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Research Article

Enhancement of Cathode Dust Collection and its Application in Improving the Efficiency of Dry Electrostatic Precipitator

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Abstract: As the main equipment of flue gas dedusting in coal fired boiler, electrostatic precipitator (ESP) can meet the requirements of emission standard for air pollutants from coal-fired power plants through improving the efficiency of ESP and combining with desulfurization system while not installing wet ESP (WESP). This paper introduces the modifications of ESP cathode structure to improve the efficiency of dust collection by reducing the secondary dust loss at cathode. The application of cathode dust collection provides a reference for the improvement of ESP dust collection efficiency.

Keywords：ESP; Dust removal efficiency improvement; Cathode dust collection

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1 Introduction

China's collaborative flue gas treatment technology is developing rapidly, and ultra-low emission technology has been rapidly developed and applied. This paper introduces a coal-fired boiler dry electrostatic precipitator (ESP) in a thermal power plant through the addition of a cathode dust collection device to achieve dust removal efficiency enhancement and emission reduction.

2 Cathode Dust Collection Technology

The core part of the ESP is the two major systems of cathode and anode. Corona discharge (ionization) and high electric field strength between cathode and anode are two necessary prerequisites for ESP. In the actual operation of the ESP, due to the large number of non-ideal factors in the dust collection space, such as secondary dust, electric wind and back corona, etc., there are not only a large number of negative ions in the dust collection space, but also a considerable amount of positive ions. For low-emission ESP, while paying attention to the anode dust collection, one cannot ignore the function of cathode dust collection where cathode is used to trap the positively charged dust. To minimize the secondary dust loss as much as possible when rapping off the dust at the cathode, it is necessary to learn from the experience of anode dust collection. By making the cathode wire into a windproof type and using programmed rapping, etc., dusts tend to form large chunks or large pieces under the action of the rapping force and fall into the lower ash hopper, which reduces the secondary dust loss when the cathode is ripped and cleaned.

Cathode dust collection devices have many structural forms. This paper introduces the working process and principle of one of the vertical airflow cathode dust collection devices. According to the dust collection mechanism, it can be divided into collection (gas and dust separation) and de-ashing.

（1）Collection (gas and dust separation): The device is composed of multiple layers (at least 2 layers) of perforated louvers. The working principle is shown in Figure 1. When the dust-laden airflow passes through the louvers, it will be accelerated. Each louver hole is a small cyclone field, under the Eulerian multiphase flow model system and the action of high-voltage elec-

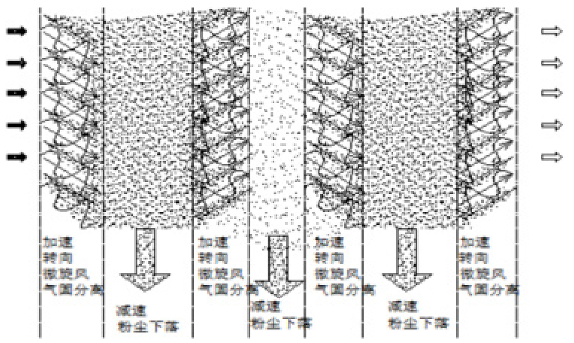

Fig. 1 Schematic Diagram of Cathode Dust Collecting Device

trostatic force, due to the different masses of gases and dusts, the centrifugal force, electric field force and friction force are different, making the dust-laden air flow accelerate. During the rotation, the dusts stay on the louvers, while the gases pass through the holes, thereby achieving the separation of gases and dusts.

（2）De-ashing: Fine particles of dust adhere, agglomerate and grow on the louvers. The oblique direction of the louvers is coupled to the staggered slits, forming a vertical airflow on the ash falling channel. Due to the coupled structure of the staggered slits, a micro-environment different from the cross-section of the electric field is created for the falling of ashes. The dusts gathered and grown on the oblique shutters slides down the inner channel, and pours down like a waterfall from the coupling channel formed by the two-layer device. The special oblique louver structure makes the dust on the outer dust collector flow back into the ash falling channel and fall in, so that the flying ash and dust are suppressed to the greatest extent.

3 Application of Cathode Dust Collection Efficiency Enhancement

3.1 Introduction on ESP of a Certain Power Plant

The ESP Unit No. 2 of a power plant was designed and manufactured by a factory in Zhuji, Zhejiang. The ESP is composed of 20 electric fields, 20 sets of cathode rapping systems, 20 sets of anode rapping systems, inlet current equalizing plate system (perforated plate), outlet current equalizing plate system (trough plate) and 40 ash hoppers. The stated parameters and the parameters before efficiency enhancement are shown in Table 1 below:

Table 1. #2 Technical Parameters of ESP Unit

Serial No.	Parameter	Unit	Value
1	Stated Dust Removal Efficiency	%	99.68
2	Guaranteed Dust Removal Efficiency	%	99.68
3	Effective Dust Collection Area	m^2	86400
4	Inlet Dust Concentration (standard state, dry basis 6%O_2)	g/m^3	15.22
5	Inlet Flue Gas Temperature	°C	128
6	Inlet Flue Gas Volume under Working Condition	m^3/h	2986700
7	Specific Dust Collection Area	m^2/（m3/s）	104.14
8	Flue Gas Flow Area	m^3	768.00
9	Air Leakage Rate	%	3.0
10	Resistance Loss	Pa	220
11	Maximum Negative Pressure	Pa	5230
12	No. of Electric Fields	pc	20
13	No. of Chambers	pc	2*2
14	Electrode Spacing	mm	400
15	Electric Field Width	m	4*12.8
16	Electric Field Height	m	14.84
17	Effective Length of Electric Field	m	5*4.5
18	Power Loss	kW	1300
19	Anode Rapping Mode	—	Sideway around Arm Hammer
20	Cathode Rapping Mode	—	Sideway Double-layer around Arm Hammer
21	Stated Coal Ash	%	19.77

Table 2. Summary of the Performance Test Results of the ESP Unit #2 before the Modifications

Serial number	Parameter	Unit	2018-06-28		
			ESP Inlet	ESP Outlet	Guaranteed Value
1	Flue Gas Volume under Working Condition	m^3/h	2846506	2880152	—
2	Flue Gas Flow Volume（standard state, dry basis）	m^3/h	1679528	1714912	—
3	Dust Emission Volume	kg/h	20871.7	25.4	—
4	Flue Gas Temperature	°C	133.8	129.0	—
5	Oxygen Content at Flue Outlet	%	5.53		—
6	Excess Air Coefficient	—	1.36		—
7	Air Leakage	%	2.1		<3.0
8	Inlet Dust Concentration（standard state, dry basis）	mg/m^3	12427.1		—
9	Outlet Dust Concentration（standard state, dry basis）	mg/m^3	14.8		—
10	Outlet Converted Emission Concentration (standard state, dry basis, 6%O_2)	mg/m^3	14.4		—
11	Dust Removal Efficiency	%	99.88		≥99.68
12	Resistance	Pa	197.9		<220
13	Unit Power	MW	600		630
14	Unit Load	%	95.2		100

When the load of unit #2 is 600MW, the mass concentration of dust at the outlet of the ESP unit #2 is 14.8mg/m^3 (standard state, dry basis) and 14.4mg/m^3 (standard state, dry basis, 6% O_2). The discharge of smoke and dust at the outlet of the device is 25.4kg/h, and the total dust removal efficiency is 99.88%, which meets the requirement that the guaranteed value of dust removal efficiency is greater than or equal to 99.68%. The air leakage rate of the ESP is 2.1%, which meets the requirement that guaranteed value of the body air leakage rate less than 3.0%. The resistance of the ESP is 197.9Pa, which meets the requirement that the resistance of the electrostatic precipitator is less than 220Pa.

3.2 The Scheme for Improving the Power Plant's ESP Cathode Dust Collection Efficiency

The efficiency enhancement scheme in this study design the ESP unit #2 with increased vertical flow at the 4^{th} and 5^{th} electric field of the cathode dust collection device.The cathode dust collection device has a punching and holding structure, was built with selected light metal materials, and was installed on the cathode frame at the end of the 4^{th} and 5^{th} electric fields to increase the equivalent dust collection area by about 10000m^2. Under the BMCR working condition, after the ESP unit #2 was modified for dust collection efficiency enhancement, the stated outlet dust concentration must be less than 10 mg/Nm^3 (standard state, dry basis, 6%O_2), the stated total resistance of the ESP is ≦ 350Pa.

3.3 The Parameters of the Power Plant's ESP Cathode Dust Collection after Efficienct Enhancement

After efficiency enhancement, the power plant's ESP unit #2 unit cathode dust collection was tested under two working conditions of low power and high power. The performance test data is shown in Table 3 and Table 4:

When the load of unit #2 is 622MW and the power consumption of the dust removal section is 942.4kW, the mass concentration of dust at the outlet of the ESP unit #2 is 8.2mg/m^3 (standard state, dry basis) and 7.6mg/m^3 (standard state, dry basis) , 6%O_2). The discharge of dust at the outlet of the ESP is 14.3kg/h, and the total dust removal efficiency is 99.91%. The pressure drop of the ESP body is 242.5Pa, which meets the requirement that the pressure drop of the ESP body is less than 350Pa.

When the unit load is 622MW and the power consumption of the dust removal section is 1382.0kW, the mass concentration of dust at the outlet of the electrostatic precipitator is 7.0mg/m^3 (standard state, dry basis) and 6.5mg/m^3 (standard state, dry basis, 6%O_2). The total dust removal efficiency is 99.93%,

Table 3. Summary of the Performance Test Results of Modified ESP Unit #2 for Efficiency Enhancement Retrofitted to Dust Removal Section Power Consumption at 942.4kW

Serial No.	Parameters	Unit	2019-04-24		
			ESP Inlet	ESP Outlet	Guaranteed Value
1	Flue Gas Volume under Working Condition	m^3/h	2900187	2946287	—
2	Flue Gas Flow Volume（standard state, dry basis）	m^3/h	1715496	1747431	—
3	Dust Emission Volume	kg/h	16452.3	14.3	
4	Flue Gas Temperature	°C	135.5	133.5	—
5	Oxygen Content at Flue Outlet	%	4.88		—
6	Excess Air Coefficient	—	1.30		—
7	Inlet Dust Concentration（standard state, dry basis）	mg/m^3	9590.4		—
8	Outlet Dust Concentration（standard state, dry basis）	mg/m^3	8.2		≤10
9	Outlet Converted Emission Concentration (standard state, dry basis, 6%O_2)	mg/m^3	7.6		—
10	Dust Removal Efficiency	%	99.91		—
11	Resistance	Pa	242.5		<350
12	Unit Power	MW	622		630
13	Unit Load	%	98.7		100

Table 4. Summary of the Performance Test Results of Modified ESP Unit #2 for Efficiency Enhancement Retrofitted to Dust Removal Section Power Consumption at 1382.0kW

Serial No.	Parameter	Unit	2019-04-24 ~ 2019-04-25		
			ESP Inlet	ESP Outlet	Guaranteed Value
1	Flue Gas Flow Volume（standard state, dry basis）	m^3/h	1715496	1747431	—
2	Oxygen Content at Flue Outlet	%	4.88		—
3	Excess Air Coefficient	—	1.30		—
4	Inlet Dust Concentration（standard state, dry basis）	mg/m^3	9590.4		—
5	Outlet Dust Concentration（standard state, dry basis）	mg/m^3	7.0		—
6	Outlet Converted Emission Concentration (standard state, dry basis, 6%O_2)	mg/m^3	6.5		≤10
7	Dust Removal Efficiency	%	99.93		—
8	Unit Power	MW	622		630
9	Unit Load	%	98.7		100

which meets the requirement that the stated value of dust removal efficiency is greater than or equal to 99.93%.

4 Conclusion

The improvement in efficiency of the modified ESP cathode dust collection in this study has reduced the dust concentration at the outlet of the ESP to less than $10mg/Nm^3$. Without the addition of WESP equipment, the total particulate matter concentration at the exhaust outlet can be achieved through the combined dust removal of the desulfurization system. The emission standard for air pollutants from power plants (DB33/2147-2018) stipulates the emission limit of $5mg/Nm^3$ for particulate matter, which opens up a new direction for the technical route of coordinated flue gas treatment, and also provides a reference for similar dust removal efficiency enhancement modifications.

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