

Effect of Different Outlet Structure of Axial Flow Cyclone Separator in Drying Tower

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Abstract: The axial flow cyclone separator used in drying tower is characterized by the diameter of the dust outlet at the tail is larger than that of the cylinder, and the dust removal efficiency is increased by a series dust outlet. The numerical analysis of its separation characteristics is carried out by using the RSM model of CFD. The results show that the separation efficiency can be increased by appropriately increasing the diameter of the dust outlet, and the separation efficiency will not change when the diameter of the dust outlet increases to a certain value. When the insertion depth of the air outlet is reduced from 150mm to 100mm, the average separation efficiency of particles with a diameter of 15-30um is reduced by 4.5%. When the insertion depth of the air outlet is greater than the width of the dust outlet, the insertion depth has no effect on the dust removal efficiency. The tandem dust outlet and parallel dust outlet have the same separation effect on small particles, and the gas flow rate is equivalent to twice the gas flow rate of a single dust outlet. The average particle separation efficiency of 1 - 30um is increased by 16.5% compared with that of a single dust outlet. The flow velocity of the tandem dust outlet is higher than that of the parallel dust outlet.

Keywords: Axial flow cyclone separator; Different outlet form; Microparticle.

1. Introduction

In the process of drying grains, a lot of dust will be produced, so the dust in the drying tower must be separated by dust removal. Cyclone separator is a commonly used dust removal equipment for drying tower. Cyclone separators are divided into tangential cyclone separators and axial cyclone separators. Tangential cyclone separator has simple structure, high separation efficiency and wide application. Axial cyclone separators have lower separation efficiency than tangential cyclone separators, but axial cyclone separators have larger gas flow, more compact structure[], and unique advantages in situations where the assembly space is small and the flow rate is large. It is difficult to study the internal flow mechanism of a cyclone because of its strong swirling flow field accompanied by intense boundary layer separation[1-2]. A lot of research has been done on tangential cyclone separators [3-7], but less on axial flow cyclone separators. Improving the separation efficiency of cyclone separator is one of the problems to be solved in cyclone separator. The axial cyclone separator for drying tower adopts the composite structure of axial cyclone separator and tangential cyclone separator. Its main structure consists of air inlet, impeller, reducing diameter, guide vane, dust outlet, air outlet, tangential cyclone dust collector compositions. The working principle of the fan is shown in Figure 1. When the impeller rotates, the dust containing impurity particles is inhaled by the air inlet and flows through the guide vane to produce swirling flow. Under the action of centrifugal force, heavier particles are separated from the dust, accumulate near the wall of the cylinder, discharged through the dust outlet, enter the tangential cyclone separator for secondary separation, and clean air is discharged through the outlet [8-9]. Compared with the common axial flow cyclone separator, the diameter of the dust outlet at the tail of the equipment is larger than the diameter of the cylinder, and multiple dust

outlets are connected in series to increase the dust removal efficiency.

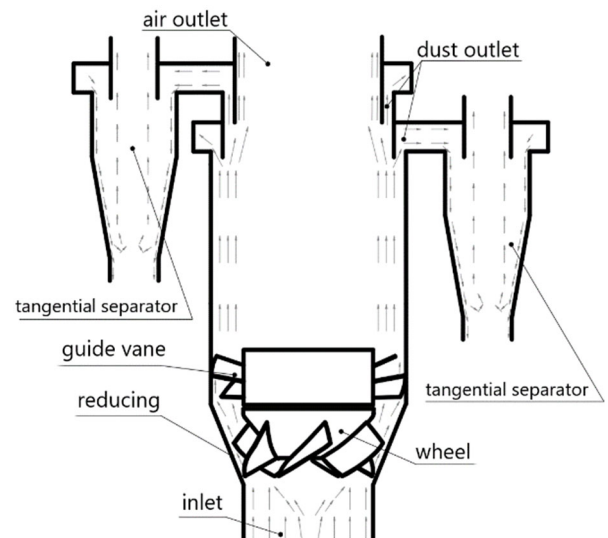


Figure 1. Working principle of axial flow cyclone dust collector

In industrial manufacturing, the separation effect is often improved by increasing the number of outlets of axial flow cyclone separators. Through previous studies, the main factors affecting the separation efficiency of cyclone separator are cylinder diameter, inlet wind speed, deflector angle, swirl tangential velocity, outlet diameter, etc. [10-14]. At present, there is a lack of theoretical research on improving the separation effect by increasing the number of air vents. This paper compares and analyzes the separation effect of two different air vents to provide theoretical support for structural optimization in this aspect. The existing products in the market are modeled, CFD numerical simulation method was

used to analyze the influence of different dust outlet forms on the separation efficiency of small particles.

2. Numerical Models and Analytical Methods

2.1. Geometric model and parameters

In order to reduce the complexity of the study and improve the accuracy of the simulation, this paper conducted 1:1 solid modeling of the guide vane, diameter reduction, cylinder, air outlet and dust outlet of the axial flow cyclone with three types of dust outlet.

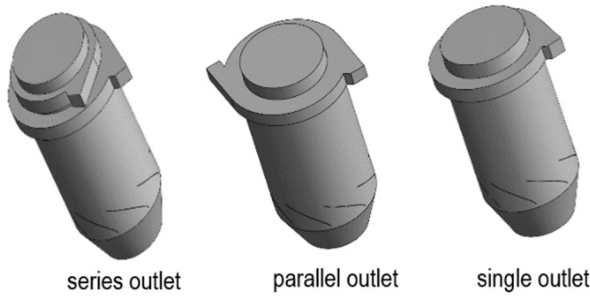


Figure 2. Model of axial flow cyclone with three different outlet modes

Fluent's Workflow was adopted for grid division in the model, polyhedral mesh was adopted, boundary layer was encrypted, and simulation results of 1 to 4 million grids were compared. After grid independence verification, the number of grids was about 2 million, and the dimensionless wall y^+ value was between 10 and 120.

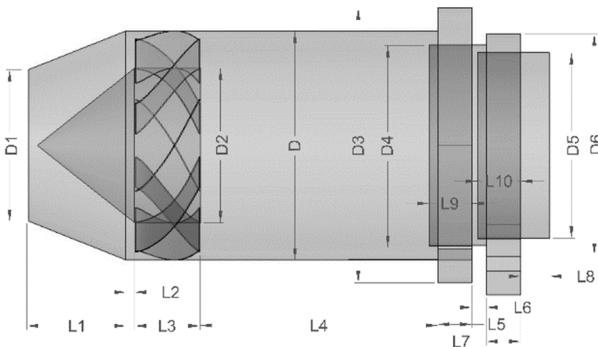


Figure 3. Schematic diagram of structure and size of axial flow cyclone separator

L1 is the length of the reducer, L2 is the distance between the guide vane and the reducer, L3 is the length of the guide vane shaft, L4 is the length of the cylinder body, L5 is the width of the first dust outlet, L6 is the distance between the two dust outlets, L7 is the width of the second dust outlet, L9 is the insertion depth of the first air outlet, L10 is the insertion depth of the second air outlet, and D1 is the diameter of the air inlet. D2 is the diameter of the guide vane shaft, D is the cylinder diameter, D3 is the diameter of the first dust outlet, D4 is the diameter of the first air outlet, D5 is the diameter of the second air outlet, D6 is the diameter of the second dust outlet, the number of guide vane is 8, guide vane exit Angle β is 30° . The dimensions of each part are shown in Table 1.

Table 1. Specific structural dimensions of axial flow cyclone separator /mm

L1	L2	L3	L4	L5
340	20	230	830	120
L6	L7	L8	D	D1
50	120	100	800	530
D2	D3	D4	D5	D6
540	960	700	650	780

2.2. Mathematical model

The internal flow field of cyclone separators is a strong swirling flow field, and currently Reynolds stress model (RSM) is considered to be the most suitable simulation for cyclone separators [15]. Fluent solver chooses a pressure-based solver, the solution algorithm adopts SIMPLEC algorithm, and the pressure base is POSTIO. The speed of the actual motor is 1450r/min, and the speed of the impeller is 1740r/min after the speed increase of the belt wheel. At room temperature, the inlet and outlet flow of the axial flow cyclone separator with a single dust outlet was measured. The gas flow of the inlet, outlet and dust outlet were respectively 4.3kg/s, 3.79kg/s and 0.51kg/s. After conversion, the average wind speed of the inlet was 16m/s. The boundary conditions of the numerical model are set as the velocity inlet, the velocity is 16m/s, the outlet is the pressure outlet [16], the medium is normal temperature air, and the particles are dust with a density of 600kg/m³. In order to verify the accuracy of the boundary conditions and the coupling algorithm, the simulated inlet and outlet flow was compared with the actual flow. The simulated outlet air volume was 0.54kg/s, with an error of 5.8%. Considering the existence of welding scars and joint in the real product, the numerical calculation of the outlet air volume should be slightly greater than the real value.

2.3. Analytical method

Keep the main size of the model unchanged, change the diameter of the dust outlet, the length of the cylinder, the insertion depth of the air outlet and the form of the air outlet of the model respectively, and analyze the gas flow rate at the dust outlet of the cyclone and the separation efficiency of small particles under different structural sizes. As shown in Table 2, model 1 is the actual size of the single dust outlet, and model 9 is the actual size of the serial dust outlet.

Table 2. Axial flow cyclone model size table /mm

Number	L4	L9	D3	D4	D5	Form of dust outlet
1	830	150	960	700	—	single
2	830	150	880	700	—	single
3	830	150	800	700	—	single
4	830	100	960	700	—	single
5	830	180	960	700	—	single
6	830	200	960	700	—	single
7	830	150	960	650	—	single
8	830	150	960	650	—	parallel
9	830	150	960	700	650	series
10	1000	150	960	650	—	parallel

3. Results and Analysis

3.1. Effect of dust outlet diameter on separation efficiency

Through the analysis of models 1, 2 and 3, it is found that when the diameter of the dust outlet increases from 800mm (which is equivalent to the diameter of the cylinder) to 880mm and 960mm, the air volume of the dust outlet is 0.509kg/s, 0.538kg/s and 0.544kg/s, respectively. The air volume of the dust outlet increases with the increase of the diameter of the dust outlet, and the increase rate decreases. As can be seen from the cloud image of pressure and velocity at the tail of the separator cylinder (FIG. 4), the diameter of the dust outlet increased from 800mm to 880mm, the high pressure area above 530Pa near the wall of the cylinder significantly decreased, and the high velocity area above 32m/s of the outlet significantly decreased. When the diameter of the cylinder again increased to 960mm, this trend was weakened.

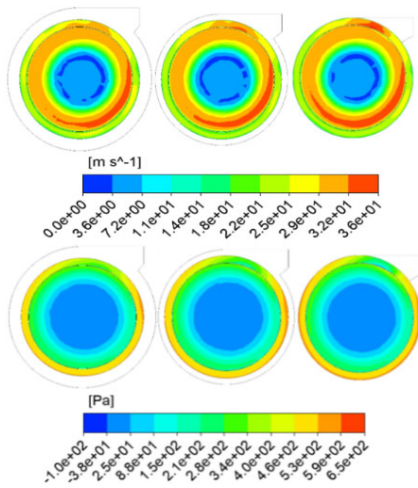


Figure 4. Cloud image of pressure and velocity at the tail of cylinder with different outlet diameters

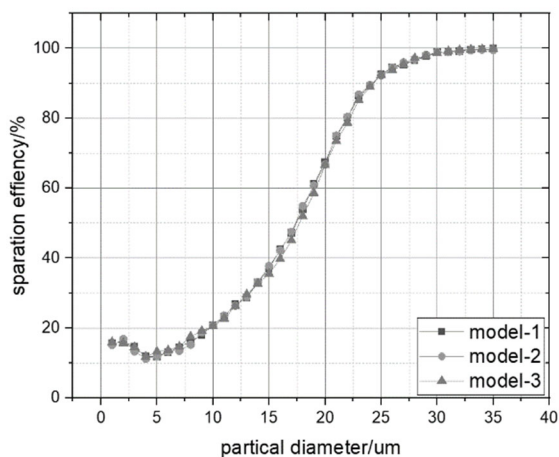


Figure 5. Influence of different outlet diameters on the separation effect of cyclone separator

As shown in Figure 5, when the diameter of the dust outlet increases from 800mm to 880mm, the separation efficiency of 15-25um particles increases by 2.3% on average, and the diameter of the dust outlet continues to increase to 960mm, with no significant change in separation efficiency. Although the gas flow of the dust outlet increases with the increase of the diameter of the dust outlet it has little effect on the

separation efficiency of small particles. The analysis is because although increasing the size of the dust outlet can reduce the maximum pressure of the dust outlet, the pressure change area is mainly concentrated in a very small part of the area near the wall of the cylinder, and the small particles are more dispersed near the wall of the cylinder, so it has little impact on it.

3.2. Influence of air outlet insertion depth on separation efficiency

Through the analysis of models 1, 4, 5 and 6, it is found that the insertion depth of the air outlet is 100mm, 150mm, 170mm and 200mm, and the air volume of the dust outlet is 0.560kg/s, 0.544kg/s, 0.537kg/s and 0.536kg/s respectively. The air volume of the dust outlet decreases with the increase of the insertion depth of the air outlet. The reduction rate gradually decreases. As shown in Figure 6, the insertion depth is reduced from 150mm to 100mm, and the average separation efficiency of particles with a diameter of 15-30um is reduced by 4.5%. When the insertion depth of the outlet is greater than the width of the dust outlet, the dust removal efficiency is not affected by changing the insertion depth. The analysis is that because the diameter of the dust outlet is larger than the diameter of the cylinder, the particles that are not discharged in time form a hovering area near the dust outlet. In addition, the pressure drop is larger the closer the outlet is. When the insertion depth of the outlet is smaller than the width of the outlet, these particles may be adsorbed by the outlet, resulting in lower separation efficiency.

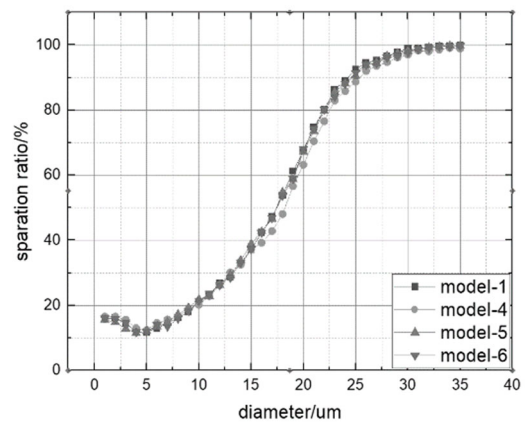


Figure 6. Influence of different outlet insertion depth on separation efficiency of cyclone separator

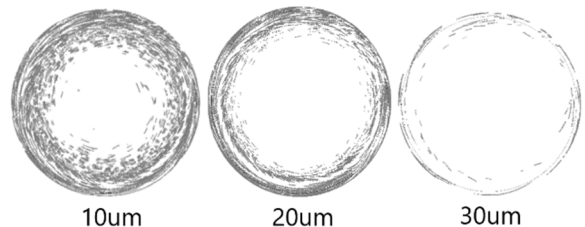


Figure 7. Distribution of particles with different diameters at the end of the cyclinder

It can be observed from FIG. 7 that because particles smaller than 10um have smaller mass and are subjected to small centrifugal force, their distribution inside the cyclone is relatively dispersed; particles larger than 30um are subjected to larger centrifugal force, which is mainly distributed in the area near the cylinder wall. Therefore, when the insertion

depth of the air outlet is changed. the effect on 10 - 30um particles is greater than that on particles below 10um and above 30um.

3.3. Influence of different dust outlet forms on separation efficiency

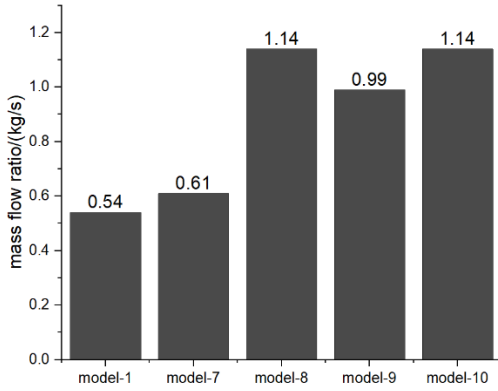


Figure 8. Dust outlet gas flow at different dust outlet forms

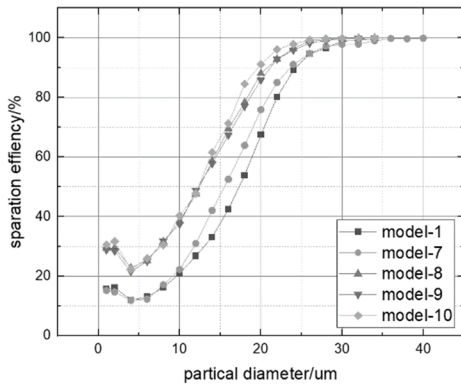


Figure 9. Separation efficiency of particles with different dust outlet forms

About models 1, 7, 8, 9 and 10, the gas flow at the dust outlet and the separation efficiency of small particles are shown in FIG. 8 and FIG. 9, respectively. The diameter of the exhaust pipe affects the separation efficiency by influencing the flow field in the annular gap separation zone and the exhaust zone[17]. In the actual product, the diameter of the series air outlet is 50mm smaller than that of the single air outlet, so the diameter of the air outlet of model 1 is reduced by 50mm, and model 7 is established. The reduced model has an average separation efficiency of 8.7% higher for particles of 10 - 25um, while the separation efficiency of particles below 10um remains unchanged. The gas flow rate of the dust outlet is increased by 0.07kg/s. Compared with model 7 and model 8, it is found that the gas flow rate of the parallel dust outlet is twice that of the single dust outlet, and the average separation efficiency of particles from 1 to 30um is increased by 16.5%. Since the overall length of the serial dust outlet is larger than that of the parallel dust outlet, in order to eliminate the influence of the cylinder length on the separation efficiency, the cylinder length of model 8 is increased by 170mm, and model 10 is established. After the cylinder length is increased, the gas flow of the dust outlet remains unchanged, and the separation efficiency of 15 - 25um particles is increased by 2.8% on average. The separation efficiency of model 8 and model 9 for small particles is similar,

indicating that the tandem dust outlet and the parallel air outlet have the same separation effect on small particles. By observing the velocity and pressure nephogram of models 8, 9 and 10, it is found that the area with the inner flow velocity of 3.8 - 7.6m/s in the series dust outlet is larger than that in the parallel dust outlet. The analysis is due to the fact that the overall inner diameter of the series dust outlet is smaller than that of the parallel dust outlet, resulting in an increase in the flow speed in the air outlet.

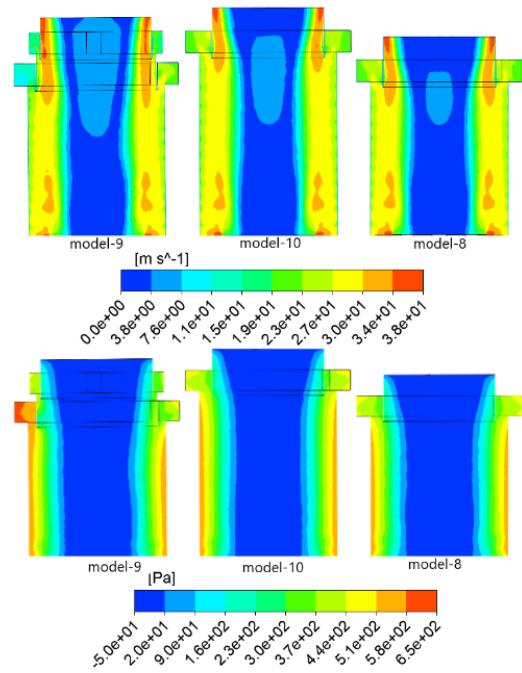


Figure 10. Velocity and pressure cloud of axial flow cyclone tail

4. Conclusion

The dust removal efficiency can be effectively improved by changing the dust outlet form of the axial flow cyclone separator and meeting the requirements of different separation occasions. Through the study on the separation efficiency of different outlet, the following conclusions are drawn:

1) The gas flow rate of the outlet increases with the increase of the diameter of the outlet, and the increase rate gradually decreases. When the diameter of the outlet increases from 800mm to 880mm, the separation efficiency of 15-25um particles increases by 2.3% on average, and the separation efficiency no longer changes as the diameter of the outlet continues to increase.

2) The air volume of the dust outlet decreases with the increase of the air outlet insertion depth, and the reduction rate gradually decreases. When the insertion depth of the outlet is reduced from 150mm to 100mm, the average separation efficiency of particles with a diameter of 15-30um is reduced by 4.5%. When the insertion depth of the outlet is greater than the width of the outlet, the insertion depth has no effect on the dust removal efficiency.

3) Increasing the number of dust outlets can effectively increase the dust removal efficiency, and the gas flow rate of the dust outlet will also increase, which is not conducive to particle settlement. The tandem dust outlet and parallel dust outlet have the same separation effect on small particles, and the gas flow rate is equivalent to twice the gas flow rate of a

single dust outlet, and the average separation efficiency of 1 - 30um particles is increased by 16.5% than that of a single dust outlet. The flow rate of the air outlet at the tail of the connected dust outlet is higher than that at the parallel dust outlet.

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