Study on the Influence of the Grading Angle of Jet Grading Machine on the Grading Effect of Calcium Carbonate Powder

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Abstract

In order to obtain the influence law of the graded knife angle calcium carbonate powder classification effect, a jet classifier model was established to numerically simulate the classification effect of the average particle size of 44μm calcium carbonate powder under different graded knife angles, and further verified by jet classifier experiment. The particle size distribution of the graded knife angle to the classification of powders of different particle sizes was obtained. The results show that with the increase of the angle θ_1 of the graded knife, the effect of the calcium carbonate powder on the classification of the fine particles is firstly increased and then decreased. The fine particle classification effect is obtained when the graded knife angle θ_1 is 7°. optimal. With the increase of the angle θ_2 of the graded knife, under the action of the classifier, the classification effect of the coarse particles showed a trend of decreasing first and then increasing. When the angle of the graded knife θ_2 was 9°, the classification effect of the coarse particles was the best. The medium-particle calcium carbonate powder exhibits a decreasing tendency, and the fine particle classification effect is best when the classification knife angle θ_2 is 1°.

Keywords

Jet classifier, graded knife, numerical simulation, experimental verification, grading effect.

1. Introduction

Calcium carbonate is widely used in rubber, plastics, papermaking, paint, ink and other industries because of its odorless, non-toxic, harmless, stable chemical properties, good biocompatibility and good dispersibility. It can also be used in dental powder, toothpaste, cosmetics and other daily chemical products. It can also be used as additives in food, medicine, feed and other industries. According to statistics, the annual output of heavy calcium carbonate and light calcium carbonate in China reached 24 million tons in 2016. At present, the price of light calcium carbonate in our market is more than twice as high as that of heavy calcium carbonate with the same fineness. Therefore, the refinement of the particle size of calcium carbonate powder is an inevitable trend of development, and it is particularly important to study the classification of calcium carbonate powder.

The average particle size of calcium carbonate is 1-10 micron, and the ultrafine calcium carbonate particle size is 0.5-1 micron [3]. At present, the production of heavy calcium carbonate is generally coarse in size, wide in size distribution and limited in use. In order to improve its performance, grading is needed to reduce the granularity. At present, the classification of calcium carbonate powder mostly uses sieve mesh, which usually needs the assistance of other equipment to make the classification system complex. In this paper, a jet classifier is used to classify calcium carbonate powder [4-5], and a narrow particle size distribution of calcium carbonate powder is obtained. By changing the angle position of the classifier cutter of the jet classifier, the classification effect of different classifier angles is compared [6], and the rule of the influence of the classifier angle on the classification effect of calcium carbonate powder is obtained.

2. Classification Principle of Jet classifier

Jet classifier is a kind of classifier which integrates the principles of inertia classification, rapid classification and Coanda effect of fine particles. It makes the classifier object (powder with different particle sizes) be accelerated by ejector in the classifier. Under the action of motion inertia and wall effect, it realizes the classification of large, medium and small particles.

The classification principle of jet classification is shown in Fig. 1. The flow field of jet classifier is divided into three zones: turbulent free jet zone, Coanda effect zone and classification zone. In the turbulent free jet zone, after the acceleration of the injection of high-pressure air, the calcium carbonate powder can obtain almost the same speed as the air flow in an instant, and enter the jet classifier through the nozzle. At the same time, turbulence causes collision and shearing of particles, which results in the classification of calcium carbonate powders. In the Coanda effect zone, the movement of calcium carbonate powder to the surface of the wall-attached curve produces wall-attached effect, which makes the fine powder with small particle size move along the wall with the main jet, and the large particles basically keep the incident direction due to the inertia force. In the grading zone, when the fluid is stable in the Coanda effect zone, the grading zone depends on the structure of the grader. The main stream can be seen as the flow around the cylinder, and the graded calcium carbonate powder flows out from the corresponding outlet. Because of the turbulent flow carrying effect, the main stream beam becomes wider and the velocity of the airflow is asymmetrically distributed. The farther the distance is, the farther the maximum velocity point is away from the wall [7-9].

The expression of jet center line is as follows:

$$r=\kappa+\alpha\theta^2 \tag{1}$$

In the formula, κ and α are constants related to the structure of the classifier, and θ is the angle at which the fluid curve moves.

Through the analysis of the force on the particles, the equation of motion can be obtained as follows:

Radial motion equation:

$$\frac{d^2r}{dt^2}=r\left(\frac{d\theta}{dt}\right)^2+\left(v_a-v_p\right)\frac{18\mu}{\rho_p D_P^2} \tag{2}$$

Tangential equation of motion:

$$\frac{d^2\theta}{dt^2}=-\frac{1}{r\frac{d\theta}{dt}\frac{dr}{dt}}+\left(U_a-U_p\right)\frac{18\mu}{r\rho_p D_P^2} \tag{3}$$

In the formula, D_p is the particle size; μ is the air viscosity; v_p, U_p is the radial and tangential velocities of particles; and v_a, U_a is the radial and tangential velocities of airflow.

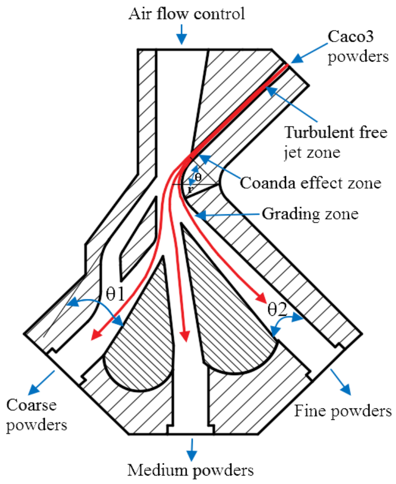


Fig. 1 Schematic diagram of jet grading

3. Numerical simulation

3.1 Modeling and meshing of jet classifier

In this paper, CPFD software Barracuda 17.0 is used to study the effect of classifier angle of jet classifier on the classification effect of calcium carbonate powder. By analyzing the structure of jet classifier and its flow field area, the flow field of jet classifier is modeled by SolidWorks. The flow field model of jet classifier is shown in Fig. 2. In this paper, based on CPLD theory, the number of barracuda grids is set to 200,000, and then the local area is refined. The total number of grids is 61854. The generated computing units are shown in Figure 3.

Fig. 2 Internal flow field model of jet classifier

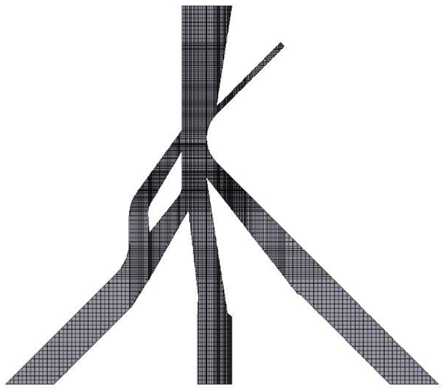


Fig. 3 Jet classifier mesh division unit

3.2 boundary condition

(1) Initial condition of particle material is CaCO3, CaCO3 density is 2710 kg/m3, particle size distribution of CaCO3 powder is shown in figure 4; fluid material is air, density is 1.172852710 kg/m3; initial flow field area is 101 325 Pa. The traction model is Wen-Yu model.

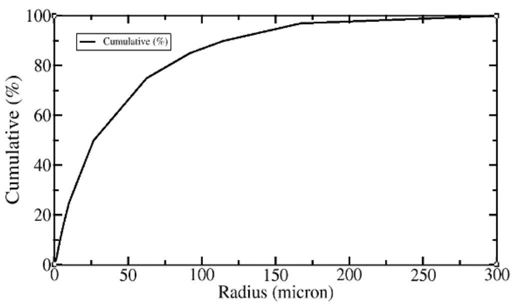


Fig. 4 CaCO3 powder particle size distribution curve

(2) boundary condition

Inlet boundary conditions: the direction of feed flow is normal surface flow, the mass flow rate of fluid is 1e-07kg/s, the pressure is 101325 Pa, the temperature is 300K, the number of particles per unit volume is 50000, and the mass flow rate of particles is 0.0001 kg/s.

Export boundary conditions: the normal direction of the outlet fluid of coarse powder, medium powder and fine powder is Z direction, the pressure of the fluid is 101325 Pa, the temperature is 300K, and the particles flow freely.

Controlling gas flow boundary conditions: the normal direction of the fluid is Z, the pressure of the fluid is 101325 Pa, the temperature is 300K, and there is no particle outflow.

The boundary conditions are set as shown in Figure 5.

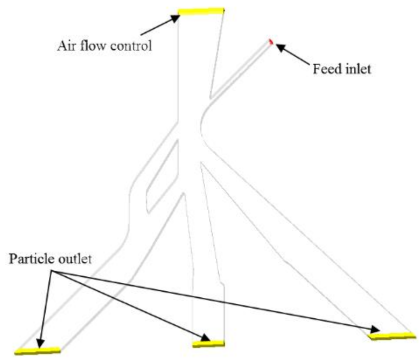


Fig. 5 boundary condition setting diagram

4. Analysis of Simulation results

4.1 Particle Size Distribution Characteristics of Calcium Carbonate Powder

The particle size distribution of calcium carbonate powder in jet classifier is shown in Fig. 6.

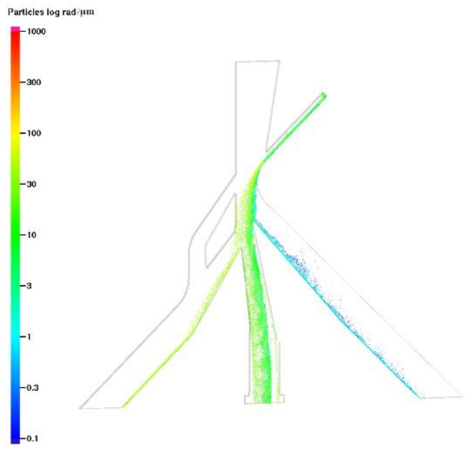


Fig. 6 Particle size distribution of calcium carbonate powder

4.2 Effect of Grading Cutter Angle on Grading Effect of Calcium Carbonate Powder

The main purpose of the simulation of jet classifier in this paper is to determine the classification effect of jet classifier on calcium carbonate powder. The jet classification simulation of calcium carbonate powder is carried out by setting different classifying knife angles. The monitoring surface is set at the outlet of coarse, medium and fine powder, and the information data of particle size, quantity, mass and volume fraction passing through the monitoring surface are monitored. These information data can be used to analyze the grading effect of different grading knife angles on calcium carbonate powder.

The angle position of the grading cutter is shown in Fig. 1. The grading cutter angle θ_1 is 4°, 7°, 10°. The grading cutter angle θ_2 is 1°, 5°, 9°.

The effect of grading cutter angle θ_1 on the grading effect of calcium carbonate powder is shown in Tables 1 and 7. Table 1 shows the variance of fine powder curve corresponding to the grading cutter angle θ_1. The variance σ can represent the dispersion degree of particle size distribution of the curve. Figure 7 shows the normal distribution curve of particle size at the outlet of coarse powder, medium powder and fine powder of jet classifier.

It can be seen from Fig. 7 and Table 1 that with the increase of the graded knife angle θ_1, the calcium carbonate powder under the action of the classifier has a trend of increasing and then decreasing the fine particle grading effect, and The fine particle grading effect is best when the grading knife angle θ_1 is 7°.

Tab. 1 Fine powder curve variance of the graded knife angle θ_1

Angle θ_1	Variance σ
4°	1.79
7°	0.76
10°	0

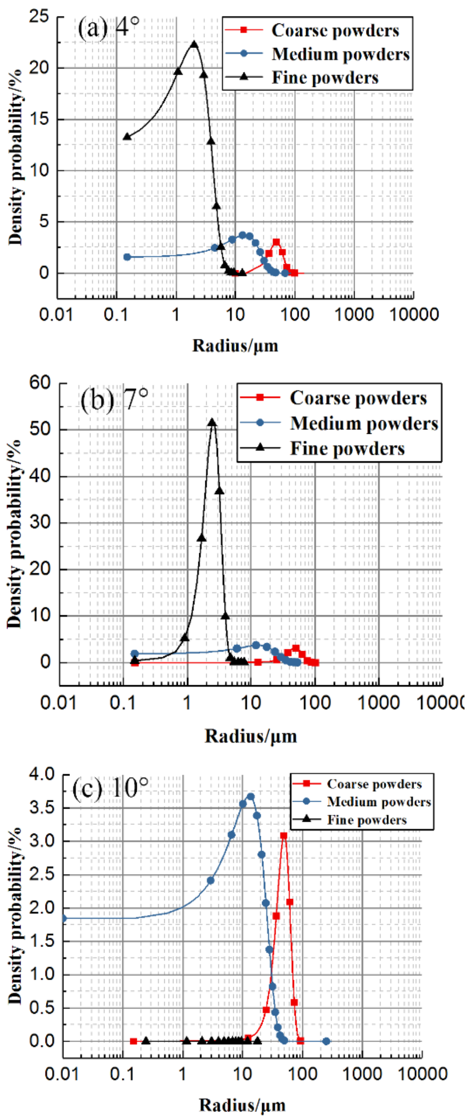


Fig. 7 Effect of graded knife angle θ_1 on the classification effect of calcium carbonate powder

The influence of grading cutter angle θ_2 on the grading effect of calcium carbonate powder is shown in figure 8. Table 2 is the variance of the curve of coarse and fine powder corresponding to the grading cutter angle θ_2.

It can be seen from figure 8 and table 2 that, with the increase of the grading knife Angle of θ_2, the grading effect of coarse particles of calcium carbonate powder under the action of the classifier shows a trend of decreasing first and then increasing, and the best grading effect is achieved when the grading knife Angle of θ_2 is 9°.The particle calcium carbonate powder showed a decreasing trend, and the best effect was achieved when the grading knife Angle of θ_2 is 1°.

Tab. 2 Fine powder curve variance of the graded knife angle θ_2

Angle θ_2	$\sigma_{\text{Coarse powder}}$	$\sigma_{\text{Medium powder}}$
1°	16.96	6.45
5°	17.45	7.62
9°	12.67	10.81

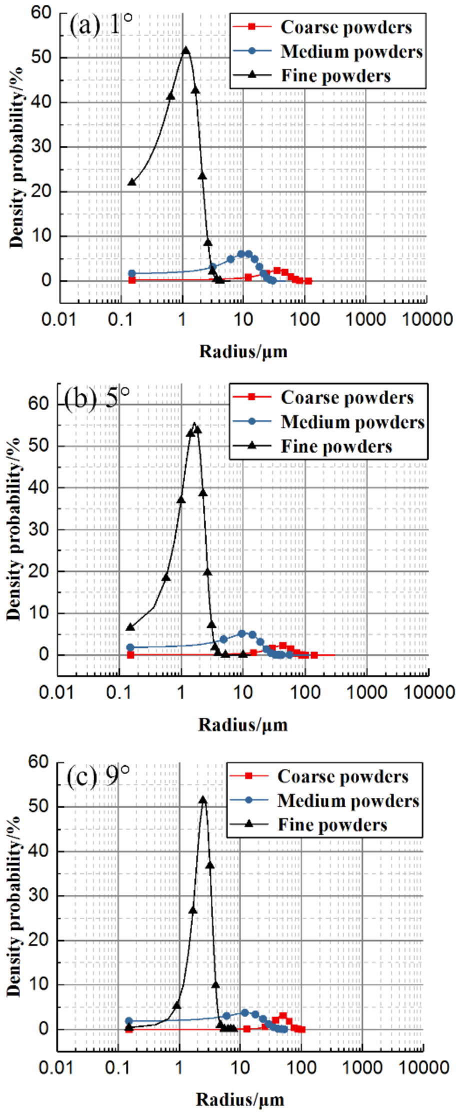


Fig. 8 Effect of graded knife angle θ_2 on the classification effect of calcium carbonate powder

5. Experimental verification of grading cutter angle

Based on the study of the classification effect of calcium carbonate powder at the angle of grading knife, the experiment of calcium carbonate powder classification was carried out by using a jet classifier with the same structure. Calcium carbonate powder with an average particle size of 44 um was used as raw material. Air was used as jet carrier to carry calcium carbonate powder. The pressure was set to 0.6-0.8 Mpa. The influence of the angle of classifier on the classification effect was explored. The particle size distribution of the original calcium carbonate powder was measured by laser particle size analyzer as shown in Fig. 9.

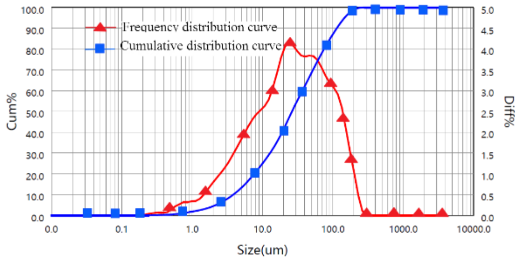


Fig. 9 Particle size distribution of raw calcium carbonate powder

By analyzing the particle size of coarse powder, medium powder and fine powder at the outlet of jet classifier, the influence mechanism of the angle of classifier on the classification effect of calcium carbonate powder was investigated, and the particle size distribution curve was drawn. The classification accuracy index K was used to characterize the classification effect.

$$K=\frac{D_{P75}}{D_{P25}} \tag{4}$$

In the formula, D_{P75} and D_{P25} have graded particle sizes of 75% and 25%, respectively. Under the ideal grading condition, "K = 1", the closer the K value is to 1, the grading accuracy is. Higher

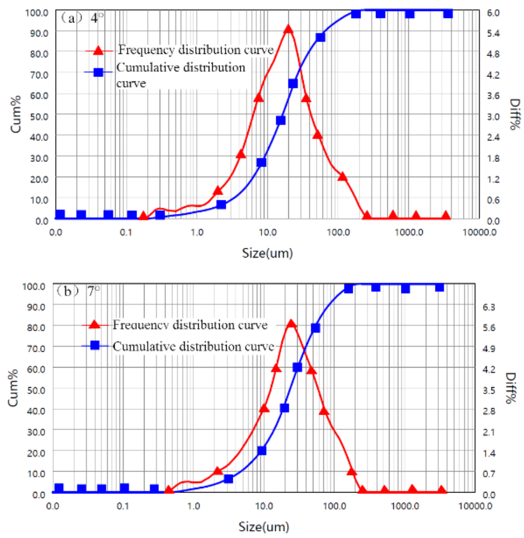
5.1 Effect of Grading Cutter Angle θ_1 on Fine Powder Grading

Tables 3 and 10 show the effect of grading cutter angle θ_1 on grading effect when they are 4°, 7°, 10°, respectively.

From Table 3 and Figure 10, it can be seen that with the increase of grading cutter angle θ_1, the grading effect of calcium carbonate powder under the action of grader increases first and then decreases, and the grading effect of fine particles is the best when the grading cutter angle θ_1 is 7° degree, so the numerical results can well match the experimental measurements.

Tab.3 Effect of the graded knife angle θ_1 on the classification effect of fine powder

Angle θ_1	K
4°	4.14
7°	4.01
10°	4.25



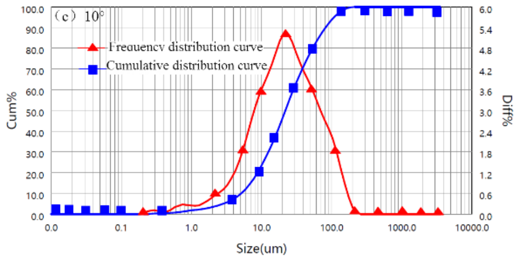


Fig. 10 The effect of the graded knife angle θ_1 on the classification of fine powder

5.2 Effect of Grading Cutter Angle θ_2 on Grading Effect of Coarse and Medium Powder

Table 4, Figure 11 and Figure 12 show the graded knife angle $\theta_2$when they are 1°, 5°, 9° And the effect of the grading effect of the powder.

Tab. 4 Effect of graded knife angle θ_2 on the classification of coarse and medium flour

Angle θ_2	$K_{Coarse\ powder}$	$K_{Medium\ powder}$
1°	2.85	3.65
5°	6.24	4.18
9°	3.04	4.88

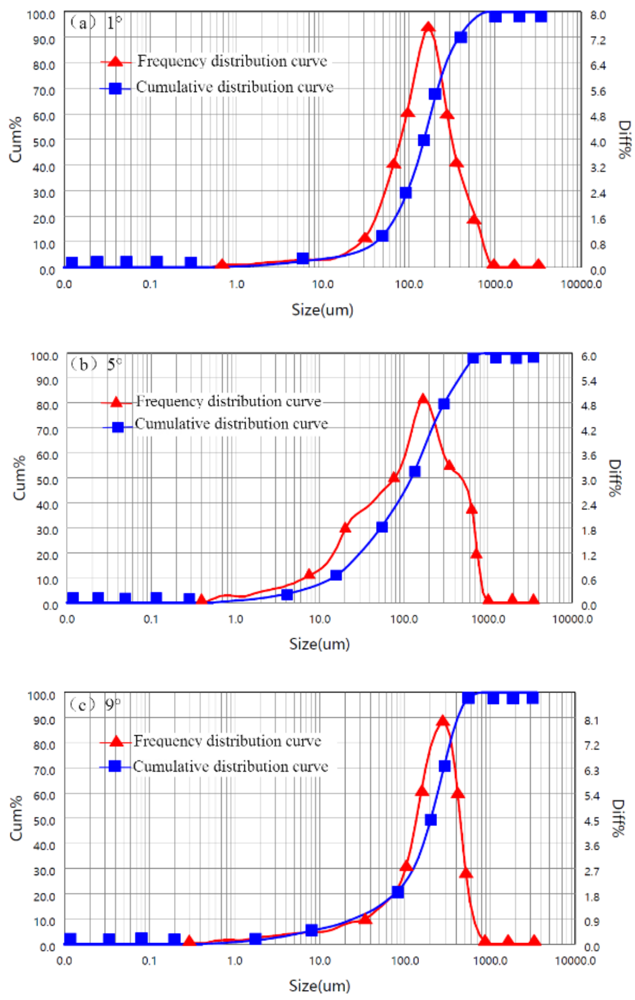


Fig. 11 Effect of the graded knife angle θ_2 on the classification of coarse powder

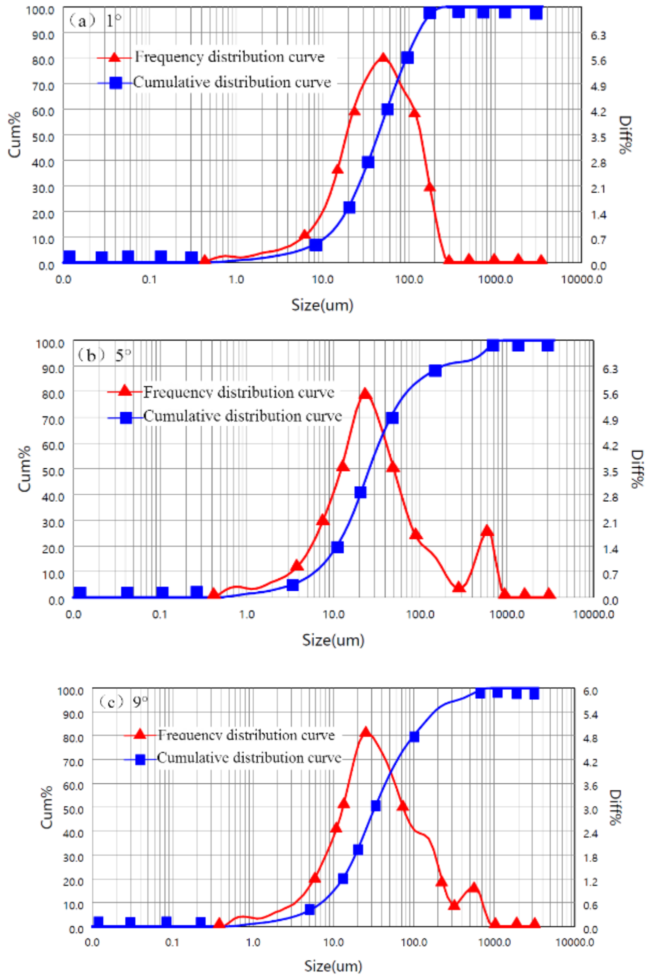


Fig. 12 Effect of the graded knife angle θ_2 on the classification effect of the medium powder

From table 4, Fig. 11 and Fig. 12, it can be seen that with the increase of grading cutter angle θ_2, the grading effect of the coarse particles flowing out of calcium carbonate powder under the action of grader decreases first and then increases, and the grading effect of the coarse particles is the best when the grading cutter angle θ_2 is 9°; The trend of decrease is the best when the angle of grading cutter is θ_2 1°, so the numerical results can well match the experimental measurements.

6. Conclusion

By using the CPFD software barracuda, the numerical simulation of the jet classifier with different classifier angles was carried out. The simulation results of the jet classifier with different classifier angles for the classification of calcium carbonate powder were obtained and compared with the actual experimental results. The following conclusions can be drawn:

(1) Jet classifier can effectively classify calcium carbonate powder, and can classify calcium carbonate powder efficiently and accurately according to the angle of different classifier.

(2) With the increase of the grading knife angle θ_1, the calcium carbonate powder under the action of the classifier, the grading effect of the fine particles flowing out appears to increase first and then decrease, and at the grading knife angle θ_1 is 7°, fine particles are classified best.

(3) With the increase of the angle of the grading knife θ_2, the calcium carbonate powder under the action of the classifier, the grading effect of the coarse particles flowing out appears to decrease first and then increase, and at the angle of the grading knife" When θ_2 is 9°, the coarse particle grading effect is the best; the medium granular calcium carbonate powder shows a decreasing tendency, and the grading knife angle θ_2 is 1° Fine particle grading works best.

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References

[1] Xu Yanwei,Jiang Xubao,Zhu Xiaoli.Research progress in powdered calcium carbonate [J]. Shandong Chemical Industry, 2015, 44(04): 30-32.

[2] Liu Tongyuan. Integrating and utilizing calcium carbonate resources to promote the economic development of Lianzhou City [J]. Modern Business, 2017 (16): 52-53.

[3] Zhao Yu,Zhao Jiangang,Li Meinan,Shi Kai,Wang Xuezhu,Yang Rui.Application of laser particle size analyzer in particle size analysis of calcium carbonate powder [J]. Geological Equipment, 2017, 18 (06): 29-31.

[4] Huang Shengqin,Liu Zhenxia,Wang Wei.Research and Simulation of Ultrafine Powder Jet Grading Technology [J]. Machinery Design & Manufacture, 2006 (03): 52-54.

[5] Zhai Hailun, Chen Haizhen,Bi Haiquan.Numerical Simulation of Airflow Grading of Ultrafine Powder Based on Coanda Effect [J]. Journal of Southwest University of Science and Technology (Natural Science Edition), 2005 (01): 42-45.

[6] Li Caobing,Wang Luyan,Liu Shanyu.Classification of Tungsten Powder Jet and Its Application in Preparation of Porous Tungsten [J]. China Tungsten Industry, 2018, 33(05): 57-63.

[7] Zheng Shaohua, Tao Zhendong, Liu Futian, Lu Hongxing.Flow Field Analysis of Ultrafine Powder Jet Classifier[J].Journal of Shandong Institute of Building Materials,1999(03):189-192.

[8] Shibin Liang. NUMERICAL STUDY OF CLASSIFICATION OF ULTRAFINE PARTICLES IN A GAS-SOLID FIELD OF ELBOW-JET CLASSIFIER [J]. Chemical Engineering Communications, 2010, 197 (7).

[9] Zhai Hailun,Chen Haizhen,Bi Haiquan.Numerical Simulation of Airflow Grading of Ultrafine Powder Based on Coanda Effect [J]. Journal of Southwest University of Science and Technology (Natural Science Edition), 2005 (01): 42-45