Measurement and Numerical Simulation Analysis of Smoke Flow Field after Dust Collector Modification

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\textbf{Abstract.} The differential pressure of dust collector bag in a power plant was improved synthetically. In this paper, the distribution of the smoke flow field in the unit dust collector system is numerically simulated and filed tested. The main technical parameters of the distribution of smoke flow field in the unit's overall dust removal system were measured on site. The actual operation results of the project show that the CFD calculation results are in good agreement with the actual situation, the airflow uniformity inside the modified dust collector is well, the dust removal efficiency is realized and the design expectation is achieved.

1 Introduction

A 200MW unit dust collector is a bag filter for semi-dry desulphurization, with low pressure pulse ash cleaning method. The unit completed the transformation of the electric bag composite precipitator in October 2017. Combining with the transformation process, it added a level of electrostatic dust removal to the original cloth bag precipitator. At the same time, some filter bags were washed and partially blocked in the bag area of the precipitator. After the transformation, there is a high differential pressure phenomenon in the operation of the unit. Meanwhile, the electric dust removal has been unable to operate normally, and the secondary current is low. There are the following problems in the distribution of the flow field at the entrance of the electric dust removal area: the airflow in the electric dust removal area is distributed unevenly along the direction of height, and the flow velocity in some areas is too large while that in other areas is too small, resulting in the failure of the normal operation of the electric field. The main reason for the uneven airflow in the electric dust removal area is the unreasonable setting of the guide plate at the entrance of the dust collector.

In 2019, the power plant underwent comprehensive treatment and transformation of dust collector bag differential pressure. This paper will analyze the test results and numerical simulation results of the distribution of smoke flow field of the dust collector after the transformation.
2 Numerical simulation analysis

2.1 Model

According to the actual flue size of the electrostatic precipitator, the original air intake mode is changed to the front air intake, the original deflector plate and channel type air distribution plate are cancelled, and instead, a two-layer perforated plate with a porosity of about 40% is added in the expansion section of the air intake. ICEM software was used to establish the model of electrostatic precipitator system in 1:1 ratio, as shown in Fig. 1.

Figure 1. Schematic diagram of dust collector structure.

According to the shape of flue inlet, outlet, guide plate, and considering the flow of flue gas in the flue, the inner guide plate and the air distribution plate are locally encrypted when the grid is divided. Hexahedral and wedge-shaped mixed meshes were used to divide. The distortion of the mesh can be controlled reasonably and the overall mesh quality is better. Considering the small particle size of dust, the flue gas is considered as an incompressible fluid in the calculation. In this paper, the standard $\kappa$-$\varepsilon$ model in FLUENT software is used to simulate the flow field inside the electric field of the electrostatic precipitator based on simple algorithm[1].

According to the current common coal quality, 100% load calculation, the flue gas parameters are 680000 $\text{m}^3/\text{h}$ at $145^\circ\text{C}$. According to the volume flow rate of the flue gas and the size of the inlet section, the boundary conditions of the inlet can be calculated. The calculated results are shown in Table 1.

Table 1. The boundary conditions.

|       | Turbulence intensity | Hydraulic diameter | Mean velocity |
|-------|----------------------|--------------------|--------------|
| Inlet | 0.0281               | 2.2m               | 10.73m/s     |

2.2 Analysis of numerical simulation results

According to the simulation calculation of the improved device scheme, it can be analyzed from Fig. 2 that the flue gas at the entrance of the precipitator flows mainly along the flue to the interior of the precipitator. As two layers of porous plates are set at the expansion flue, the flue gas flows mainly to the dust collector's working area. According to the flow diagram in Fig. 3, the flue gas flow in the dust collector is basically free of eddy current,
which will not increase the resistance of the system, and the flow field distribution has been significantly improved.

![Figure 2. Velocity distribution of flue gas in vertical section of electrostatic precipitator.](image)

**Figure 2.** Velocity distribution of flue gas in vertical section of electrostatic precipitator.

![Figure 3. Smoke flow diagram of electrostatic precipitator.](image)

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The velocity cloud at the entrance of the electrostatic precipitator shows that the velocity of flue gas near the wall is slightly higher than that in the central area, and the flue gas in the pipeline has a higher degree of filling and a smaller deviation on both sides, which is a good running state.

Section 2 and section 3 (shown in Fig.1) are the internal cross sections of the ESP. It can be seen from the velocity cloud images of the two sections in Fig. 4 and Fig. 5 that the flow of flue gas in the interior is basically uniform on the upper part of the ash hopper. Furthermore, it is proved that this modification scheme is very good to improve the operation effect of electric field.

In order to see the change of velocity more intuitively, several points of velocity at different positions of the inlet and outlet of the precipitator were selected and plotted into a broken line diagram, which can be seen in Fig.6. The average velocity of the ESP inlet at different cross sections is uniform and about 10.75m/s. The average velocity of the ESP outlet at different cross sections is uniform but different from 12m/s to 13.7m/s, whose maximum velocity difference is about 1.7m/s.
Figure 4. Velocity distribution cloud image of section 2.

Figure 5. Velocity distribution cloud image of section 3.
3 Field test

The grid method was used to measure the wind speed of 168 test points in 6 test holes (3 holes on each side) at the inlet and outlet of the ESP[2]. The results are shown in Fig. 7.

According to the above test results, it is found that the wind speed at the side of each pipe is higher than that at the middle part, which indicates that the flue gas in the pipe has a higher degree of filling and a smaller deviation on both sides, which is a better running state in accordance with the laminar flow. The average velocity of the cross section is 12.19 m/s, and the maximum deviation is 2.6 m/s. The deviation velocity will not cause significant wear to the inlet equipment. The smoke flow field is uniform and there is basically no deviation.

4 Conclusions

After the dust collector of the unit underwent differential pressure control transformation, the dust removal system was numerically simulated and the smoke flow field distribution was tested. The smoke flow field of each section was basically uniform, and the deviation range of the denitrification inlet velocity was normal, which would not cause the wear problem of denitrification and the heat exchange equipment at the rear end.

The laminar flow field at the inlet of the electrostatic precipitator is in a good state. The minimum measured wind speed is 9.56 m/s, and the maximum flow speed is 13.91 m/s. The maximum flow rate will not cause large wear problems at the inlet of the electrostatic precipitator. The flow field at the outlet of the electrostatic precipitator has good uniformity.
References

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