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DUST EXHAUSTING STRUCTURE OF CYCLONE SEPARATION CHARACTERISTICS IMPACT STUDY

MA Xin, LIJie, LAI Ke

(Institute of Electrical and Mechanical Engineering, Southwest Petroleum University, Chengdu, Sichuan 610500, China)

ABSTRACT

In order to study the effect of dust outlet geometry on the performance of cyclone separators, the gas-solid flow characteristics in four cyclone separators with different dust outlet geometries (without dustbin, with dustbin, with dipleg and with dustbin plus dipleg) have been computationally simulated. The gas flow fields were simulated with Reynolds Stress Model(RSM).The effect of instantaneous turbulence on particle tracking was taken into account by mean of the stochastic tracking approach and the two-way coupling between gas and solid was considered. The results show that the value and the distribution of tangential velocity is similar for the four cyclone separators, and the difference of the maximum tangential velocity between those cyclones is within 2 m/s. The axial velocity curves of all cyclones show bimodal asymmetric distribution , The inner axial velocity of the cyclone separator with dustbin plus diplegis 3m/s, larger than that the other separators because of sudden decrease of diameter. The shapes of the grade collection efficiency curves of all models have a so-called “S” shape. The cyclone separator with dipleg and dustbin has an efficient separation efficiency, because of the provision of an additional separation space for ash dust, creating a favorable condition for its further separation. The influence of the dust outlet geometry on the pressure drop is small, and the separation efficiency is greatly influenced. If the cyclone performance parameters are estimated without the dust outlet geometry, an error will exist in the performance prediction and numerical simulation.

Key Words: Cyclone separator；Dust outlet geometry；Numerical simulation
；Performance；Effect

INTRODUCTION

Cyclone separator is an important purification equipment, because of its simple structure, no moving parts, high separation efficiency and moderate pressure drop, especially for high temperature and high pressure and high dust concentration conditions, the use of petrochemical, Coal-fired power generation and environmental protection and many other industries have been widely used [1]. Design of high efficiency, low pressure drop cyclone separator is the common needs of various industries. At present, there are many studies on the structure and size parameters of the cyclone separator, but more is to study the effects of different air intake and exhaust pipe structures on the efficiency of the cyclone, while the dust removal structure is less studied [2].

Common cyclones The dust structure of the cyclone row can be divided into four types: cyclone with no hopper Cyclone1, cyclone with only hopper Cyclone2, cyclone with straight tube Cyclone3, with straight pipe and hopper Cyclone 4. The gas flow field, separation efficiency and pressure drop of the four models were analyzed by CFD software FLUENT14.5. The effect of the change of dust removal structure on the separation characteristics of the cyclone was studied and Optimization to provide a certain reference value.

1Physical model and numerical calculation

1.1Size parameters

The structural dimensions of the four models are shown in Fig. 1, where the four models use the same structural dimensions in the separation zone above the dust discharge port and show a difference in the dust removal structure. Among them, the structural dimension of model 1 is mainly based on the standard Stairmand type cyclone model, and the height of dust removal structure in models 2, 3 and 4 is the same.

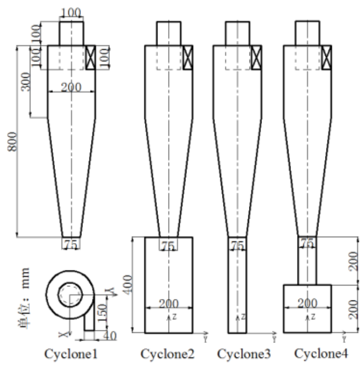


Fig1. Configurations of four cyclones with different dustoutlet geometries

1.2Meshing and Boundary Conditions

The fluid domain of the cyclone separator is discretized by ANSYS ICEM CFD. The fluid domain is discretized by the hexahedral structure grid. The boundary layer of the fluid domain is divided into the boundary layer and the local mesh is subdivided. The number of grids is 250224,463112,320286,424068, and the number of grids is tested by grid independence, as shown in Fig 2.

Boundary conditions are the same as those in [13]. The gas is air at room temperature and pressure, with a density of 1.22 kg/m3 and a viscosity of 1.78 x 10-5 Pa • s. With the speed of imports, the size of 18 m/s; free outflow outbound border outflow; with no slip, smooth wall. And the normal recovery coefficient and the tangential recovery coefficient of the wall are set to determine the amount of change in the momentum of the particles that collides with the wall. Particle density of 2650 kg/m3 ,mass flow of 0.001 kg/m3. The outlet exhaust pipe is set to escape the escape, the bottom of the model 1, the model 2 and the bottom of the hopper of the model 4, the bottom of the straight pipe of the model 3 is set as the particle trap trap, the other wall is set to reflect, Collapse with the wall [11]. Using the Reynolds stress turbulence model, the random trajectory model is used to simulate the trajectories of the particles in the turbulent flow field. The characteristic length L and the turbulence intensity I are 44 mm and 5.5% respectively [12].

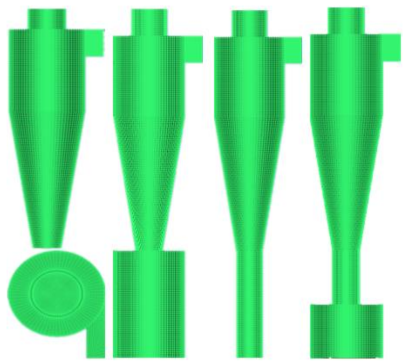


Fig2. Meshing of four cyclone

2 Results and analysis

2.1Numerical model correctness verification

Verify the correctness of the numerical model, compare the numerical simulation results with the experimental data. The structure of model 1 conforms to the standard Stairmand cyclone structure size, taking the cyclone model 1 studied in the paper, the tangential velocity Vt and the axial velocity Va and Hoekstra [13] measured at Z = 1050 m In comparison, where the inlet speed is V, the bottom of the gray hopper of model 4 is Z = 0 and positive. It can be seen from Fig. 3 that the axial velocity and the tangential velocity are in good agreement with the experimental results. Therefore, the turbulence model and the numerical calculation method can be used to simulate the flow field of the cyclone.

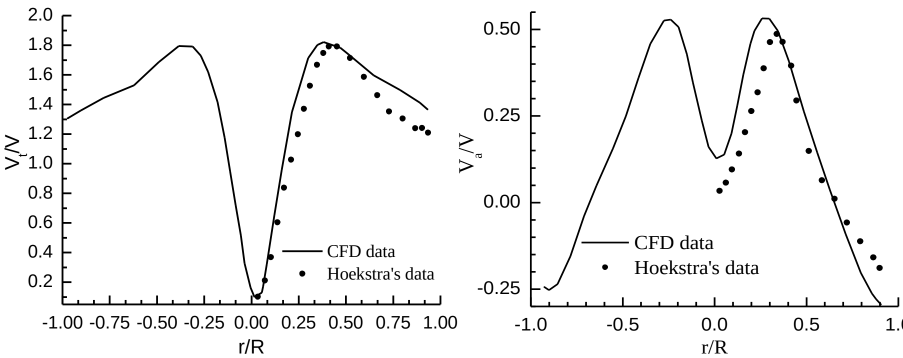
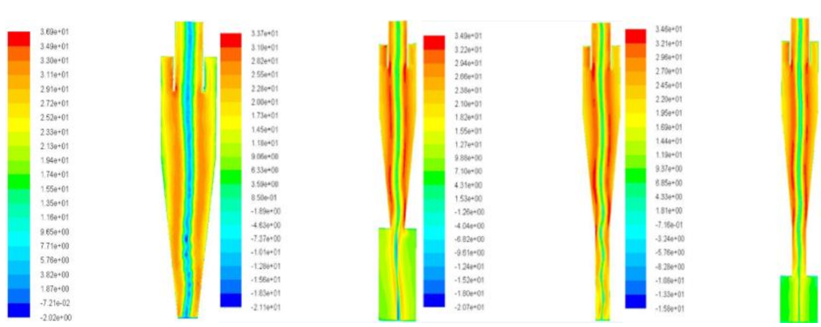


Fig3. Comparison of tangential and axial velocity of numerical simulation with Hoekstra's data

2.2Tangential velocity

The tangential velocity is used to describe the main velocity component of the internal airflow of the cyclone, which directly affects the separation efficiency of the separator. The increase in tangential velocity increases the centrifugal force of the dust particles, and the more it escapes from the airflow, it is trapped to the wall and is captured to improve the separation efficiency.

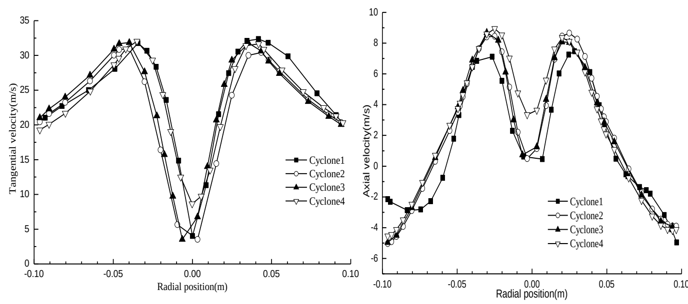
Comparing the tangential velocity skins of each model, it can be seen that the airflow inside the four separators in Figure 4 is relatively symmetrical. The inlet side of the speed of the larger, more down to go, the size of the speed and the vector direction of the symmetry of the better. This shows that the strong rotation of the airflow within the separator weakens the asymmetry caused by the unilateral inlet. The separation of the central area of the formation of the vortex, can clearly see the lower position of the rotation and swing [14]. The oscillations of models 1, 2 and 3 are larger and the amplitude of the model 4 is smaller. And the greater the amplitude of the vortex, the more obvious the eccentric vortex [15], the gas disturbance is more powerful, it will be easy to gather in the wall of the particles re-hoisted up into the internal swirling flow, the impact of separation efficiency.



（a）cyclone1（b）cyclone2（c）cyclone3（d）cyclone4

Fig4. Tangential velocity cloud of four cyclones at X=0 profile

In comparison with the tangential velocity curve of each cyclone, as shown in Fig. 5 (a), the tangential velocity has a good symmetry on Z = 1100 mm in the same position. The tangential velocity shows a small difference in numerical values, and the difference between the maximum tangential velocity at the same position is within 4 m/s. The maximum tangential velocity of model 1 is the largest, and the main reason is that the friction energy of the wall is less, but the difference between the maximum values is only 2 m / s or less. Each model is at the center of the minimum. In general, the tangential velocity curves of the four models exhibit an inverted "W".



（a）Tangential velocity（b）Axial velocity

Fig5. Comparison of tangential and axial velocity of four cyclones in z=1100mm

2.3Axial velocity

The maximum axial velocity of each model is 7.2 m/s, 8.5 m/s, 8.2 m/s and 8.5 m/s, respectively. But the axial velocity of the trough position in model 4 is 3m/s, while the axial velocity of the other model troughs is close to zero, and the trough position axial velocity is quite different. This is mainly due to the fact that the hoisting of the hopper in the model 4 is increasing due to the sudden increase in the velocity of the hopper [17], and more kinetic energy is used to overcome the effect of the inverse gradient so that the axial velocity at the center is increased , The axial velocity at the trough increases. The model 2 did not appear this phenomenon is due to the center of the return is too large, increased kinetic energy cannot overcome the impact of reverse pressure. Model 1 and Model 3, the rising air flow in the process of rising without the contraction of the outer diameter.

2.4Separation efficiency and pressure drop

Conventional cyclone separators have high efficiency at 5 μm, so the separation characteristics of each cyclone separator below 5 μm are mainly analyzed. The separation efficiency of the four cyclones is shown in Fig. 8. Overall, the classification efficiency curves of the four cyclones are approximately "S". The separation efficiency of model 4 is high, the cutting particle size is 1.1 μm, slightly higher than that of other cyclone, and the separation efficiency of model 1 is poor, and the cutting particle size is 1.5 μm. Mainly due to the addition of a straight tube to extend the separation of space, the smaller particles in the straight pipe for further separation.

The separation characteristics of each model are shown in Table 1. The difference between the model 1 and the model 2, the model 3 and the model 4 is not much different, the difference is less than 40Pa, and the difference between the model 3 and the model 2 is larger Is due to separation of space and dust removal structure of the friction loss caused by the difference between the pressure loss. The separation efficiency of the four models is also different, the cutting size of the four models is different, the smaller the cutting particle size, the higher the separation efficiency. The dust removal structure will affect the flow field of the cyclone separator. Although the neglect of the dust removal structure will save a lot of numerical simulation work, the relative error, the pressure drop error and the separation efficiency error will be affected by the pressure drop and separation efficiency 4% And about 27%.

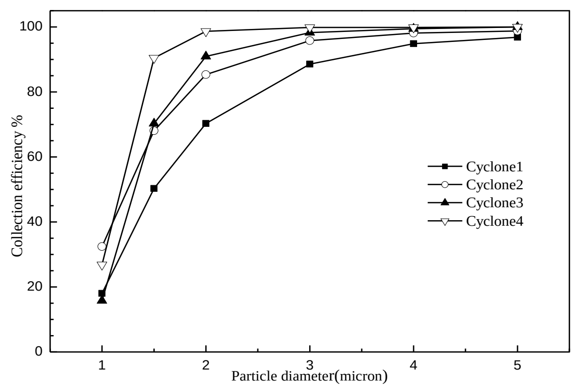


Fig.8.The grade efficiency curves for the four cyclones

Tab1. Separation characteristics of the four cyclones

Separation characteristics	Cyclone1	Cyclone2	Cyclone3	Cyclone4
pressure（pa）	1034	994	1078	1042
Cut off diameter(μm)	1.5	1.2	1.25	1.1

Conclusion

(1) The maximum tangential velocity of the four models is similar to the distribution position, and the maximum tangential velocity difference is only 2 m / s. And the vortex core in the middle of each model has obvious deviation and swing in the lower end position, in which

the swing amplitude of model 1, 2, 3 is larger, and the amplitude of the model 4 is smaller and the turbulence pulsation is small.

(2) The axial velocity of the four models is different. Although the axial distributions of the four models are asymmetric bimodal distributions, the axial velocity in the middle of model 4 is significantly larger than that in the middle of the other models Speed, and the center of the minimum axial velocity of 3m / s, mainly because the internal swirl on the spin when the straight tube due to the sudden increase in speed and speed.

(3) due to the different dust discharge structure will lead to separation efficiency and pressure drop there are differences. In addition, the separation efficiency is the highest and the cutting particle size is 1.1 μm, but the friction loss increases and the pressure loss increases due to the increase of the wall surface. The traditional cyclone separator due to the dust in the external rotation to the cone at the end of the cone, the smaller particles have not yet captured with the internal flow from the exhaust pipe escape, the separation efficiency is low, cutting particle size of 1.5 μm.

(4) The effect of dust removal structure on the pressure drop is small, which has a great influence on the separation efficiency. Can not ignore the impact of dust removal structure on the cyclone, otherwise it will be in the performance prediction and numerical simulation caused a greater error.

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Author: Xin Ma (1973-), master, associate professor, research direction for the chemical machinery and equipment; Jie Li,