Powder Technology 312 (2017) 277–286

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Design of a new double layer spreading plate for a turbo air classifier

Shubo Wu [a], Jiaxiang Liu [b], Yuan Yu [a,*]

[a] College of Mechanical and Electrical Engineering, Beijing University of Chemical Technology, Beijing 100029, China
[b] Beijing Key Laboratory of Electrochemical Process and Technology for Materials, Beijing University of Chemical Technology, Beijing 100029, China

ARTICLE INFO

Article history:
Received 2 November 2016
Received in revised form 6 January 2017
Accepted 16 February 2017
Available online 21 February 2017

Keywords:
Turbo air classifier
CFD
Spreading plate
Cut size
Sharpness of separation

ABSTRACT

In order to improve the material dispersion and reduce the probability of collision and aggregation of particles in a turbo air classifier, compared to a single layer spreading plate, a new double layer spreading plate based on theoretical analysis on the material dispersion is presented in this paper. Discrete phase simulations between the single and double layer spreading plates are implemented using Fluent 6.3.26. The different travelling time of particles via the upper and lower plates indicates the double layer spreading plate can improve the material dispersion and the simulated Tromp curves of the single and double spreading plates also show the cut size and the imperfection are decreased while the sharpness of separation is increased for the turbo air classifier with the double layer spreading plate. Calcium carbonate classification experimental results are in agreement with the simulated results. Compared to single layer spreading plate, the cut size can be decreased up to 25.24% and the sharpness of separation can be increased up to 52.47% for double layer spreading plate, and the imperfection of Tromp curve for double layer spreading plate is smaller that means it closer to the ideal classification curve. It shows the double layer spreading plate put forward in this paper can effectively improve the material dispersion in the classifiers.

1. Introduction

The rapid development of the superfine powder application means that the classification equipment is required to have smaller particle size and higher sharpness of separation than ever. With the strong classification force field, the turbo air classifier is used widely to ensure that the particle size distribution of the powder after classification meets the requirements of product quality [1,2]. In the process of classification using a turbo air classifier, the higher material dispersion is, the lower probability of collision and aggregation is, which is conducive to improve the sharpness of separation [3–6]. So the material dispersion is very important during the classification. The material should be fully dispersed in the classifier before classification to improve the sharpness of separation. The spreading plate is one of the most widely used methods of dispersion. The particles are forced to disperse and provided the initial velocity by the rotation of the spreading plate, and then they move into annular classification region to be separated into coarse particles and fine particles under the action of air flow. Considering the important role of the spreading plate in the classifier, many studies have been conducted on it. Li [7] designed the double layer spreading plate with circular holes on upper plate, the experimental results showed that the double layer spreading plate can reduce material amount per unit area by 37.31%, which can effectively improve the material dispersion. Li [8] put forward a propeller spreading plate to improve the material dispersion. Strauss [9] installed coaxial spreading plate at different vertical distance to improve the material dispersion in centrifugal classifier.

The classifier is a complex system, the structural changes may have an effect on the internal flow. Moreover, measurement of internal flow field in a classifier is difficult. In recent years, Computational Fluid Dynamics (CFD) has become a powerful tool to solve flow field distribution for one-phase flow or multi-phase flow. Hybd [10] found that the Euler-Lagrange method provides a better insight of particle dynamics, enabling an easy treatment of particle transients, particle collisions and coalescence and wall collisions. Yue [11] introduced a new strategy to determine the cut size of a turbo air classifier using DPM model and the simulated results were in good agreement with the theoretical calculate results. Guizani [12] used the RSM and DPM model to find “fish hook effect” caused by the flow recirculation and vortex breakdown. The experimental studies of the structure for spreading plate are focused on in the previous studies. However, CFD two-phase flow simulation based on theoretical analysis for spreading plate is rarely reported. The structural design to improve the material dispersion by means of two-phase flow simulation should be studied further. In order to improve the material dispersion and reduce the probability of collision and aggregation in a turbo air classifier, a new double layer spreading plate with the radial barriers of each sector is designed and its influences on the classification performance are discussed in this paper. Theoretical calculations on the material dispersion area and discrete phase simulations are carried out for single and double layer spreading plates. The experimental data are validated

* Corresponding author.
E-mail address: yuyuanjd@263.net (Y. Yu).

http://dx.doi.org/10.1016/j.powtec.2017.02.044
0032-5910/

against simulated results, demonstrating that the double layer spreading plate can effectively improve the material dispersion in a turbo air classifier.

2. Theoretical analysis on spreading plate of the turbo air classifier

2.1. The principle of a turbo air classifier

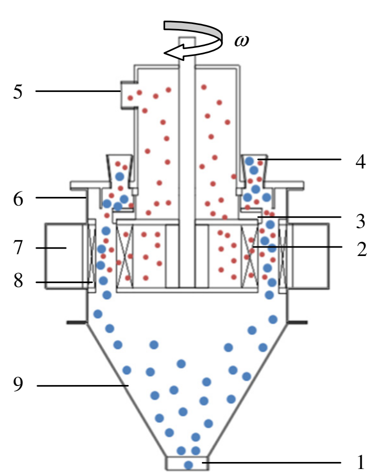
The schematic diagram of a turbo air classifier is shown in Fig. 1. With the pumping action of the air-blower, the negative pressure is formed in the center of the rotor cage, which draws the air flow into the classifier horizontally along two 180° air inlets (7). Then the rotating flow field is formed by air flow guided by guide blades (8) and volute (6). The particles dropping onto the spreading plate (3) from the feeding inlet (4) are thrown into the annular classification region between the inner edge of guide blades and the outer edge of the rotor cage (2). The particles are mainly influenced by air drag force, inertial centrifugal force and gravity. When the inertial centrifugal force exerted on the particles is larger than the air drag force, the particles move outward to cone (9) and are collected as the coarse particles by the coarse powder outlet (1) ultimately, whereas when the inertial centrifugal force exerted on the particles is smaller than the air drag force, the particles move inward and are collected as the fine particles by the fine powder outlet (5).

2.2. Particle motion analysis and the design of the double layer spreading plate

2.2.1. Particle motion analysis on the single layer spreading plate

The following simplifications and assumptions are made in this paper to analyze the particle motion conveniently. The particles are assumed to be spherical. Particles are only sliding without beating and rolling on the spreading plate. The initial velocity of the particles falling on the spreading plate is zero without overlap. The interactions between particles are ignored.

The single layer spreading plate with radial barriers is shown in Fig. 2-(a). For the above assumptions the particles not only rotate along with the plate, but also slide along the radial barriers, the force analysis of a particle is shown in Fig. 2-(b), where r_1 and r_2 are inner and outer radii of the spreading plate, F_r and F_t are radial resultant force(intertial centrifugal force and friction force) and tangential resultant force(normal force of the radial barriers) when particles are on the spreading plate; V_r, V_t and V are radial velocity, tangential velocity and resultant velocity when particles are thrown away from the spreading plate.



1-Coarse powder outlet 2-Rotor cage 3-Spreading plate 4-Feeding inlet
5-Fine powder outlet 6-Volute 7-Air inlet 8-Guide blades 9-Cone

Fig. 1. The schematic diagram of a turbo air classifier.

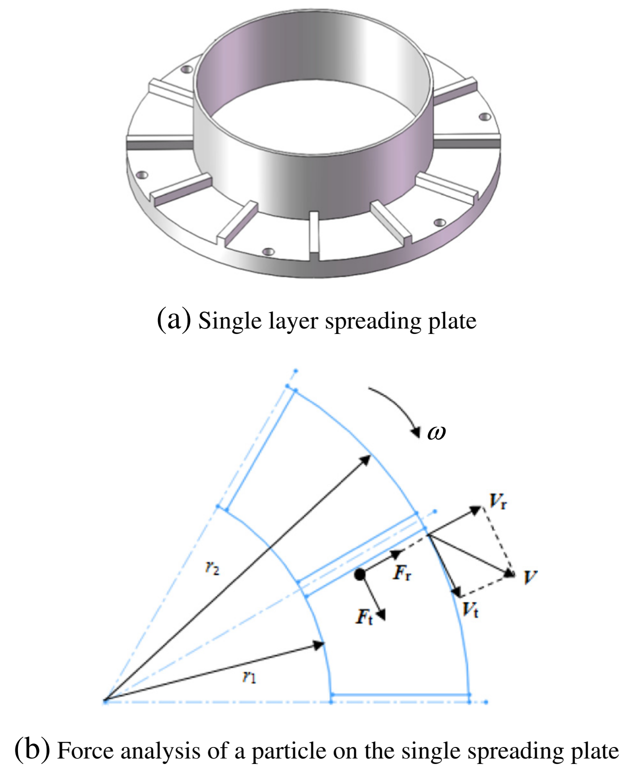


Fig. 2. The single layer spreading plate and force analysis of a particle.

The equation of the particle motion in polar coordinates is [13]:

$$\frac{d^2 r}{dt^2} = \frac{F_r}{M} i + \frac{F_t}{M} j \tag{1}$$

Where, r is particle displacement on the spreading plate, M is particle mass, i and j are radial and tangential unit vector.

The tangential displacement of the particles is zero because of the constraint from radial barrier. So,

$$r = r \cdot i \tag{2}$$

The derivation of r using Leibniz's equation [14] is expressed as:

$$\frac{dr}{dt} = \frac{dr}{dt} i + r \frac{di}{d\theta} \cdot \frac{d\theta}{dt} = \frac{dr}{dt} i + r\omega j \tag{3}$$

$$\frac{d^2 r}{dt^2} = \frac{d^2 r}{dt^2} i + \frac{dr}{dt}\omega j + \omega \frac{dr}{dt} j - \omega^2 r i \tag{4}$$

Where, ω is angular velocity of the spreading plate, θ is polar angle.

The radial and tangential acceleration of the particles on the basis of Eqs. (1) and (4) are:

$$\frac{d^2 r}{dt^2} i - \omega^2 r i = \frac{F_r}{M} i \tag{5}$$

$$2\frac{dr}{dt}\omega j = \frac{F_t}{M} j \tag{6}$$