**Optimization of structural parameters of rotary separator**

**Wang Peng**, Sun Zhi-li, Zhang Zhen-wei, Jin Ying-ying

Institute of Mechanical Engineering and Automation, Northeastern University, Shenyang 110819, China

*Corresponding author’s e-mail: 812750705@qq.com

**Abstract.** The rotary separator is an important part of the thermal power generation milling system. The quality of the separation performance directly affects the economics and safety of the milling system. In this paper, the influence of the structural parameters of the rotary separator on the separation performance is studied by the analysis software FLUENT. The structural parameters include the height of the middle cylinder of the impact cone, the taper of the impact cone and the number of the impeller blades. Through the numerical simulation analysis of the rotating separators with different structural parameters, it is concluded that when other structural parameters are fixed, the higher the middle cylinder of the impact cone, the worse the separation effect. The larger the cone taper is, the worse the separation effect is. The more the number of blades, the better the separation effect.

1. **Introduction**

Rotary separator, as one of the important auxiliary equipment of the coal mill, plays an indispensable role in controlling the fineness of coal powder in the milling system[1-3]. The rotating separator mainly depends on centrifugal separation, supplemented by gravity separation and impact separation. In the rotating separator, the mixture of gas and pulverized coal particles is entered by the entrance. First, it collides with the cone surface of the impact cone, and the pulverized coal with large particle diameter is reproduced from the pulverized coal pulverizer to the pulverizer. The remaining pulverized coal particles move to the annular area between the impact cone and the outer cylinder driven by the airflow. The gravitational separation of pulverized coal whose gravity is greater than the buoyancy force is returned to the coal mill along the return tube. Then, when the coal powder enters the rotating impeller area, a part of the coal powder is subjected to the combined action of centrifugal force and gravitational force. When the centrifugal force of the pulverized coal is greater than the gravitational force, it escapes from the rotating area and returns to the coal mill [4-5]. When the centrifugal force of the pulverized coal is less than the pulling force, it will go with the air flow to the exit and send to the furnace. This part of the pulverized coal is qualified pulverized coal. At the same time, after the pulverized coal collides with the blade, the fine powder is sent to the combustion, and the particle is broken and becomes fine, and the aforementioned movement is repeated.

2. **Structure of rotating separator**

The rotary separator is composed of an upper outlet, a moving impeller, an inner cone, a shock cone, a lower outlet and an inlet[6]. The schematic diagram of the impact cone structure is shown in Figure 1.

It consists of an upper and lower cone and an intermediate cylinder. Among them, \(d_1\) and \(h_1\) are the diameter and height of the upper cone, \(d_2\) and \(h_2\) are the diameter and height of the middle cylinder, \(d_3\) and \(h_3\) are the diameter and height of the lower cone, and the \(d_0\) is the diameter of the inlet pipe.
The structure of the impact cone plays a decisive role in the primary separation effect of the separator, and the first-stage separation effect lays a foundation for improving the comprehensive separation efficiency. If the primary separation efficiency is too low, the secondary and tertiary separations will be affected, which will also have an adverse effect on the overall separation efficiency. The moving impeller of the rotary separator adopts a conventional straight impeller, and the structure is shown in Figure 2. The blade has a certain impact on the particles, causing the particles to break again and improving the fineness of the outlet. In this paper, the separation of coal powder is simulated by changing the height of the impact cone, the diameter of the impact cone and the number of blades, and the influence of these three parameters on the separation performance is analyzed [7].

3. Meshing and solution settings
In this paper, SolidWorks is used to establish the three-dimensional model of rotary separator and a hybrid mesh method is adopted. The flow field is divided into five parts: entrance, exit, impact cone, inner cone and leaf sector, and the grid is divided. Since the blade sector is rotating around the axis, although the hexahedral structure grid is of high quality but difficult to move to the grid operation, the unstructured grid is used for the leaf sector, and the other four regions use the hexahedral structure grid to ensure the quality of the grid. The meshing diagram is shown in Figure 3.

The model meshes are imported into FLUENT software and relevant gas-phase medium parameters and boundary conditions are set up. The flow velocity of the gas phase in the separator is generally 8m/s-20m/s, and the greater the wind speed, the greater the resistance, so the inlet wind speed is selected to be 16m/s. The initial value of the rotational speed of the impeller is set to 60 rpm. The UFD file is introduced to realize the rotation of the mesh of the impeller area, and the gas flow is simulated by the RNG model[8-9].

4. Influence of impact cone height on separation performance
The separation performance of the rotary separator is described by the single particle separation efficiency[10]. The separation efficiency of single particle is defined as the ratio of the number of escaped particles to the number of trace particles. The higher the separation efficiency is, the better the separation efficiency of the small particle pulverized coal, the smaller the better the separation efficiency of the large particle pulverized coal. With $R_{90}$ as a criterion, 30 µm, 60 µm and 80 µm are selected for numerical simulation, and these sizes are divided into two groups, small particles less than 90 µm and larger particles larger than 90 µm. The formula for calculating the separation efficiency is shown in formula (1).

$$\eta = \left[ \frac{(100 - R_i^2)A}{(100 - R_i^2)B - R_i^2A} \right] \times 100\%$$

\[ (1) \]
In the formula, $r_i^p$ is the fineness of imported pulverized coal, $r_o^p$ is the fineness of export pulverized coal, $A$ is the total amount of pulverized coal exported, and $B$ is the total amount of imported pulverized coal.

In the case of other structural parameters, only changing the size of the impact cone height changes the distance between the impact cone and the entrance. The higher the height indicates the closer the impact cone is to the entrance to the entrance. The values of $h_2$ are 60mm, 90mm, 120mm and 150mm, respectively, as shown in Figure 4.

![Figure 4. Four kinds of impact cone with different height](image)

After FLUENT numerical simulation, the tracking number of each typical particle is 1653, a total of 11571, and the specific value is shown in Table 1.

| Particle radius (μm) | The height of the middle cylinder $h_2$ (mm) |
|---------------------|-------------------------------------------|
|                     | 60   | 90   | 120  | 150  |
| 30                  | 1647 | 1478 | 1294 | 1142 |
| 60                  | 1023 | 782  | 471  | 174  |
| 80                  | 701  | 528  | 284  | 69   |
| 100                 | 273  | 192  | 108  | 31   |
| 120                 | 97   | 44   | 21   | 4    |
| 150                 | 30   | 14   | 0    | 0    |
| 200                 | 0    | 0    | 0    | 0    |

The particle separation efficiency of the rotary separator at different $h_2$ values is shown in Figure 5(a). First, on any curve, the separation efficiency of fine particle coal powder is high and the separation efficiency of coarse particle coal powder is low. Secondly, the change of $h_2$ has a great effect on the separation efficiency of fine powder 30 μm, 60 μm and 80 μm. The increase of each time is accompanied by a significant reduction in the efficiency of the separator 8%-10%. The effect of the separation efficiency of coarse particles is not so large, only the decrease of 1%-2.5%. This causes the increase of $h_2$ to reduce the amount of fine powder in the export coal powder, that is, the separation effect becomes worse.

![Figure 5. Separation efficiency of particles with different $h_2$, taper and number of leaves](image)
The main reason is that the larger the $h_2$ the closer the impact cone is to the exit, and the narrower the basin space is. On the one hand, the resistance of gas-solid two-phase flow in this basin increases, and the upward movement of fine particles is hindered, which reduces the percentage of pulverized coal in the export. On the other hand, because the watershed becomes smaller, coarse particles are carried away by airflow before gravity separation is completed, which increases the percentage of coarse particles.

5. Influence of cone taper on Separation Characteristics

![Figure 6. Four kinds of impact cone with different taper](image)

In this paper, the other structural parameters are kept unchanged, and only the diameter $d_3$ of the lower cone is changed to achieve the purpose of changing the taper of the impact cone. The bigger the $d_3$ is, the smaller its taper, and the values of $d_3$ are 60mm, 70mm, 80mm and 90mm, as shown in Figure 6. The numerical results obtained by the FLUENT simulation are shown in Table 2.

The particle separation efficiency of the rotary separator at different tapers is shown in Figure 5(b). First, the separation efficiency on any curve decreases with the increase of particle size. Secondly, the change of taper has obvious effect on the separation effect of fine powder, and the decrease of each taper is accompanied by a large increase in the separation efficiency of fine powder, and the separation efficiency of the coarse powder particle has little change. Therefore, the reduction of taper results in the increase of the percentage of fine particles in the pulverized coal, and the separation effect is good. This is because when the taper of the impact cone is small, its flow conductivity is good, small particles of pulverized coal can smoothly reach the exit under the traction of the air flow, reducing the loss. The large cone impact cone has poor diversion effect and large resistance to gas-solid two-phase flow. Some of the two-phase flow will be rebounded to the outlet, resulting in poor separation effect.

| Particle radius ($\mu$m) | Diameter of lower cone $d_3$(mm) | 60    | 70    | 80    | 90  |
|-------------------------|---------------------------------|-------|-------|-------|-----|
| 30                      |                                 | 970   | 1102  | 1376  | 1539|
| 60                      |                                 | 640   | 861   | 1074  | 1206|
| 80                      |                                 | 634   | 790   | 858   | 1062|
| 100                     |                                 | 103   | 68    | 36    | 15  |
| 120                     |                                 | 23    | 4     | 4     | 0   |
| 150                     |                                 | 18    | 0     | 0     | 0   |
| 200                     |                                 | 10    | 0     | 0     | 0   |

6. The influence of the number of leaves on the separation characteristics

The influence of the number of blades of the traditional straight impeller on the separation characteristics is studied here. The number of leaves is 16, 20, 24 and 28 respectively. The numerical results obtained by the FLUENT simulation are shown in Table 3.
Table 3. Escape number of each particle size with different number of leaves

| Particle radius (μm) | Number of leaves |
|---------------------|------------------|
|                     | 16   | 20   | 24   | 28   |
| 30                  | 1024 | 1123 | 1306 | 1539 |
| 60                  | 276  | 483  | 801  | 1079 |
| 80                  | 175  | 357  | 493  | 692  |
| 100                 | 138  | 98   | 54   | 31   |
| 120                 | 127  | 71   | 30   | 4    |
| 150                 | 52   | 11   | 0    | 0    |
| 200                 | 8    | 5    | 0    | 0    |

The particle separation efficiency of the rotary separator under different number of blades is shown in Figure 5(c). It can be seen from the diagram that the separation efficiency of fine pulverized coal with diameter less than 90 μm is greatly affected and increases with the increase of the number of blades. The separation efficiency of coarse-grained pulverized coal with greater than 90 μm is less affected, but decreases with the increase of leaf number. The separation efficiency of different particle sizes on any curve is the higher the particle size is, the higher the separation efficiency is, the larger the particle size is, the lower the separation efficiency is, which is a good embodiment of the separation characteristics. The increase of the number of impeller blades not only effectively improves the separation efficiency of fine powder, but also reduces the escape number of coarse powder. This shows that the proportion of coarse particles in the fine powder separated by the rotary separator is very small, and the separation effect is good. This is because the increase of the blade increases the probability of collision between coarse particles and blades, and the coarse powder is crushed into fine powder to escape. Therefore, in practice, the number of blades of the moving impeller can be increased appropriately to enhance the separation effect.

7. Conclusion
(1) When other structural parameters are fixed, the increase of the height of the cylinder in the middle of the impact cone reduces the efficiency of the pulverized coal separation, and the greater the impact cone taper is, the lower the separation efficiency is. In practice, the separation efficiency can be improved by properly reducing the height and taper of the middle cylinder of the impact cone.

(2) The difference in the number of impeller blades also has a certain effect on the separation characteristics. In the case of other structural parameters, the efficiency of pulverized coal separation increases with the increase of the number of blades. In practice, the separation effect can be optimized by increasing the number of blades.

References
[1] Yang, P.J., Hu, D.J., Zhao, W.D., et al. (2013) Model calculation and experimental study of static and dynamic leaf combined rotary separator[J]. Thermal Power Generation, 42(6).
[2] Wang, H. (2010) Adjustment strategy in the operation of rotary separator of medium speed coal mill[J]. Journal of Automation, (12): 72-73.
[3] Weng, J.S. (2014) Numerical Simulation of Combined Rotary Separator Model Machine [D]. Huazhong University of Science and Technology.
[4] Jia, C.Y. (2016) Research on optimization of moving blade structure of rotary pulverized coal separator[D]. North China Electric Power University.
[5] Zhang, P.Y., Liang, Y.F. (2013) Application of Dynamic Rotary Separator in Double Inlet and Double Out Coal Mill[J]. China New Technology and New Products, (12): 4-4.
[6] Kong, W.J., Cheng, S.M. (1997) Determination of Main Structure Size and Rotor of Rotary Pulverized Coal Separator with Pre-Separation Device[J]. Proceedings of the CSEE, 17(4): 238-242.
[7] Zhao, Z.G., Zhang, J.B., Ming, Y. (2011 )Design Optimization of Rotor Blades for Rotary Coarse Powder Separator[J]. Science and Technology,(20): 115-115.
[8] Zhu, H.W., Lin, Y.H., Xie, L.H. (2011) Fluid Analysis and Engineering Simulation of FLUENT12[M]. Beijing: Tsinghua University Press.

[9] Sun, Z.Y., Wu, X.R. (2008) Discussion and application of numerical simulation method for computational fluid dynamics[J]. Journal of Water Resources Science and Technology, 14(2): 126-128.

[10] Yan, S.L., Dong, B., Chen, H.G., et al. (2012) Analysis of performance evaluation index of coarse powder separator[J]. Applied Energy Technology, (4): 24-27.