as fluidization wind speed increases, Meso regional energy overall showed a trend of increase, that movement between increase makes the gas-solid fluidization wind speed is more intense.

4. Conclusion

In this paper, the main conclusions about nanoparticle fluidization are as follows:

(1) On basis of high packing, nanoparticles fluidization properties is different from others. The high filler increases material concentration in the process of fluidization, the collision frequency between poly group is more frequently, it can accelerate the poly group growth processes.

(2) The fluidization velocity was the main factor influencing the nanoparticles fluidization, with the increase of wind speed. With the increase of gas-solid drag force, between material integral fluidized height, local pressure drop increases, at the same time, it can enhance the degree of turbulent fluidization process, and promote the growth of the poly group process, poly group scale is bigger, moving along the axial energy exchange more frequent.

(3) The initial height is mainly affected by material concentration of nanoparticle fluidization process. With the increase of initial height, it can increase the overall material concentration, and increase the rate of tube gap decreases, gas-solid drag force. At the same time, it can promote the expansion material, material along the axial movement of the frequency and amplitude are gradually increased. More frequent severe collision between poly group, so as to promote the growth of the poly group.

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