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Effects of axial inclined guide vanes on a turbo air classifier

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ABSTRACT

For a turbo air classifier, the upward axial velocity in the annular region will cause the negative influence on the stability of flow field, and it is also detrimental to material dispersion. As a result, the classification accuracy will be reduced. In order to decrease the upward axial velocity, a downward force must be introduced to offset it. According to the guiding principle of guide vanes, the axial direction of airflow will be changed when the guide vanes are inclined. In this paper an axial inclined guide vane model was designed. Four models (T-0, T-2.5, T-5, T-7.5) were established with axial inclined angles of 0°, 2.5°, 5° and 7.5°. Fluent software was used to simulate the inner flow field of different structures. The simulation results show that axial inclined guide vanes can decrease the upward axial velocity in the annular region. Especially, when the inclined angle is 2.5°, the upward axial velocity is decreased and the tangential velocity is increased. This is favorable to keep the flow field stable. At the same time the classification force field is enhanced to improve the dispersion of the powders. Discrete phase simulation results reveal that particle residence time in the annular region of structure T-2.5 is shorter than it is in the annular region of structure T-0. This can reduce the collision probability of particles and the energy cost is reduced. The partial classification efficiencies of T-2.5 are higher than that of T-0. From the numerical Tromp curves, it is observed that the cut size of T-2.5 is smaller than that of T-0. The classification accuracy of T-2.5 is 90.7%, while that of T-0 is 88.5%. That means that the classification performance is improved with the new structure. Calcium carbonate classification experiment results also show that the cut size decreases by 0.97–8.42 μm and the accuracy increases by 6%–9% for the structure T-2.5, compared to the structure T-0. Therefore, the structure T-2.5 is more favorable for classification than the structure T-0. These actual experimental results are in good agreement with the simulation results and the significance of this optimization is proved.

1. Introduction

As the important air classification equipment, turbo air classifier is widely used in a variety of fields, such as building materials, chemical industry, food and medical industry, etc. [1,2]. With the rapid development of materials science, higher demand for classification efficiency and accuracy has been raised [3]. For air classifier, the evaluation model on classification performance has been established to optimize the operating parameters [4–6]. However, to improve the classification performance, the most effective method is to design a uniform flow field. Given the complexity of the classifier structure, few tools can accurately measure its inner flow field. Computational fluid dynamics (CFD) is a mathematical tool capable of modeling a wide range of single-phase or multiphase flows [7]. The main objective of CFD simulation for a classifier is to analyze its inner flow field characteristics. So, in recent years, some researchers used the computational fluid dynamics to predict accurately the separation efficiency and the cut size in order to make design improvements. Robert Johansson [8] simulated the influence of the design and the geometrical parameters of a gravitational air classifier on the flow field and evaluated air classification performance using the CFD technique. Guofeng Zhu et al. [9] investigated the fluid flow and particle separation ability of a 5 mm diameter mini-hydrocyclone through CFD modeling. Liping Gao [10] introduced a new strategy to determine the cut size of a turbo air classifier using the Fluent DPM model and the simulation results were in good agreement with the experimental results.

A reasonable structure design can improve the classification performance for an air classifier. Therefore, many studies have been conducted on the structure of an air classifier, especially on the structure of rotor cage [11–13]. In recent studies, the guide vane as an important functional unit in a turbo air classifier, which maintains the uniform of the annular region flow field, has been paid more attention than ever. For instance, Li [14] designed an L-shaped guide vane, and showed that the phenomenon of particle back-mixing was improved. Huang [15] positively and negatively curved the straight blade, the simulation results and experimental results showed that a turbo air classifier with positively bowed guide blades produced smaller cut size and a higher classification precision index than with straight guide blades. And the past study showed the velocity distribution in the annular region of turbo air

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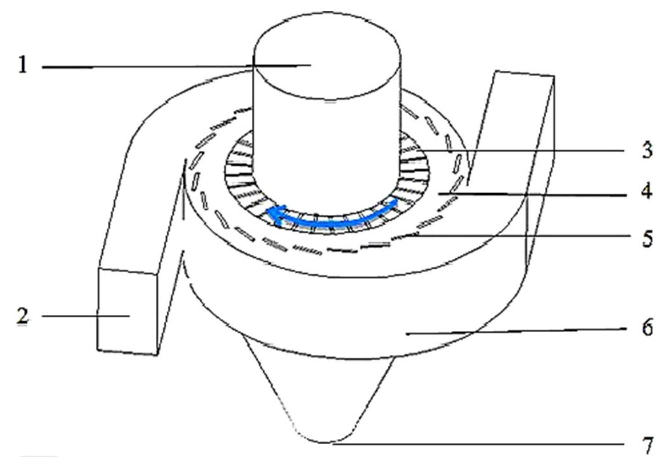

Fig. 1. Schematic diagram of the turbo air classifier. 1—Fine powder outlet; 2—air inlet; 3—distribution plate; 4—annular region; 5—guide vane; 6—volute; and 7—coarse powder outlet.

classifier was uniform when the install angle along the horizontal direction was 15° [16].

In these studies, radial velocity and tangential velocity were always used to determine the stability of the flow field. However, the air axial velocity in the annular region was usually ignored. In fact, there is an upward axial velocity in the annular region and this fact has been confirmed by using the laser Doppler velocimeter (LDV) [17]. The upward axial velocity in the annular region will lead to a change of the airflow velocity direction and decrease the stability of the flow field [18]. So it is detrimental to classification. In order to achieve a good classification performance, it is meaningful to reduce the upward axial velocity in the annular region. According to the principal of guide vanes, a new design of guide vanes which incline along the rotating axis is introduced in this paper. The flow field conditions and particle trajectories are simulated using the Fluent software. It is confirmed that the axial inclined guide vanes can decrease the upward axial velocity in the annular region and keep the flow field more uniform. Discrete phase simulation results show that particle residence time in the annular region of the new structure is shorter than before, and the energy costs are reduced. Compared to the Tromp curves of the two structures, it can be seen that the cut size decreases while the classification accuracy increases with the guide vane inclined. The classification performance is improved with the new structure. The simulation results were supported experimentally.

2. Theoretical analysis

2.1. Classification principle of a turbo air classifier

The schematic diagram of a turbo air classifier is shown in Fig. 1. The powders to be classified are fed through the material feed port and fall to the distribution plate, which has a high rotary speed in the clockwise direction. By rapidly rotating the distribution plate, powders are dispersed and then dropped into the annular region. There are two dominant forces acting on the particle along the radial direction in the classification region, the inertia centrifugal force and the fluid drag force. The two forces have different influence on different sizes of particles. As a result, the raw materials divide into coarse and fine powders in the annular region. Fine powders run into the rotating rotor cage and flow out from the fine powder outlet with airflow, are collected eventually. Coarse powders fall into the cone and out from

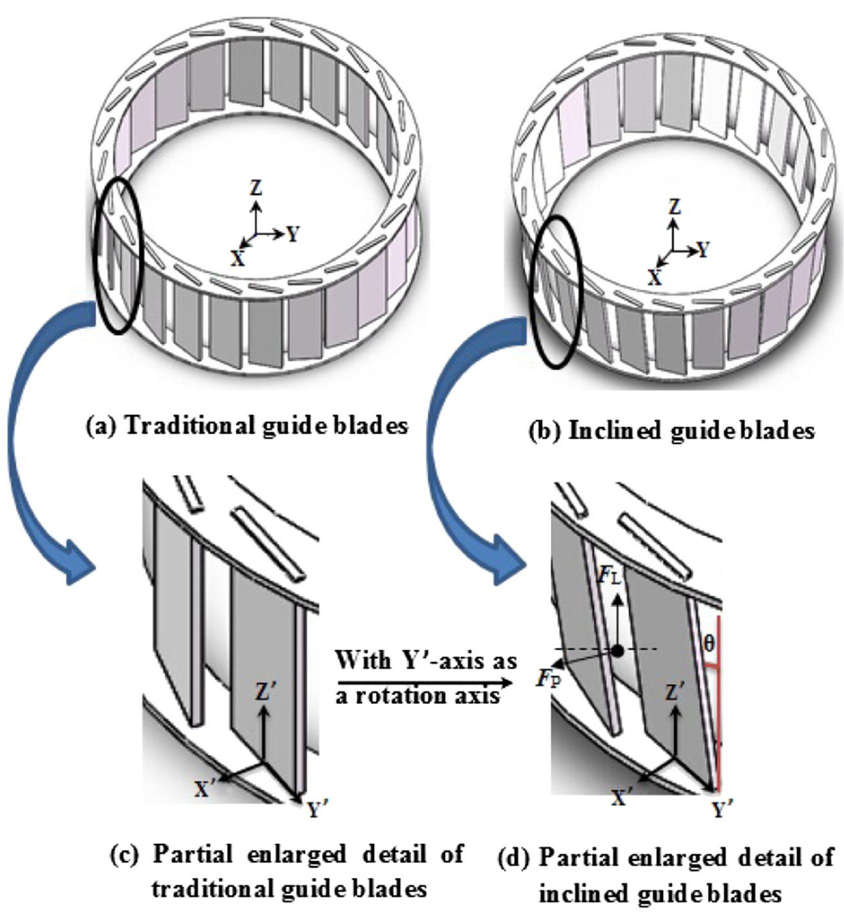

Fig. 2. Schematic diagram of the guide vanes.