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Study on the cut size of a turbo air classifier

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ABSTRACT

Cut size is regarded as an important indicator for evaluating the classification performance of turbo air classifiers. However, traditional methods of cut size calculation by theoretical analysis have some deviations. In this paper, a new strategy was introduced to determine the cut size using the FLUENT discrete phase model (DPM) coupled with material experiments. The simulation results revealed that: the closer the feeding point position approached the inner edge of annular region, the shorter the time the particle moved into the area between the two neighboring blades of the rotor. The same small diameter particles which were fed at three different positions in annular region could all enter into the area between the two neighboring blades of the rotor, and ultimately were discharged by the fine powder outlet. When air inlet velocity was 8 m/s, rotor cage rotary speed was 800 r/min, the cut size of talcum powder could be calculated as 30–40 μm, and the cut size of quartz sand powder could be calculated as 40–50 μm. When rotor cage rotary speed was 1200 r/min, the cut size of talcum powder could be calculated as 20–30 μm, and the cut size of quartz sand powder could be calculated as 30–40 μm. The contrastive experiments of material classification were in good agreement with simulation results. Simulation method provides a new method to determine the cut size of a turbo air classifier, as well as provides a reference method to study the cut size of various types of classifier.

1. Introduction

The dynamic classification of ultra-fines with a certain particle size distribution has been a subject of great interest over the past decade due to the potential applications in various industries, including chemical engineering, mining, and industrial pharmacy. As one of the most important indicators to evaluate the classification effect, the cut size of classifiers draws considerable concern. To date, a number of methods have been developed to calculate cut size in theory [1,2]. Different size particles have different moments of inertia and withstand different forces from air in gas–solid flows. Based on this phenomenon, different particle sizes in the turbo air classifier can be effectively separated from one another. Cut size d_{50} is usually defined as the diameter of a spherical particle for which the inertial centrifugal force offsets the radial viscous force, keeping a serial movement on a certain cylinder theoretically. Liu et al. conducted particle force analysis in turbo air classifiers and calculated the cut size of turbo air classifiers using the following equation [3]:

$$d_{50} = 3C_D\rho_a R{v_r}^2/4{v_\theta}^2\rho_P \tag{1}$$

Where C_D is the drag coefficient, R is the external semidiameter of the rotor cage, v_r is the radial velocity of airflow, v_θ is the tangential velocity of airflow, ρ_a is the density of airflow and ρ_P is the density of particles.

Based on a systematic analysis of calculation formulas obtained under different assumptions for finding the cut size of turbo air classifiers, Liu et al. [2] obtained a simplified equation as follows:

$$d_{50} = k\frac{Q^\varepsilon}{n^\delta} \tag{2}$$

where Q is airflow rate and n is rotor cage rotary speed, ε, δ, and k are the parameters related to the property of materials, the temperature, humidity, and pressure of air, and the structure of classifiers.

However, these methods suffer from a serious deficiency: the theoretical results deviate from the actual values. Zhang et al. [4] showed that theoretical values of d_{50} are larger than the actual ones under different rotor cage rotary speeds. They said that maybe the theoretical air flow is greater than the actual air flow. Literature [5] showed that rotor cage rotary speed played an important part on d_{50}. The deviation of d_{50} increased to 42.5% when Q was 500 m^3/min and rotor cage rotary speed decreased to 165 r/min from 265 r/min. In view of this shortcoming, new methods with sufficient accuracy and precision are highly desirable to determine the cut size of classifiers. Computational Fluid Dynamics (CFD) technology has become a promising tool to solve complex flow problems [6–9]. For example, FLUENT, the dedicated CFD software for fluid flow problems in complex geometric regions has been widely used in analyzing flow field characteristics

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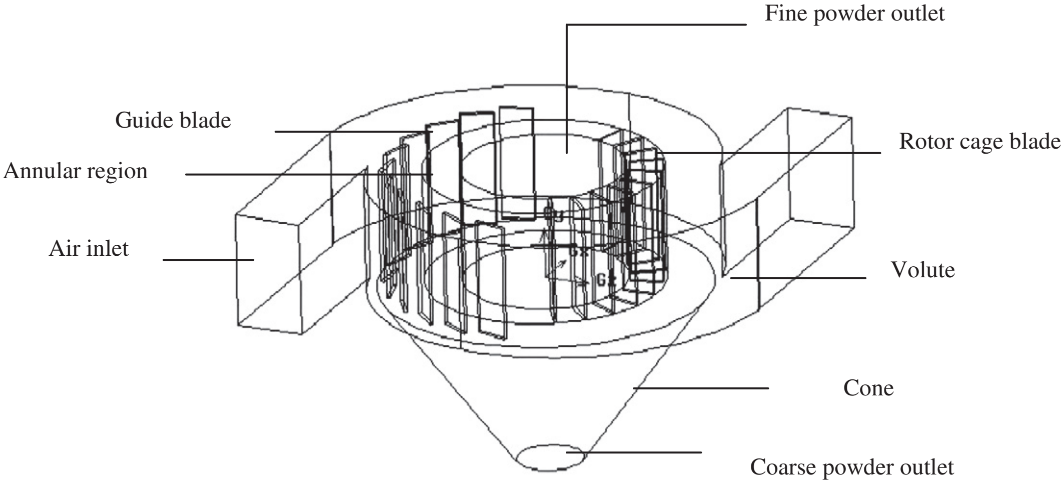

Fig. 1. Schematic diagram of the turbo air classifier.

and particle trajectories [10–13]. In the present study, a novel, convenient, and accurate strategy for calculating the cut size of classifiers was developed using a FLUENT-based simulation of particle trajectories in turbo air classifiers. The proposed strategy was the first example using the simulation of particle trajectories to determine cut size. Simulation and material experimental results revealed that the developed method held great potential as a convenient and precise platform for determining the cut size of classifiers.

2. Model descriptions

The schematic diagram of the turbo air classifier used in the present study is shown in Fig. 1. The main geometric dimensions of the classifier are as follows: (1) the outer and inner semidiameters of the rotor cage are 106 and 76 mm respectively; 24 blades are radially installed and evenly distributed across the circumference of the rotor cage; (2) the air inlet is 95 mm in height and 62 mm in width; and (3) 24 guide blades (95 × 30 × 3 mm) are distributed uniformly along the circumference of a circle with a radius of 136 mm.

The discrete phase model (DPM) used by FLUENT requires the discrete phase to be present at a fairly low volume fraction, usually less than 10%–12%. Particle volume fraction in the turbo air classifier was measured about 0.039% at a feed rate of 35 kg/h, air inlet velocity of 8 m/s, talcum powder material density of 2800 kg/m^3, and quartz sand powder material density of 2650 kg/·m^3, meeting the requirement of DPM. Thus, particle trajectories in the turbo air classifier

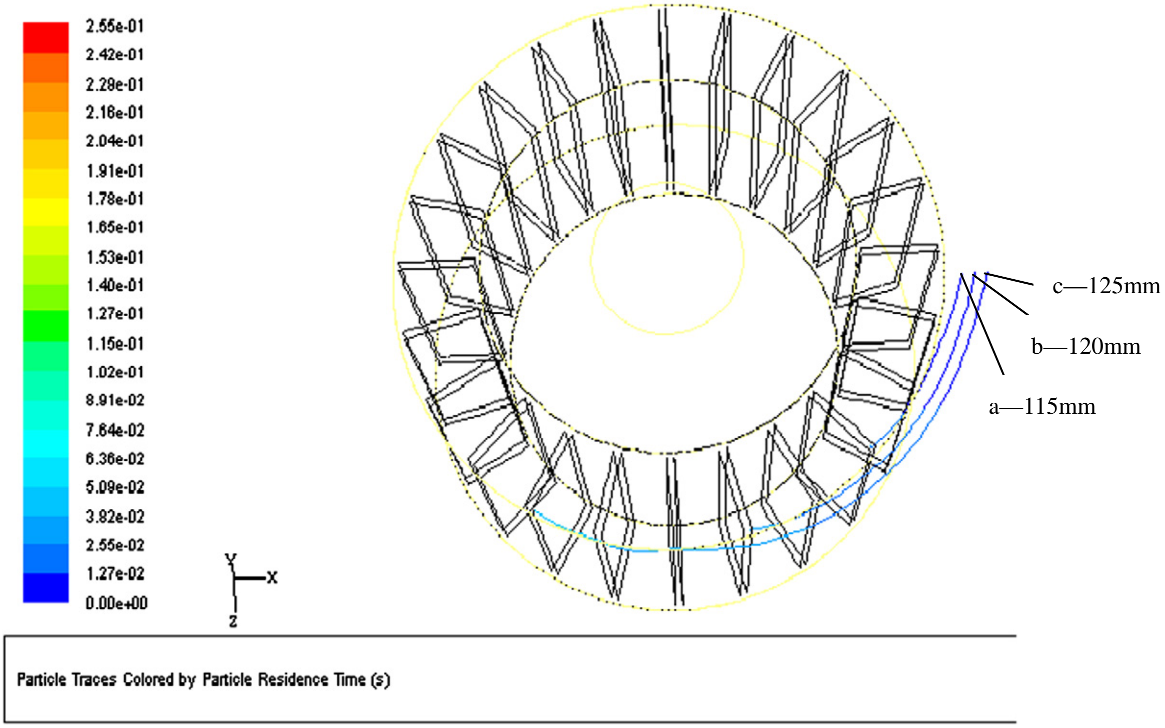

Fig. 2. Trajectories of 20 μm talcum particle.